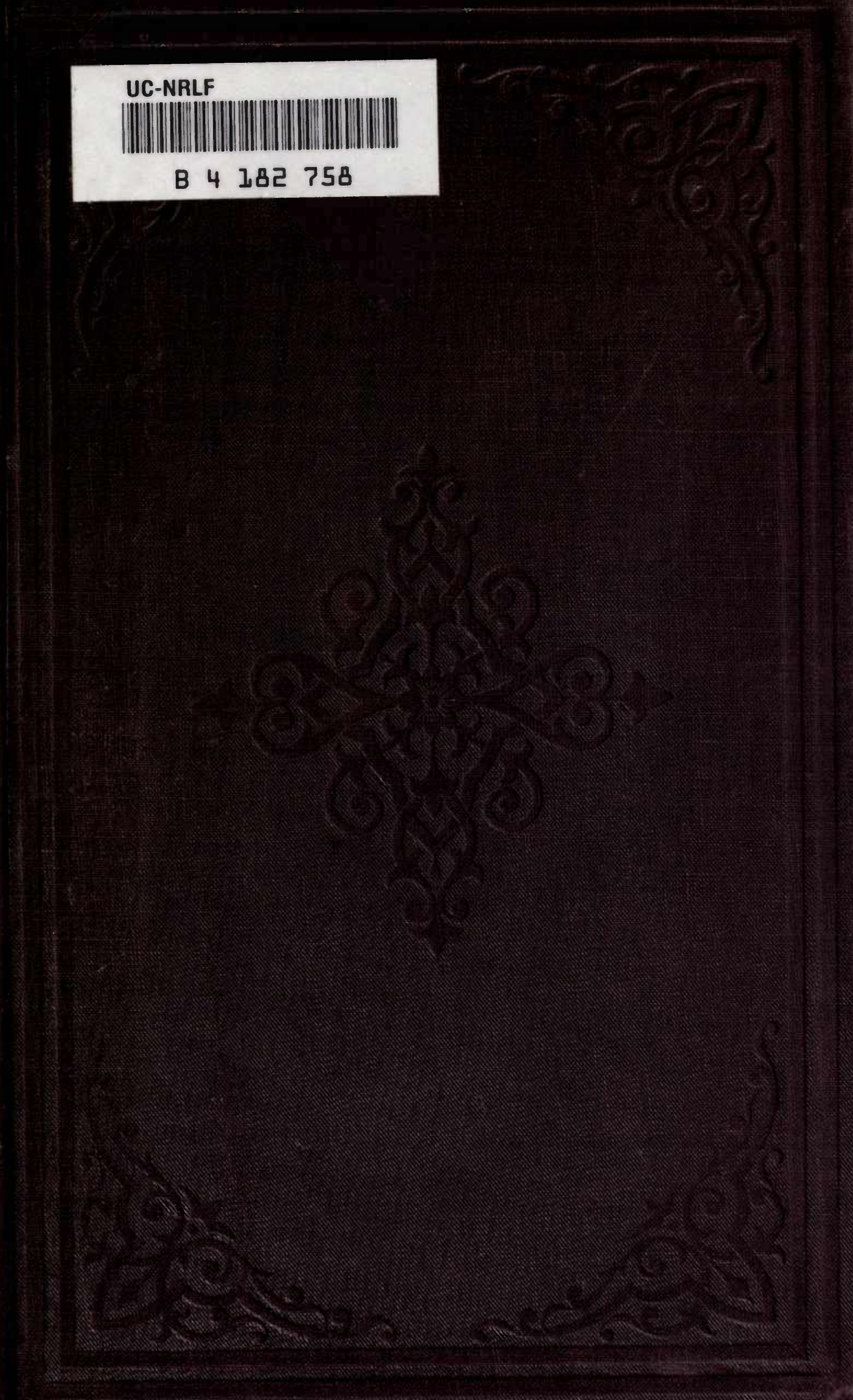


MINERALOGY SIMPLIFIED.

MINERALOGY SIMPLIFIED.

EASY METHODS OF IDENTIFYING MINERALS, INCLUDING ORES,

BY MEANS OF THE BLOWPIPE, BY FLAME REACTIONS,
BY THE SPECTROSCOPE, AND BY HUMID
CHEMICAL ANALYSIS,

BASED ON PROF. VON KOBELL'S TABLES FOR THE
DETERMINATION OF MINERALS.

WITH AN INTRODUCTION TO MODERN CHEMISTRY.

BY

HENRI ERNI, A.M., M.D.,

LATE PROFESSOR OF CHEMISTRY, SOME-TIME CHIEF CHEMIST OF THE UNITED STATES
DEPARTMENT OF AGRICULTURE.

SECOND EDITION, REVISED AND ENLARGED.

ILLUSTRATED BY ONE HUNDRED AND TWENTY-ONE ENGRAVINGS.

PHILADELPHIA:
HENRY CAREY BAIRD & CO.,
INDUSTRIAL PUBLISHERS, BOOKSELLERS, AND IMPORTERS,
810 WALNUT STREET.
LONDON: E. & F. N. SPON, 125 STRAND.
1885.

COLLINS, PRINTER.

PUBLISHERS' PREFACE.

THE favor with which the former edition of Dr. Erni's Mineralogy Simplified was received induced the publishers some time since to request the author to prepare a new edition, which should bring the subject down to the present time. This he has done with his accustomed thoroughness.

He has retained, in the present edition, the admirable system of classifying and determining the mineral species established by von Kobell, which is universally conceded by mineralogists to be the most trustworthy, serviceable, and practical for the purposes of experimental study.

Professor Erni introduces the subject of Determinative Mineralogy with a series of chapters embracing the principles of modern chemistry, descriptions of the apparatus employed, with practical instructions as to the mode of using it, with special reference as to the proper use of the blowpipe, and an exhaustive and lucid description of the reactions by which the various chemical substances may be recognized.

To the student, the amateur mineralogist, the civil engineer, the miner, the prospector, and all others to whom a knowledge of mineralogy may be serviceable, the book can be recommended as a most valuable guide.

The lamented death of Dr. Erni, which occurred while the present edition was passing through the press, necessitated the publishers to place the correction of the proof-sheet in other hands. They secured for this important work the services of a competent critic; and they believe that he has performed the duty in a thoroughly satisfactory manner.

PHILADELPHIA, October 1, 1885.

CONTENTS.

PART I.

CHAPTER I.

CHEMICAL PHILOSOPHY.

CHAPTER II.

AUXILIARY APPARATUS AND MANIPULATIONS IN THE LABORATORY.

CHAPTER III.

PREPARATION OF REAGENTS MOST FREQUENTLY REQUIRED FOR ANALYSIS IN THE WET WAY.

CHAPTER IV.

BLOWPIPE ANALYSIS AND APPARATUS.

CHAPTER V.

REACTION OF OXIDES WITH GENERAL REAGENTS.

CHAPTER VI.

COLORED FLAMES, FLAME REACTIONS, AND SPECTRUM ANALYSIS.

CHAPTER VII.

SPECIAL METHODS FOR DETECTING CERTAIN ELEMENTS, OR SOME OF THEIR COMBINATIONS WHEN PRESENT IN COMPLEX CHEMICAL COMPOUNDS.

CHAPTER VIII.

FUSING AND FLUXING.

PART II.

DETERMINATIVE MINERALOGY.

CHAPTER IX.

ON THE DETERMINATION OF MINERALS BY MEANS OF SIMPLE EXPERIMENTS WITH A BLOWPIPE AIDED BY HUMID ANALYSIS.

CHAPTER X.

CHARACTERISTIC BEHAVIOR OF THE MOST IMPORTANT ORES BEFORE THE BLOWPIPE AND WITH SOLVENTS.

APPENDIX.

MINERALOGY SIMPLIFIED.

PART I.

CHAPTER I.

CHEMICAL PHILOSOPHY.

The New or Unitary System of Chemistry, or Substitution Theory.

THIS term Gerhardt applied to his system of notation, based on the reduction of all formulæ to one common standard, they being derived one from the other by substitution.

BERZELIAN THEORY.

The older *Berzelian* or *electro-chemical theory* being founded upon *dualism*, whence it is also known as *binary theory*. According to this great chemist, each chemical combination, however complicated, contained two integrant parts—either single or compound—both being as it were in opposition to one another. Chemical affinity,* or attraction, would result from this opposition between two contrary forces always striving to neutralize each other, and these opposing forces, controlling all chemical

---

* Not to be confounded with quantivalence. Affinity is the force by which one atom attracts another. An element may have a strong affinity for other elements and yet be univalent. Another may possess a weak affinity and yet be quadrivalent. Chlorine has a strong affinity for hydrogen, yet they both are univalent elements.

phenomena, were assumed to be of an electrical nature. There are two electric fluids, a negative and a positive one, hence every compound contained, according to *Berzelius*, an electro-positive (basic, basylic), and an electro-negative (acid) constituent.

Thus nitric acid was represented by the formula $N_2O_5H_2O$; it was a combination of the second order, nitric acid anhydride $= N_2O_5$ forming the electro-negative, water $= H_2O$, the electro-positive constituent.

In the nitrate salts we find this nitric acid united to an oxide, *e. g.*, KO,N_2O_5. Nitrate of potassa (saltpetre). To halve the formula N_2O_5,H_2O, as is done at present, viz., HNO_3, would be like attempting to destroy the very foundation of the old BERZELIAN THEORY.

The discovery of *substitution* by Dumas and others struck a death-blow at the electrical theory. It was found that the most opposite elements, like chlorine and hydrogen, could replace one another in a compound without altering its chemical nature, or its characteristic general properties.

Thus in the marsh gas $= CH_4$, the four atoms of hydrogen can gradually be substituted by chlorine, so that the following substitution products were actually obtained:

$$C^{IV}H_4;\ C^{IV}H_3Cl;\ C^{IV}H_2Cl_2;\ C^{IV}HCl_3;\ C^{IV}Cl_4.$$

Gay-Lussac's Law of Combination by Volume.

If Dalton succeeded in placing the laws of chemical combination on a firm basis, to Gay-Lussac belongs the honor of having discovered the law regulating the combination of gases by volume. It was in 1805 that Gay-Lussac and A. Humboldt found, by actual experiment, that 1 volume of oxygen gas unites with exactly 2 volumes of hydrogen, to form 2 volumes of water-gas or steam.

The molecules* of compound bodies in the gaseous state,

---

* A molecule is the smallest particle of a compound or element that is capable of existence in a free state. Atoms are the indivisible

both organic and inorganic, with a few exceptions, probably only apparent, occupy twice the volume of an atom of hydrogen. No matter what may be the number of atoms, or volumes, that enter into the compound, they all become condensed into 2 volumes, thus:

1 volume (1 atom) of hydrogen and 1 volume of chlorine form 2 volumes of hydrochloric acid = HCl.

2 volumes (2 atoms) of hydrogen and 1 volume of oxygen form 2 volumes of water-gas or steam = H_2O.

3 volumes (3 atoms) of hydrogen and 1 volume of nitrogen form 2 volumes of ammonia = H_3N, etc. etc.

Another law, enunciated by Gay-Lussac, states that the weights of the combining volumes of the gaseous elements bear a simple ratio to their atomic weights. Thus, taking the unit volume of hydrogen gas to weigh = 1, as the lightest substance known, we find that

The unit	volume of	nitrogen	gas	weighs,	14.01
"	"	oxygen	"	"	15.96
"	"	chlorine	"	"	35.37
"	"	bromine	"	"	79.76
"	"	iodine	"	"	126.54

and these numbers are identical with the atomic weights of these elements. In other words, nitrogen is 14.01, and oxygen 15.96 times (nearly 16) as heavy as hydrogen, etc. etc.

Avogadro's Law.

From Gay-Lussac's fundamental law, and the great law of Avogadro, that all substances in the condition of gases, under like circumstances of temperature and pressure, contain in equal volumes the same number of atoms, it follows that the formula of water is not HO as formerly expressed, when the

---

constituents of molecules. They are the smallest particles that can take part in chemical reactions, and most of them are incapable of existence in the free state but are found in combination with other atoms, either of the same kind or of different kinds.

combining weight of oxygen was = 8 (hydrogen taken as unit = 1), but H_2O, whence the atomic weight of oxygen (that of 1 atom = 1 volume of hydrogen taken as 1) must be 16.

Changes of Notation in the New Chemical System.

The following changes, induced by the new system of chemistry, must be remembered by the student.

1. The doubling of all the atomic weights, except those of the monad or univalent elements (H, Cl, K, Na, etc.), and also of Bi, As, Sb, N, P, and Bo, whose oxides are now written Bi_2O_3, instead of BiO_3, etc. etc. Corresponding to this change of binary compounds, involving the monad elements, as in the case of water cited, are written H_2O instead of HO, Na_2O for NaO, Na_2S for NaS, etc.; also $CaCl_2$ instead of CaCl, SiF_4 instead of SiF_2, etc.

2. The method of viewing the composition of ternary compounds. (See Acids and Salts.)

The name "acid," in its former acceptation and significance, is not necessary, if not absolutely wrong in teaching chemistry. Modern chemistry gives the following definition of an acid.

1. *Acids* and *Halogens*, viz., Chlorine, Bromine, Iodine, and Fluorine.

The properties which characterize acids are the following:—

1. They have an acid or sour taste.

2. They turn blue litmus red.

3. They act upon metals, hydrogen being evolved, and its place being taken by the metals, the products obtained are called SALTS. For instance:

$2(HCl)$	$+$	Zn	$=$	$ZnCl_2$	$+$	$2H.$
Hydrochloric acid.		Zinc.		Zinc chloride.		Hydrogen.

H_2SO_4	$+$	Mn	$=$	$MnSO_4$	$+$	$2H.$
Sulphuric acid.		Manganese.		Manganese sulphate.		Hydrogen.

4. They act upon metallic hydroxides, forming neutral substances and water, as follows:

HCl	+	KOH	=	KCl	+	H_2O.
Hydrochloric acid.		Potassium hydroxide.		Potassium chloride.		

HNO_3	+	$NaOH$	=	$NaNO_3$	+	H_2O.
Nitric acid.		Sodium hydroxide.		Sodium nitrate.		

H_2SO_4	+	$Ca(OH)_2$	=	$CaSO_4$	+	$2H_2O$.
Sulphuric acid.		Calcium hydroxide.		Calcium sulphate.		

ACIDS are divided into

a. OXYGEN ACIDS.

b. SULPHUR ACIDS, and

c. HYDROGEN ACIDS.

An acid may be looked upon as a salt of hydrogen. It consists of an acid radical (either simple or compound) united with hydrogen, which latter can be exchanged for a metal, this being then the formation of a regular *salt*. The hydrogen is the *base* of the *acid*, as the *metal* is the *base* of the *salt*. Sulphuric acid, for instance, is sometimes written hydrogen sulphate $= H_2SO_4$.

All acids contain hydrogen.

Oxacids are those whose radicals contain oxygen, as HNO_3, nitric acid.

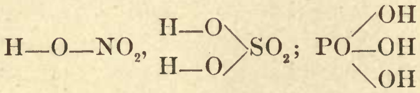
Hydracids are those whose radicals contain no oxygen, as HCl, hydrochloric acid, H_2S, sulphydric acid, etc. The anhydride of an oxacid is what remains after removing from the acid its basic hydrogen and enough oxygen to form water with the hydrogen. The anhydride of H_2SO_4 is SO_3. That of carbonic acid $= H_2CO_3$ is CO_2. Acids that contain but 1 atom of basic H are termed *monobasic*, as HNO_3 and HCl; those with 2 atoms of replaceable hydrogen, dibasic, as H_2SO_4; those with 3 atoms H, tribasic, as H_3PO_4 (phosphoric acid); those with 4 atoms H, tetrabasic, as H_4SiO_4, silicic acid.

HYDROXYL ACIDS. In those acids which consist of hydrogen and an *acid* or *negative radical* of greater or less complexity, *e. g.*, HNO_3, H_2SO_4, H_3PO_4 (oxygen being nearly always a constituent of said radical, sulphur only in few cases), it is believed that their radicals are united to hydrogen by means of oxygen. In other words, the oxacids are compounds of negative radicals with hydroxyl (OH). They are *acid hydroxides.*

The above-mentioned acids would thus have the formulæ:

$$(NO_2)'\,(OH)\,;\ (SO_2)''\,(OH)_2;\ (PO)'''\,(OH)_3;$$

or still more definite,



$$H{-}O{-}NO_2,\quad \left.\begin{matrix}H{-}O\\H{-}O\end{matrix}\right\rangle SO_2;\quad PO\left\langle\begin{matrix}OH\\OH\\OH\end{matrix}\right.$$

THE HYDROGEN ACIDS are formed by the combination of the halogens with hydrogen. They neutralize oxygen bases with formation of haloid salts and water, *e. g.*,

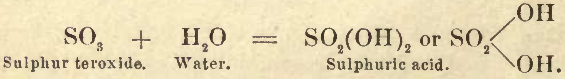
$$\underset{\text{Sodium monoxide.}}{Na_2O} + \underset{\text{Hydrochloric acid.}}{2HCl} = \underset{\text{Sodium chloride.}}{2NaCl} + \underset{\text{Water.}}{H_2O.}$$

SULPHUR ACIDS, like sulphydric acid $= H_2S$, etc., are hydrogen acids of the same chemical constitution. They combine with sulphur bases, forming sulphur salts. For instance, potassium hydrosulphide $= K\,S\,H$, etc.

OXYGEN BASES are compounds of basic (positive) radicals with hydroxyl. In its relation to other bodies *hydroxyl* is analogous to the simple *halogen radicals*, Cl, Br, I, F.

In a majority of cases oxygen acids may be formed by the reaction of an anhydride, *i. e.*, an oxide of an electro-negative element upon water, *e. g.*,

$$\underset{\text{Nitric pentoxide.}}{N_2O_5} + \underset{\text{Water.}}{H_2O} = \underset{\text{Nitric acid.}}{2(NO_2OH)}$$



$$\underset{\text{Sulphur teroxide.}}{SO_3} + \underset{\text{Water.}}{H_2O} = \underset{\text{Sulphuric acid.}}{SO_2(OH)_2} \text{ or } SO_2\left\langle\begin{matrix}OH\\OH.\end{matrix}\right.$$

2. BASES.

Bases have properties which are opposite to those possessed by acids. Those soluble in water turn reddened litmus paper blue, and yellow turmeric paper brown. They all contain oxygen and hydrogen, and these elements are combined as *hydroxyl.*

The *oxygen bases*, or *basic hydroxides*, may also result from the action of an oxide of an electro-positive body upon water.

$$K_2O + H_2O = 2KOH$$

Potassium monoxide. Water. Potassium hydroxide.

When oxygen acids act upon metallic oxides, or hydroxides, the metal of the latter takes the place of hydrogen, and an *oxygen salt* is formed, while at the same time water is produced, *e. g.*,

$$NO_2(OH) + KOH = NO_2OK + H_2O.$$

Nitric acid. Potassium hydroxide. Potassium nitrate. Water.

$$SO_2(OH)_2 + K_2O = SO_2(OK)_2 + H_2O, \text{ and}$$

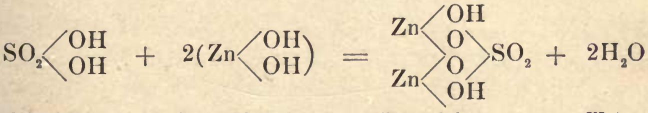
Sulphuric acid. Potassium monoxide. Potassium sulphate (normal salt). Water.

$$SO_2(OH)_2 + KOH = SO_2\begin{cases} OH \\ OK \end{cases} + H_2O$$

Sulphuric acid. Potassium hydroxide. Hydrogen potassium sulphate (acid salt). Water.

$$SO_2\begin{cases} OH \\ OH \end{cases} + Zn\begin{cases} OH \\ OH \end{cases} = SO_2\begin{cases} O \\ O \end{cases}Zn + 2H_2O$$

Sulphuric acid. Zinc hydroxide. Zinc sulphate (normal salt). Water.



$$SO_2\begin{cases} OH \\ OH \end{cases} + 2\left(Zn\begin{cases} OH \\ OH \end{cases}\right) = \begin{matrix} Zn\begin{cases} OH \\ O \end{cases} \\ Zn\begin{cases} O \\ OH \end{cases} \end{matrix} SO_2 + 2H_2O$$

Sulphuric acid. Zinc hydroxide. Zinc sulphate (basic salt). Water.

HYDRATES AND OXIDES OF METALS.

According to the quantivalence of the metals with which *hydroxyl* is combined, we have bases with one, two, three, etc., hydroxyl groups in a molecule, *e. g.*,

$Na(OH)$, sodium hydroxide. $Al(OH)_3$, aluminium hydroxide.
$Ca(OH)_2$, calcium hydroxide. $Cr(OH)_3$, chromium hydroxide.
$Ba(OH)_2$, barium hydroxide. $Fe(OH)_6$, ferric hydroxide.

3. SALTS.

Compounds formed by the action of acids upon bases are called *salts.*

According to the new system, ternary substances are no longer regarded as compounds of an "*oxide*" and a so-called "*acid*," but as compounds, for the most part, of the several elements concerned, and hence a metal in a salt is believed to be replaceable by another metal, and not an oxide by another. The discovery of salts which contained neither an acid nor a basic oxide, but only two single radicals like the common salt $= NaCl$, was sufficient to eventually dispose of the old *dualistic theory.*

a. NORMAL (neutral) SALTS are those in which the acid and base saturate one another, in which, therefore, all the hydroxyls, whether of acid or base, are eliminated (in the form of water), and the acid radical remains united to the metal by means of oxygen, *e. g.*, potassium, nitrate, etc.

b. ACID SALTS are those which retain a part of the acid hydroxyl, *e. g.*, hydrogen potassium sulphate.

c. BASIC SALTS are those in which a part of the hydroxyl of the base, or of the oxygen of the *positive* oxide, remains in combination, *e. g.*, basic zinc sulphate.

The common form of sulphuric acid is di-basic; sulphates may therefore be *acid*, *normal*, or double salts. Let M stand for a monad metal, and they may be represented thus graphically:

$$\begin{array}{cccc} \left.\begin{matrix}H\\H\end{matrix}\right\}SO_4 & \left.\begin{matrix}M\\H\end{matrix}\right\}SO_4 & \left.\begin{matrix}M\\M\end{matrix}\right\} & \left.\begin{matrix}M\\m\end{matrix}\right\}SO_4 \\ \text{Acid.} & \text{Acid salt.} & \text{Normal salt.} & \text{Double salt.} \end{array}$$

Examples:

a. *Normal Salts.*

Potassium chlorate, $KClO_3$.
Calcium sulphate, $Ca''SO_4$.
Bismuth phosphate, $Bi'''PO_4$.
Sodium silicate, Na_2SiO_3.

b. *Acid Salts.*

Hydro-sodium sulphite, $HNaSO_3$.
Hydro-cæsium carbonate, $HCsCO_3$.
Hydro-barium phosphate, $HBaPO_4$.
Hydro-cupric silicate, H_2CuSiO_4.

c. *Basic Salts.*

Lead hydro-nitrate, $H(NO_2)'PbO_2$.
Copper hydro-acetate, $H(Ac)'CuO_2$.
Mercuric hydro-iodite, $H(JO)'HgO_2$.
Alumic hydro-silicate, $H_2Si^{IV}Al_2O_6$.

d. *Double Salts.*

Potassio-sodium selenate, $KNaSeO_4$.
Sodio-calcium antimonate, $NaCa''SbO_4$.
Bario-zincic silicate, $Ba''Zn''SiO_4$.
Cæsio-rubidic carbonate, $Cs'Rb'CO_3$.

Quantivalence, Valence, or Atomicity of Elements.

Every atom of an element has an inherent power of holding in combination a certain number of other atoms, this number being dependent upon the combining power of the atoms held in combination. The simplest atoms would represent the unit of this power, and we must distinguish between these simplest or unit-atomicity and such as have the power of holding in combination two, three, four, five, or more unit-atoms.

Bodies whose *atomic capacity* is

One,	are termed	Monads, Monatomic, Monadic, or Univalents.
Two	"	Dyads, Diatomic, Dyadic, or Bivalent.
Three	"	Triads, Triatomic, Triadic, or Trivalent.
Four	"	Tetrads, Tetratomic, Tetradic, or Quadrivalents.
Five	"	Pentads, Pentatomic, Pendadic, or Quinquivalents.
Six	"	Hexads, Hexatomic, Hexadic, or Sexivalent.
Seven	"	Heptads, Heptatomic, Heptadic, or Septivalent.

Elements of even valency, viz., the *dyads*, *tetrads*, and *hexads*, are also included under the general term *artiads*, and those of uneven valency, viz., the *monads*, *triads*, *tetrads*, and *hexads* are designated as *perissads*.

4. *Indices of Valence, Bonds of Attraction, or Linking of Atoms.*

The quantivalence of elements may be expressed in different ways, as follows:

Monads.	Diads.	Triads.	Tetrads.	Pentads.	Hexads.
H^{I}	O^{II}	N^{III}	C^{IV}	N^{V}	Fe^{VI}

Instead of these Roman numbers the valency is expressed by dashes, *e. g.*, S'', Bi''', Sb''', Sn''''. In chemical formulæ each dash, either horizontal, vertical, or inclined, indicates a "bond" or unit of valence, and implies chemical combination between the atoms or groupings whose symbols are thus connected.

The + sign and period are employed to express "molecular combination," *i. e.*, combination not amenable to the generally received quantivalence, as in the case of crystal water.

Varying Valence in the same Element.

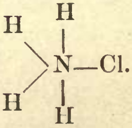
Many elements are not limited to one of valence; thus nitrogen may act either as a trivalent or quinquivalent body, etc., *e. g.*,

Trivalent.

$$\begin{array}{r} H \\ | \\ H{-}N \\ | \\ H \end{array}$$

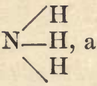
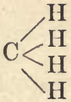
Ammonia gas.

Quinquivalent.

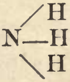


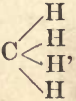
Ammonic chloride.

5. GERHARDT'S RESIDUES.

Most chemical compounds are more complicated than those we have been hitherto considering. If we take any of the following formulæ, as, for instance, H—Cl, H—O—H, , and 

and divide them at any part, we obtain two *residues* of *equal valence*, *e. g.*, if we divide H—Cl we obtain H and Cl, both univalent; if we divide H—O—H (water) we obtain H, and the univalent residue OH (hydroxyl), which requires an univalent atom to saturate it. If we divide

, we obtain H and NH_2, or H_2 and NH;

by the former division there are left two univalent, by the latter two bivalent factors. If we divide the formula , the following cases are possible: H and CH_3, H_2 and CH_2, H_3 and CH; leaving in the first case two univalent, in the second two bivalent, and in the third two trivalent residues. If we abstract from H_2SO_4 two atoms of hydrogen, we obtain a residue SO_4, acting like a bivalent radical; again by taking away from HNO_3 the hydrogen, the residue NO_3 will act as a univalent radical. The residue then may be considered as a radical of equal atomicity as the sum of the atoms of basic hydrogen, eliminated from the original compound radicals, viz.,

HNO_3, H_2SO_4, H_3PO_4, etc.

*Table of Atomic Weights of the Elements according to the New System.**

Name.	Symbol of the atoms, their valence or atomicity.	Atomic weights or combining weights. $H = 1$.
HYDROGEN	H	1†
Aluminium	$Al^{III, VI}$	27.
Antimony (Stibium)	$Sb^{III, V}$	120.
Arsenic	$As^{III, V}$	75.
Barium	Ba^{II}	137.
Beryllium or	Be^{II} or ^{III}	9.
Glucinum	Gl^{II} or ^{III}	
Bismuth	$Bi^{III, V}$	208.
Boron	$Bo^{III, V}$	11.
Bromine	$Br^{I, III, V, VII}$	80.
Cadmium	Cd^{II}	112.
Cæsium	Cs^{I}	133.
Calcium	Ca^{II}	40.
Carbon	$C^{IV, II}$	12.
Cerium	$Ce^{II, VI}$	141.2
Chlorine	$Cl^{I, III, V, VII}$	35.4
Chromium	$Cr^{IV, VI}$	52.
Cobalt	$Co^{II, IV}$	59.
Columbium	Cb^{V}	94.
(Niobium)	Nb^{V}	
Copper (Cuprum)	Cu^{II}	63.2
Didymium	Di^{IV}	142.2
Erbium	E^{II}	166.0
Fluorine	F^{I}	19.
Gallium	Ga^{IV}	69.
Gold (Aurum)	$Au^{I, III}$	196.
Hydrogen	H^{I}	1.

---

* According to the latest determinations.

† The lightest of the elements, or the unit of the series

Table of Atomic Weights.—Continued.

Name.	Symbol of the atoms, their valence or atomicity.	Atomic weights or combining weights. H = 1.
Indium	$\mathrm{In}^{\mathrm{III}}$	113.4
Iodine	$\mathrm{I}^{\mathrm{I, III, V, VII}}$	127.
Iridium	$\mathrm{Ir}^{\mathrm{II, IV, VI}}$	193.
Iron (Ferrum)	$\mathrm{Fe}^{\mathrm{II, IV, VI}}$	56.
Lanthanum	$\mathrm{La}^{\mathrm{IV}}$	138.
Lead (Plumbum)	$\mathrm{Pb}^{\mathrm{II, IV}}$	207.
Lithium	Li^{I}	7.
Magnesium	$\mathrm{Mg}^{\mathrm{II}}$	24.
Manganese	$\mathrm{Mn}^{\mathrm{II, IV, VI, VII}}$	55.
Mercury (Hydrargyrum)	Hg	200.
Molybdenum	$\mathrm{Mo}^{\mathrm{VI}}$	96.
Nickel	$\mathrm{Ni}^{\mathrm{II, IV}}$	58.
Nitrogen	$\mathrm{N}^{\mathrm{III, V}}$	14.
Osmium	$\mathrm{Os}^{\mathrm{II, IV, VI, VIII}}$	195.
Oxygen	O^{II}	16.
Palladium	$\mathrm{Pd}^{\mathrm{II, IV, VI}}$	106.
Phosphorus	$\mathrm{P}^{\mathrm{III, V}}$	31.
Platinum	$\mathrm{Pt}^{\mathrm{II, IV, VI}}$	195.
Potassium (Kalium)	K^{I}	39.
Rhodium	$\mathrm{Rh}^{\mathrm{II, IV, VI}}$	104.
Rubidium	Rb^{I}	85.5
Ruthenium	$\mathrm{Ru}^{\mathrm{II, IV, VI, VIII}}$	103.5
Samarium	Sm	150.
Scandium	Sc	44.
Selenium	$\mathrm{Se}^{\mathrm{II, IV, VI}}$	79.
Silicon (Silicium)	$\mathrm{Si}^{\mathrm{IV}}$	28.
Silver (Argentum)	Ag^{I}	108.
Sodium (Natrium)	Na^{I}	23.
Strontium	$\mathrm{Sr}^{\mathrm{II}}$	87.5
Sulphur	$\mathrm{S}^{\mathrm{II, IV, VI}}$	32.
Tantalum	Ta^{V}	182.
Tellurium	$\mathrm{Te}^{\mathrm{II, IV, VI}}$	125.
Terbium	Tb ?	?.
Thallium	$\mathrm{Tl}^{\mathrm{I, III}}$	204.
Thorium	$\mathrm{Th}^{\mathrm{IV}}$	232.
Tin (Stannum)	$\mathrm{Sn}^{\mathrm{IV}}$	118.
Titanium	$\mathrm{Ti}^{\mathrm{IV}}$	48.

Table of Atomic Weights.—Concluded.

Name.	Symbol of the atoms, their valence or atomicity.	Atomic weights or combining weights. H = 1.
Tungsten (Wolframium) .	W^{IV}	184.
Uranium	$U^{VI, IV}$	239.
Vanadium . . .	$V^{III, V}$	51.
Ytterbium . . .	Yb^{III}	173.
Yttrium	Y^{III}	89.
Zinc	Zn^{II}	65.
Zirconium . . .	Zr^{IV}	90.

CHAPTER II.

AUXILIARY APPARATUS AND MANIPULATIONS IN THE LABORATORY.

1. Pulverization.

Minerals usually require preparation for the blowpipe, as for solution, by pulverization. They may be broken in small pieces with a hammer, and then crushed in a diamond steel mortar (Fig. 1), in which *A* is a rim removable from bottom

Fig. 1.

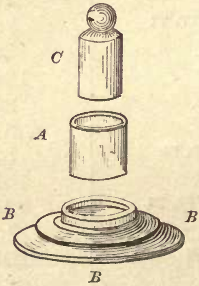


Fig. 2.

B. Pestle *C* fits the rim closely, and is driven by a heavy hammer into the rim upon the mineral. If repetition of this process does not soon prepare the mineral for the blowpipe, grinding in an *agate mortar* (Fig. 3) may be resorted to, as is generally necessary for solution.

Fig. 3.

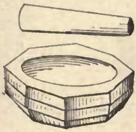
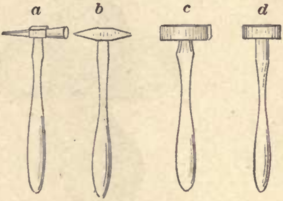


Fig. 4.



Some minerals may be sufficiently reduced by wrapping them in strong, clean paper, and giving them a blow with a hammer, taking care not to contract any impurity. A small jeweller's steel hammer will answer for blowpiping, but for trimming minerals and for geological and mining purposes, larger and variously shaped steel hammers have been adopted and are sold.

Fig. 4, *a*, *b*, *c*, *d*, represent four different forms of hammers.

a, Freiberg's pattern, one end flat, the other pointed.

b, Hutchinson's form, sharpened on both ends for trimming.

c, von Buch's form, one end flat the other sharpened.

d, Hausmann's pattern, both ends sharpened.

Fig. 5.

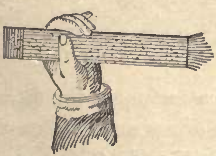
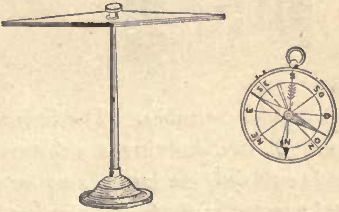


Fig. 6.

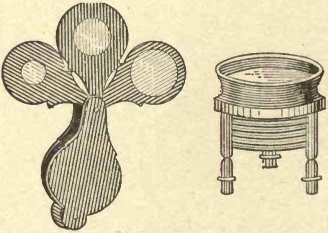


Anvil. A square, flat piece of hardened steel answers well for an anvil.

Cutting pliers or *nippers* are useful for cutting off small fragments from a mineral specimen.

Magnets. A small steel bar magnet (Fig. 5), and a small compass (Fig. 6), or a suspended magnetic needle are needed for recognizing magnetic metals.

Fig. 7.



A good magnifying glass (Fig. 7) is useful in examining metallic sublimations or deposits.

2. Solution and Carbonic Dioxide (CO_2) Test.

In qualitative analysis small quantities are usually employed, therefore the solution of solids may be most conveniently conducted in a test-tube which can be readily heated over an alcohol lamp or a gas-burner. Figs. 8 and 9 show two forms of racks with test-tubes. The latter has an attachment for filtration. If, in dissolving a substance, a colorless and inodorous gas is evolved, the latter may be carbonic dioxide (CO_2), and can be tested in the following simple manner: During evolution of gas in tube *a* (Fig. 10), the lip of the tube may be brought upon that of tube *b*, containing clear lime-water. As the gas

Fig. 8.

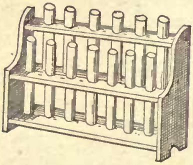
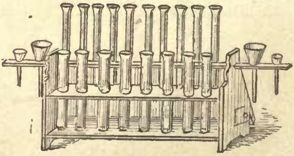


Fig. 9.



from tube *a* flows into tube *b*, the water will become *milky* from formation of calcium carbonate $CaCO_3$.

Fig. 10.

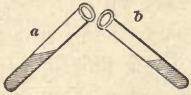


Fig. 11.

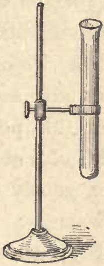


Fig. 12.

Fig. 11 shows a metallic test-tube stand with test-tube; and Fig. 12 a test-tube holder of brass with wooden handle, both employed for heating purposes.

3. Precipitation and Decantation.

Many circumstances are to be considered in deciding whether a precipitate will be produced with a given reagent, such as temperature, concentration, or dilution; the presence of some disturbing agent, or absence of a substance which might favor the action by the influence of some affinity. Therefore a single trial should not satisfy the student; the experiment should be varied, especially if resort be had to *heat*, agitation, and time.

Fig. 13.

The beaker (Fig. 13), made of Bohemian glass of uniform thickness, and a test-tube, serve best for precipitation, the liquid in the former being agitated by a glass rod. When the precipitation is complete, the subsidence of the precipitate often allows the mother liquor to be removed by *decantation.*

Precipitation of baryta, for example, may be readily separated and washed without filtration. To avoid spilling in decanting, a portion of the lip of the vessel should be smeared internally and externally with tallow, and then this portion brought against a glass rod held obliquely, when the liquid will flow gently down the rod without danger of waste.

Fig. 14.

Figs. 14 and 15 show how a stream of liquid flowing from a beaker or basin (porcelain dish) should be guided by a glass rod placed against the point whence the stream emerges. If the vessel be too large or too full to handle with convenience, the wash-water may be drawn off by a siphon, as shown in miniature in Fig. 16. A siphon is a tube of glass, metal, gutta-percha, or India-rubber, bent in the form of a V or U, filled with water, and inverted; one end immersed in the wash-water and the other allowed to hang over the side of the vessel; so long as the outer orifice of the instrument is below the level of the liquid in the vessel, so long will that liquid flow from within outwards until the vessel be empty.

Fig. 15.

Fig. 16.

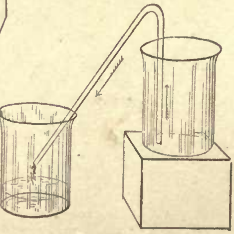


Fig. 17 represents a set (nest) of beakers without spout, all of uniformly thin glass, bearing well the heating of liquids which they contain, in a sand-bath or over a free fire.

Fig. 18 shows a set of beakers with spout.

Fig. 17.

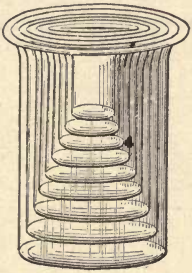


Fig. 18.

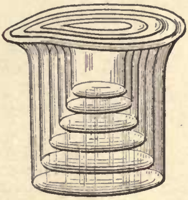


Fig. 19.

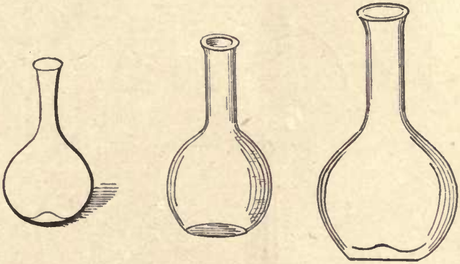


Fig. 19 exhibits German flasks of white glass with long neck and flat bottom, in which liquids may be boiled, or minerals dissolved in acids, over a free fire.

4. Filtration.

Precipitates are generally separated from the mother-liquor by filtration, as shown in Fig. 20, through paper expressly prepared for the purpose (Swedish is best, but a cheaper article answers for qualitative analysis). The paper, as seen in Fig. 21, is cut in a circular form, *a*, then folded in the shape of a quadrant, *b* and *c*, the pointed part finally placed deep in a glass funnel, and one of the folds, *d*, spread back so that the paper completely lines the glass, though it must not quite reach the top. When fitted, the paper is moistened by a jet of water to

Fig. 20.

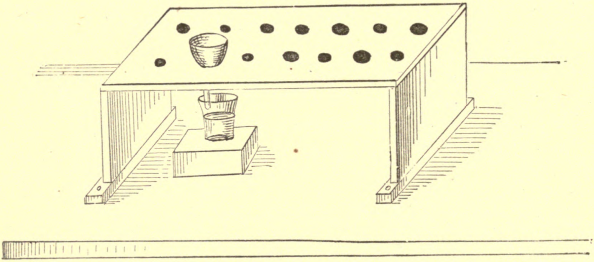


Fig. 21.

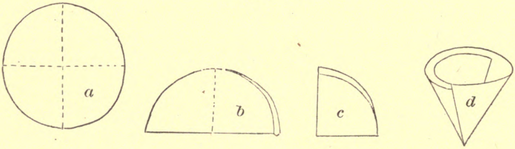
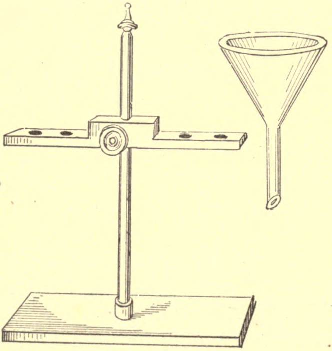


Fig. 22.



cause it to adhere to the glass. If a precipitate subsides, the supernatant liquid should first be run through the filter by itself (to accelerate filtration).

Figs. 22 and 23 show additional forms of filtering stands. The latter, being made of iron, can also be used as a retort-stand in distillations.

Fig. 23.

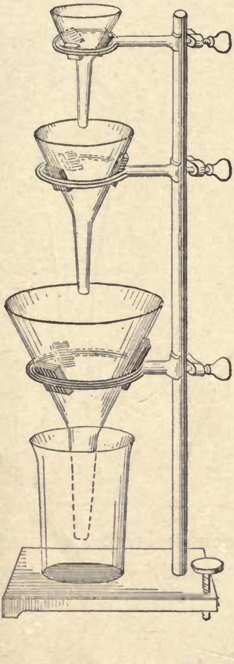


Fig. 24.

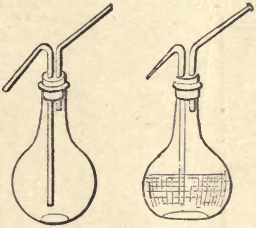


Fig. 25.

Washing Precipitates.

Fig. 24 represents the ordinary wash-bottle for washing precipitates from the side of a filter by a jet of water, by compression of the air in the bottle, caused by blowing (see Fig. 25). To test whether the washing has been complete, a drop of the filtrate coming from the funnel is evaporated on a platinum spatula; if no solid residue remains behind, the operation must be discontinued.

In Fig. 26 a platinum spatula is shown in its natural size, and Fig. 27 shows a convenient wooden holder for spatula, wire, and spoon for heating operations.

Fig. 26.

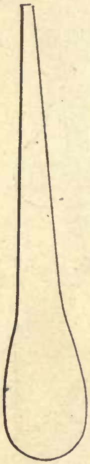


Fig. 27.

Fig. 28.

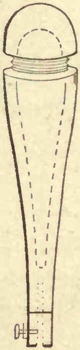


Fig. 28 is a holder for platinum spoon and wire, with screw fastening. The handle is hollow to contain wire and spoon, screw cap.

5. Evaporation.

After filtration the mother-liquor becomes so much increased by washing as often to require concentration before being treated for substances yet in solution. Evaporation may be conducted in a porcelain dish, either over a lamp or on the sand-bath. Boiling should be avoided, and for this purpose the dish can be securely placed upon a water-bath of copper (about five inches in diameter), shown in Fig. 29, which is provided with rings to receive dishes of different sizes, and is supported by a tripod or a retort-stand. Being partly filled with water, it is heated by a small alcohol lamp or a gas-burner. To prevent dust from falling into the dish, it may be covered with filter-paper (supported by a glass rod, or closely bent over the edge of the dish). When the dish is nearly full, the substance may often be prevented from running over the margin by slightly touching the latter with tallow. In evaporating to dryness, the process is facilitated by stirring. Fig. 30 shows a simple tripod of iron, and Fig. 31 is a tripod with chimney, by Bunsen, to be used in connection with his gas-burner. A square piece of iron-wire gauze is frequently put under dishes, beakers, or flasks, heated on these tripods, or iron retort-stands, to moderate the effect of the direct flame of a gas-burner. Figs. 32 (1 and 2) are tripods with rings of different sizes.

Fig. 29.

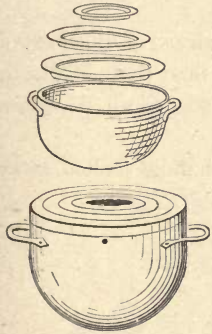


Fig. 30.

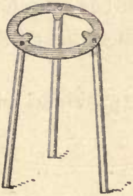


Fig. 31.

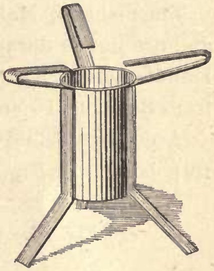
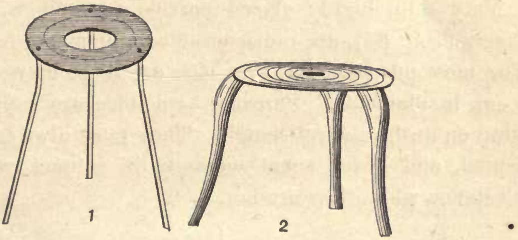


Fig. 32.



6. Porcelain Dishes and Crucibles.

Open dishes, which will bear heat without cracking, are necessary implements in the laboratory for conducting the evaporation of liquids. The best evaporating dishes are those made of Berlin porcelain, glazed both inside and out, with a small lip projecting beyond the rim.

The dishes of Meissen porcelain are not glazed on the outside, and are not so durable, but much cheaper than those of Berlin manufacture. Evaporating dishes are made of all diameters from 3 cm. to 15 cm.

A deep porcelain dish, provided with a handle (called cassarol), is seen in Fig. 33.

Fig. 33.

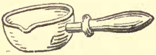
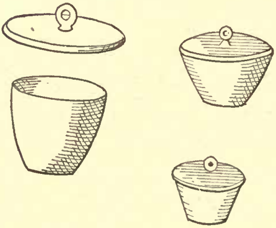


Fig. 34.



Very thin, highly glazed porcelain crucibles, with glazed covers (Fig. 34), are indispensable implements to the chemist. For most purposes the best sizes are those between 3 cm. and 5 cm. in diameter. Porcelain crucibles are supported over a lamp on an iron-wire triangle. They must always be gradually heated, and never come suddenly in contact with any cold substance while they are hot.

7. Platinum Apparatus: Crucibles, Dishes, or Capsules.

Platinum does not oxidize in the air at any temperature, nor is it attacked by any of the common acids used separately.

This comparative inertness as a chemical agent, taken in connection with its infusibility, renders platinum an extremely useful metal to the chemist.

It is employed in the laboratory for crucibles, evaporating dishes, stills, spatulæ, forceps, wire, blowpipe-tips, etc., and lately in the shape of perforated cones for filtering phosphate precipitates over a layer of asbestos wool.* When a filter-pump is on hand, other insoluble precipitates collected on an ordinary paper-filter may be quickly washed when placed in such a cone, and the latter in a glass funnel.

Fig. 35.

Fig. 36.

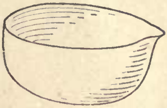


Fig. 35 represents a platinum crucible with a capsule-shaped lid, convenient for the incineration of filters, etc. Fig. 36 shows a platinum evaporating dish with lip.

8. Crucible Tongs.

The following three convenient forms for removing hot crucibles from the fire are generally found in laboratories.

Fig. 37 represents plain tongs of malleable iron. Fig. 38

Fig. 37.

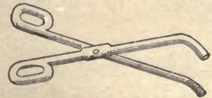
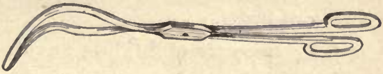


Fig. 38.

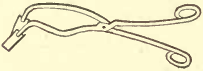


---

* See Fresenius's Quantitative Analysis (New System). Second American edition, by Allen & Johnson. New York, 1883. Pages 100 and 101.

shows tongs with a double curve. Fig. 39 exhibits somewhat expensive, but durable, crucible tongs, made of German silver with platinum points attached.

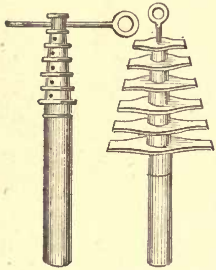
Fig. 39.



9. Corks.

For chemical purposes these should be made of soft cork-wood cut across the grain to prevent forming continuous channels for the passage of gases or liquids. Pierced corks are used to form joints with retorts, gas-bottles, and other chemical apparatus. Boring holes through corks to receive glass tubes, necks of retorts, etc., may be done with a round file (rat-tail), or better, by a hollow cylinder of sheet brass sharpened at one end. Fig. 40 represents a set of cylinders of graduated sizes, slipping one within the other into a very compact form. A stout wire of the same length as the cylinders accompanies the set, which serves a double purpose; passed transversely through two holes in the cap which terminates each cylinder, it gives the hand a better grasp of the tool while penetrating the cork; and when the hole is made, the wire thrust through the opening in the top of the cap expels the little cylinder of cork which else would remain in the cutting cylinder of brass.

Fig. 40.



Rubber stoppers of flexible unvulcanized caoutchouc, cast in moulds of various sizes, and provided with 1, 2, and 3 holes, are now employed in laboratories instead of cork stoppers. Fig. 41 represents different samples. These will not harden, and sell for $4 per pound. Caoutchouc stoppers of good quality are much more durable than corks, and are in every respect to be preferred. Caoutchouc stoppers can be bored like corks by means of suitable cutters, and glass tubes can be fitted into the holes thus made with a tightness unattainable with corks. Stoppers can be bought provided with all the necessary holes of various sizes.

Fig. 41.

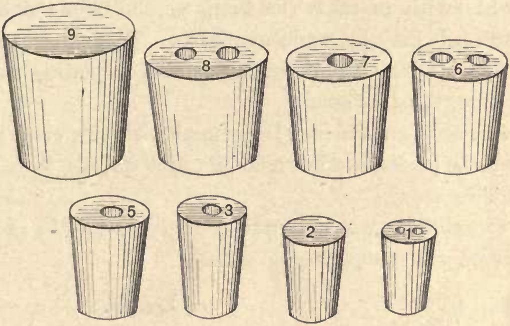
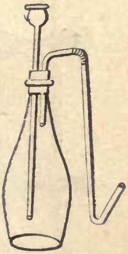


Fig. 42.



In Fig. 42 is seen a gas-bottle, fitted with perforated stopper, funnel-tube, and jointed delivery-tube.

10. Sand-bath, Wire Gauze, Triangular Supports for Crucibles.

As a general rule it is not best to apply the direct flame to glass or porcelain vessels; hence a piece of wire gauze is stretched loosely over the largest ring of an iron stand, and bent downward a little for the reception of round-bottomed vessels. On this gauze, flasks, retorts, and porcelain dishes are usually supported. In cases requiring a very gradual and equable heat the wire gauze is replaced by a small sand-bath, *i. e.*, a shallow sheet-iron pan filled with dry sand (Fig. 43). *Crucibles* or *dishes* of *porcelain* or *platinum*, too small for the smallest ring belonging to the stand, are

Fig. 43.

conveniently supported on an equilateral triangle made of three pieces of soft iron, copper, or platinum wire, twisted together at the apexes; this triangle is laid on one of the rings of the stand. An iron tripod (Fig. 30) may be often used instead of a stand, but it is not so generally useful because of the difficulty of adjusting it to various heights; with a sufficiency of wooden blocks wherewith to raise the lamp or the tripod as occasion may require, it may be made available. The whole apparatus for ignition, in its various arrangements, is plainly shown in the following illustrations.

Fig. 44 shows an ordinary iron stand with two rings; on the upper one is placed a wire triangle, and on the lower one a piece of wire gauze.

Fig. 45 exhibits two such wire triangles, *a* and *b*; the latter, *b*, is covered with tobacco-pipe stems.

Fig. 44.

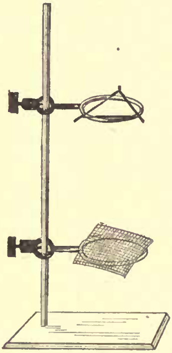


Fig. 45.

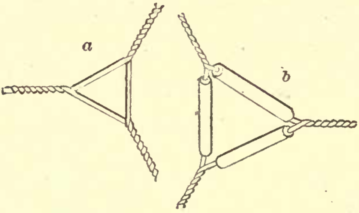


Fig. 46 is a support of iron with fork for holding a Bunsen burner, with rubber gas-tube attached. The burner with chimney heats a crucible, resting on a wire triangle.

In Fig. 47 is seen the burner by itself with a star screwed on for the support of a chimney and an arrangement to slide on the fork of the iron stand.

Fig. 48 shows a burner with a support screwed on for holding small porcelain dishes.

An ordinary plain Bunsen gas-burner is seen in Fig. 49.

Fig. 46.

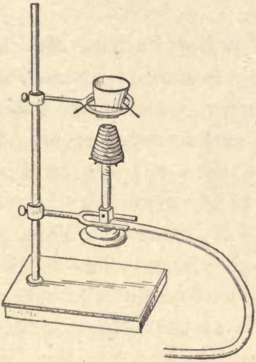


Fig. 47.

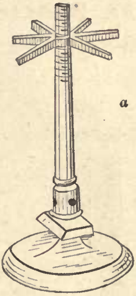


Fig. 48.

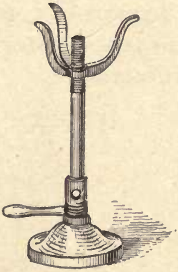
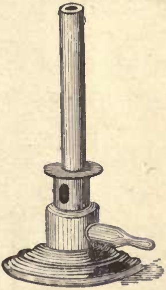


Fig. 49.



11. FLETCHER'S BURNERS.

Fig. 50. Fletcher's Blast-Bunsen for high temperatures. This is a Bunsen combined with a powerful blowpipe, and is one of the most generally useful arrangements known in the chemical laboratory. The blowpipe flame obtained with the blast tube, when confined by the loose cap B, is compact and extremely powerful, owing to the fact that the air mixture is partially made before the blast begins to act. When the object to be heated is fragile it can be warmed by the Bunsen flame

and the blast slowly turned on by the tap C. The convenience of having a powerful flame at command under an ordinary retort-stand without the necessity of readjusting the height or position will be fully appreciated.

Fig. 51. Fletcher-Plattner Blowpipe Furnace, for Capsules, or Crucibles, $\frac{3}{4}$ in. diameter. This is made of Fletcher's patent non-conductor, which does not require renewing, and does not require the objectionable wire support of Plattner's pattern, which generally fails at the most critical moment. This pattern, like that of Plattner, has the hole for the blowpipe flame at the side; but if the hole is at the bottom, and an upright blowpipe is used, the improvement is very great. With the blast Bunsen (as shown in Fig. 50) and a good foot blower, 100 grains of cast iron can be perfectly fused in two minutes; the temperatures being, at the same time, under the most perfect control.

Fig. 50.

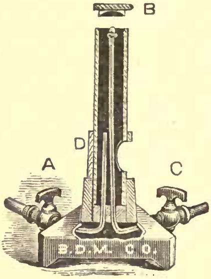


Fig. 51.

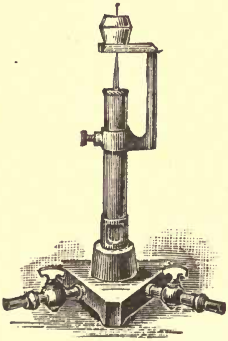
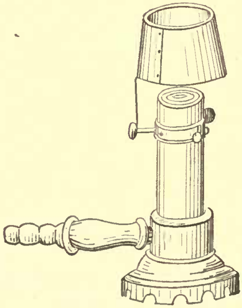


Fig. 52.



In Fig. 52 is seen Erlenmeyer's Argand Burner for heating purposes. It has met with much favor among chemists for the intense, steady heat it gives. It may be used for simple fusions of silicates nearly as well as a blast lamp.

12. Foot Blowers.

Fig. 53 is a simple, compact, and powerful arrangement. The step for the foot is very low, and enables the blower to be used with ease whether the operator is standing or seated. The pressure is perfectly steady and equal. If the rubber disk is distended until forced against the net, the pressure can be increased to almost any extent desired. It will give, if required a heavy and continuous blast through a pipe of $\frac{1}{4}$ inch clear bore.

Fig. 53.

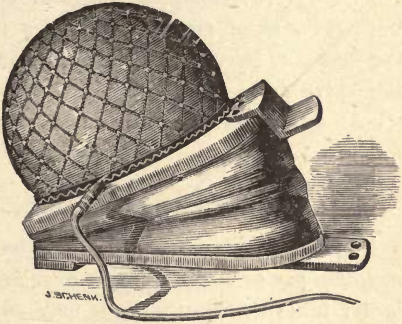


Fig. 54.

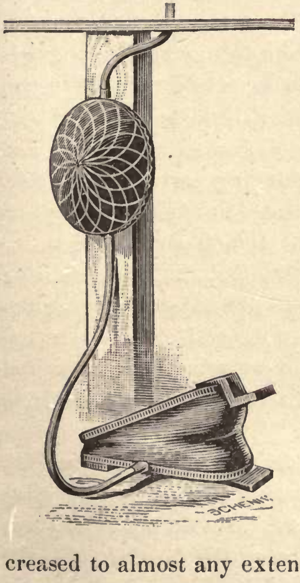
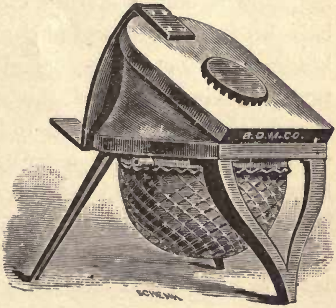


Fig. 55.



A great advantage is obtained in blowpipe work by attaching a stopcock to the air-pipe, thereby controlling the blast as with the mouth. With the blast Bunsen lamp, connected with such a blower, small quantities of cast iron can be perfectly fused in a few minutes.

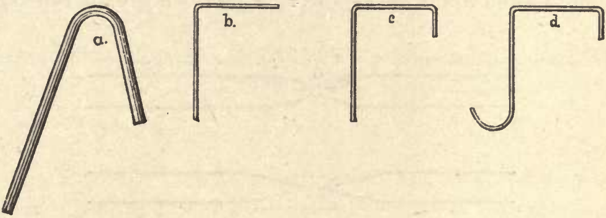
Fig. 55, reversing the position of the blower, does away with the risk of mechanical injury to the disk, and obviates the necessity for a wood casing or protection. It also prevents the valve from picking up dirt from the floor, keeping the whole arrangement cleaner, and the valves in more perfect order.

13. Bending and Closing Glass Tubes.

Small bore tubing can generally be worked in the flame of a common gas or spirit-lamp, or over an ordinary gas-burner; for larger tubes the blast-lamp is necessary (see Figs. 50 and 51). Glass tubing must not be introduced suddenly into the hottest part of the flame, or laid at once upon a cold surface. Gradual heating and gradual cooling are alike necessary, and more so, the thicker the glass is. In heating a tube, whether for bending, drawing-out, or closing, the tube must be constantly turned between the fingers, and also moved a little to the right and left in order that it may be uniformly heated all around, and that the temperature of the neighboring parts may be duly raised. If a tube or rod is to be heated at any part except an end, it should be held between the thumb and the first two fingers of each hand in such a manner that the hands shall be below the tube or rod, with the palms upward, while the lamp-flame is between the hands. When the end of a tube or rod is to be heated, it is best to begin by warming the tube or rod about 2 cm. from the end, and from thence proceed slowly to the end.

In bending tubing to make gas delivery-tubes and the like, attention should be paid to the following points: 1st, the glass should be equally hot on all sides; 2d, it should not be twisted, pulled out, or pushed together, during the heating; 3d, the bore of the tube at the bend should be kept round and not altered in size; 4th, if two or more bends be made in the same piece of tubing (Fig. 56), *c* and *d*, they should all be in the same plane, so that the finished tube will lie flat upon the level table.

Fig. 56.

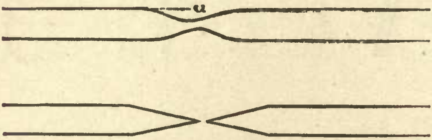


When a tube or rod is to be bent or drawn close at its extremity, a temporary handle may be attached to it by softening the end of the tube or rod, and pressing against the soft glass a fragment of a glass tube which will adhere strongly to the softened end. The handle may subsequently be removed by a slight blow, or by the aid of a file.

If a considerable bend is to be made, so that the angle between the arms will be very acute, as in a siphon, for example at *a*, Fig. 56, the curvature cannot be well produced at one place in the tube, but should be made by heating, progressively, several centimetres of the tube, and bending continuously from one end of the heated portion to the other. Small and thick tubes may be bent more sharply than large or thin tubes. In order to draw a glass tube down to a finer bore, it is simply necessary to thoroughly soften, on all sides, one or two centimetres' length of the tube, and then, taking the glass from the flame, to pull the tube by a cautious movement of the hands. The larger the heated portion of the glass, the longer will be the tube thus formed. Its length and fineness also increase with the rapidity of motion of the hands.

To obtain a tube closed at one end, it is best to take a piece of tubing open at both ends, and long enough to make two closed tubes. In the middle of the tube a ring of glass, as narrow as possible, must be made thoroughly soft. The hands are then separated a little to cause a contraction in diameter at the hot and soft part. The point of the flame must now be directed, not upon the narrowest part of the tube, but upon what is to be the bottom of the closed tube. This point is indicated by the line *a* in Fig. 57. By drawing with the right hand, the narrow part of the tube is attenuated, and finally melted off, leaving both halves of the original tube closed at one end, but not of the same form ; the right-hand half is drawn out into a long point, the other is more roundly closed. It is not possible to close handsomely the two pieces at once. The tube is seldom perfectly finished by the operation ; a superfluous knob of glass generally remains upon the end. If small, it may be got rid of by heating the whole end of the tube, and blowing moderately with the mouth into the open end. The knob being hotter, and therefore softer than any other part, yields to the pressure from within, spreads out and disappears. If the knob is large it may be drawn off by sticking to it a fragment of a tube, and then softening the glass above the junction. The same process may be applied to the too pointed end of the right-hand half of the original tube, or to any misshapen result of an unsuccessful attempt to close a tube, or to any bit of tube which is too short to make two closed tubes. When the closed end of a tube is too thin, it may be strengthened by keeping the whole end at a red heat for two or three minutes, turning the tube constantly between the fingers. It may be said in general of all the preceding operations before the lamp, that *success depends on keeping the tube to be heated in constant rotation in order to secure a uniform temperature on all sides of the tube.*

Fig. 57.



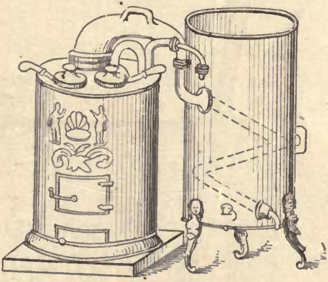
CHAPTER III.

PREPARATION OF REAGENTS MOST FREQUENTLY REQUIRED FOR ANALYSIS IN THE WET WAY.

1. Chemically Pure Water = H_2O.

The first reagent which the private chemical student must prepare for himself is *chemically pure water*. Clean rain-water, or some other very pure water, may be rendered suitable for many laboratory purposes by simply boiling and filtering. But it is usually better to distil water, rejecting the first eighth which goes over, and leaving a yet larger quantity in the retort at the close of the distillation. The retort should always be well washed before *refilling*. Water thus purified should be preserved in closely stoppered demijohns or stone jars. One of the best and most convenient distilling apparatus, is that of Beindorf, represented in Fig. 58, for the use of pharmaceutists and chemists, for distilling, rectifying, evaporating, cooking, extracting, drying, and similar chemical operations, besides melting. It consists of the following parts: a furnace of wrought iron; water-bath of copper, 5 gallons capacity and tinned inside; a still of block tin, 1½ gallons capacity, with head of

Fig. 58.



block-tin, and having all the contrivances necessary for steam distillations, etc., all made of pure block tin; two evaporating

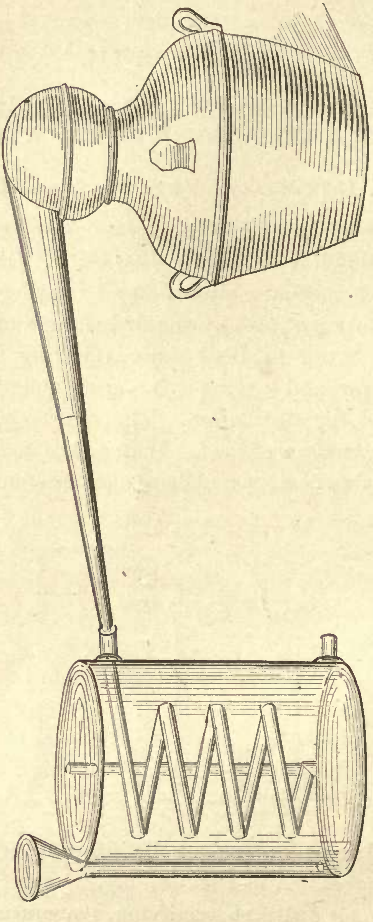


Fig. 59.

dishes; two infusion jars; a complete condenser of the latest construction, etc.

Fig. 59 represents a heavy copper still with movable head, and lined inside with tin coating; connected with a block-tin condensing worm, inclosed in a zinc vessel, with inlet for cold and outlet for the warm water.

For most purposes a glass retort (3 quarts) may be employed, or the distilling apparatus shown in Fig. 60, in which *h* is a large glass retort resting on an iron stand or on a small coal furnace; *a* is Liebig's condenser, with an iron foot, *g*; *b* is a flask used as a receiver, which may be placed upon a stand or block, or if necessary in a bowl of cold water. The condenser, *a*, consists of a copper tube through which a glass tube passes,

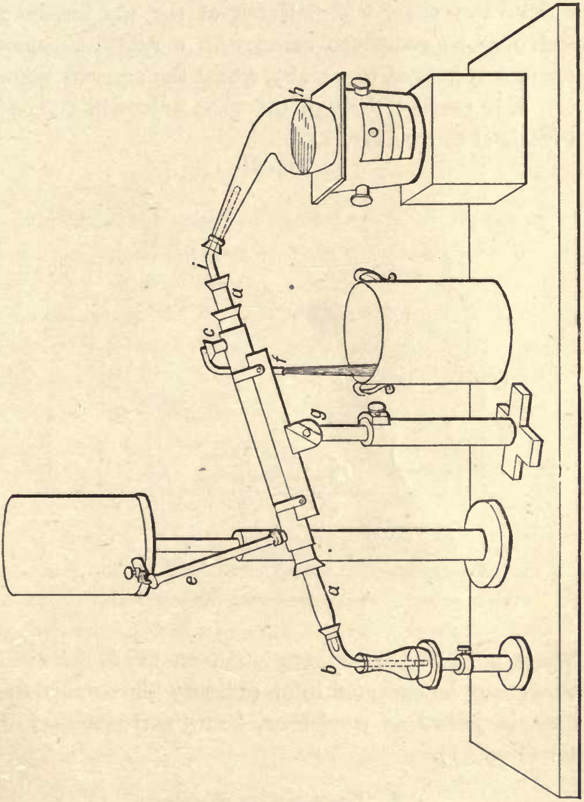
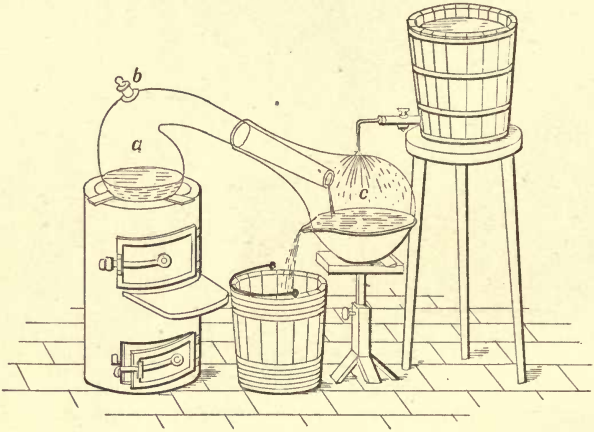


Fig. 60.

fitting water-tight at the ends. Both ends of the glass-tube are usually provided with corks, except at the connection with the flask. Now if cold water (put ice in the supply-vessel, if necessary) be allowed to flow continuously into the funnel tube, *e*, the copper tube will be filled with cold water, and the warm water will flow out at the top by the tube, *f* (which may be connected again with a rubber-tube, and the water thus conveyed to a sink), whilst the aqueous vapor from retort, *h*, in passing through the glass tube will be condensed and retained in receiver, *b*.

Fig. 61.



When a Liebig's condenser is not on hand, the distillation of water may be executed in an ordinary glass-retort, to which a flask is joined as condenser, being surrounded with cold water (Fig. 61).

2. Testing of Water.

The common tests for water,* supposed to be pure, are :

1. Evaporation to dryness. (Salts.)

---

* Rain water collected in the open air may, in many cases, be substituted for distilled water.

2. Test-paper. (Red and blue litmus paper.)
3. Perfectly clear lime-water. (Carbonic dioxide.)
4. Solution of silver nitrate. (Chlorine.)
5. Solution of barium chloride. (Sulphuric acid.)
6. Solution of ammonia oxalate. (Lime.)
7. Nessler's test* for ammonia.

The first should leave *no residue*, and the others should show *no reaction*. (A few drops of the reagent must be added to a portion of water in a clean test-tube.)

Preparation of Test Papers.

1. *Blue Litmus Paper.*—Digest 1 part of litmus of commerce with 6 parts of water, and filter the solution; divide the intensely blue filtrate into two equal parts; saturate the free alkali in the one part by repeatedly stirring with a glass rod dipped in very dilute sulphuric acid, until the color of the fluid just appears red; add now the other part of the blue filtrate, pour the whole fluid into a dish, and draw strips of filter paper through it; suspend these slips over threads, and leave them to dry. The color of the litmus paper must be uniform, and neither too light nor too dark.

2. *Reddened Litmus Paper.*—Stir blue solution of litmus with a glass rod dipped into dilute sulphuric acid, and repeat this process until the fluid has just turned directly red. Steep slips of paper in the solution and dry them as in 1.

3. *Turmeric Paper.*—Digest and heat 1 part of bruised turmeric root (or turmeric powder) with 4 parts of alcohol and 2 of water, filter the tincture obtained, and steep slips of fine paper in the filtrate. The dried slips must exhibit a fine yellow tint. Test paper must be kept in closed boxes, or in black bottles, away from light and fumes.

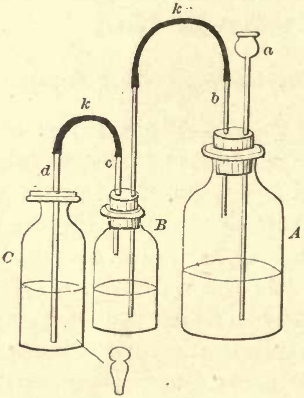
---

* Biniodide of mercury is dissolved in iodide of potassium, and the colorless solution rendered powerfully alkaline by the addition of soda or potassa hydrate. This reagent poured into water containing mere traces of ammonia produces a yellow to brown color.

3. Hydric Sulphide, Sulphohydric Acid, Sulphuretted Hydrogen $= SH_2$.

A colorless gas which should be evolved at the moment of using it. For this purpose monosulphide of iron, or ferrous sulphide FeS, is prepared by mixing intimately 5 parts of flowers of sulphur with 8 parts of iron filings, and bringing the mixture, in small portions at a time, into a red-hot Hessian crucible (around which, when supported on a brick in a furnace, a coal fire is built) which is covered with a piece of fire-brick until the whole mass glows. When cool, the sulphide of iron in fragments of the size of a pea, is placed in a bottle, *A*, Fig. 62, and covered with pure water. Through funnel tube, *a*, concentrated sulphuric acid is added by degrees, and the evolved gas can escape only through *b* into flask *B*, which should contain some water for washing the gas. From *B* the gas is forced through tubes *c* and *d* (connected by India-rubber tubes, *k*) into flask *C*, which contains the solution to be treated. Generally obtained by the reaction, $FeS + (H_2SO_4 + Aq.) = (FeSO_4 + Aq.) + H_2S$.

Fig. 62.



A very handy apparatus for generating H_2S, in small quantities, is Babo's, mounted on a stand with rubber connection, as shown in Fig. 63.

Fig. 64 represents a gas bulb for passing sulphide of hydrogen (or chlorine gas) into liquids in test-tubes. After being charged the orifice on the top is closed with a cork.

Fig. 63.

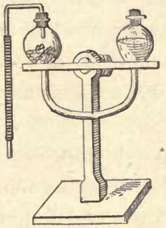
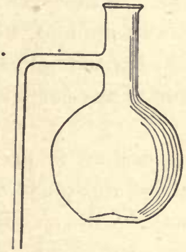
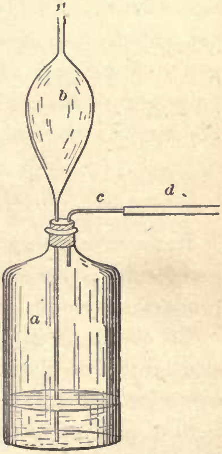


Fig. 64.



The following simple contrivance has lately been devised by Capanema* to saturate a solution with hydrosulphuric acid without the annoyance of the bad odor of the excess of gas. Fig. 65 represents the apparatus; *a* is a bottle to which is fitted a doubly perforated stopper provided with a pipette, *b*, with a large pear-shaped bulb, and a bent tube, *c*, communicating by means of rubber tube, *d*, with the gas generator. The liquid to be saturated or precipitated is introduced in the bottle, *a*, and the pipette at first drawn up, until the lower end of its tube is above the liquid. Hydrosulphuric acid is now allowed to pass in until the atmospheric air in the flask and pipette is displaced, and the pipette then pushed down until the lower end of its tube nearly touches the bottom of the flask. The pressure of the gas will force some of

Fig. 65.



---

* In Fresenius, Zeitschr. f. anal. Chemie, 1881, p. 519.

the liquid into the pipette. By cautious swinging of the apparatus, new portions of the liquid are successively brought in contact with the gas, and in consequence of its absorption, the liquid in the pipette descends, sometimes with great rapidity. The saturation or precipitation (of a metal) is completed whenever the liquid no longer descends from the pipette. The current of gas is then shut off, the whole briskly agitated, the pipette drawn up, and, when all the liquid has run out, carefully washed with distilled water, ejected from a wash-bottle, to free it from any particle of the precipitate which may adhere to it.

If it is desired to prevent the escape of odor entirely, the upper end of the pipette may be provided with an additional tube, charged with a loose pellet of cotton and a quantity of filter-paper saturated with a solution of acetate of lead (sugar of lead), which greedily absorbs the gas.

4. SULPHIDE OF AMMONIUM $(NH_4)_2S$.

Should be often freshly prepared, and preserved in well-stoppered bottles. It is obtained by conducting sulphydric acid gas $= H_2S$, into aqueous ammonia until the latter absorbs no more of the gas. The apparatus, Fig. 62, will serve for the purpose by the addition of a loose stopper to flask *C*, in which the aqueous ammonia is to be placed.

5. HYDROFLUORIC ACID HFl.

In experimenting with this acid, especially in a gaseous form, great care is necessary, since the fumes, when inhaled, may produce dangerous effects.

To obtain it in more or less concentrated liquid form, a small retort of platinum or lead is used, on which, during the operation, a helm is luted. The retort is previously charged with 1 part of finely powdered fluor-spar and 2 parts of concentrated sulphuric acid. After the charge is thoroughly mixed by a platinum spatula, heat is applied. If a dilute acid is desired, the receiver, consisting of a platinum dish, must contain some water and be well cooled from without with ice or a freezing mixture.

A glass plate may now be covered with etching-ground (consisting of 6 parts of gum mastic, 1 part asphaltum, and 1 part of wax), and parts of it removed with an etching needle (drawing). The glass plate thus prepared may now be acted upon (etched) either by the gaseous or liquid acid; in the former case the drawing is lustrous (like the original glass), while in the latter the drawing appears dull or opaque. The etching-ground can be removed with oil of turpentine.

For testing minerals for HFl with sulphuric acid, it is well to employ a platinum crucible, the cover of which has an opening in the middle upon which a piece of glass is placed; the crucible and contents may then be heated over a lamp. Many silicates containing fluorine, like topaz, give off no trace of fluorine in this way. To prove its presence 2 grams of the powdered mineral are mixed with caustic potash and a little liquid silicate of potash (water glass), and the whole fused in a silver crucible for a quarter of an hour. The cold mass is then dissolved in water, the silica precipitated with a solution of sal-ammoniac, and filtered off. To the filtrate, acidulated with HCl, we add a solution of chloride of calcium, and precipitate with ammonia the fluoride of calcium. This, after being well dried, is further tested with sulphuric acid.

6. WET REAGENTS GENERALLY. WATER = H_2O.

In all analytical operations for solutions of other reagents, etc., pure distilled water ought to be used.

Hydrochloric or *Muriatic acid* = HCl, both concentrated and diluted.

Nitric acid = HNO_3, both concentrated and diluted.

Aqua regia, nitro-muriatic acid, is a mixture of 2–4 parts of concentrated hydrochloric and 1 part of nitric acid.

Sulphuric acid (oil of vitriol) $= H_2SO_4$ or $SO_3 + H_2O$, concentrated and diluted with water.*

Common phosphoric acid or (Ortho-phosphoric acid) $=$ $P_2O_5 + 3H_2O$ or (H_3PO_4). It can easily be prepared from phosphorus and (diluted) nitric acid.

Ammonia. Ammonic hydrate. Liquor ammoniæ, AmHO $= NH_3HO = NH_4O$.

Carbonate of Ammonia. Ammonic carbonate (NH_4, CO_3).

Chloride of ammonia. Ammonic chloride. Sal-ammoniac $=$ AmCl.(N_4Cl).

Phosphate of soda. Sodic phosphate $= (Na_2HPO_4, 12H_2O)$. The commercial salt ought to be purified by solution in water and recrystallized by evaporation.

Nitrate of baryta, *Baric nitrate* $= Ba_2NO_3$.

Nitrate of silver, *Lunar caustic*, *Argentic nitrate* $= AgNO_3$.

Chloride of platinum $= PtCl_4$.

Place a fragment of platinum in a little aqua regia and set the vessel aside in a warm place, adding more acid from time to time if necessary, a solution of perchloride of platinum $=$ $PtCl_4$ results. Evaporate the solution to remove excess of acid, and complete the desiccation (drying) over a water-bath. Dissolve the residue in 10 parts of water as a reagent for detecting potassa in the presence of soda and lithia. It precipitates, however, also salts of ammonia.

Molybdate of Ammonia $= (NH_4)_2MoO_4$. It is obtained by pulverizing and roasting the native sulphide of molybdenum $=$ MoS_2, whereby molybdic tri-oxide, or anhydride $= MoO_3$, is formed; dissolve the latter in water, adding ammonia, filtering, evaporating, and crystallizing.

To prepare the molybdenum solution used for precipitating phosphoric and arsenic acids, 100 grams of molybdenum trioxide are dissolved in 50 c.c. ordinary aqueous ammonia, and 80 c.c. water, and pouring the solution into a mixture of 500

---

* In diluting "oil of vitriol" the acid must gradually, and little at a time, be poured into water; the reverse action may prove very dangerous.

c.c. nitric acid and 300 c.c. water, and if a precipitate forms it must be filtered off.

Oxalate of ammonia or *Oxalate of ammonium* $= 2(NH_4)_2C_2O_4$, can be synthetically prepared according to the following formula:

$$\underset{\substack{\text{Oxalic}\\ \text{acid.}}}{2H_2C_2O_4} + \underset{\substack{\text{Carbonate of}\\ \text{ammonium.}}}{N_4H_{16}C_3O_8} = \underset{\substack{\text{Oxalate of}\\ \text{ammonium.}}}{2(NH_4)2C_2O_4} + \underset{\substack{\text{Carbonic}\\ \text{di-oxide}\\ \text{set free.}}}{3CO_2} + \underset{\text{Water.}}{2H_2O}$$

To a nearly boiling solution of 1 part of oxalic acid in about 8 of water, add carbonate of ammonium until the liquid is neutral to test-papers, filter while hot, and set aside for the formation of crystals. The mother liquors are further evaporated to crystallization. To obtain the pure salt it ought to be re-crystallized a second time. Dissolve 1 part of the pure salt in 30 parts of water.

Caustic potash or *Potassic hydrate* $=$ KHO or K_2O,H_2O. Dissolve some sticks of potassa in water, and separate the clear solution from the sediment (SiO_2,Al_2O_3) by decantation.

Chloride of barium. *Baric chloride* $= BaCl_2$.

CHAPTER IV.

BLOWPIPE ANALYSIS AND APPARATUS.

1. THE MOUTH BLOWPIPE.

THIS simple instrument of very ancient origin is a most convenient apparatus for heating, melting, volatilizing, oxidizing, or reducing mineral substances on a small scale. By blowing air into the interior of a flame, always a burning gas, *i. e.*, carbo-hydrogen, the combustion is of course rendered more complete and rapid, and hence the intensity of heat increased. It is of the greatest service to the chemist, mineralogist, and practical miner, for the recognition of minerals and ores, and the detection of certain chemical constituents, such as metals and others.

The improved chemical blowpipe, Fig. 66, consists of a chamber, *c*, near the extremity of the instrument, which collects the condensed moisture; this is connected with two tubes with ground joints. To the longer one, *a*, is attached a mouthpiece for blowing, of different shapes, and made of horn or ivory. The shorter exit-tube is generally furnished with a movable tip, *e*, made of solid platinum, which may be easily cleansed from soot collecting upon it by simply heating it in the flame of a spirit-lamp.

Fig. 66.

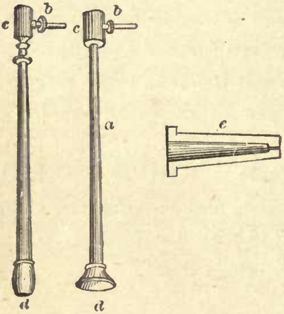


Fig. 67.

Fig. 68.

The best shape of the tip is that represented in its natural size, Fig. 66, at *e;* it always produces a well-defined and conical flame. Fig. 67 represents Plattner's blowpipe,* with gas-blast attachment, and marked regulating stopcock. The above

---

* This convenient blowpipe is used at Harvard College laboratory, and is highly recommended.

attachment is sold separate from the rest of the blowpipe, and can be fastened to other blowpipes.

Fig. 68 is Fletcher's hot-blast chemical blowpipe—a pattern of the ordinary chemical blowpipe with the patent hot-blast arrangement.

2. Blowing with the Blowpipe.

To keep up a continuous current of air through the blowpipe is at first a difficult task. This, however, is easily overcome by attending to the following directions: Closing the mouth, keep the cheeks distended with air during a number of inspirations and expirations performed through the nostrils. Next attempt the same with the ivory mouth-piece of the blowpipe between the lips. Now, as this provides an exit for the air in the mouth, unless a fresh supply be kept up from the lungs, the cheeks will soon collapse; in order to prevent this, at the moment of inspiration through the nose, a sufficient quantity of air must be allowed to enter the mouth to preserve their distension. In this way the air in the mouth is constantly subject to the same compression, and flows in a uniform manner from the little orifice. Having thus acquired the habit of keeping up a continued stream of air from the blowpipe, the beak with platinum cap is now brought within the border of the flame.

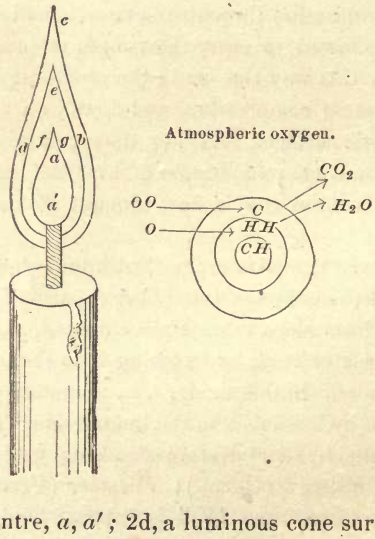
A good way to acquire a practical knowledge of this instrument, and of the effects of the different parts of the flame, is to convert, for instance, a minute piece of lead, placed upon charcoal, into oxide of lead, by exposing it to the outer flame, and afterwards to reduce this oxide, *i. e.*, to restore it to its original metallic state by heating it in the inner flame. The reduction is much facilitated by an admixture of soda or cyanide of potassium.

Flaming, *Flattern* (Germ.); *Flamber* (French).—In many cases when a transparent bead is intermittingly heated in the flame, or is repeatedly taken out of the flame, peculiar effects are obtained. This operation has obtained the name of "flaming." Clear beads frequently become opaque, milk-white, or even colored. This depends upon the fact that certain compounds which dissolve at a high temperature separate out on being heated to a somewhat lower temperature, appearing as peculiar crystals, which are sufficiently well formed in most cases to be visible under the microscope when the bead has been flattened whilst hot, or when it has been dissolved in dilute acid so as to isolate the crystals.

3. The Blowpipe Flame.

The blowpipe serves to conduct a continuous fine current of air into a gas-flame, or into the flame of a candle or oil lamp. The flame of a candle (and equally so that of gas or of an oil lamp), burning under ordinary circumstances, is seen to consist of three distinct parts, as shown in Fig. 69, viz., 1st, a dark nucleus in the centre, a, a'; 2d, a luminous cone surrounding this nucleus, e, f, g; and 3d, a feebly luminous mantle encircling the whole flame, b, c, d. The dark *nucleus* is formed by the gases which the heat evolves from the tallow or oil, and which

Fig. 69.



cannot burn here for want of oxygen. In the *luminous cone* these gases come in contact with a certain amount of air, insufficient for their complete combustion. In this part, therefore, it is principally the hydrogen of the *carbides of hydrogen* evolved which burns, while the carbon separates in a state of intense ignition, thus imparting to the flame the highly luminous appearance observed. In the outer coat the access of air is no longer limited, and all the gases not yet burned are consumed here. This part of the flame is the hottest; oxidizable bodies oxidize therefore with the greatest possible rapidity when placed in it, since all the conditions of oxidation are here united, viz., high temperature and an unlimited supply of oxygen. This outer part of the flame is therefore called the *oxidizing flame.*

On the other hand, oxides having a tendency to yield up their oxygen, suffer *reduction* when placed within the *luminous* part of the flame, the oxygen being withdrawn from them by the carbon and the still unconsumed carbide of hydrogen present in this sphere. The luminous part of the flame is therefore called the *reducing flame.* The effect of blowing a fine current of air across the flame is, first, to alter the shape of the latter, which, from tending upward, is now driven sideways in the direction of the blast, and at the same time lengthened and narrowed; and, in the second place, to extend the sphere of combustion from the outer to the inner part. As the latter circumstance causes an extraordinary increase of the heat of the flame, and the former a concentration of that heat within narrower limits, it is easy to understand the exceedingly energetic action of the blowpipe flame. The way of holding the blowpipe, and the nature of the current, will always depend upon the precise object in view, viz., whether the operator wants a *reducing*, or an *oxidizing* flame. The easiest way of producing efficient flames of both kinds is by means of coal-gas delivered from a tube. The task of keeping the blowpipe steadily in the proper position may be greatly facilitated by resting that instrument firmly upon some movable metallic support, such as, for instance, Bunsen's gas-lamp, Fig. 83.

Fig. 70 shows the flame for reducing, and Fig. 71 the flame for oxidizing.

Fig. 70.

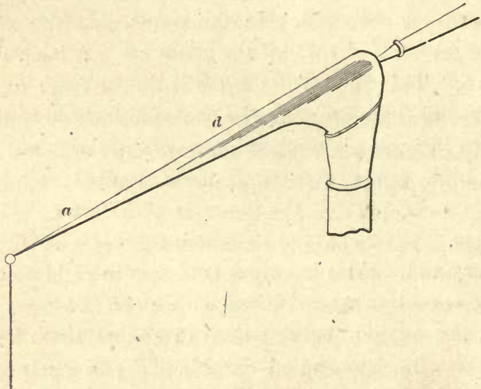
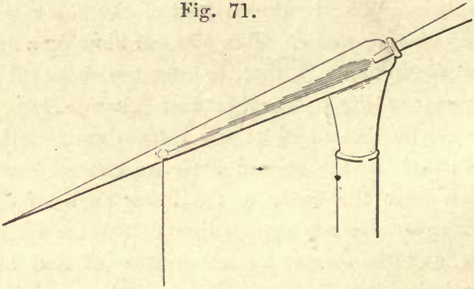


Fig. 71.



The reducing flame is produced by keeping the tip of the blowpipe just on the border of a tolerably strong gas-flame, and driving a moderate blast across it. The resulting mixture of the air with the gas is imperfect, and there remains between the inner bluish part of the flame, and the outer barely visible part, a luminous and reducing zone, of which the hottest point lies somewhat beyond the apex of the inner cone.

To produce the *oxidizing* flame, the gas is lowered, the tip of the blowpipe pushed a little further into the flame, and the strength of the current somewhat increased. This serves to effect an intimate mixture of the air and gas, and an inner pointed bluish cone, slightly luminous towards the apex, is formed and surrounded by a thin, pointed, light bluish, barely visible mantle. The hottest part of the flame is at the apex of the inner cone. Difficultly fusible bodies are exposed to this part to effect their fusion ; but bodies to be oxidized are held a little beyond the apex, that there may be no want of air for their combustion.

4. Supports for the Assay.

I. *Charcoal*, well burnt and of uniform texture, forms an ordinary support for assays. The piece should be about six inches long, one end wrapped in paper, and in the other a small cavity must be cut, half the size of a pea, either with the point of a knife, or by means of charcoal borers, Figs. 72, 73, and 74. Fig. 75 represents two forms, after Plattner, with wooden handles ; *a* is club shaped, *b* is four cornered. The heating of an assay on charcoal in the blowpipe flame is illustrated in Fig. 76.

Fig. 72.

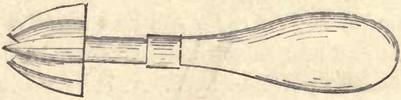


Fig. 73.

Fig. 74.

Fig. 75.

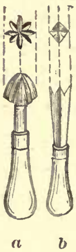
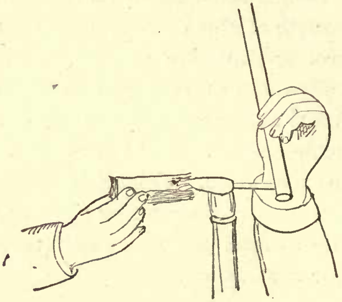


Fig. 76.



II. *Porcelain Supporters.*—Foster and Fletcher in England use pieces of glazed porcelain made of the size and shape of charcoal supporters. On the end of these porcelain plates are cavities into which small pieces of charcoal are fitted, upon the surface of which the blowpipe assay is placed. The whole surface of the porcelain is blackened over a lamp. This coat of soot takes up and exhibits films or coatings as well as charcoal.

III. *Aluminium Plate as a Support in Blowpipe Analysis.*—The latest and best substitute for charcoal is aluminium foil, first introduced by Colonel W. A. Ross.* A strip of such foil should be 5 inches long, $1\frac{1}{2}$ inch wide, and about the thickness of a ten cent piece; one end should be turned up to form a ledge, as directed by Ross, this ledge being between $\frac{1}{2}$ to $\frac{3}{4}$ inch wide, and making rather less than a right angle with the rest of the plate. Sheet aluminium, even of much greater thickness than this, can be bent easily without any cracking, by heating it in a Bunsen burner, and working it while hot.†

---

* Alphabetical Manual of Blowpipe Analysis by Lieut.-Colonel W. A. Ross. London: Trübner & Co., 1880.

† Messrs. Johnson, Matthey & Co. in London are recommended as dealers by Col. Ross. They furnish it of any thickness or dimensions for 7*s.* 6*d.* per ounce. Some German aluminium plates of somewhat lesser thickness the writer found impure, and fusing too easily over a Bunsen burner.

After turning up the ledge, and rounding off the edges and corners with a file, the plate should be well scoured with bone ash and polished with leather and whiting, and may then be used for a long time.

The test samples are either placed directly upon the metallic edge, or are received on a small piece of charcoal half an inch square, and of the thickness of a penny piece, which can easily be cut and kept ready in large numbers.

When in use the plate is best held with spring forceps, described by Ross, though other forceps can be made to serve the purpose, the handles being covered with felt or flannel, as they get very hot. It is held so as to be almost vertical, only just enough inclined to prevent the assay and the slip of charcoal from falling off the ledge. A little practice enables the worker to hold it quite steadily with as much ease as he does the ordinary piece of charcoal. The plate, it is said, is not only a great gain as to portability, cleanliness, and economy, but also gives, in most cases, much better indications of the volatile substances sought for, which collect upon the larger vertical portion of the plate. Such a plate will last any length of time, as the hottest blowpipe flame, even one worked with a small handblower, does it no injury, and there is scarcely any substance (except melted gold) which may not be heated directly upon it with perfect safety. The one side being kept for sublimates, the other may be used for such purposes as calcining sulphides, etc., before testing in beads, for which it is far superior to charcoal, especially in the case of very fusible minerals. A fragment of the substance about half the size of a small pea, or if it decrepitates, a corresponding amount of powder made to a paste with water, is laid upon the ledge close up to the angle.

The following are the principal advantages of aluminium over charcoal, according to W. M. Hutchings:—

1. It enables us to get several sublimates in succession from the same fragment of substance. Heated very gently on the

bare plate, only the most volatile constituents are given off.* As the heat increases, more and more are given off, but a limit is reached beyond which nothing is obtained, the less volatile constituents not being given off at all, or only very slightly, as long as the substance is cooled by lying directly on the aluminium. The same fragment being then placed on a slip of charcoal on the ledge, these less volatile constituents are obtained in the separate sublimates.

2. The sublimates are generally much more concentrated on the aluminium, as compared with ordinary charcoal, which, when exposed to the flame for any length of time, gets red hot some distance in front of the assay. The aluminium remains comparatively cool; and the vertical surface prevents the sublimates being swept along by the blast as much as on the nearly horizontal charcoal.

3. When the sublimate is once formed, the aluminium has no further action upon it, and many very characteristic changes may be observed by applying an oxidizing or reducing flame, most of which cannot be obtained at all on charcoal, partly because its being black would hide them, but chiefly because it immediately begins to glow under the sublimates when the flame is applied to them.

5. FUEL LAMPS.

1. *Good stearine candles* will answer for most purposes.

2. *Olive Oil.*—A much better fuel is *olive oil* or *rape-seed oil*, burnt in a brass lamp having a circular neck. This and the opening for filling the lamp are covered by screw caps, preventing all leakage.

Fig. 77 represents the form of blowpipe lamp invented by Berzelius, and improved by Plattner.

Fig. 78 is the Freiburg pattern of the same style of lamp as the preceding, but revolves on its axis, permitting the flame from the blowpipe to be directed at any angle.

---

* When first applying heat, the point of the blowpipe flame ought to be held at a distance of 1–2 cm. from the assay.

Another convenient lamp for using oil or petroleum is Fletcher's improved blowpipe lamp, Fig. 79.

Fig. 77.

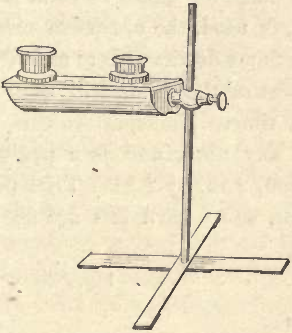
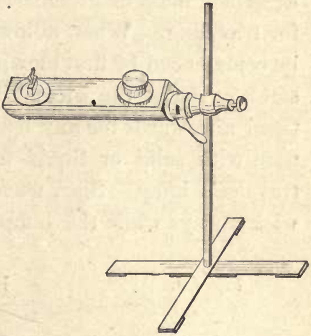
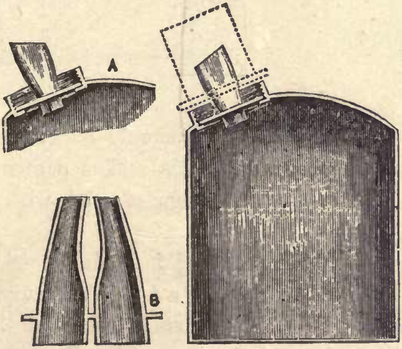


Fig. 78.



The wick holder will be found one of the best forms ever made, in addition to the fact that the angle can be adjusted as required by simply revolving it in the fixed collar. The wick holder, *A*, lifts out for refilling. The lamp is engraved half size.

Fig. 79.



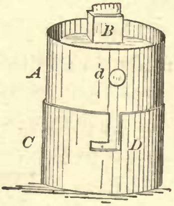
An ordinary *alcohol lamp* of glass, Fig. 80, may also be used for blowpipe experiments, if the alcohol is mixed with turpentine or benzol (1 part of turpentine or 3 parts of benzol to 12 parts of strong alcohol of 80 to 90 per cent.).

3. *Solid Fats.—Lamps filled with solid fats, such as tallow, paraffine, etc.*, have lately been introduced, which are convenient in traveling. Fig. 81 exhibits a modified form of the previously described lamp of Fletcher. It is made for tallow or solid fats for traveling. When tallow, etc., is used, the operation must be commenced by first blowing the flame downwards to melt the solid fat round the wick. The heat of the flame will keep it fused afterwards for any length of time. This pattern can be used with solid or liquid fats of any kind, and is a perfect traveler's lamp. Size, when closed, 2 in. by 2 in. Trim the wick always while the lamp is hot, when hard fats are used.

Fig. 80.

Fig. 81.

Fig. 82.



The curved bottom of the lamp should stand on the open end of the cover when in use. This makes a steady base, and admits of adjustment of the angle of wick without reversing or re-trimming.

In Foster's lamp, Fig. 82, solid fat is likewise used, *e. g.*, paraffine or tallow. It serves as a traveler's lamp, and consists of a cylindrical vessel, *A*, to which the wick holder, *B*, is soldered. When in use, the flame is at first directed downwards to melt the fat next to the wick, after which it yields a steady flame for hours. The cover, *C*, forms also a support, and is fastened by a bayonet-socket, *D* (*d*).

6. Illuminating Gas.

The most convenient combustible for blowpipe work is illuminating gas. The burner used is the ordinary Bunsen gas-burner, Fig. 83. For this purpose it is provided with an extra tube, *g h*, to slip over the small gas jet at *j*, in the interior of the burner, *e f*, in such a manner as to shut off all excess of air at *a*. The tube is flattened at the top, see *f*, and made a trifle lower at one side, so that the blowpipe flame may be directed downward when necessary. The gas is then lighted at the flattened end, *h*. A cock, at the foot of the burner for regulating the flow of the gas is useful.

When testing substances for sulphur, the gas flame should not be employed, since the ordinary coal gas contains usually enough of sulphur to vitiate the results.

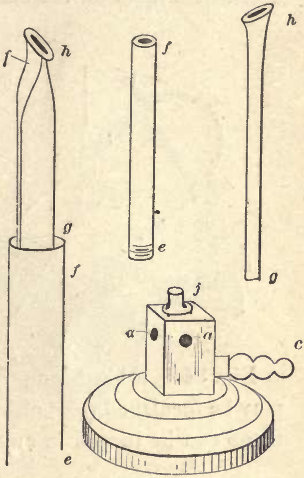


Fig. 83.

7. Fixed Blowpipes and Blast-lamps.

For many experiments it is of great advantage to have the blowpipe fixed to a support in order to leave the hands free for manipulation. The following, Fig. 84, represents an improved Herapath blowpipe for general use. This is a modification of the well-known Herapath, from which it differs in its great simplicity, and in its power of adjustment in any possible position. The jet tube may be raised or lowered to any height, and turned in any direction. A touch will direct the flame on any point while the blowpipe stands in the same position on the table; there being no necessity for raising, lowering, or adjusting work before it.

Fig. 85, letter *c*, represents a blowing machine to be worked either by the hand or the foot; it forces air into the expanding regulator, *b*, and thence in a regular blast into the blowpipe, *a*. The attachment on the stand permits motion in any direction.

Fig. 84.

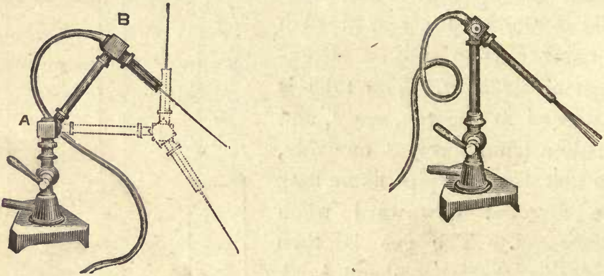


Fig. 86 is a blast-lamp for gas; brass, small size. The blast may be furnished from either the mouth or small bellows. The flame can be turned in any direction.

Fig. 85.

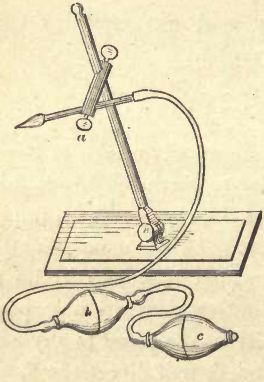


Fig. 86.

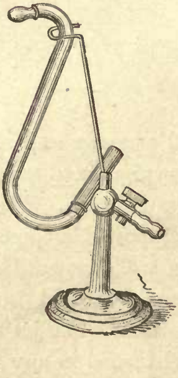


Fig. 87, Fletcher's special Chemical Blowpipe with folding stand, adjustable at any height or angle. It can be used either with the mouth, or the small hand blower can be attached and the blowing done by the fingers. With this blowpipe is supplied one jet with, and one without the patent coil, to enable a larger variety of flame to be obtained. The lamp or a weight should be placed on the stand when in use. The blower when not in use shuts up flat for the pocket. The pressure of air is adjusted by a delicate lever tap on the air tube.

Fig. 87.

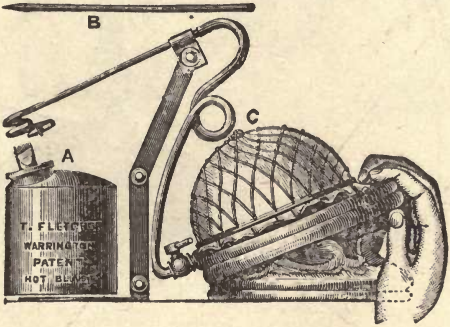


Fig. 88 represents double bellows for hand use; two rubber bulbs for use with the blowpipe or other small blasts.

Fig. 88.

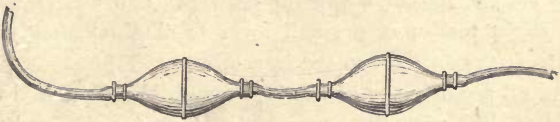


Fig. 89 is Bunsen's improved gas-blowpipe and blast-lamp united. The nozzle of the blowpipe, *a*, is surrounded with a brass casing, *b*. The blast from a double bellows is thrown through a flame of illuminating gas, giving sufficient heat to ignite a crucible, and can also be used as a glass-blower's lamp or blowpipe. The flame can be turned in any direction. Three different brass nozzles, adapted for different purposes, accompany each.

The following devices, invented and patented by Thomas Fletcher, are very excellent patterns of blowpipes :—

Fig. 89.

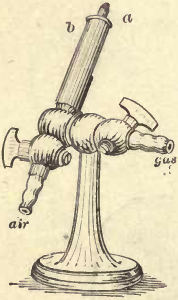
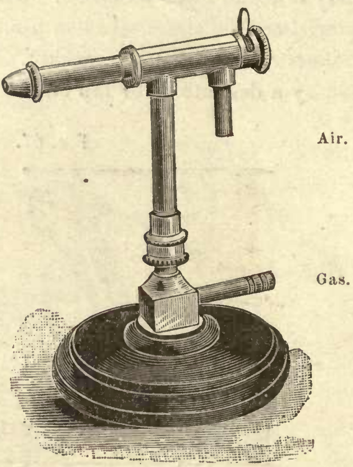


Fig. 90.



1*st*. *The Automaton Blowpipe.*—This blowpipe (Fig. 90) is mounted on a stand, with a universal ball-joint, so as to enable it to be used at any angle or in any position. The ball-joint can be secured fast in position.

It is simple, self-adjusting for both gas and air, requiring only a slight motion of a small lever to obtain instantly any flame, from the smallest to the largest.

It has all the delicacy of the best mouth blowpipe used with the utmost skill, with the power and advantages obtained with a mechanical blower.

A slight motion from side to side of the pin *A* changes the power and character of the flame instantly as required, or stops the power without extinguishing the flame, the blowpipe being both self-lighting and self-adjusting.

2*d*. *The Automaton Hand Blowpipe.*—Fig. 91 shows the hand blowpipe, with both tubes underneath, and will be found the most convenient pattern for small work, brazing, annealing, etc.

The power of a blowpipe depends not only on the size of the air-jet and gas supply, but on the *pressure* of the air supplied by the blower. The foot-blowers are so perfect for all blowpipe work as to leave nothing to be desired. After ten years they remain beyond the possibility of improvement in the slightest detail, unapproached by any other form.

Fig. 91.

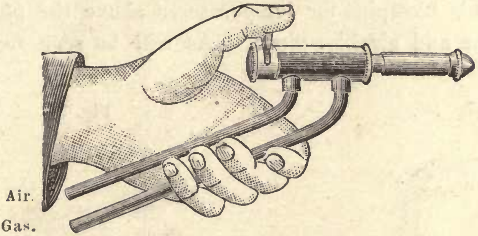
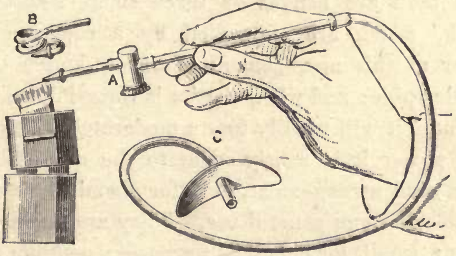


Fig. 92.



3*d*. *Fletcher's New Patent Mouth Blowpipe.*—Fig. 92 represents this blowpipe. The improved nickel-plated mouthpiece, *c*, is said to cause no strain on the lips, while the tongue has the necessary control over the opening.

The blowpipe proper is held as a pencil, the chamber, *A*, on the stem stops all condensed moisture, and prevents the heat traveling up the end; it is sold with two tips, *A*, for cold, and *B*, hot blast. It might easily be fastened to an immovable stand, and connected with a hand- or foot-blower.

4th. Fletcher's Hot-Blast Blowpipe. — Figs. 93 and 94 represent this blowpipe for temperatures above the power of ordinary gas and air blowpipes. As will be seen from the engraving, the air-pipe is coiled round the gas-pipe in a spiral form, and both are heated by three small Bunsen burners underneath, which are controlled by a separate stopcock. The power of this arrangement is about double that of an ordinary blowpipe; and when the jet is turned down to a small point of flame it will readily fuse a moderately thick platinum wire. In power it is nearly equal to the oxy-hydrogen jet, and it is a good arrangement, both for chemical purposes and also for soldering and general use. They are made with three sizes of jet: small, for chemical purposes; medium and large, for soldering, etc.; and the size of jet or the purpose for which it is required should be specified in ordering.

Fig. 93.

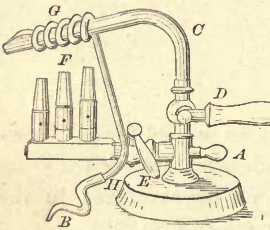
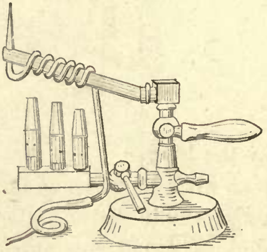


Fig. 94.

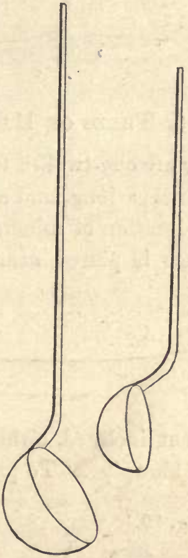


8. PLATINUM APPARATUS AND APPLIANCES.

Platinum wire is used as a support when an assay is to be fused with borax or salt of phosphorus (Bx., S. Ph.), etc., to ascertain the color of the beads produced. One extremity of the wire, about three inches long and of the thickness of horsehair, is bent into a hook or is coiled. This wire may be fused into a small glass-tube for a handle (Fig. 95). Before being used, it should be thoroughly cleaned, by placing it in dilute sulphuric acid and rinsing with water.

Fig. 95.

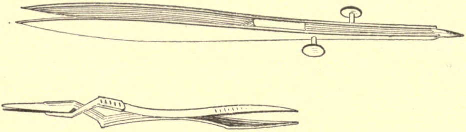
Fig. 96.



Platinum spoons (Fig. 96, natural size) are very useful for melting assays and other operations. A glass, wooden or cork-handle should be adapted to it. A piece of platinum foil, properly bent, may answer for the same purpose as a spoon.

Forceps with platinum points (Fig. 97) to hold small laminæ of minerals in the flame to ascertain their fusibility.

Fig. 97.



9. Tubes of Hard Glass, free from Lead.

They are one-twelfth to one-fourth inch in diameter, and four to six inches long, and are absolutely necessary. They serve for the ignition of mineral fragments in a current of air. The substance is placed near the end, and the tube is then held somewhat inclined, either in the flame of a Bunsen burner or of the blowpipe. To prevent the falling out of the substance the tube may be slightly bent as represented in Fig. 98. For each new operation a clean tube must be employed.

Fig. 98.

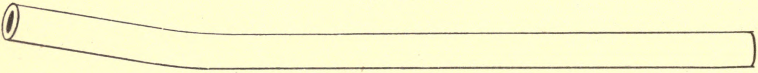


Fig. 99.

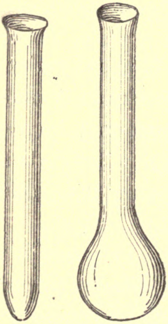
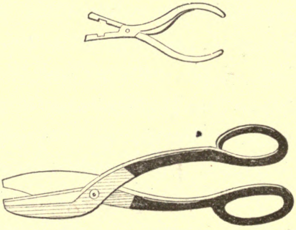


Fig. 100.



Closed tubes and glass bulb-tubes, or matrasses (Fig. 99), are used for heating bodies out of contact with air. They are easily made of hard glass tubing before a glass-blower's lamp, or a Bunsen-burner connected with a blast, as previously described. For chemical experiments a variety of *soft glass* tubing ought to be on hand; which, in the flame of a blast-lamp, can be readily bent or drawn out and sealed at one end.

A triangular file is used for cutting glass. A notch is cut in one side of the tube, when it is easily broken in two.

Watch-glasses are used for keeping powdered minerals and for various other purposes.

For other accessory apparatus—mortars, flasks, test-tubes, etc.—see *Laboratory Apparatus and Manipulations*, page 38–58; and for acids and other chemicals, see *Wet Reagents*, page 59–69.

10. CUTTING PLIERS; STEEL MAGNET; MAGNETIC NEEDLE.

Cutting pliers (Fig. 100) are useful for detaching fragments from mineral specimens.

A common *steel magnet* (Fig. 5, page 39) serves to recognize magnetic bodies.

A *magnetic needle* (compass, Fig. 6, page 39) is useful for delicate determinations.

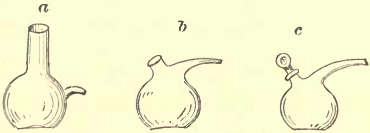
11. BLOWPIPE REAGENTS.

The quantities used are small and there are but few, which, however, have to be scrupulously pure. The dry preparations are generally purchased from dealers.

Carbonate of soda, called simply *soda*, Na_2CO_3. *Biborate of soda* or *borax* with water of crystallization $= Na_2O, 2B_2O_3 + 10H_2O$ or $Na_2B_4O_7 + 10H_2O$, and fused boric acid, $= B_2O_3$, for the detection of copper in lead. Phosphate of soda and ammonia, or salt of phosphorus or microcosmic salt $=$ $(Na_2O, NH_4O, H_2O)\ P_2O_5 + 4H_2O$ or $Na(NH_4)HPO_4 + 4H_2O)$. Cyanide of potassium $= KCN$ or KCy (a *dangerous* *poison*). Bisulphate of potash or acid potassium sulphate $HKSO_4$, or strong H_2SO_4. Nitrate of potash—saltpetre—K_2O, N_2O_5, or KNO_3. Iodide of potassium, KI. Sulphur, S. Flowers of sulphur. Nitrate of cobalt, $Co(NO_3)_2 + 6H_2O$ in solution. The crystals of the nitrate are dissolved in ten parts of water. For use the cobalt solution is most conveniently kept in dropping glasses.

Fig. 101, *a*, *b*, *c*, show different forms of this apparatus. *a*, according to Bunsen; *b* and *c*, according to Schuster, with and without a ground glass-stopper.

Fig. 101.



Oxalate of nickel, or nitrate of nickel, $Ni(NO_3)_2 + 6H_2O$. Black oxide of copper, or cupric oxide $= CuO$. Fluoride of calcium (Fluor spar) $= CaF_2$. The powder must be deprived of water by ignition. Nitroprusside of sodium for detecting sulphur.

Iron: Fine sifted iron filings. Ferrum pulveratum, or *alcoholisatum* of the druggists.

Lead: Pure lead or proof lead.

Tin: Strips or tin-foil.

Zinc: Strips of common sheet zinc.

Magnesium: Bits of foil or wire are useful in detecting phosphoric acid.

Silver-foil for the detection of sulphur. A smooth bright silver coin, however, will answer every purpose.

Bone-ash: A little cup of bone ashes, called a *cupel*, is used for the cupellation of gold and silver.

Test-papers: Blue litmus paper, red litmus paper, turmeric paper, and Brazil wood paper.

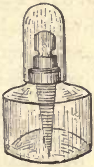
Charcoal.

Aluminium plate.

A small alcohol lamp.

Bottle for hydrochloric acid to test for carbonates, with a ground, tight glass stopper, reaching nearly to the bottom, thus enabling one to withdraw and use a single drop of acid. It may also be used for cobalt solution, Fig. 102.

Fig. 102.



12. Preliminary Tests of Inorganic Solid Substances.

The substances must be dry and in the form of fine powders. In most of the following experiments, the blowpipe may be replaced by a Bunsen burner. The beads must be examined both hot and cold.

1. Easily volatilized when heated upon charcoal (or upon platinum foil or in a dry test-tube).	Water; compounds of ammonia, mercury, and some of arsenic. Sulphur and its acids. Carbon burns by ignition in the air; all organic compounds are decomposed when heated, most of them with separation of carbon (blackening).
2. Deflagrate when heated upon charcoal platinum.	Nitrates, chlorates, iodates, bromates, etc.; common salt, and other salts, as likewise many minerals, *decrepitate*.
3. Fusible without volatilizing and without changing color.	Most *salts of the alkalies* and some of those of the *alkaline earths*. After intense ignition in the R. F. they color moist tumeric paper brown.
4. B. B. infusible, or difficultly fusible, without changing color.	The *earths* and their salts; most of the *alkaline earths* and their salts. When heated they glow with white light. The *earths* proper show no alkaline reaction after ignition. *Silica* and many of its compounds. Metals: Fe, Ni, Co, Pl, Mo, W, Pd, Ir, Rh.

5. Give when ignited with soda or soda and cyanide of potassium in the R. F. upon charcoal, or the luminous flame of a Bunsen burner.	*a. Garlic odor:* Most compounds of arsenic. *b. Hepar:* All compounds of sulphur. The mass when moistened blackens silver, and with acids develops sulphide of hydrogen. *c. Metallic grains:* Sn, Ag, Cu, Au. Gray *magnetic* powder: Fe, Ni, Co. Non-magnetic: Mo, W, Pl, Ir. Brittle: Sb, Bi. Malleable: Pb. Incrustation: Zn (white), Cd (brown).
6. Give, when heated in a glass open at both ends, and held obliquely.	*a. Odorous gases: Metallic* sulphides, of burning sulphur. Selenides, of decaying radishes. Arsenides, of garlic. Some ammoniacal salts yield NH_3 turning moistened red litmus paper blue. *b. Metallic coating:* Mercury and arsenic compounds. *c. White coating:* Metallic arsenides, antimonides, sulphide of lead, some salts of ammonia, such as sal-ammoniac.
7. Color the non-luminous flame of a Bunsen gas-lamp (O. F.).	*a. Yellow:* Na. *b. Violet:* K, Cs, Rb. *c. Crimson:* Li, Sr. *d. Blue:* As, Sb, Pb, Se. *e. Green:* Boracic acid; borates after moistening with sulphuric acid.
8. With phosphorus salt or borax upon platinum wire in O. F. and R. F.	*a. Colorless bead:* Silica. *b. Yellowish brown or reddish:* Iron. *c. Amethyst color:* in O. F. (not in R. F.) manganese. *d. Blue:* copper (in the O. F. only), cobalt. *e. Yellowish-green:* Chromium.

CHAPTER V.

REACTIONS OF OXIDES WITH GENERAL REAGENTS.

THE following reactions of oxides with borax and salt of phosphorus are taken from Wurtz's Dictionnaire de Chemie, vol. i., art. Chalumeau; the others from Landauer's Löthrohranalyse, 2d edit., Berlin, 1881.

1. BEHAVIOR OF METALLIC OXIDES WITH BORAX.

Color of the bead.	In the oxidizing flame.		In the reduction flame.	
	Hot.	Cold.	Hot.	Cold.
Colorless.	Si, Al, Su, Ba, Sr Ca, Mg, Gl, Y, Zr, Th, La, Te, Ta, Nb, W, Mo, Ti, Zn, Cd, Pb, Bi, Sb, only in s. q. or yellow.	Si, Al, Sn, Ba, Sr, Ca, Mg, Gl, Y, Zr, Th, La, Te, Ta, Nb, Ti, W, Mo, Zn, Cd, Pb, Mo, Zn, Ag, white by fl., Fe in s. q.	Si, Al, Sn, Ba, Sr, Ca, Mg, Gl, Y, Zr, Th, La, De, Mn, Nb, only in s. q., or else gray and op., Ag, Zn, Cd. Pb, Bi, Sb. Ni, Te by c. b. or else gray and op.	Si, Al, Sn, Di, Mn, Ba, Sr, Ca, Mg, Gl, Y, Zr, Th, (saturated), La, Ce, Ta, white and op. by fl., Nb, in s. q., or else gray and op., Ag, Zn, Cd, Pb, Bi, Sb, Ni, Te, by c. b., or else gray and op., Fe, in s. q.
Gray and opaque.	"	"	Ag, Zn, Cd, Pb, Bi, Sb, Ni, Te, especially cold and by little blowing, or else colorless, Nb, in s. q.	Ag, Zn, Cd, Pb, Bi, Sb, Ni, Te, by blowing little, or else colorless; Nb, in s. q.
Very pale yellow.	Ag, in s. q.	Ag, in l. q. by fl.	"	"
Pale yellow.	Ag, Cd, Zn, in l. q.	"	"	"
Yellow.	Ti, W, Pb, Sb, Mo, in l. q., U, in s. q.	Va, Fe, Ce, white op. by fl., U, yellow, op. by fl.	Ti, in s. q. or else bluish-violet, Mo, in s. q., in l. q. brown, W, Va.	Mo in l. q. op., and brown, W. in l. q. brown.
Orange.	Cr, Fe, in l. q., Bi, in l. q.	"	U.	"
Red.	Ce	"	"	"
Deep red.	Fe, in l. q.	Mn (violet-red).	"	"
Brownish-red.	Cr, U	Ni	Cu by blowing little (muddy).	Cu, by blowing little (muddy).
Violet.	Mn, Ni, Di	Di	"	Ti, op. by fl.
Blue.	Co	Co, Cu green when getting cold.	Co	Co, Cu, nearly colorless by c. b.
Green.	Cu	Cr, yellowish when getting cold.	Fe, Cr, brownish. Cu, nearly colorless by c. b.	Fe, U, bottle-green, Cr, Va, emerald-green.

NOTE.—Abbreviations employed: s. q., small quantity; l. q., large quantity; fl., by flaming; c. b., continued blowing; op., opaque.

2. BEHAVIOR OF METALLIC OXIDES WITH SALT OF PHOSPHORUS.

Color of the bead.	In the oxidizing flame.		In the reduction flame.	
	Hot.	Cold.	Hot.	Cold.
Colorless, a portion of the substance undissolved (silica skeleton).	Si	Si	Si	Si
Colorless.	Al, Sn, Ba, Ca, Mg, Gl, Y, Zr, Th, La, Nb, Te, in all proportions; Ta, Ti, W, Zn, Cd, Pb, Bi, Sb, in s. q. or else more or less yellow.	Al, Sn, Ba, Sr, Ca, Mg, Gl, Y, Zr, Th, La, Te, W, Zn, Cd, Pb, Bi, Sb, Fe, in s. q.	Al, Sn, Ba, Sr, Ca, Mg, Gl, Y, Zr, Th, La, Ce, Di, Mn, Ta, Ag, Zn, Cd, Pb, Bi, Sb, Ni, Te, by very c. b., or else gray and op.	Al, Sn, Ba, Sr, Co, Mg, Gl, Y, Zr, Th (saturated), La, op. by fl. Ce, Di, Mn, Ta, Ag, Zn, Cd, Pb, Bi, Sb, Ni, Te, by c. b. or else gray and op. Fe in s. q.
Gray and opaque.	"	"	Ag, Zn, Cd, Pb, Bi, Sb, especially when cold, Te, Ni.	Ag, Zn, Cd, Pb, Bi, Sb, Te, Ni.
Pale yellow.	Sb, Zn, in l. q.	Ag, Fe	"	Fe (greenish in l. q.).
Yellow.	Pb, very l. q., Bi, Cd. Ta, Ti, W, in l. q., Ag, Ca, Ni, U, Va, Cr, Fe, in s. q.	Fe, in l. q; Ni, in s. q., U (greenish), Va.	Ti	Fe (greenish in l. q.).
Orange.	Cr, Fe, in l. q.	Ni, in l. q.	Fe in s. q. Va.	Fe while getting cold.
Red.	"	"	Fe (brown)	"
Deep red.	"	"	"	Cu, op.
Reddish-brown.	Fe, Cr, in very l. q.	"	Cr	Cu, op.
Violet.	Mn, Di	Mn, Di	Nb in l. q.	Nb, Ti
Blue.	Co	Co, Cu (greenish when getting cold).	Co, W, Nb, in very l. q.	Co, W, Nb, in very l. q.
Green.	Cu, Mo. (yellowish)	Mo, U, (yellowish), Cr, emerald green.	U, Mo, Cu	Cr. U, Mo. Va.

NOTE.—Abbreviations employed: s. q., small quantity; l. q., large quantity; fl, by flaming; c. b, continued blowing; op., opaque.

3. Examination of Minerals with Soda (*Sodium Carbonate*), Na_2CO_3.

The examination with soda is generally performed on charcoal in the reduction flame, and, as a general rule, the flux is added successively in small portions. It is sometimes better to form the finely pulverized assay into a paste with moistened soda before placing it upon the charcoal. This is particularly necessary when the assay is to be tested for its fusibility with soda, since a great many minerals and ores behave quite differently with different quantities of flux.

Instead of sodium carbonate, the neutral *potassium oxalate* or *potassium cyanide* may advantageously be used for all experiments of reduction, since these reagents exercise even a more powerful reducing action than soda. They are for this reason frequently employed when the presence of such metallic oxides is suspected, whose conversion into metals requires a high temperature and the aid of a very efficient deoxidizing agent.

In subjecting a body to the treatment of soda, we must direct our attention to two points. Some substances unite with soda to *fusible compounds*, others form *infusible compounds*, and others again are not *fused at all;* in the last case the soda is simply absorbed by the charcoal, and the assay is left completely unchanged.

With soda, the following substances produce fusible compounds with effervescence of carbon dioxide (CO_2) :—

Silicic oxide.—Silica (SiO_2)* fuses to a transparent glassy bead which, after cooling, remains transparent if the soda has not been added in too great excess.

Titanium dioxide (TiO_2) fuses to a transparent glassy bead,

---

* Silica belongs to the class of acid-forming oxides, and the silicic acid corresponding to the oxide SiO_2 must have the formula H_4SiO_4 or $Si(OH)_4 = SiO_2 + 2H_2O = H_4SiO_4$. Silicic acid is just as little known as is sulphurous acid $= H_2SO_2$, or carbonic acid $= H_2CO_3$, and, like these acids, it has a great tendency to split up into water and the acid-forming oxide.

which is dark-yellow while hot, but on cooling becomes turbid and crystalline.

Tungsten trioxide (WO_3)* and *Molybdenum trioxide* (MoO_3)†, after the carbon dioxide is driven off, are absorbed by the charcoal.

Tantalum pentoxide (Ta_2O_5), *Vanadium pentoxide* (V_2O_5), and *Columbium* (*niobium*) *pentoxide* (Cb_2O_5) or (Nb_2O_5) also yield fusible compounds and sink into the charcoal.

Lime, magnesia, zirconia, thoria, yttria, and glucina (beryllium oxide), as well as cerium and uranium oxides, are not attacked: they remain unchanged, while the soda sinks into the charcoal.

The salts of barium and strontium form, with soda, fusible compounds, which are absorbed by the charcoal.

Sodium carbonate is also used for the detection of—

a. Sulphur, *selenium*, and *tellurium compounds*, which give with it a fused mass,‡ yielding a black, or brown, stain when laid upon a piece of silver and moistened with water.

b. Manganese and *chromium*, with the soda alone, or, better, with addition of sodium nitrate, yield colored masses; the former a green mass of manganate, and the latter a yellow mass of chromate.

The second point to be observed is the elimination of metallic matter.

When treated with soda on charcoal in the R. Fl., the following metallic oxides are reduced: the oxides of the noble metals and the oxides of arsenic, antimony, bismuth, indium, cadmium, copper, cobalt, iron, lead, mercury, nickel, tin, zinc, molybdenum, tungsten, and tellurium. Of these, arsenic and mercury vaporize so rapidly that frequently not even a coating is left on the charcoal. Antimony, bismuth, cadmium, lead, zinc, and tellurium are partially volatilized, and form distinct coatings on the charcoal.

---

[*] Tungstic acid (wolframic acid) = H_2WO

[†] Molybdic acid = $H_2MoO_4 + H_2O$.

[‡] Hepar sulphuris (liver of sulphur).

The non-volatile reduced metals are found mixed with the soda. To separate them from the adhering soda and charcoal powder, we proceed in the following manner: The fused mass of soda and metal, and the portion of the charcoal immediately below and around the assay, are placed in a small mortar, ground to powder, then mixed with a little water and stirred up. The heavy metallic particles settle to the bottom, a portion of the soda dissolves, and the charcoal powder remains suspended in the water. The liquid is carefully poured off, and the residue treated repeatedly in the same manner until all foreign matter is removed. The metal remains behind as a dark heavy powder; or, when the metal is ductile or easily fusible, in the shape of small flattened scales with metallic lustre. These may be examined with the magnifying glass and also with the magnet. If the substance under examination contains several metallic oxides, the metallic mass obtained is usually an alloy, in which the several metals may be detected by processes to be described hereafter. It is only in some exceptional cases that separate metallic globules are obtained, as, for example, in substances containing iron and copper.

4. Examinations of Metals with Sodium Thiosulphate (Hyposulphite of Sodium), $Na_2S_2O_3$.

With all the metals which can be precipitated in the *wet way* by hydrogen sulphide, the same reaction may be obtained in the *dry way* by heating the powdered substance with powdered *thiosulphate of sodium* in a reagent tube. After the decomposition has taken place—recognized by the evolution of hydrogen sulphide—the melted mass exhibits very clearly the peculiar coloration of the metallic sulphides produced. In many cases this reaction is enhanced by a small addition of *oxalic acid.*

Since the *thiosulphate of sodium* contains considerable water of crystallization, the greater portion of this must be removed from this reagent before experimenting, or the glass-tube must be held horizontally to prevent its cracking, in which case the open end had better be closed with cotton-wool.

The sulphide reactions of the metals are demonstrated in the following table, in which their behavior with *borax* on platinum wire is shown by way of comparison. These methods supplement each other very instructively.

5. TABULAR ARRANGEMENT SHOWING THE BEHAVIOR OF OXIDES, WHEN TREATED BEFORE THE BLOWPIPE, WITH SODIUM THIOSULPHATE, TOGETHER WITH THEIR REACTIONS WITH BORAX.

Metallic oxides.	Behavior with $Na_2S_2O_3$.	Behavior with borax on platinum wire (the bead cold).	
		Oxidizing flame.	Reducing flame.
Antimony oxide	Orange-red,	Colorless,	Gray to colorless.
Arsenic "	Lemon yellow,	(Vaporizes),	(Vaporizes).
Bismuth "	Black,	Colorless,	Gray to colorless.
Cadmium "	Yellow,	"	" " "
Chromium "	Green,	Grass-green,	Emerald-green.
Cobalt "	Black,	Blue,	Blue.
Copper "	"	Bluish-green,	Brown.
Gold "	"	Reduced to metal	without dissolv'g.
Iron "	"	Yellow,	Bottle-green.
Lead "	"	Colorless,	Gray to colorless.
Manganese "	Light-green,	Violet (amethyst)	Colorless.
Mercury "	Black,	Vaporizes,	Vaporizes.
Molybdenum "	Brown,	Colorless,	Brown.
Nickel "	Black,	Reddish-brown,	Gray to colorless.
Platinum "	"	Reduced to metal	without dissolv'g.
Silver "	"	Colorless,	Gray to colorless.
Thallium "	"	"	Colorless.
Tin "	Brown,	"	"
Uranium "	Black,	Yellow,	Bottle-green.
Zinc "	White,	Colorless,	Gray to colorless.

6. EXAMINATION WITH ACID POTASSIUM SULPHATE OR CONCENTRATED SULPHURIC ACID.

To determine the presence of volatile acids, a small quantity of the substance is heated with acid potassium sulphate, or with concentrated sulphuric acid (in the latter case, however, not to the boiling-point of the acid), and the following appearances noticed :—

1. A COLORED GAS IS EVOLVED.

a. Nitrogen tetroxide (NO_2) fumes are recognized by their reddish-brown color and characteristic odor; evolved from nitrates and nitrites. With nitrates the reaction is promoted by the addition of copper filings.

b. Chlorine tetroxide (hypochloric acid), Cl_2O_4, yellowish-green, odor like chlorine, bleaches litmus paper. The evolution of this gas by this treatment indicates the presence of chlorates.*

c. Iodine, from iodides, may be recognized by its violet vapors, which color starched paper blue. Iodates* give this reaction after the addition of ferrous sulphate (copperas).

d. Bromine; reddish-brown vapors, with pungent, unpleasant odor, which turn starch-paste yellow. Yielded by *bromides* and *bromates*. The color of the vapor is best seen on looking down the tube.

2. A COLORLESS, ODOROUS GAS IS EVOLVED.

a. Sulphur dioxide (sulphurous acid), evolved from sulphites and polythionates, is easily recognized by its suffocating odor and bleaching properties (litmus, etc.).

b. Hydrochloric acid, from chlorides, recognized by its odor and by the clouds of ammonium chloride (sal-ammoniac) which are formed, when a glass-rod, moistened with ammonia-solution, is held over the tube.

c. Hydrofluoric acid, from fluorides, smokes, has a very suffocating odor, and strongly etches glass.

d. Hydric sulphide (sulphydric acid, sulphide of hydrogen, sulphuretted hydrogen), H_2S, from sulphides, of a repulsive odor, blackens paper moistened with lead acetate (sugar of lead) solution.

e. Cyanic acid, from cyanates, has a characteristic pungent odor; it brings tears to the eyes, and renders lime-water turbid.

f. Acetic acid, from acetates, is known by its pungent, "vinegar" odor, and also by yielding fragrant acetic ether on heating with sulphuric acid and alcohol.

---

* The chlorates, iodates, and bromates deflagrate when heated on charcoal.

3. A Colorless and Odorless Gas is Evolved.

a. Carbon dioxide (carbonic acid gas) $= CO_2$, is expelled from carbonates with effervescence; it renders lime-water turbid.

b. Carbon monoxide (carbonic oxide), CO, which burns with a bluish flame, may arise from oxalates, formates, cyanides, ferrocyanides, and ferricyanides.

c. Chromic acid evolves *oxygen*, and the liquid turns brown or green.

d. Organic acids are recognized by the blackening due to the separation of carbon (except oxalic acid, which yields CO and CO_2).

The acids which cannot be detected by the above methods, though easily detected in other ways, are: sulphuric, phosphoric, arsenic, boric, silicic, tungstic, molybdic, and titanic.

7. Examination with Zinc and Hydrochloric Acid after previous Decomposition (Fusion) of the Mineral.

A mixture of sodium carbonate and nitre is added to the finely-powdered assay, the mass is moistened slightly, and placed in a small spiral of platinum wire, of about 2 to 3 mm. diameter. After fusing for a short time, the glowing mass in the spiral is thrown off into a porcelain dish and digested with a little water in a test-tube. Afterwards, a little hydrochloric or sulphuric acid is added, and a strip of zinc is brought into the solution. By the reducing agency of the nascent hydrogen thus formed various colors are produced, as shown in the following table:—

Molybdic trioxide (molybdic acid): blue, then green, finally blackish-brown.

Tungsten trioxide (Wolframic acid): blue, then copper-red.

Columbium (niobium) *pentoxide* (niobic acid); blue, often also brown (with strongly acid solution).

Vanadium pentoxide (vanadic acid): blue, then green, finally violet.

Chromium trioxide (chromic acid): green.

Titanium dioxide (titanic acid): violet.

8. Examination with Cobalt Solution.

A few substances, when moistened with a solution of cobalt nitrate and exposed to the action of the O. Fl. assume a peculiar color. The use of this test is, however, very limited, since the reaction can only be clearly seen in those bodies which, after having been acted upon by the O. Fl., present a white appearance or nearly so.

Substances which are sufficiently porous to absorb a liquid are merely moistened with a drop of cobalt solution, held with the platinum-forceps, and submitted to the O. Fl. Other substances must be powdered, the powder placed on charcoal, moistened with a drop of cobalt solution, and treated as above. The color can only be distinguished after cooling. A bluish color of more or less purity, but rather dull, indicates the presence of alumina, and a flesh-color (pale-reddish color) that of magnesia. It must, however, be borne in mind that the alkaline and some other silicates, when heated with cobalt solution to a temperature above their fusing point, also assume a blue color, owing to the formation of cobalt silicate. In testing for alumina, therefore, the heat must not be raised so high as to cause fusion of the assay. In testing for magnesia this precaution is not necessary; as, on the contrary, the color will appear the brighter and the more distinct the higher the temperature to which the assay is exposed. The alumina and magnesia reactions are prevented by the presence of colored metallic oxides, which generally produce a gray or black mass, unless present in too minute quantity.

Among the oxides of the heavy metals, those of zinc and tin assume characteristic colors with solution of cobalt. The reaction is best seen when the assay, alone or mixed with soda, is exposed to the R. Fl. on charcoal. The ring of oxide which is deposited around the assay is then moistened with solution of cobalt and treated with the O. Fl. Zinc takes a fine yellowish-green, and tin oxide a bluish-green color.

Besides the compounds above mentioned, there are some others which, when exposed to the action of cobalt solution and heat, experience a change of color, but still this reagent does not justify its employment for their recognition. In fact, only the colorations of alumina, magnesia, zinc, and tin are of real use in the determination of these substances.

The following table gives the more definite colorations caused by cobalt solution :—

Blue: Alumina ; deep color ; infusible.
  Silica and silicates ; pale blue ; with much solution, black or dark gray. Thin edges of assay fuse to a reddish-blue glass at a high temperature.
  Phosphates, borates, and silicates of the alkalies yield a blue glass.
Green: Zinc oxide }
  Titanium dioxide } yellowish-green.
  Tin oxide ; bluish-green.
  Antimony oxide ; impure-green.
Flesh-red: Magnesia ; pale flesh-red or pink.
  Tantalum pentoxide ; hot, light gray ; cold, flesh-red.
Violet: Zirconia ; impure violet.
  Magnesium arsenate and phosphate fuse and become violet-red.
Brown: Baryta ; hot, reddish-brown or brick-red ; cold, colorless.
Gray: Strontia ; dark-gray to black.
  Lime ; gray.
  Glucina ; bluish-gray.
  Columbium (niobium) pentoxide ; brownish-gray.

CHAPTER VI.

COLORED FLAMES, FLAME REACTIONS, AND SPECTRUM ANALYSIS.

1. Examination of the Assay in the Platinum Forceps for Flame Colorations.

Many substances, especially the alkalies and alkaline earths, when brought into a non-luminous flame, impart to it distinct colorations, affording in many cases characteristic means for detecting them even in the minutest quantities, *e. g.*, sodium salts tinge the flame yellow; potassium compounds, violet; strontium salts, scarlet red; lithium salts, carmine-red; etc.

The Bunsen burner, previously described (Fig. 49), is especially well adapted to such observations. The coloring substance may be brought on a platinum wire loop into the zone of fusion of the flame. When mixtures of different flame-coloring substances are examined, indecisive tests are usually produced; thus, in a mixture of sodium and potassium salts, only the yellow sodium flame is evident, but by viewing the flame, according to Bunsen and Merz, through colored glasses or fluids, the mixed colors may be dissected.

The following table gives the more definite colorations:—

Red Flames.

Lithium: carmine-red.
Strontium: scarlet-red.* }
Calcium: yellowish-red.* } Barium salts obscure the reaction.

Violet Flames.

Potassium: violet-red. Sodium and lithium salts obscure the reaction.
Caesium: }
Rubidium: } Like potassium.

Yellow Flames.

Sodium salts.

Green Flames.

Copper oxide: emerald-green; when moistened with HCl, blue.
Thallium: grass-green.
Phosphoric acid: bluish-green. }
Boric acid: yellowish-green. } After their salts are moistened with sulphuric acid.
Barium salts: yellowish-green.*
Molybdic acid: faint yellowish-green.
Tellurious acid: green, giving off fumes.
Nitric and nitrous acid: bronze-green, disappearing quickly.
Zinc: whitish-green.

Blue Flames.

Copper chloride: azure-blue, afterwards green.
Iridium: indigo-blue (in both flames).

---

* Especially after moistening with HCl.

Selenium: cornflower blue, accompanied by the odor of rotten horse-radish.
Arsenic: bluish.
Antimony: faint greenish-blue.
Lead: blue.

2. Apparatus.

The apparatus for these observations is simple, viz., a blue, a violet, a red, and a green glass. The stained glasses found in commerce possess generally the proper shades of color. Indigo solution may be substituted for blue glass. A hollow prism (Figs. 103 and 104), made of plate glass, whose principal section forms a triangle 150 millimetres in length, and 35 millimetres in diameter at the thick end. The solution with which it is filled is prepared by dissolving 1 part of indigo powder in 8 parts of strong sulphuric acid, heating the mixture on the sand-bath, and stirring it frequently with a glass rod. The syrupy solution thus obtained is diluted with 1500 to 2000 parts of water,* and filtered through felt or thick blotting paper.

Fig. 103.

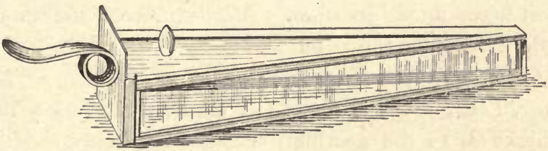


Fig. 104.

3. Experiments.

In the following experiments the prism is moved horizontally before the eye, so that the rays of the flame always pass through gradually thicker layers of the fluid medium. The alkaline

---

* The cold indigo solution must be gradually poured into the proper amount of water, the reverse operation might prove dangerous.

substances, brought singly into the flame, exhibit the following changes :—

a. *Chemically pure calcium chloride*,* $CaCl_2$, produces a yellow flame, which, even with very thin layers of the indigo solution, passes through a tinge of violet into the original blue-lamp flame.

b. *Chemically pure sodium chloride*, NaCl, the same.

c. *Chemically pure potassium carbonate*, K_2CO_3, or potassium chloride, KCl, appears of a sky-blue, then violet, and at last of an intense crimson color, even when seen through the thickest layer of the solution. Admixtures of sodium or calcium do not hinder the reaction.

d. *Chemically pure lithium carbonate*, Li_2CO_3, or *lithium chloride*, LiCl, gives a violet-red flame, which, with increasing thickness of the medium, becomes gradually feebler, and disappears before the thickest layers pass before the eye. Calcium and sodium are without influence on this reaction.

A Blue, a Violet, a Red, and a Green Glass.

The stained glasses found in commerce possess generally the proper shades of color. The blue is colored by cobalt protoxide; the violet by manganese sesquioxide; the red (partly colored and partly uncolored) by cuprous oxide; and the green by iron sesquioxide and cupric oxide. Merz,† who has made a complete study of this subject, employs with these glasses Bunsen's burner, and also a flame of pure hydrogen. The substances which he describes as giving characteristic colors to the flame of a Bunsen burner, in addition to those previously known, are nitric and chromic acids, while phosphoric and sul-

---

* Chlorides, on account of their volatility, yield generally the best coloration, and for this reason the substance under examination is moistened with hydrochloric acid, or is treated with silver chloride and again heated. The substance is held in the one hand and the colored glass in the other.

† G. Merz, Flammenfärbungen, Journ. f. pract. Chemie, Bd. 80, p. 487.

phuric acids give a peculiar coloration to the dark core of the flame of hydrogen.

The flame of Bunsen's burner, which is preferred for these reactions, gives three sorts of colors.

1. *Border colors.* These are of course peculiar only to the most volatile substances. To produce them, the loop of platinum wire is held outside of the flame about one or two millimetres from the lower portion of the outer limit.

2. *Mantle colors.* Those which are seen when the substance is held in the bright blue-colored mantle which forms the outer portion of the flame.

3. *Flame colors.* To produce these, the loop is to be held horizontally and in the hottest part of the mantle. The *hydrogen flame* yields another fourth species of color, viz., the

4. *Core colors.* These are produced only by sulphuric and phosphoric acids, which communicate respectively a blue and green tinge to the cold core of the hydrogen flame.

4. TESTING CHEMICAL MIXTURES.

In order to detect several flame-coloring elements when occurring together it is best to use the spectroscope (Figs. 111, 112), the theory, construction, and use of which will be found fully described on page 127 and following pages, to which the reader is referred for information. The direct-vision pocket spectroscope, such as that of Browning and others, is well adapted for blowpipe investigations.

All flame-coloring substances may, according to their volatility, be arranged in three classes: 1, certain acids; 2, alkalies; and 3, alkaline earths, to which may be added the heavy metal copper. If the substances are brought into the flame of the Bunsen burner mentioned on page 111, we may detect

Acids.

a. Nitric and nitrous acids give a bronze-green border color, usually with an orange-colored margin. The assay is to be previously dried in the flame, and then either moistened with

HCl, or dipped into a solution of acid potassium sulphate, according as we wish to test for nitrous or nitric acid. Ammonium and cyanogen compounds give the same reaction but more faintly.

b. Phosphoric acid gives a gray yellowish-green border color, after moistening with sulphuric acid. In the presence of boric acid, phosphoric acid can only be discovered by the intense green flame produced by heating the assay in a hydrogen flame after moistening with a solution of hydrofluosilicic acid. For this purpose the hydrogen is delivered from a platinum jet, for instance, the side tube of a blowpipe.

c. Boric acid gives a beautiful green mantle color, which is so intense that this acid may be recognized in the presence of considerable quantities of phosphoric acid. Borates require to be first decomposed with sulphuric acid.

d. Molybdic acid yields a yellowish-green flame similar to that shown by barium salts.

e. Hydrochloric acid gives a very weak greenish-blue border color which lasts but an instant, and hence frequently escapes detection.

f. Sulphuric acid produces a fine blue core color, being reduced to sulphur dioxide. The free acid gives the color when the platinum wire loop is held in the border of the flame, but a sulphate must be held in the middle of the flame. In the latter case it is best to first dip the assay into concentrated hydrochloric or hydrofluosilicic acid.

Chromic acid gives a dark brownish-red border color and a rose-red mantle color. The dry assay is to be moistened with concentrated *sulphuric acid*, and held in the border. *Chromic oxide* gives no color, and should be first oxidized to chromic acid by moistening with a solution of sodium hypochlorite and drying.

Alkalies.

a. Potassium gives a grayish-blue mantle color and a rose-violet flame color. The color appears reddish-violet through a blue glass* (detection in presence of sodium), violet through violet-colored glass, and bluish-green through green glass. The assay is to be moistened with sulphuric acid, and repeatedly exposed to the flame for a short time.

b. Sodium gives an orange-yellow flame color, which in quantity appears blue through blue glass, but which is invisible when present in small amounts. Seen through green glass the flame has an orange color, characteristic of all sodium compounds. If a crystal of potassium-bichromate is held near to the sodium flame, the former becomes quite colorless, and a red spot of mercuric iodide on paper becomes white with a faint tinge of fawn color. The assay is moistened with sulphuric acid, dried, and then held in the hottest part of the flame.

c. Lithium yields a carmine-red flame color, which appears violet-red through blue glass, and carmine-red through violet glass. In the presence of sodium, lithium is detected by the blue glass. In the presence of potassium, Bunsen's method is employed. The assay is brought into the zone of fusion of a Bunsen gas-lamp, and this flame is compared simultaneously, through an indigo prism, with one obtained from a pure potassium salt held in the corresponding part of the flame opposite to the assay. Through the thinnest layer of the solution the lithium flame appears redder than the pure potassium flame; through thicker layers the flames appear equally red, when the proportion of lithium to potassium is very small. If, however, lithium predominates in the assay, the intensity of the red flame diminishes rapidly as the prism is moved; whilst the pure potassium flame is scarcely any feebler. Sodium, when not present in large excess, modifies these effects but slightly.

Potassium and lithium are not likely to be confounded with strontium if the assay be treated as described under potassium, since strontium compounds are not volatilized at the low temperature thus obtained.

---

* Cartmell, Phil. Mag., May, 1858, p. 328.

Alkaline Earths.

The assay is repeatedly moistened with sulphuric acid, dried and placed in the hottest part of the mantle. After all the alkalies are volatilized the following reactions appear:—

a. Barium gives a yellowish-green flame color, which appears bluish-green through green glass. If the green disappears, and a red color makes its appearance, the assay is to be repeatedly moistened with hydrochloric acid, and immediately introduced while wet into the hottest part of the flame. When the bluish-green color is no longer seen we proceed to test for calcium.

b. Calcium is present when the red-flame color, on evaporating the last portion of hydrochloric acid (spitting of the assay), appears finch-green through the green glass.

c. Strontium is known by the purple to rose color, which appears through blue glass, as the assay spits in the flame after being moistened with HCl. Under identical conditions calcium gives a faint greenish-gray color.

Copper.

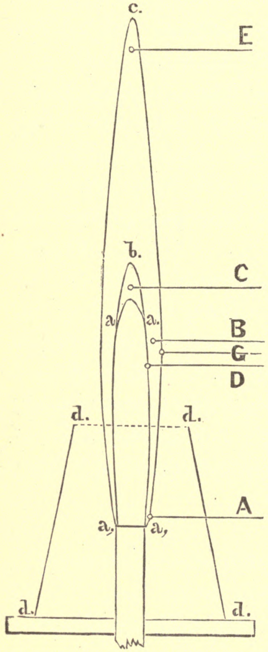
Copper chloride yields a sky-blue flame color; the nitrate gives a pure green one. By the combined observations of both colors, copper may readily be distinguished from all other metals which give similar colors.

The remaining flame-coloring metals, such as arsenic, antimony, tin, lead, mercury, and zinc, exhibit, especially in the form of chlorides, more or less intense bluish or greenish mantle colors, which, however, are of no great value in analysis. As a rule the appearance of these colors can be prevented by moistening with sulphuric acid. It is best, however, to expel on charcoal the metals which give an incrustation, before testing for alkalies or alkaline earths by flame coloration.

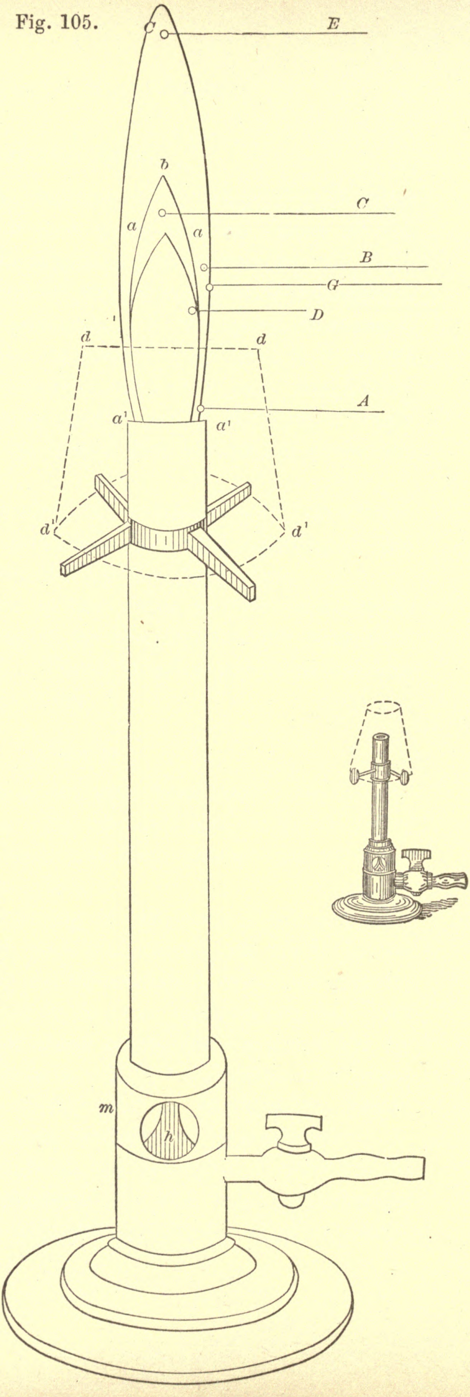
In order to detect the alkalies in silicates it is sufficient to decompose the assay on platinum wire with some pure gypsum (sulphate of lime). If, on the contrary, the alkaline earths

To face p. 111.

Fig. 105.



a,, *a*, *a*, *a*,, the dark nucleus
a,, *c*, *a*,, *b*, the flame mantle.
a, *b*, *a*, the luminous point not in the normal flame, but formed, when needed, by partially turning the collar.



are looked for, the decomposition must be effected by means of sodium carbonate. The substance is fused with the reagent in a platinum spoon, the fused mass extracted with water, and the residue treated with HCl, when silicic acid separates out, and the solution is then examined in the flame.

5. Bunsen's Flame Reactions. Bunsen's Gas-lamp.

According to Bunsen,* most of the tests obtainable with a blowpipe can be produced by means of the non-luminous flame of a Bunsen burner, Fig. 105, provided with a movable collar, *m* (by turning of which the access of air may be regulated), and a conical chimney, *d*, *d*, *d′*, *d′*, of such dimensions, that the flame burns perfectly steady. The flame should have the dimensions shown in Fig. 105.

The *six portions* of the flame, which serve for conducting the different reactions, are distinguished as follows:—

I. The *base of the flame* at A, having the *lowest temperature*, is especially adapted for separating from a mixture of flame-coloring substances the most volatile ones first.

II. The *zone of fusion* at B, having the *highest temperature*, is therefore particularly suited for testing the fusibility, volatility, etc., of an assay.

III. The *lower oxidizing flame* at G, is especially employed for the higher oxidation of oxides dissolved in fused beads.

IV. The *upper oxidizing flame* at E, acts with the *greatest power* when the draft holes, *h*, are completely opened. All the roastings and oxidations are here executed, provided that not too high a temperature is required.

V. The *lower reducing* flame at D, less energetic than the

---

* Annal. der Chem. u. Pharm., Bd. 138, p. 257; also, J. Landauer, "Löthrohr Analyse," 2te Aufl. Berlin, 1881, p. 62.

A new edition of R. Bunsen's flame reactions has lately appeared, entitled: Flammen Reactionen, Heidelberg, 1880, which the author was unable to consult, however, but made free use of many descriptions given by J. Landauer, in his "Löthrohr Analyse," Berlin, 1881.

Extracts are also found in Annal. Chem. und Pharm. cxxxviii. p. 257, and Philos. Mag. [4] xxxii. p. 81 (translated by Prof. Roscoe).

following, gives for that very reason peculiar reactions; it serves especially for reductions on charcoal, and of beads of fused salts.

VI. The *upper reducing flame* at C. The point *a b a*, above the *dark cone* of the flame, is not visible when the draft holes, *h*, are entirely open; but if this luminous point is made *too* large, soot is deposited, which is not admissible. This part of the flame is particularly suitable for the reduction of metals which it is desired to collect as metallic incrustations or coatings.

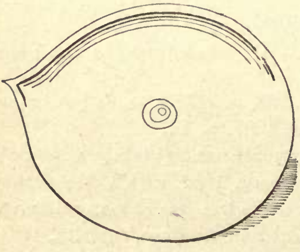
The following apparatus serves as a support for bringing test specimens into the flame:—

6. APPARATUS AND METHOD EMPLOYED FOR SUBMITTING TEST SUBSTANCES TO THE FLAME.

Behavior of the Elements at High Temperatures.—This is one of the most important reactions which can be employed for the detection and separation of substances. To produce with the flame alone a temperature as high or higher than that of the ordinary blowpipe, the radiating surfaces of the heated body must be as limited as possible, and therefore be on a very small scale.

By bringing the moistened loop of the platinum wire (of the thickness of a horsehair) in contact with the powdered substance that is to be examined, a portion of it adheres; and when the loop is held for some time near the flame, and finally within it, the substance sinters or fuses firmly upon the wire. When the substances act upon platinum, a thread of asbestos is used. Salts that decrepitate are ground to the finest powder on the porcelain lamp plate, Fig. 106, with the elastic blade of the knife, Fig. 107, and

Fig. 105.



drawn up on to a moistened strip of one square centimetre of Swedish filter paper. If the paper is then burnt, being held with the platinum forceps, or better, between two rings of fine platinum wire, the sample remains as a coherent crust, which may now, without difficulty, be heated in the flame.

Fig. 106.

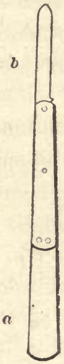


Fig. 107.

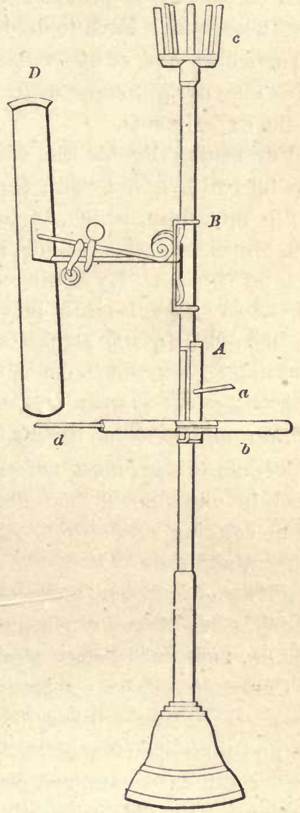


Fig. 108.

The substance under examination may be kept for any length of time in a given part of the flame by means of a *Bunsen holder*, Fig. 108. The arm, *a*, is fastened to the carrier, *A* so fixed on the stand by a self-clamping spring slide, that it can be moved both horizontally and vertically. The glass tube, *d*, is fastened on this arm, *a*, and the fine platinum wire (fused into the glass tube) thus held in the flame. Splinters (fibres) of asbestos are inserted in the glass tube, *b*, which slips into the holder, and may be moved with the carrier, *A*. The carrier, *B*, is provided with a spring-clamp for holding test-tubes, which have to be heated for a considerable time in a particular *part* of the flame. The little turn-table, *c*, contains nine upright supports for storing the wire tubes employed in the experiments.

For testing liquids, the wire of the loop is flattened by a few taps with a hammer; then, if dipped into the substance, it lifts up a drop, which, by holding it near the flame, slowly evaporates, and the residue, if any, may be brought into the *zone of fusion.* By means of these arrangements, a small particle of the substance may be brought into the flame, and its behavior in the coldest and hottest parts of the flame ascertained, the substance being examined with a lens after each change of temperature.

Platinum wire, no thicker than a horsehair (*i. e.*, a piece 1 decimetre long, must not exceed 0.034 grms. in weight), is used in experiments for examining the fusibility, volatility, flame coloring, and also for reactions with borax, salt of phosphorus, and soda.

Fibres of asbestos, about one-fourth as thick as an ordinary match, serve instead of platinum (where this metal is attacked), and are moistened before receiving the test substance.

Charcoal rods as a substitute for ordinary charcoal. They are prepared from ordinary friction matches; the head is broken off and three-quarters of its length coated with fused, crystallized sodic carbonate, and charred in the flame with a rotary motion. The rods when thus glazed are partially protected against combustion.

Tubes of thin glass 3 cm. long, 2 to 3 mm. wide, and closed at one end.

7. REAGENTS.

The following chemical reagents are specially employed for Bunsen's flame reactions:—

Stannous chloride ($SnCl_2$). The solution must be kept in a glass-stoppered bottle. In order to prevent its transformation to stannic chloride ($SnCl_4$) a few small grains or pieces of metallic tin are placed in the bottle. The salt is a powerful reducing agent, and serves to distinguish metallic coatings, and for the recognition of *Gold*, *Molybdenum*, *Tungsten* (*Wolfram*), etc.

Caustic soda solution ($NaOH$) is likewise employed for recognition of metallic coatings, as also for the recognition of *Cobalt*, *Nickel*, *Tin*, etc.

Nitrate of silver solution ($AgNO_3$), quite neutral, is used to distinguish coatings and for detecting *Chromium* and *Vanadium.*

Fuming hydriodic acid (IH), obtained by the action of moist air on phosphorus tri-iodide. To prepare the latter, 1 part of phosphorus is dissolved in carbon di-sulphide, and gradually 12.3 parts of iodine added. This solution is now gently heated to expel most of the di-sulphide of carbon, and next placed in some cooling mixture, whence crystalline laminæ of phosphoric tri-iodide separate, which fuse at 55° C. These are put into a wide-necked, flat-bottomed glass flask, which can be tightly closed with a glass stopper. The small porcelain dishes with the adhering coatings on their surfaces may thus be placed over the flask and readily exposed to the fumes of the hydriodic acid, converting these deposits into iodine compounds. When the fuming of this reagent ceases, it is rendered active again upon the addition of some *anhydrous phosphoric acid.* These coatings may likewise be turned into iodides by saturating an asbestos-rod with an alcoholic solution of iodine, firing it, and moving the flame to and fro, beneath the coated porcelain dish. Should a brown-colored product, resulting from the separation of free iodine, condense on the porcelain dish, it may be removed by careful heating.

Ammonia (NH_3) and *ammonium sulphide* (or *ammonium sulphydrate*), NH_4HS, are employed for determining such coatings.

Bromine (Br), kept in a wide-necked, well-closed flask, is used for exposing substances to its vapor, which, in the presence of water, acts as an oxidizing agent.

Ferrocyanide of potassium (yellow prussiate of potash), $K_4Fe''Cy_6$, or $4KCyFe''Cy_2$, serves in solution for the recognition of *Iron*, *Copper*, and *Molybdenum*.

Plumbic acetate ($Pb_2C_2H_3O_2$) is used for tracing *Chromium*.

Bismuthous nitrate, $Bi'''(NO_3)_3, 5H_2O$, or $Bi_2O_3, 3N_2O_5$ $10H_2O$, as reagent for *Tin*.

Acetic acid ($C_2H_4O_2$) is employed in investigations of *Chromium*, *Vanadium*, *Manganese*, and *Uranium*.

Mercuric cyanide, $Hg''(CN)_2$, or $Hg''Cy_2$. Its solution is sometimes used for the detection of *Palladium*.

Hydrochloric and *nitric acid*, as well as a mixture of the two, or *aqua regia*, are quite frequently employed—the latter in testing for *gold*, *platinum*, etc.

For test operations, only very minute quantities of the substances are used. Decrepitating bodies, as already stated, are ground into very fine powder, and absorbed by a moistened strip of filter paper (1 centimetre square). If this is placed between two rings (coil) made of hair-fine platinum wire and then burnt, a cohering crust remains which may be tested in the flame without any difficulty.

When substances require to be held in the flame for a long time, it is very convenient to use a Bunsen stand, which is provided with horizontal clips and arms, movable horizontally and vertically on the vertical support. The arms carry small glass tubes supporting platinum wire or asbestos fibres, and the clips are used for holding the test tubes.

8. Methods of Examination.

A. *Ignition of the Elements at High Temperatures.*

When heating small assays the following phenomena must be considered:—

1. The *emission of light*, which is ascertained by holding the substance on platinum wire in the *hottest* part of the zone of fusion. The emissive power is estimated as *low*, *medium*, or *high*, according as the luminosity of the specimen falls below, equals, or exceeds that of the platinum wire, introduced at the same time.

2. The *fusibility*, or melting point, is expressed by a scale of temperature of the following *six grades*, distinguishable by the appearance of a thin platinum wire in different portions of the flame, viz:—

a. Below red heat.
b. Incipient red heat.
c. Red heat.
d. Incipient white heat.
e. White heat.
f. Intense white heat.

3. The *volatility* is determined by the time required to volatilize a weighed bead (0.01 grm.) in the zone of fusion, and comparing it with the time required to volatilize an equal weight of sodic choride, the volatility of which is taken as a unit of comparison. The odor evolved, if any, must be observed.

4. *Flame coloration.*—Many volatile substances may be detected by placing the test specimen in the *upper reducing flame* at C, when the colorations appear in the *upper oxidizing* flame at E. Mixtures of flame-coloring bodies may first be tested in the coolest part of the flame base at A, to obtain (for a moment only) the coloration produced by the most volatile bodies, unmixed with the less volatile ones.

B. *Oxidation and Reduction of Substances.*

1. *Fused Glass Beads.*—The oxidation and reduction of fused substances are executed on platinum wire. The beads adhering to the ends of the wires are *oxidized* in the *lower oxidizing flame at G, and reduced in the lower reducing* flame at *D.*

2. *Reductions in Closed-glass Tubes.*—The completely dried test specimen is heated together with soda and carbon (soot of turpentine is the best) or with metallic sodium, or metallic magnesium wire-clippings. The tubes made of thin glass are 3 mm. wide, and 3 cm. long. The sodium is freed from the naphtha, in which it was preserved, with blotting paper, next rolled between the fingers into a small cylinder which is placed in the tube, and surrounded by the test specimen. The tube is now heated to its own melting point (whereby usually a combustion takes place in the interior). The cold tube is then crushed, and the reduced material carefully collected on glazed paper for further investigation.

3. *Reduction on the Charcoal Rod.*—On the point of the small charcoal rod, already described, we place the test specimen, of about the size of a mustard seed and previously mixed with a drop of fused sodic carbonate, into the lower oxidizing flame at G, for the purpose of fusion, and next pass it into the hotter portion of the lower reducing flame opposite at D. After the reduction has taken place, recognizable by the violent boiling up and frothing of the soda, the specimen is allowed to cool in the dark interior of the flame. The end of the charcoal rod is then nipped off, placed in an agate mortar, and ground with a few drops of water. After lixiviating the charcoal, the products of reduction are kept for further investigation.

C. *Incrustations or Coatings on Porcelain.*

The volatile elements reducible by hydrogen or carbon may either be separated as such from compounds, or as oxides, and collected upon glazed porcelain. Such deposits may next be converted into iodides, sulphides, or other combinations having characteristic qualities, by means of which they can be recognized. The incrustations or films consist in the centre of a thick layer surrounded on all sides by a thinner coating passing to the merest tinge. These reactions are so sensitive, that in many cases 0.1 or 0.001 grm. of material suffice to produce them, surpassing in delicacy Marsh's arsenic test.

The *incrustations produced* are as follow :—

a. Metallic Films or Incrustations are prepared by heating a very small particle of the substance placed on an asbestos fibre, in the *upper reducing flame* at C (not *too* large, and perfectly free from smoke), with one hand, whilst holding at the same time in the other a thin and glazed porcelain capsule (0.1 metre in diameter), filled with cold water, and placing it closely over the asbestos fibre into the upper reducing flame. The volatile metals, if present, will be deposited as a dark incrustation, either dull or lustrous. This deposit is then further examined as to its solubility in dilute nitric acid (containing 20 per cent. of anhydrous acid).

b. Oxide Incrustations.—These are formed by holding the porcelain capsule in the preceding experiment, at some distance from the test-specimens, into the upper oxidizing flame at E. It may then be tested—

1st, by a drop of stannous chloride; if no reduction is effected we add :—

2. Caustic soda solution until the precipitated hydride of tin oxide is redissolved, and observe whether a reduction is the result.

3. The incrustation is touched with some drops of neutral argentic nitrate solution by means of a glass rod spread out, and ammonia vapor blown upon it.* If a precipitate is formed, the color is observed, etc.

---

* The latter is best accomplished by using a small sized ordinary wash bottle, in which the blowing-tube extends under the ammonia solution, and the *pointed ejection-tube* only to the lower end of the perforated cork.

c. Iodide Films.—These are formed by placing the oxide incrustation on the cold capsule over the wide-mouthed glass flask containing hydriodic acid and phosphorous acid (derived from the gradual deliquescence of phosphoric tri-iodide). The iodide coating may be further tested by the moist breath (solubility), and by having ammonia vapor blown upon it.

d. Sulphide Incrustations are produced from the iodide incrustation by blowing a current of sulphide of ammonium vapor upon it, and expelling the superfluous ammonium sulphide by gently heating the porcelain capsule. The sulphide incrustation left is then further tested to examine its *solubility* in water by blowing the warm breath upon it, or by adding a drop of water, and for its solubility in ammonium sulphite, either by blowing or dropping the reagent upon it.

9. General Review of Flame Reactions.

The elements which may be recognized by the flame-reactions may be divided into three groups, according to their behavior during their oxidation and reduction.

A. Volatile elements, separable by reduction as incrustations (see the table of volatile elements appended hereto).

B. Reducible metals furnishing no incrustations.

C. Elements which may best be recognized from the deportment (reactions) of their compounds.

By considering, in addition, those substances recognizable by their flame coloration, the following general schedule of flame-reactions may be given, and their further chemical behavior, elsewhere described, may be considered and compared with it.

A. *Table of Volatile Elements which can be reduce*
to thei

	Metallic Incrustation and Coating.	Oxide Incrustation and Coating.	Oxide Incrustation with $SnCl_2$.	Oxide Incrustation with $SnCl_2$ and NaHO.	Oxide Incrustation with $AgNO_3$ and NH_4HO
TELLURIUM,	Black; with brown coating.	White.	Black.	Black.	White, tinged yellowish.
SELENIUM,	Cherry-red; with brick red coating.	White.	Brick-red.	Black.	White.
ANTIMONY,	Black; with brown coating.	White.	White.	White.	Black; insoluble in NH_3.
ARSENIC,	Black; with brown coating.	White.	White.	White.	Lemon-yellow or brownish-red; soluble in NH_3.
BISMUTH,	Black; with soot-brown coating.	Yellowish-white.	White.	Black	White.
MERCURY,	Gray; non-coherent coating.				
THALLIUM,	Black; with brown coating.	White.	White.	White.	White.
LEAD,	Black; with brown coating.	Light ochre-yellow.	White.	White.	White.
CADMIUM,	Black; with brown coating.	Brownish-black; with white coating.	White.	White	White coating becomes blue-black.
ZINC,	Black; with brown coating.	White.	White.	White.	White.
INDIUM,	Black; with brown coating.	Yellowish-white.	White.	White.	White.

s Films or Coatings on Porcelain, arranged according eactions.

e Incrustation nd Coating.	Iodide Incrustation with NH_3 (blown upon it).	Sulphide Incrustation and Coating.	Sulphide Incrustation with $H(NH_4)S$.	Color of flame and odor.	Action of dilute nitric acid HNO_3+Aq.
n; breathed disappears time.	Disappears permanently.	Black to blackish-brown.	Disappears for a time.	Upper reduction zone faded blue; upper oxidizing flame green; no odor.	Substances whose metallic incrustations are scarcely affected by dilute nitric acid.
n; breathed does not lly disappear.	Does not disappear.	Yellow to orange.	Orange, then disappears for a time.	Fine blue; odor of rotten horseradish.	
ge-red; breathpon disappears time.	Disappears permanently.	Orange.	Disappears for a time.	Upper reduction-zone faded green.	
ellow; breathpon disappears time.	Disappears permanently.	Lemon-yellow.	Disappears for a time.	Upper reduction-zone faded blue; odor of garlic.	
h-brown; with -red to crim- red coating; thed upon dis- ars for a time.	Crimson-red to egg-yellow; chestnut-brown when dry.	Umber-brown; with coffee-brown coating.	Does not disappear.	Bluish, not characteristic.	Substances whose metallic incrustations are with difficulty dissolved by dilute nitric acid.
ine and lemon- ow; breathed does not dis- ar.	Disappears for a time.	Black.	Does not disappear.		
n-yellow; thed upon does lisappear.	Does not disappear.	Black; with bluish-gray coating.	Does not disappear.	Light grass-green.	
yellow to le -yellow; thed upon does lisappear.	Disappears for a time.	Brownish-red to black.	Does not disappear.	Faded blue.	Substances whose metallic incrustations are instantly dissolved by dilute nitric acid.
White.	White.	Lemon-yellow.	Does not disappear.		
White.	White.	White.	Does not disappear.		
owish-white.	Yellowish-white	White.	Does not disappear.	Intense indigo-blue.	

Method employed.	Reactions obtained	Indications of:
I. We endeavor to obtain a metallic incrustation in a porcelain capsule.	An incrustation which is to be tested in regard to its solubility in dilute nitric acid, thus :	Scarcely attacked : Te, Se, Sb, As. With difficulty dissolved : Bi, Hg, T (Thallium). Instantly dissolved : Pb, Cd, Zn, I (Indium).
II. The substance is heated with addition of sodic carbonate on a charcoal rod.	*a.* A gray powder :	magnetic : Fe, Ni, Co. Non-magnetic : Pd, Pt, Rh, Ir.
	b. A metallic globule :	Cu, Sn, Ag, Au.
III. The mass, mixed with Na_2CO_3 and KNO_3 is heated on a platinum wire.	*a.* A white or colorless fusion :	Mo, W (tungsten), Ti, Ta, Nb, Si.
	b. A yellow fusion :	Cr, V.
	c. A green fusion :	Mn.

IV. Special proceedings for finding : U, P, S (described in our special methods of detection).

V. Flame-coloration : K, Na, Li, Sr, Ba, Ca.

Besides the characteristic flame-coloring by which certain substances may be recognized, there is a large series of general flame-reactions, which may be systematized as follows : (See Table A.)

B. *Reducible to Metals, but yielding no incrustations.*

IRON COMPOUNDS.—*Reduction on the charcoal rod* furnishes neither metallic globules nor lustrous scales ; ground fine in an agate mortar the reduced mass is attracted by a magnet in the form of a black, dull brush, which, when rubbed upon paper, then touched with a drop of aqua regia and gently warmed, produces a yellow spot that turns deep blue by the addition of a drop of ferrocyanide of potassium solution. The paper ought previously be tested for iron.

Borax Bead.—Ignited in oxidizing flame with some oxide furnishes whilst hot, according to the quantity, a yellowish-red to brownish dark-red glass, which, on cooling, turns yellow to brownish-yellow. In reduction flame the bead is red whilst hot, and bottle-green when cold.

NICKEL COMPOUNDS.—*Reduction on the charcoal rod* furnishes white, lustrous, ductile, metallic spangles, which are attracted by the magnet. Rubbed on paper the metal yields, with a drop of nitric acid, a green solution which, when touched with a drop of caustic soda on a glass rod, thence exposed to bromine vapor, and again touched with caustic soda, furnishes a black spot of peroxide of nickel.

Borax Bead.—Oxidizing flame dirty violet; upper reducing flame gray from metallic nickel, which at times unites to a silver-white nickel sponge, whilst the bead turns colorless.

COBALT COMPOUNDS.—*Reduction on the charcoal rod* yields white, shiny, ductile, metallic spangles, which are attracted by the magnet. Rubbed on paper the metal furnishes, in contact with nitric acid, a red solution which, when touched with a drop of hydrochloric acid and then dried, yields a green spot which, when moistened with water, again disappears. By means of caustic soda and bromine vapor we obtain, as with nickel, a brownish-black spot of peroxide of cobalt.

Borax Bead.—Oxidizing flame and reducing flame deep blue.

PALLADIUM COMPOUNDS. *With Soda on Platinum Wire.*—In the upper oxidation flame we obtain a gray mass similar to platinum sponge which, when rubbed in an agate mortar, forms silver-white, lustrous, ductile, metallic spangles, which form a red solution with nitric acid. Adding a drop of mercury cyanide and blowing a current of ammonia vapor over the liquid, a white flaky precipitate is produced, which is redissolved by an excess of the reagent.

PLATINUM COMPOUNDS. *With Soda on Platinum Wire.*—In the upper oxidizing flame they are reduced to a spongy mass which, ground in an agate mortar, yields silver-white, shiny, ductile spangles, insoluble in nitric or hydrochloric acid, but easily soluble in aqua regia (a mixture of both), with a light yellow color when the platinum is pure; with a brownish-yellow color, if palladium, rhodium, or iridium is present.

Mercury cyanide with a current of ammonia vapor gives no white precipitate, but a yellow crystalline one of ammonium platinum chloride.

IRIDIUM COMPOUNDS. *With Soda on Platinum Wire.*—In the upper oxidizing flame a metallic reduction takes place; the mass ground in an agate mortar is not shining nor ductile, and is insoluble in acids, including aqua regia.

RHODIUM COMPOUNDS.—Distinguished from iridium compounds, only that the metallic powder, when fused with potassium sulphate, is partly oxidized, and forms a rose-red solution.

OSMIUM COMPOUNDS.—In the oxidizing flame osmium acid is produced, possessing a chlorine-like, pungent odor, attacking the eyes.

GOLD COMPOUNDS. *With Soda on a Charcoal Rod.*—A yellow, lustrous granule is obtained, which, in a mortar, yields golden yellow spangles. Insoluble in nitric and hydrochloric acids, but soluble in aqua regia. The light yellow solution imbibed by white blotting (filter) paper, and touched with a drop of stannous chloride ($SnCl_4$) produces a splendid purple color (purple of Cassius), used in the arts for imparting to glass a ruby color.

SILVER COMPOUNDS. *With Soda on a Charcoal Rod.*—A white, ductile globule is produced which, when heated, is dissolved in nitric acid. Hydrochloric acid throws down from the solution a white, curdy precipitate, soluble in ammonia, but insoluble in nitric acid.

COPPER COMPOUNDS. *With Soda on a Charcoal Rod.*—A copper-red, ductile globule is obtained, soluble in nitric acid with a blue color. If some of the solution is imbibed by white blotting paper, and a drop of ferrocyanide of potassium added, a brown spot is produced.

Borax Bead.—The oxidizing flame furnishes a blue bead which, in the lower reduction flame, upon the addition of a little stannic oxide yields a brownish-red color of cuprous oxide (Cu_2O). By alternating the oxidizing and reducing process a ruby red, transparent bead is obtained; which is best obtained when the reduced bead is allowed to oxidize slowly.

TIN COMPOUNDS. *On a Charcoal Rod.*—White, bright, ductile globule, dissolving slowly in hydrochloric acid; by nitric acid it is not dissolved, but is converted into insoluble, white, stannic oxide. In tin solutions bismuthic nitrate and an excess of caustic soda, furnishes a black precipitate.

C. *Elements which can best be recognized from the reactions of their compounds.*

MOLYBDENUM COMPOUNDS. *With Soda on the Charcoal Rod.*—Reducible with difficulty to a gray powder.

Borax Bead (not very characteristic).—The bead in the oxidizing flame is at first colorless, but when completely saturated, forms a bluish enamel.

Special Reactions.—The finely powdered substance is mixed with soda (best obtained by fusion of a fragment of a soda crystal), and this mixture fused within a platinum spiral of 2–3 mm. diameter exposed to the flame of a Bunsen lamp. The mass, when heated to a white heat, is knocked off and dissolved in a few drops of warm water. The clear liquid, above the sediment, is imbibed by a strip of blotting paper, and submitted to the following tests: After being acidulated with hydrochloric acid, the addition of ferrocyanide of potassium produces a red brown spot. Stannous chloride, added gradually, forms at once, or after gentle heating, a blue color. Ammonium sulphide produces a brown color, and upon the addition of hydrochloric acid, a brown precipitate, whereby the paper often turns blue.

TUNGSTEN (WOLFRAMIUM) COMPOUNDS.—A fusion is produced like that described by *molybdenum.* The aqueous solution is absorbed by blotting paper. Hydrochloric acid and ferrocyanide of potassium give no reactions. Stannous chloride furnishes at once a blue color, or after slight warming. Ammonium sulphide causes neither alone nor with hydrochloric acid a precipitate, but turns (especially after slight heating) the paper blue or greenish.

TITANIUM COMPOUNDS. *With Salt of Phosphorus.*—In oxidizing flame, colorless; in reduction flame of a feeble amethystine color; adding to the bead some ferrous sulphate, it assumes in the lower reduction flame a red color.

With Soda on Platinum Wire.—Fuses to a colorless transparent mass turning turbid when cold. If the bead while hot is touched with stannous chloride, and heated in the lower reduction zone, a gray mass is obtained which, with hydrochloric acid, and slightly heated, gives a pale amethyst color.

TANTALUM AND NIOBIUM COMPOUNDS exhibit the same deportment as titanium compounds.

CHROMIUM COMPOUNDS. *With Soda in the Platinum Spiral.*—Such compounds fused with repeated additions of saltpetre assume a light yellow color, soluble in water with the same color. The liquid removed from the sediment, then acidulated with acetic acid and imbibed by blotting-paper, yields with solution of lead acetate, a yellow; with silver salts, a reddish-brown precipitate. Ammonium sulphide, stannous chloride, or the evaporation with aqua regia turn the yellow colored solution green.

Borax Bead.—In both flames emerald green.

VANADIUM COMPOUNDS. *Fusion with Soda and Saltpetre in the Platinum Spiral.*—A yellow fusion is obtained. The solution when acidulated with acetic acid, is colored yellow by silver solution. When the solution is mixed with aqua regia and evaporated, we obtain *not* a green, but a yellow or yellowish-brown liquid which is turned blue by stannous chloride.

Borax Bead.—Oxidizing flame, greenish-yellow; reduction flame, green.

MANGANESE COMPOUNDS. *Borax Bead.*—Oxidizing flame, amethyst color; reduction flame, colorless.

With Soda and Saltpetre in the Platinum Spiral.—The fused mass obtained is green, and the aqueous solution likewise. Upon the addition of acetic acid the liquid turns red; later, colorless with separation of brown flakes.

URANIUM COMPOUNDS. *Borax Bead.*—Oxidizing flame, yellow; reduction flame, green. From the similar iron reaction, the hot uranium bead is distinguished by emitting a bluish-green light.

Phosphorus Salt Bead.—Reduction flame, fine green; while iron yields, when cold, a reddish or colorless bead.

With Acid Potassic Sulphate in the Platinum Spiral.—The fused mass is ground together with a few granules of crystallized soda, moistened with water, and absorbed by blotting-paper. When acidulated with acetic acid, ferrocyanide of potassium produces a brown spot.

SILICIC COMPOUNDS. *Phosphorus Salt.*—Small splinters of silicates yield a gelatinous, infusible, silica mass, suspended or swimming in the bead.

With Soda on Platinum Wire.—In oxidizing flame a clear bead is produced with strong effervescence. When this bead is treated with water and acetic acid, and the solution carefully evaporated, a gelatinous mass of hydrous silicic acid separates.

PHOSPHORUS COMPOUNDS.—The completely dried sample is put into a glass tube together with a few cuttings of magnesium wire, or a small piece of metallic sodium, and heated over the burner until the whole mass glows and fuses. The tube is now broken and the contents moistened with water, when the characteristic odor of phosphide of hydrogen is evolved, resembling that of rotten fish.

SULPHUR COMPOUNDS. *With Soda on the Charcoal Rod.* —In the lower reduction zone a fused mass is obtained which, when placed upon silver-foil, or a silver coin, and then moistened with a drop of water, produces a *black spot.* However, this reaction is only reliable, when the *coal gas*, used in the burner, is free from sulphur, and after the absence of selenium and tellurium has been ascertained, since these elements yield the same reaction.

Metallic sulphides show their contents of sulphur by the evolution of sulphorous acid gas (SO_2), bleaching vegetable colors, such as litmus, and having the well-known suffocating odor of burning sulphur.

10. SPECTRUM ANALYSIS.*

An entirely new branch of chemical analysis of great delicacy and importance, was developed in 1859, chiefly by the researches of R. Bunsen and G. Kirchhoff, the principles of which may here be briefly stated.

It had long been known that certain chemical substances, especially the salts of the alkalies and alkaline earths, when strongly heated in the blowpipe, or other nearly colorless flame, impart to that flame a peculiar color by the occurrence of which the presence of the substance may be detected. If many of these substances are present together, the detection of each by the naked eye becomes impossible, owing to the colors being blended and interfering with each other. Thus a small trace of soda giving to the flame an intense yellow color prevents the eye from recognizing the purple tint of potassium salts, even if large quantities of these are present. This difficulty is completely overcome, and this method of observation rendered extremely sensitive, if, instead of regarding the flame

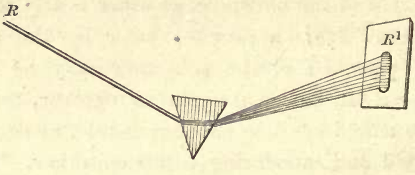
---

* Prof. Roscoe's "Lessons in Elementary Chemistry, Inorganic and Organic." London. Same author: Spectrum Analysis with Engravings, etc. Prof. Lockyer's Three Manchester Science Lectures. London. Same author: "Studies in Spectrum Analysis." Young on "The Sun." The two last named volumes in the "International Scientific Series."

with the naked eye, it is examined through a prism. This consists of a triangular piece of glass, in passing through which the light is refracted or bent out of its course—each differently colored ray being differently refracted, so that if a source of white light, such as the flame of a candle, is thus regarded, a continuous band of differently colored rays is observed—the. compound white light being resolved into all its single, variously colored constituents. The colored band is called *spectrum*, and each source of pure white light gives the same *continuous spectrum*, stretching from red (the least refrangible) to violet (the most refrangible) color, identical in fact with the colors of the rainbow.

The light of the sun and of celestial bodies in general, as well as that of the electric spark and of all ordinary flames, is of a compound nature. If a ray of light from any of the sources mentioned be admitted into a dark room by a small hole in a shutter, or otherwise, and suffered to fall upon a glass prism in the manner described below, it will not only be refracted from its straight course, but will be decomposed into a number of colored rays, which may be received upon a white screen placed behind the prism. When solar light is employed, the colors are extremely brilliant, and spread into an oblong space of considerable length. The upper part of this image or *spectrum* will be violet and the lower red, the intermediate portion, commencing from the violet, being indigo, blue, green, yellow, and orange, all graduating imperceptibly into each other. This is the celebrated experiment of Sir Isaac Newton; and from it he drew the inference that white light is composed of

Fig. 109.



seven primitive colors, the rays of which are differently refrangible by the same medium, and hence capable of being thus separated. The violet rays are most refrangible, and the red rays least.

If these colored flames are examined by means of a *prism*, the light being allowed to fall through a narrow slit upon the *prism*, it is at once seen that the light thus refracted differs essentially from white light, inasmuch as it consists of only a particular set of rays, each flame giving a spectrum containing a few *bright lines.* Thus the spectrum of the yellow soda flame contains only one fine bright yellow line, while the purple potash flame exhibits a *spectrum* in which there are two bright lines, of a poppy-red color, one lying at the extreme red, and the other of a bluish-purple color at the extreme violet end. These peculiar lines are always produced by the same chemical element, and by no other known substance, and the position of these lines always remains unaltered. When the spectrum of a flame tinted by a mixture of *sodium* and *potassium* salts is examined, the yellow ray of *sodium* is found to be confined to its own position, while the potassium-red and bluish-purple lines are as plainly seen as they would have been had no sodium been present.

The colored flames which are exhibited by the salts of *lithium*, *barium*, *strontium*, and *calcium*, all give rise, likewise, to a peculiar spectrum by which the presence or absence of very small quantities of these substances can be ascertained with certainty when mixed together, simply by observing the presence or absence of the peculiar *bright lines* characteristic of the particular body. The advantage which this new method of analysis possesses over the older processes lies in the extreme delicacy, as well as in the great facility with which the presence of particular elements can be detected with certainty.*

---

* A little of the substance under examination is put upon the loop of a clean platinum wire, and inserted in the flame of the Bunsen gas burner. Then, almost at a glance, whatever spectra may be present can be recognized.

Thus a portion of sodium salt less than $\frac{1}{180,000,000}$th part of a grain can be detected; and compounds are found to be most widely disseminated throughout the earth, which were supposed to occur very rarely. The extreme delicacy of the method is seen when we learn that every substance which has ever been exposed to the air for a moment gives the soda line, when placed in a colorless flame; and when we find that the *lithium compounds*, which were formerly supposed to be contained in only four minerals, by aid of spectrum analysis, are found to be substances of most common occurrence, being observed in almost all spring waters, in tea, tobacco, milk, and blood, but existing in such minute quantities as to have altogether eluded recognition by the older and less delicate analytical methods; for example, $\frac{1}{180,000,000}$ of a grain of sodium, or $\frac{1}{6,000,000}$ of a grain of lithium, will reveal its presence immediately. Thus, in a drop of native spring water, Li can be detected if a platinum wire is dipped into it and held in the flame. A most striking proof of the high value of spectrum analysis lies in the fact of the recent discovery of four new elements by its means. Two new alkaline metals, *cæsium* and *rubidium*, having been found together with soda and potash in certain mineral springs, and two new metals, *thallium* and *indium*, having been respectively discovered in iron pyrites and zinc ores. The new alkaline metals resemble potassium so closely in their properties, that it would be nearly impossible to have detected them by the ordinary analytical methods, although their spectra exhibit very distinct bright bands not seen in the potassium or any other known spectrum. The metal thallium was discovered by observing a splendid green line which did not belong to any known substance; whilst indium was recognized by the presence of the two lines, In α in the indigo and In β in the violet portion of the solar spectrum.

It is not only those bodies which have the power of imparting color to the flame which yield characteristic spectra, for this property belongs to every elementary substance, whether metallic, non-metallic, solid, liquid, or gaseous, and it is always observed when such element is heated to the point at which its vapor becomes luminous; for then each element emits the peculiar light given off by it alone, and the characteristic bright lights become apparent when its spectrum is observed.

Spark Spectra.

Most metals require a much higher temperature than that of the non-luminous flame, in order that their vapor should become luminous; but they may be easily heated up to the requisite temperature by means of the electric spark, which, in passing between two points of the metal in question, volatilizes a small portion, and heats it so intensely as to enable it to give off its peculiar light. Thus all the metals, among others iron, platinum, silver, and gold, may each be recognized by the peculiar bright lines which their spectra exhibit. It is to be remembered, however, that the bright lines of the gases through which the spark passes (the air lines) will likewise be observed.

Spectra of Permanent Gases.

The permanent gases also yield characteristic spectra when they are strongly heated by the passage of an electric spark. Thus if the spark be passed through an atmosphere of hydrogen gas, the light emitted is one bright red, one green, and one blue line; whilst in nitrogen gas the spark has a purple color, and the peculiar and complicated spectrum of nitrogen is observed when this spark is examined with a prism.

In order to detect several flame-coloring elements when occurring together, it is easiest and best to use the spectroscope. If a colored flame be observed by means of the spectroscope, bright colored lines upon a dark ground are perceived. This arises from the fact that each element gives out a light peculiar to itself, which is resolved into single rays by the prism of the spectroscope, and these rays form the lines seen in the apparatus. The lines vary in color, position, and manner of grouping with each element: these characteristic differences form the basis of the most sensitive and exact method of analysis, the so-called *spectrum analysis.*

The spectrum lines of the most important elements are given in the following table. The numbers in this table indicate the divisions of a scale on which the various lines fall when the sodium line coincides with the fiftieth division. The heavy figures represent the prominent characteristic lines, which only appear at high temperatures and then soon disappear.

SPECTRUM LINES OF THE MOST IMPORTANT FLAME-COLORING ELEMENTS. (SODIUM LINE = 50.)

Elements.	Red lines.				Orange lines.		Yellow lines.	Green lines.			Blue lines.				Violet lines			
0	10	20	30		40	50	60	70	80	90	100	110	120	130	140	150	160	170
Sodium	...	...	...	...	...	**50**												
Potassium	...	**17**	27	...	...	...	...	...	...	...	...	...	...		...	...	**153**	
Lithium	...	...	...	**31**	...	45												
Cæsium	...	...	27	**31**	38	**41**	51;56 57	62;63 66;68 69	71	...	...	106 109						
Rubidium	...	13;15	...	...	...	**40;42** 43;45	55;57	65;67	71;73 76;78		...	...	...	...	**135** **137**			
Barium	...	...	...	35	39	41;43 **44;45** 47;50	52;55 57	**61;67**	**71;77**	90								
Strontium	...	...	30	...	36 38	**42;45**	...	...	...	...	...	**105**						
Calcium	...	...	...	**32** **34**	37	**42;46** 49	52;55	**62**	...	...	...	...	...	...	135			
Thallium	...	...	...	...	...	...	...	**67**										
Indium	...	...	...	...	...	...	...	...	...	...	...	...	**111**	...	...	**147**		

Solar and Stellar Chemistry.

If sunlight be allowed to fall upon the slit of the spectroscope, it is observed that the solar spectrum thus obtained differs essentially from the spectra which we have hitherto considered, inasmuch as it consists of a band of bright light passing from red to violet, but intersected by a very large number of *fine dark lines*, of different degrees of breadth and shade, which are always present, and always occupy exactly the same relative positions in the solar spectrum. The student is recommended to consult the colored charts which are published, giving the general appearance of the solar spectrum and the position of some of the most important of these dark lines, marked with the letters of the alphabet. These lines indicate the absence in sunlight of particular rays, and they may be considered as *shadows, or spaces* where there is no light; they are called "*Frauenhofer*" *lines*,* after a German optician who first satisfactorily mapped and described them.

In the last few years the existence of these lines has become a matter of great importance and interest, as it is by their help that the determination of the chemical constitution of the sun and far-distant stars has become possible. The spectra of the moon and planets (reflected sunlight) are found to exhibit these same lines in unaltered position, while in the spectra of the fixed stars, dark lines also occur, but these stellar lines are different from those seen in direct and reflected sunlight. Hence the conclusion has been drawn that the Frauenhofer lines are in some way produced in the body of the sun itself; but it is only recently that the cause of their production has been discovered by the joint labors of Bunsen and Kirchhoff, and thus the foundation laid for the science of *solar* and *stellar chemistry.*

If the position of these dark lines in the solar spectrum be carefully compared in a powerful spectroscope with those of the

---

* Dark lines running lengthwise of the spectrum often confuse the beginner. They are due to dust-specks on the slit of the spectroscope.

bright lines in the spectra of certain metals, such as sodium, iron, and magnesium, etc., it is seen that each of the *bright* lines of the particular metal coincides not only in position but also in breadth and intensity with a *dark* solar line; so that, if the apparatus be so arranged that a solar and metallic spectrum be both allowed to fall, one below the other, in the field of the telescope, the bright lines of the metal are all seen to be continued in *dark solar lines.* In the case of metallic iron alone, more than sixty such coincidences have been observed, and the higher the magnifying power employed, the more striking and exact does this coincidence appear.

With other metals, such for instance as gold, antimony, lithium, no single coincidence can be noticed, while all the lines of certain other metals have their dark representatives in the sun. From these facts it is clear that there must be some kind of connection between the bright lines of these metals and the coincident dark solar lines. Are such coincidences of the *dark solar* lines with the *bright* iron lines caused by the presence of iron in the *sun?* And if so, how do these lines come to appear *dark* in the solar spectrum?

The explanation of this is given by an experiment in which the *bright metallic lines* are *reversed* or changed into *dark* lines. Thus the bright yellow soda lines (coincident with Frauenhofer's line "D") can be made to appear as a dark line, by allowing the rays from a strong source of white light, such as the oxyhydrogen light, to pass through a flame colored by soda, and then fall upon the slit of the spectroscope.* Instead of then seeing the usual soda spectrum of a *bright yellow double line* upon a dark ground, a double *dark line*, identical in posi-

---

* The experiment may be made thus: Between the strong light, capable of giving a continuous spectrum, and the slit in the spectroscope, a layer of sodium vapor is interposed, produced by heating a little metallic sodium in an iron spoon. This sodium vapor absorbs the yellow ray which the more intensely heated sodium vapor of the oxyhydrogen light emits, and a dark line will be seen in its place, *i. e.*, the sodium line has been *reversed.*

tion and breadth with the soda line, will be seen to intersect the continuous spectrum of the white light. Here then the yellow flame has absorbed the same kind of light as it emitted, a consequent diminution of intensity in that part of the spectrum occurred, and a *dark* line made its appearance. In like manner the spectra of many other substances have been *reversed*, each substance in the state of vapor having the power of absorbing the same rays it emits, or being opaque to such rays.*

The explanation of the existence of dark lines in the solar spectrum, coincident with bright metallic lines, now becomes evident. These dark lines are caused by the passage of white light through the glowing vapor of the metals in question, present in the sun's atmosphere, and these vapors absorb exactly the same kind of light which they are able to emit. The sun's atmosphere, therefore, contains these metals in the condition of glowing gases; the white light proceeding from the solid or liquid strongly heated mass of the sun which lies in the *interior.*

By observing the coincidences of these *dark* lines with the *bright* lines of terrestrial metals, we arrive at a knowledge of the presence of such metals in the solar atmosphere with as great a degree of certainty as we are able to attain in any question of physical science. The metals hitherto detected in the sun's atmosphere are *nine* in number, viz., iron, sodium, magnesium, calcium, chromium, nickel, barium, copper, and zinc. Hydrogen and oxygen are also known to exist in the sun.

Stellar Chemistry.

The same methods of observation and reasoning apply to the determination of the chemical constitution of the atmospheres of the fixed stars, as these are self-luminous suns; but the experimental difficulties are greater, and the results, therefore,

---

* This is in accordance with the physical law that substances when cold absorb the same rays which they give out when hot.

are as yet less complete, though not less conclusive, than is the case with our sun.

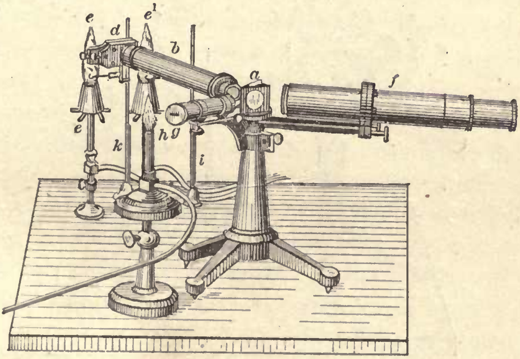
The spectra of the stars contain dark lines, but these are for the most part different from the solar lines, and differ from one another; hence we conclude that the chemical constitutions of the solar and stellar atmospheres are different. Many of the substances known on the earth have been detected in the atmosphere of the stars by Mr. Huggins and Prof. W. A. Miller, to whom we owe this most important discovery.

The bright star *Aldebaran*, for instance, contains hydrogen, sodium, magnesium, calcium, iron, antimony, mercury, bismuth, and tellurium.

Spectroscope.

The instrument used in these experiments is termed a spectroscope. It consists of a prism, *a* (Fig. 110), fixed upon a firm iron stand, and a tube, *b* (collimator), carrying the slit, *d*, through which the rays from the colored flames, e' and e, fall upon the prism, being rendered parallel by passing through a lens. The light having passed through the prism, and having been refracted or split up into its constituents, the differently colored rays are received by the telescope, *f*, and the image

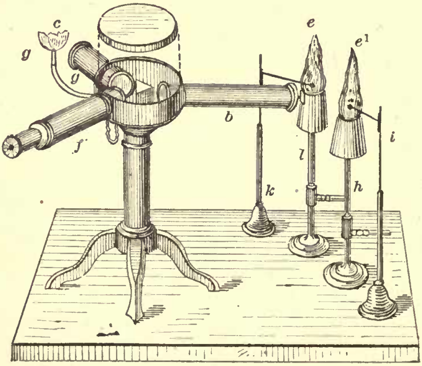
Fig. 110.



magnified before reaching the eye. The rays from each flame are made to pass into the telescope, *f*, one set through the uncovered half of the slit, the other by total reflection through a small prism through the lower half; thus bringing the two spectra into the field of view at once, so as to be able to make any desired comparison of the lines.

Measuring the Spectrum.—But for scientific purposes the instrument requires the most accurate means for measuring the spaces of the spectrum. For this purpose a third tube, *g*, has been added. At its outer end there is a glass plate upon which is engraved or photographed a scale of minute divisions. A lamp, *h*, placed in front of this tube, *g*, throws the image of this scale through the tube and lens at the end nearest to the prism, so that it falls upon the face of the prism, *a*, at such an angle as to be reflected through the telescope, *f*, to the eye. The scale is permanent, and parallel with it the observer sees the spectrum of whatever light is employed, and can thus fix and compare the position of the lines with exactness.

Fig. 112.



In Fig. 111 is seen the tube, *g*, containing the photographed scale, illuminated by a gas jet, *c*, and the manner in which both are fastened to the brass case, having a cover to keep off foreign light as well as dust, from the prism. The Bunsen burners, *l*, *h*, together with the two supporters, *i*, and *k*, serve for volatilizing the substances to be investigated. If the flames, *e* and *e'*, are brought in proper position relative to the slit of tube, *g*, the brass case, together with prism and tubes, is then turned until the intensity of the spectrum light has attained its maximum value. As the illuminating lamp, *c*, and the scale, *g*, are likewise fastened to the brass case, all must turn together, and the illumination of the scale will remain the same.

CHAPTER VII.

SPECIAL METHODS FOR DETECTING CERTAIN ELEMENTS, OR SOME OF THEIR COMBINATIONS WHEN PRESENT IN COMPLEX CHEMICAL COMPOUNDS.

1. Alumina, Al_2O_3. This may be traced in most of the infusible minerals by the blue color which the assay assumes when, after being strongly heated, it is moistened with cobalt solution and reheated. Very hard minerals, such as corundum, must previously be very finely pulverized.

Native crystallized alumina, such as corundum, ruby, sapphire, emery, are, like strongly ignited amorphous alumina, almost entirely insoluble in acids, but when fused with bisulphate of potassium, caustic or carbonate of potassium pass into a soluble condition. The colorless alumina salts are either insoluble or soluble in water, losing the acid upon ignition. Caustic alkalies precipitate from solutions a gelatinous basic salt, soluble in an excess of the precipitant. From this solution alumina is thrown down by sal-ammoniac (or better, after the neutralization with HCl, by ammonia or carbonate of ammonium). Ammonia, carbonate of ammonium, and sulphide of ammonium, precipitate gelatinous hydroxide $= Al_2(OH)_6$, soluble somewhat in the first, insoluble in the other reagents mentioned, *e. g.*,

$$(SO_4)_4Al_2K_2 + 6NH_3 + 6H_2O = 3[SO_4(NH_4)_2] + SO_4K_2 + Al_2(OH)_6.$$

In the presence of magnesia the precipitate, resulting from alkalies, contains magnesia, readily separated by repeated solutions in HCl, and reprecipitation by ammonia, or preferably by boiling with sal-ammoniac solution until no ammoniacal odor can be perceived, when the magnesia passes into solution as an ammoniacal double salt.

Phosphate of soda precipitates from alumina salts gelatinous *phosphate of alumina*, soluble in potassa, but insoluble in acetic acid (distinctive from lime phosphate). Chloride of barium, or aqueous baryta solution, removes from a solution of phosphate of alumina in potassa, all the phosphoric acid in the form of phosphate of baryta. From an alkaline solution of alumina the addition of silicate of potassa (soluble glass) produces a precipitate of silicate of alumina, leaving in solution all the phosphoric acid.

2. AMMONIA. The substance is mixed with some caustic soda, potash or lime in the closed tube (a common reagent tube will answer), and the mixture heated, when ammonia gas is evolved, recognizable 1st, by its pungent odor (hartshorn); 2d, by turning moistened red litmus paper blue; 3d, by its producing dense white fumes with the vapor of concentrated hydrochloric acid, when the latter, suspended on a glass-rod, is brought near it; 4th, by Nessler's test. The fact must not be overlooked, however, that organic nitrogenous bodies evolve ammonia as a product of decomposition, when these are heated to redness with a sufficient excess of powdered caustic potash or soda, or a mixture of caustic (burnt) lime and soda.

Ammonia may be obtained even from a nitrate salt by ignition with potash-lime, provided that a non-azotized body, like sugar, be added to the mixture, but only when the latter is in great excess, *e. g.*, 1 part nitre and 40 parts sugar, has been found to be the best proportion.

Platinic chloride precipitates from ammonia solutions a yellow precipitate, insoluble in alcohol or ether. It leaves upon ignition pure, *spongy platinum.*

3. ANTIMONY. The ores of antimony afford usually white fumes or charcoal when heated on aluminium foil, which are inodorous. In the open tube antimony gives a white sublimate, coating the glass. Antimony sulphides give at a strong heat in the closed tube a sublimate which is black while hot, brownish-red when cold. Treated with nitric acid, compounds of antimony deposit white antimonic oxide (Sb_2O_5).

In order to trace antimony when combined with other volatile metals, the white coating on coal is touched with a drop of hydriodic acid,* and once more heated. When its coating consists of antimony it turns to a fine red ; if bismuth, to brown ; if lead, to a light yellow ; if cadmium, to white. Since these colored coatings are very distinct and different, all the metals quoted may be recognized when present together (Haanel).

When antimony is combined with lead and bismuth it is best detected by treating the substance with fused boric acid on the O. F. When the oxides of lead and bismuth are aborbed by the boric acid, and the charcoal becomes coated with a sublimate which, when the blowing has not been too strong, consists of oxide of antimony, only free from the oxides of lead and bismuth.

When antimony is combined with copper it is separated from it with difficulty, and the coating of antimony is scarcely recognizable on the charcoal. Under these circumstances the alloy is heated in the O. F. with a bead of S. Ph. until the latter has dissolved a portion of the antimony, the glass is then removed from the remaining metallic granule, placed on charcoal and heated with tin in the R. F. If the bead turns turbid

---

* HI is obtained when pulverized iodine is suspended in water and a current of sulphide of hydrogen gas passed through it.

and black, antimony is indicated. However, as bismuth gives the same reaction, it is best to separate and distinguish them in the *wet way.*

When the oxides of antimony, tin, and copper are combined together, we treat the mineral powder with a mixture of soda and borax in the R. F. on coal. The metallic globules are removed from the glassy mass and fused with 3–4 parts (by volume) of pure test-lead and *fused boric acid*, when metallic copper remains behind, while tin goes into the slag, and antimony coats the coal white.

Sulphides of lead and antimony are mixed with soda and treated in the R. F. on charcoal; when near the assay the yellow lead coating appears, and beyond this the white sublimate of antimony.

Compounds of antimony are, according to Plattner, heated for a short time in the open tube, when they yield a mixture of crystals (compare arsenic) and amorphous antimonious acid. A small amount of antimony mixed with sulphide of arsenic is detected by heating the dry mixture gently in a closed tube; the *sulphide of arsenic* volatilizes, while the *dark colored sulphide of antimony* remains where the assay was originally placed. The tube is then cut off between the two sulphides, and the dark sulphide of antimony transferred to an open tube. By applying heat the characteristic antimony reaction will appear. When the quantity is extremely small, the tube is crushed, and the fragments, with the adhering sulphides, are introduced into the open tube.

Antimony fuses at 425° C. (797° F.), and volatilizes slowly at a white heat. By fusing it in the air it takes fire, forming a dense white, inodorous vapor, consisting of antimonious oxide, Sb_2O_3. Antimony is very nearly insoluble in HCl, and H_2SO_3; in aqua regia easily soluble to antimonious or antimonic chloride, $SbCl_3$ and $SbCl_5$. With nitric acid it forms a mixture of white antimonious and white antimonic oxide, insoluble in the acid. Hot sulphuric acid dissolves it, forming antimonious sulphate with evolution of SO_2. All the sulphur compounds of antimony are soluble in hot concentrated HCl, forming $SbCl_3$ with evolution of H_2S.

Sb_2O_3 is volatile at red heat, easily soluble in hydrochloric and tartaric acids, insoluble in nitric acid. Its unstable salts are decomposed with much water, a white basic salt separates, while the acid solution contains yet Sb_2O_3, viz., $4SbCl_3+5H_2O=2SbOCl+Sb_2O_3+10HCl$. Tartaric acid prevents this reaction. Zinc separates from solutions of Sb_2O_3, in the absence of nitric acid, a black powder of metallic Sb. When a few drops of a compound of antimony, previously acidulated with HCl (nitric acid is injurious) is brought together with a little zinc upon platinum foil, the latter becomes covered with a black or brown deposit. This reaction is very sensitive, and takes place even with a dilute solution, a brown spot being formed at once,* soluble in warm nitric acid, antimonic acid being produced.

H_2S produces in acid solutions of antimonious acid salts, orange-red Sb_2S_3, easily soluble in $(NH_4)_2S$, or in caustic alkali, but very little soluble in ammonia, and insoluble in bicarbonate of ammonium and dilute acids. Warm HCl dissolves it to $SbCl_3$, while H_2S escapes. A dilute solution of tartar emetic is colored orange by H_2S, but is precipitated by the addition of acid. Caustic alkalies, alkaline carbonates, as well as ammonia, and carbonate of ammonia, throw down white amorphous antimonious hydroxide, $Sb(OH)_3$, soluble in caustic alkali, insoluble in ammonia.

There are two hydrogen antimoniates or acids: *antimonic acid*, $H_2OSb_2O_5$, or $HSbO_3$ (monobasic) and *metantimonic acid* $(H_2O)_2Sb_2O_7$ (dibasic), or isomeric with antimonic acid, and monobasic.

The normal antimoniates, as $KSbO_3$, are all insoluble in water, except a hydrated potassium antimoniate, and this is made anhydrous and insoluble by boiling the solution.

The super-antimoniates, as $(K_2O)_2Sb_2O_5$, are all insoluble in water.

---

* A characteristic difference from arsenic and tin compounds.

The monobasic potassium meta-antimoniate, $KSbO_3$, is used as a precipitant for sodium (with all other acids soda forms *soluble salts*), and is prepared by fusing *antimonic acid* with a large excess of potassium hydrate; then dissolving, filtering, evaporating, and digesting hot the *syrupy solution*, with large excess of potassium hydrate, best in a silver dish, decanting the alkaline liquor, and stirring the residue, to granulate dry; this reagent must be kept dry, and only dissolved when required for use to precipitate soda. The reagent is of course not applicable to acid solutions.

On the insolubility of meta-antimoniate of soda rests one of the best methods for the separation of antimony from other metals, and particularly from arsenic. Any compound of antimony (except the sulphide) being intimately mixed in a porcelain crucible with four parts of nitrate of soda and two parts of anhydrous carbonate of soda, and heated until the mass becomes entirely white, then treated, when cold, with water (or still better with very dilute alcohol), all the antimony remains as meta-antimoniate of soda, the arsenic as an *arseniate* of the alkali is found in the solution.

For the formation of and reaction of antimonious hydride, SbH_3, compare arsenic.

4. ARSENIC (Arsenicum). A steel-gray, lustrous, brittle, and easily pulverizable non-metallic element, vaporizing directly from the solid state at 356° C. (673° F.) in closed vessels; the vapor being colorless, with a strong *garlic odor*.

Arsenious and arsenic acids are reduced to the elementary metallic state by several methods of great analytical importance. By the action of hydrogen gas, generated from an acid solution (Marsh's test), it is reduced from all its soluble compounds when it enters into a combination with the hydrogen, to arsenious hydride, AsH_3, which is gaseous and extremely *poisonous*. The latter can be identified by numerous reactions, and from it the arsenic can again readily be obtained in its free elementary state. The hydrogen is generated by sulphuric acid diluted with 6 to 8 parts of water and zinc (both free from arsenic).

$$Zn + H_2Sb_4 = ZnSb_4 + 2H.$$

The hydrogen removes the oxygen from either oxide of arsenic,* forming water, and then combines with the arsenic, two atoms of hydrogen taking the place of one atom of oxygen.

$$H_3AsO_3 + 3(Zn + H_2SO_4) = 3ZnSO_4 + 3H_2O + AsH_3.$$

Arsenious hydride gas (arsine) burns with a somewhat luminous and slightly bluish flame (distinct from *pure hydrogen*).

If a piece of cold porcelain is held in the flame the reduction of temperature prevents the oxidation of As, which is at once deposited in dark, steel-gray spots.

Arsenious hydride is decomposed by heat alone. In passing through glass tubes, heated to incipient redness, the gas is decomposed, the arsenic adhering to the inner surface of the tube beyond the heated part, as a steel-gray mirror coating. The following reactions exhibited by these deposits will serve to distinguish *arsenic* from *antimony.*

ARSENIC SPOTS.	ANTIMONY SPOTS.
Dissolve in hypochlorite of soda, (NaClO).	Do not dissolve in hypochlorite.
Warmed with a drop of ammonium sulphide form *yellow* spots soluble in ammonium carbonate, insoluble in HCl.	Warmed with sulphide of ammonium form *orange* spots, insoluble in ammonium carbonate, soluble in HCl.
A drop of hot nitric acid dissolves them.	A drop of hot dilute nitric acid turns them white.
This clear solution mixed with a drop of solution of silver nitrate, gives when treated with vapor of ammonia (evolved from a glass rod, moistened with ammonium hydrate) a *brick-red* or a yellow color.	These white spots, treated with silver nitrate and vapor of ammonia, give *no color*, but when warmed with a drop of ammonium hydrate they assume a *black color*.

---

* Free arsenic and arsenious sulphides are not acted upon by the nascent hydrogen.

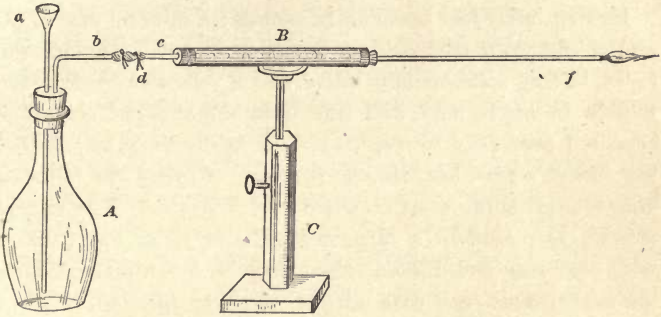
With vapor of iodine the color turns yellow, by formation of arsenious iodide *readily volatile* when heated.	With vapor of iodine color more or less carmine-red, by formation of antimonious iodide *not readily volatile* by heating.
ARSENIC MIRROR.	ANTIMONY MIRROR.
Deposited beyond the flame, the gas being decomposed at a red heat.	Deposited before or on both sides ; the gas being decomposed considerably below a red heat.
By vaporization in the stream of gas arsenic escapes with a *garlic odor*.	The vapor has *no odor*.
By the *slow vaporization* of arsenic in a current of air, established in an open glass tube, containing the assay, which should be held obliquely over a lamp, a deposit of *octahedral crystals* (see Fig. 113) is obtained beyond the source of heat. Should enough As be present, a dense, white coating is deposited which, when examined with a magnifying glass, may exhibit crystalline forms. This white sublimate of As_2O_3 is soluble in water, and the solution can be tested in the wet way.	*By vaporization* in a current of air a white amorphous coating is obtained, insoluble in water, soluble in HCl, and giving reactions for antimony.

Fig. 113.

Apparatus for "Marsh's" Tests above mentioned.

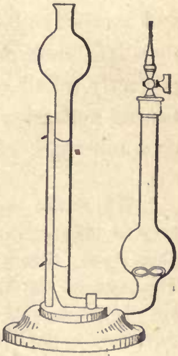
In Marsh's apparatus, Fig. 114, *A* is the gas evolving bottle, provided with funnel tube *a*, and escape tube *b*. *B* is a chloride of calcium tube supported by stand *C*. Tube *b* is connected to *c* by India-rubber joint *d*. The gas issues at point of tube *f*, where it may be inflamed.* A simple apparatus, consisting of a test-tube provided with a cork and delivery tube, may serve in many experiments.

Fig. 114.



A convenient form of Marsh's instrument is that shown in the drawing (Fig. 115); it consists of a bent tube having two bulbs blown upon it, fitted with a stopcock and narrow jet. Slips of zinc are put into the lower bulb, which is afterwards filled with the liquid to be examined. On replacing the stopcock, closed, the gas collects and forces the fluid into the upper bulb, which then acts by its hydrostatic pressure, and expels the gas through the jet as soon as the stopcock is opened. It must be borne

Fig. 115.



---

* The inexperienced experimenter is cautioned not to light the gas before all the air has escaped, otherwise an explosion, and destruction of the apparatus may take place.

in mind that both common zinc and sulphuric acid often contain traces of arsenic.*

Test for Arsenic in Minerals containing no Sulphur, as Whitneyite (Cu_9As).

Having lately had occasion to examine a mineral new to me, and of unknown composition, made up of small, angular granules, having a submetallic lustre, and a yellowish-brown color, soluble in nitric acid, and free from sulphur, but containing copper, I proceeded to test for arsenic in the usual way, including Marsh's test, but without success. I found the following simple process the most accurate and delicate:† The mineral powder is placed in a large test-tube or small flask, treated with pure zinc and diluted sulphuric acid, and a piece of filtering paper, moistened with nitrate of silver solution, tied over the mouth. If arsenic be present, arsenious hydride (AsH_3) is evolved which, acting upon the nitrate of silver, will in a short time blacken it, more especially after some standing.

Should sulphur be present in a mineral the interference of H_2S thus formed may be avoided by causing the gas to pass through cotton-wool moistened with a solution of lead acetate, and carefully placed within so as to fill the neck of the flask, then left standing for several hours. This operation may be perfectly relied upon for negative results, and is well suited for testing preliminarily the purity of the reagents employed, viz., zinc and sulphuric acid.

---

* Where the amount of arsenic present is small, it becomes necessary to take advantage of the effects of heat, and cause the gas to pass slowly through a red-hot tube, until all the zinc is dissolved. The reduced arsenic will be deposited on the cool part of the tube just beyond the heated portion. In all cases in using the above test, it is necessary to ascertain the purity of the zinc and acid by trial, previous to the addition of the suspected liquid.

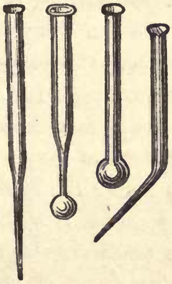
† Qualitative Chemical Analysis, by Drs. S. H. Douglas and A. B. Prescott. New York, D. Van Nostrand, 1880, p. 117.

Arsenious and arsenic acids, and their salts, as well as the sulphides of arsenic, are examined by pulverizing and placing them in a glass bulb, covering them with six times their weight of a dry mixture of equal parts of cyanide of potassium and carbonate of soda. The mass is next gently heated, and the moisture, if any be present, removed by inserting a piece of bibulous paper. The operation is repeated until the mixture is perfectly dry. Finally, the bulb is strongly heated over an alcohol lamp, or by the blowpipe flame, when a mirror metallic arsenic deposits in the cool part of the above tube.

Very small traces of arsenious acid can also be detected according to Berzelius by introducing the assay into a closed glass tube, drawn out to a small diameter (Fig. 116), and inserting a splinter of charcoal above it from *a* to *b*. The charcoal is first heated, and then the assay; the arsenious acid is reduced as it passes over the hot charcoal, and As is deposited in the form of a metallic mirror at *c*. If the tube be cut off between the mirror, *c*, and the sealed end, *a*, the mirror, upon heating, gives off the arsenical odor of garlic.

Fig. 116.

Fig. 117.



Arsenic tubes, for the reduction of arsenical compounds and sublimation of arsenic, should all be made of hard German or Bohemian glass, free from reducible metals.

They are usually about three inches long. Fig. 117 represents the forms mostly used for this purpose, and which the student may readily prepare for himself from glass tubing of suitable width with the aid of the Bunsen blast-burner.

Reinsch's test is founded upon the fact that metallic copper reduces arsenious acid from a hot hydrochloric acid solution.

A bright slip of copper foil is boiled in the liquid previously acidulated with hydrochloric acid, the copper withdraws the arsenic and becomes covered with a white alloy. By heating the metal in a glass tube the arsenic is expelled and oxidized to arsenious acid.

5. BARYTA.—All salts of baryta, except silicates and phosphates, yield the characteristic yellowish-green coloration of the flame, especially after moistening with HCl. Even the insoluble sulphate $BaSO_4$ (heavy spar), obtained when any soluble mineral containing baryta is dissolved in HCl, and the solution precipitated by dilute sulphuric acid, causes the same coloration. When observed through green glass (colored with oxide of copper) the baryta flame appears bluish-green. See flame coloration, page 104.

Strontia may interfere with the baryta reaction. The presence of sulphate of baryta with the sulphate of strontia can be detected by fusing the mixture with 3 or 4 parts of chloride of calcium in a platinum spoon, and boiling the fused mass with water. If a cloudiness is produced by adding to the clear dilute solution a few drops of chromate of potassa, the presence of baryta is indicated. Strontia is only precipitated from the concentrated solution (Chapman).

Sulphate of baryta (heavy spar) fuses B. B.; the fused mass reacts alkaline with test-paper; on charcoal it is reduced to sulphide. With soda by continued blowing it yields hepar, which placed on a clear silver surface, and moistened with a drop of water, yields black sulphide of silver.

6. BISMUTH.—Fuses and gives off inodorous fumes. When treated alone or with soda in the R. F. on charcoal, it pro-

duces a dark-brown oxide, which turns pale-yellow on cooling. The presence of other metals renders this reaction sometimes unsafe, and the wet way for its detection is preferable. If a compound of bismuth be treated with a mixture of equal parts of iodide of potassium and flowers of sulphur, and fused B. B. on charcoal, a beautiful red sublimate of iodide of bismuth will be deposited (von Kobell). Compounds containing lead treated in the same manner yield a yellow coating; their presence does not interfere with the reaction for bismuth.

Bismuth is insoluble in HCl, but easily soluble in nitric acid or aqua regia, forming a nitrate $(NO_3)_3Bi$, or a chloride $BiCl_3$ also soluble in hot sulphuric acid, producing a sulphate $(SO_4)_3Bi_2$.

The teroxide of bismuth, Bi_2O_3, is formed by a strong ignition of the metal in the air, or by heating the nitrate salt. The salts are colorless; their solutions, if there is not too much acid present, are decomposed by water, and a white basic salt is precipitated. The acid which has been set free always holds some teroxide in solution,

$$(NO_3)_3Bi + H_2O = NO_3Bi(OH)_2 + 2NO_3H.$$

The decomposition of the chloride is more complete,

$$BiCl_3 + H_2O = BiOCl + 2HCl.$$

In examining small quantities of a substance for minute amounts of bismuth, the HCl solution is evaporated to a few drops, and these thrown in water. The white precipitate is insoluble in tartaric acid or tartrate of potassa, which distinguishes it from the oxide of antimony, which is soluble. H_2S and $(NH_4)_2S$ precipitate brown sulphide, (Bi_2S_3), insoluble in an excess of sulphide of ammonium. Ammonia and caustic alkali throw down white hydroxide, $BiO.(OH)$, insoluble in an excess. Chromate of potassium throws down yellow chromate of bismuth. If into a clear solution of stannous chloride in an excess of potassa we drop a solution of a bismuth salt, a black precipitate falls which is bismuth monoxide, BiO.

7. Boric (boracic) acid is recognized by the intense green color it or its compounds, especially silicates, impart to the

flame at the instant of fusion, when melted with three parts of the flux, called "*Turner's reagent*" (a mixture of two parts of fluor-spar and one of bisulphate of potassium). The trial should be made in a dark place.

Borate of sodium alone tinges the flame pure yellow, but if it be moistened with H_2SO_4, boric acid is set free, tinging its mixture with alcohol, when ignited, lively green.

Another very delicate and reliable reaction is that of Iles. The finely pulverized mineral is moistened with H_2SO_4 on platinum foil, the excess of acid evaporated at a gentle heat, and the residue worked into a paste with glycerine, which, when brought on a platinum wire into the flame colors it *yellowish-green.* Compounds of boric acid with an alkali, or an alkaline earth, are tested with turmeric paper as follows: The compound is dissolved in dilute HCl (till blue litmus is reddened by it); a strip of turmeric paper is then half immersed in the solution for some time, and then dried in a watch-glass at a gentle heat (not over 100° C. or 212° F.). If boric acid is present, the immersed portion of the paper assumes a brownish-red color* (Rose).

If this brownish-red turmeric paper is treated with some alkali or alkaline carbonate, it turns to a bluish or greenish-black; hydrochloric acid restores the original color.

If alcohol is poured over a borate with the addition of a sufficient quantity of concentrated sulphuric acid to liberate the boric acid, and the alcohol be kindled, the flame appears distinctly green, especially upon stirring with a glass rod and after heating the alcoholic mixture.

Bromine.—When bromides are added to a bead of S. Ph., which has previously been saturated with oxide of copper, and is exposed, B. B., to the point of the blue flame, the bead is surrounded with a beautiful greenish-blue color on the edges. (Chlorine acts, however, similarly.)

---

* This color must not be mistaken for the blackish-brown shade produced by concentrated HCl.

If a bromide is fused in a mattrass with bisulphate of potassium, red bromine vapor is set free, which may also be recognized by its characteristic odor. (Berzelius.) If moistened starch-paper is exposed to this vapor yellow bromide of starch is formed.

The method proposed by Goldschmidt for the detection of a bromine compound alone, or in the presence of iodine and chlorine, is as follows: If a bromine compound is fused in an open glass tube with pulverized bismuth sulphide (made by fusing metallic bismuth with sulphur), a yellow sublimate is formed. An iodine compound treated in the same way forms a red sublimate and a chlorine compound a white one. With a little care these elements can be readily recognized in the presence of one another.

8. CADMIUM.—The pulverized substance for examination is heated B. B. in the R. F. on charcoal whereby the metal is oxidized to a reddish-yellow oxide, which being volatile coats the coal reddish-yellow.

To detect a minute quantity of cadmium (one per cent. or even less, found in zinc or its ores), the assay powder is mixed with soda and heated B. B. in the R. F. on charcoal for a short time, when the latter is coated near the assay with reddish-brown oxide of cadmium. The zinc being less volatile forms a white coating only after continued blowing.

Caustic potash throws down from solutions of cadmium salts a white precipitate of hydrated oxide, $Cd(HO)_2$, insoluble in an excess.

Alkaline carbonates, also carbonate of ammonium, throw down the white carbonate of cadmium CO_3Cd, not soluble in excess. In the presence of free ammonia no precipitate takes place. Cyanide of potassium dissolves the precipitate and gives with salts of cadmium a white precipitate soluble in an excess, whereby a double salt (K_2CdCy_4) is formed, from which sulphydric acid precipitates yellow sulphide of cadmium.

Sulphydric acid and sulphide of ammonium precipitate yellow sulphide of cadmium from saline solutions, easily soluble in acids. An acid solution, therefore, must be strongly diluted before it is acted upon by H_2S. Sulphide of cadmium is insoluble in cyanide of potassium, while sulphide of copper is soluble. Hence, in order to separate these two metals, qualitatively as well as quantitatively, their solution is precipitated by KCy, and redissolved in an excess of the reagent. By conducting a current of H_2S into their joint solution yellow sulphide of cadmium falls while the copper remains in solution, and can only be recovered by decomposition of the cyanide of copper by means of concentrated sulphuric acid added until no longer any hydrocyanic acid escapes. From the resulting solution of sulphate of copper, black oxide of copper is precipitated by caustic potash at a boiling heat.

9. CARBON.—It is found in a free state and crystallized in the form of diamond and graphite. In the ordinary stonecoal, in anthracite, soot, etc., the carbon is amorphous; with oxygen it forms mainly two compounds which we shall briefly consider.

1. *Carbon monoxide* (Carbonic Oxide), CO.—A colorless gas, burning in the air with a blue characteristic flame to *carbonic acid*, CO_2. It is a poisonous gas resulting from incomplete combustion. We obtain it by conducting carbonic acid (CO_2) over ignited coal, and by the ignition of many organic compounds, *e. g.*: 1, *oxalic acid*; 2, *ferrocyanide of potassium*, with concentrated sulphuric acid—

1. $C_2H_2O_4 + SO_4H_2 = SO_4H_2 + H_2O + CO_2 + CO.$
2. $Fe(CN)_2 + K_4(CN)_4 + 6SO_4H_2 + 6H_2O = 2SO_4K_2 + SO_4Fe + 3[SO_4(NH_4)_2] + 6CO.$

It combines in direct sunlight with chlorine at a common temperature to a compound, $COCl_2$, having a characteristic suffocating odor.

Most organic acids, except oxalic and formic acids, leave, after ignition, carbon behind.

CO gas is very slightly soluble in water, but is readily absorbed in a solution of *cuprous chloride in hydrochloric acid.* A loose compound, Cu_2Cl_2, $CO+2H_2O$, is formed, which by boiling, indeed by mere dilution with water, is decomposed, and CO set free.

Carbonic Dioxide (Carbonic Acid) CO_2.—It is soluble in water, the solution turning blue litmus paper to a dark red.

Carbonic dioxide renders a solution of caustic lime turbid, forming insoluble carbonate of lime, and yields no hydrate. It is a feeble acid, and many metals like aluminium, etc., form monocarbonates. Only the carbonates of the alkalies are soluble in water.

Fused with saltpetre carbon detonates, carbonate of potassium being thereby produced. Carbonates effervesce when treated with a drop or two of dilute hydrochloric acid, etc.; a few kinds require previous pulverization, and in some cases even heat must be applied before effervescence takes place.

Some carbonates (lime, etc.) lose their carbonic acid by simple heating in the closed tube.

10. CERIUM is found in the mineral cerite $(Ce,LaDi)_2SiO_4+Ag$. The mineral may be decomposed by hydrochloric acid, aqua regia, and sulphuric acid, but more completely by fusion with carbonate of soda. If the finely-powdered mineral be heated along with sulphuric acid, a few drops of nitric acid being added, and then cold water be poured on it, the sulphate of the above oxides of cerite will be dissolved out and the silicic acid be left behind. A hot saturated solution of sulphate of potassium in a moderately dilute solution of cerite precipitates the three oxides as double salts, which, after being washed with a saturated solution of sulphate of potassium, and dissolved in boiling water containing some hydrochloric acid, are precipitated while warm by excess of potassa. Cold and very dilute nitric acid extracts the oxide of lanthanium as the nitrate from the brown mixture of these oxides (freed from sulphuric acid), which, after its precipitation by carbonate of ammonium and its ignition, is white.

By repeated treatment of the mixture of these oxides with strong potassa lye and chlorine gas the cerium passes into yellow insoluble proto-sesquioxide, Ce_3O_4, while lanthanium and didymium remain in solution as chlorides. Metallic Ce,La, and Di are obtained by reducing the chlorides with sodium in the form of gray powders, which decomposes water at a common temperature, dissolve in dilute acids with evolution of hydrogen.

The *protoxide of cerium* (CeO) is bluish-gray, the hydroxide, $Ce(OH)_2$, colorless. The former quickly passes, on ignition, into Ce_3O_4, which is yellowish-white, and when heated orange-yellow. It is soluble in sulphuric (but not in hydrochloric and nitric acid) with a yellow color. Ceroxide, Ce_2O_3, is reddish-yellow, soluble in hot concentrated sulphuric acid with a yellow color; decomposable by concentrated HCl, with addition of alcohol with production of chloride.

11. CHLORINE.—Chlorides like bromides may be detected, B. B., by adding a small portion of them to a bead of S. Ph., which has previously been saturated with oxide of copper; the bead is at once surrounded with an intensely blue flame without the green tinge observed with bromides. The presence of chlorine may also be detected by the blue color which it causes on a paper moistened with a solution of potassium iodide and starch paste. An excess of chlorine removes the color again. Bromine, ozone, nitrous fumes, etc., produce, however, the same effect.

If a metallic chloride is mixed with solid potassium dichromate and concentrated sulphuric acid in a small glass vial a bright brownish-red gas of chloro-chromic acid is given off, condensing to drops of a like color. Ammonia turns them yellow.

Soluble chlorides placed upon a piece of clean silver, along with a fragment of sulphate of copper or sulphate of iron, produce at once a black stain on the silver. Insoluble chlorides must previously be melted, together with soda, on a platinum wire to produce this reaction. Bromides yield the same reaction.

Nitrate of silver produces, even in very dilute solutions of hydrochloric acid or metallic chlorides, a white curdy precipitate of chloride of silver, turning dark when exposed to sunlight.

12. CHROMIUM (B. B.).—Chromic oxide and chromic salts dissolve in beads of S. Ph. and of Bx., in both the O. F. and R. F., with a yellowish-green tint while hot, becoming emerald-green when cold. Chromium must not be confounded with vanadium, which gives the same reactions in the R. F., but differs by yielding a yellow bead with S. Ph. in the O. F.

Minerals containing but little oxide of chromium, associated with other metals (Fe, Cu, etc.) which color the fluxes, are best treated by fusing on platinum wire, or in a platinum spoon, with a mixture of equal parts of soda and nitre in the O. F., whereby red chromic acid is formed. The fused mass is dissolved in water, and the solution poured off from the residue; to this solution a few drops of acetic acid, and, afterwards, a crystal of acetate of lead (sugar of lead), are added, when an orange-colored precipitate of chromate of lead is formed. This may be collected on a filter, washed, and tested with Bx. and S. Ph. A silicate which contains a small trace of chromium besides iron, and is not decomposed by nitre, is fused upon charcoal in the O. F. with one part of soda and one-half part of borax to a clear bead; this is pulverized, dissolved in HCl, evaporated to dryness, and dissolved in water, and the residue of SiO_2 filtered off; the protochloride of iron is changed to sesquichloride by boiling with a few drops of nitric acid, and the chromium, alumina, iron, etc., precipitated with ammonia. The precipitate is filtered off, washed, and tested as above.

The *sesquioxide of chromium*, Cr_2O_3, is a green powder in water, and, after ignition, insoluble in acids. The chromates are green or violet, partly soluble in water, partly only in acids. Ammonia produces a bluish-green or greenish-gray hydrate (chromhydroxide), $Cr_2(OH)_6$, which is partly soluble in excess of the reagent, giving a reddish solution.

Caustic potassa or *soda* likewise precipitates the hydrated sesquioxide, readily soluble in an excess, furnishing a green color. If this alkaline solution is boiled for some time the sesquioxide is reprecipitated, and the supernatant liquid becomes colorless.

Alkaline carbonates as well as sulphide of ammonium throw down also hydroxide or a basic salt. In the presence of magnesia, zinc, or lead salts, the precipitate with alkalies has the formula MO,Cr_2O_3.

If the green solution of Cr_2O_3 in caustic alkali is boiled with some peroxide of lead, chromic acid, CrO_3, is formed and turns yellow, and the filtrate when acidulated with acetic acid or neutralized with nitric acid separates yellow chromate of lead.

The Cr_2O_3, insoluble in acid, becomes soluble by fusion with bisulphate of potassium; by fusion with carbonate and nitrate of an alkali mixed together it becomes converted into a soluble chromate of alkali. This deportment is made use of in searching for the Cr_2O_3 in insoluble compounds, and for its separation from oxides like magnesia, alumina, and sesquioxide of iron, which, undergoing no further oxidation, remain undissolved in the alkaline liquid.

Chromic acid, CrO_3, is known only as an anhydride, forming scarlet-red, deliquescent crystals. Its salts are red, like, for instance, the acid potassium salt, $Cr_2O_7K_2$, or yellow, like the neutral potassium salt, CrO_4K_2. The alkaline salts and those of the alkaline earths are both soluble in water; nearly all the other salts are either insoluble, or with difficulty soluble, in water.

Chloride of barium precipitates from soluble chromates yellow CrO_4Ba; lead salts throw down a yellow precipitate, CrO_4Pb; salts of bismuth produce a yellow, nitrate of silver a purple-red, and mercurous salts a brick-red precipitate. All these precipitates are soluble in nitric acid except chromate of lead, which is soluble in potassa, and can be thrown again by acids.

Chromic acid is reduced to green sesquioxide by H_2S,SO_2, by alcohol and sugar (in the presence of a free acid), by oxalic and tartaric acid, and by any metal which (like zinc) disengages hydrogen.

13. COBALT may generally be recognized B. B. by the blue bead it affords with Bx. and S. Ph. in both flames. This color will, however, be modified by the presence of other metals. Thus, if iron be present the bead will appear green while hot, and blue when cold. The sulphurets should be roasted on Ch. before testing for cobalt with Bx. on Ch.

Cobalt forms two well-marked oxides, both of which represent bases in corresponding classes of salts: *cobaltous* and *cobaltic* salts.

Cobaltus oxide (*protoxide*), CoO, is an olive-green powder, or, when in the condition of a hydrate, $Co(HO)_2$, rose-red; its salts are generally blue when anhydrous, or in solutions containing free concentrated acids, through their aqueous solutions are pink.

H_2S and $(NH_4)_2S$ precipitate black CoS, quite insoluble in $(NH_4)_2S$; once formed it is with great difficulty soluble in *dilute nitric*, *sulphuric*, and *acetic acid.* A solution of a salt of cobalt when previously mixed with some acetate of sodium and warmed, is more readily and completely precipitated by H_2S than a salt of nickel under like circumstances (separation of Co and nickel from manganese).

Ammonia produces, in acid solutions of cobaltous salts, or in solutions containing ammonia salts, only a red color, which soon passes into brown. *Caustic potash* throws down all the cobalt as a blue *basic salt*, which, by exclusion of air (and quickly by heating), passes into *rose-red cobaltous hydroxide*, $Co(OH)_2$, and this in the air turns to olive-green *cobaltous cobaltic hydrate.*

Alkaline carbonates precipitate peach-blossom red basic carbonate, which is readily soluble in excess of *carbonate of ammonium*, retaining the same color, but only slightly soluble in the *carbonate of sodium* and potassa. Ferrocyanide of potassium produces a green; ferricyanide of potassium a brownish-red precipitate. If to a neutral solution of a cobaltous salt, we add *nitrite of potassium* in excess; and next, acetic or dilute nitric acid, a yellow, crystalline precipitate, $(NO_2)_3Co + 3NO_2K$, is thrown down, containing nearly all the cobalt. The precipitate is with difficulty soluble in cold water; insoluble in potassium salts and in alcohol of 80 per cent.

Cobaltic oxide, peroxide of cobalt, Co_2O_3. It yields salts, while the corresponding NiO_3 cannot form any, and attempts to produce them yield protoxide salts.

To detect nickel together with cobalt we proceed thus: The solution, which must only contain these two metals (and be free from manganese for instance) is feebly acidulated with HCl, cyanide of potassium added in excess, and heated to boiling; if now, upon addition of dilute HCl or H_2SO_4, a precipitate follows, nickel is present.

14. COLUMBIUM, Cb, or NIOBIUM, Nb.—Marignac has shown that nearly all tantalites and columbites contain both tantalum and columbium. To obtain free columbic acid, Cb_2O_5, and tantalic acid, Ta_2O_5, the powdered minerals are fused with six parts of bisulphate of potassium until completely dissolved. The fused mass is treated with hot water, when both acids remain behind, while the bases and titanic acid, if present, will be dissolved, and can thus be separated. The residue is washed with ammonia and sulphide of ammonium to remove tungstic acid and oxide of tin, while hydrochloric acid dissolves iron. The filtered and thoroughly washed residue is now treated with either HCl or H_2SO_4 in a porcelain dish, and metallic zinc added. If a tantalate alone be present, no coloration or but a slight one ensues. A columbate thus treated assumes a blue color, which gradually fades and finally turns brown.

15. COPPER.—It is easily detected by the green color which most copper compounds impart to the B. B. flame. The production of a red bead with salt of phosphorus in R. F. is rendered more certain by the treatment of the bead on charcoal with a small amount of tinfoil.

Copper may also be detected by saturating a salt of phosphorous bead with the substance containing it, and adding common kitchen salt (NaCl), when the bead will color the flame beautifully blue, owing to the formation of chloride of copper.

Many minerals give this reaction by simply moistening with HCl, and exposing them in the platinum forceps to the flame. Silicates should first be pulverized, moistened with HCl, and evaporated to dryness in a porcelain capsule, then made into a paste with water, and heated on platinum wire, when the green color is imparted to the R. F. Sulphurets of copper are first roasted on coal and then examined with salt of phosphorus. Hot sulphuric acid dissolves copper with evolution of SO_2; nitric acid with evolution of NO.

1. $Cu + 2SO_4H_2 = SO_4Cu + 2H_2O + SO_2$.
2. $Cu_3 + 8NO_3H = 3(NO_3)2Cu + 4H_2O + 2NO$.

Cuprous oxide, Cu_2O, is red when anhydrous, orange as hydroxide, $Cu_2(OH)_2$. It is formed by ignition of cupric oxide, CuO, with metallic copper, or from the cupric oxide salts, by the reducing action of sugar, arsenious acid, etc., in the presence of free alkali. With sulphuric acid it is decomposed into metallic copper and cupric sulphate. HCl forms white cuprous chloride, Cu_2Cl_2, little soluble in water, but readily soluble in HCl. Its nearly colorless solutions, in acids and in ammonia, turn, in the air, rapidly into blue or green cupric compounds.

Cupric oxide, CuO, is black when anhydrous, greenish-blue as hydroxide, $Cu(OH)_2$, insoluble in water, soluble in nearly all acids. Its anhydrous salts are nearly white, the hydrates green or blue. H_2S and $(NH_4)2S$ precipitate from solutions black sulphide of copper, soluble in cyanide of potassium. Caustic potassa in the cold throws down greenish-blue *hydroxide*, at a boiling heat, *black oxide.* Ammonia precipitates at first a green basic salt, next blue hydroxide, which, with an excess of the precipitant, form a beautiful azure blue solution. Iodide of potassium precipitates, in the presence of SO_2, or ferrous oxide, salts, all the copper as white Cu_2I_2, soluble in *hyposulphite of soda*, and in ammonia in the air.

Ferrocyanide of potassium precipitates brownish-red ferrocyanide of copper, $FeCy_2 + 2CuCy_2$, insoluble in HCl, soluble in NH_3. Iron and zinc precipitate in solutions, acidulated with HCl, metallic *copper.* If a solution of copper is put into a platinum dish, a little HCl and a piece of zinc added, red metallic copper is thrown down, visible even in a state of great dilution. Nitric acid is the best solvent of the metal or its compounds, a cupric nitrate, $(NO_3)_2Cu$, being formed. The solution in hot sulphuric acid contains SO_4Cu, that in aqua regia $CuCl_2$. Oxide of copper, CuO, is black when anhydrous, as a hydroxide, $Cu(OH)_2$, greenish-blue, both insoluble in water, but soluble in nearly all acids. The anhydrous salts are almost all white, as hydrates, green or blue. Hydrosulphuric acid and sulphide of ammonium precipitate from solutions black sulphide of copper, CuS, easily oxidizing in the air, soluble in KCy, insoluble in HCl. Caustic potash throws down in the cold a greenish-blue hydroxide, $Cu(OH)_2$, and at a boiling heat black oxide (CuO); *ammonia* throws down at first a greenish basic salt, then the blue hydrate, which is soluble in excess of the reagent, giving a beautiful azure blue, perceptible even in highly diluted solutions. Carbonate of ammonium acts similarly. Ferrocyanide of potassium precipitates in very dilute solutions brownish-red ferrocyanide of copper, $FeCy_2 + 2CuCy_2$, insoluble in HCl, soluble in NH_3. Iron and zinc precipitate from solutions containing some free HCl, metallic copper.

16. DIDYMIUM, Di.—It is trivalent. Sesquioxide of didymium, Di_2O_3. Didymium chloride, $DiCl_3$. Didymium hydroxide, $Di(OH)_3$ or $Di_2(OH)_6$. Potassium hydrate, or sodium hydrate, throws down, from solution of the salts, a white bulky precipitate of $Di(OH)_3$, not soluble in an excess. Ammonia shows the same behavior, but the precipitate is soluble in a hot solution of sal ammoniac, B. B. With borax the sesquioxide yields in both flames a colorless, in large quantities an amethyst colored glass. Phosphorus salt dissolves it in the R. Fl. to an amethystine colored rather violet bead. Carbonate of sodium yields in the O. Fl. a grayish colored mass (dis-

tinction from manganese). Didymium is found in the minerals cerite, monazite, gadolinite, fluocerite, orthite, euxenite, etc.

Solutions of didymium salts exhibit a well-marked *absorption-spectrum*, containing two black lines, inclosing a very bright space. One of these black lines is in the yellow, immediately following Frauenhofer's line "D," the other is situated between "E" and *b*. These characters can be distinctly recognized in a solution half an inch deep, containing only 0.01 per cent. of didymium salt. Lanthanium salts do not exhibit an absorption-spectrum.

17. ERBIUM.—Its oxide, EbO, obtained by ignition of erbium nitrate or oxalate, has a faint rose color. It does not melt at the strongest white heat, but aggregates to a spongy mass glowing with an intense *green* light, which, when examined by the spectroscope, exhibits a *continuous spectrum* intersected by a number of bright bands. Solutions of erbium salts, on the other hand, give an absorption-spectrum, exhibiting dark bands, and *the points of maximum intensity of the light bands in the emission-spectrum coincide exactly in position with the lines of greatest darkness in the absorption-spectrum.* The position of these bands is totally different from those in the emission and absorption-spectra of didymium (Bahr and Bunsen).

18. FLUORINE.—When fluorides are heated in a glass tube with 4 parts of bisulphate of potassium, hydrofluoric acid is given off. This imparts to red Brazil-wood paper a straw-yellow color, and etches the tube immediately above the assay, especially visible after the cleansing and drying of the tube.

The best method for the detection of fluorine, even when present in minute quantities, is to heat the assay with previously fused salt of phosphorus (both finely pulverized) in an open glass tube in such a manner that the flame passes into the end of the tube. This latter is thereby rendered opaque where the hydrofluoric acid formed is condensed. This acid is further recognized by its pungent odor and its action on Brazil-wood paper, *i. e.*, coloring it straw-yellow.

19. Fluorine.*—*Hydrofluoric* acid, HFl, and *fluorides.* Conc. HFl gives off fumes in the air which are greedily absorbed by water. The aqueous solution dissolves many metals and metallic oxides, forming fluorides. Gold and platinum are not attacked, lead with difficulty. HFl has the distinguishing property of dissolving silica or silicates not affected by other acids with great facility, forming $SiFl_4$. Upon this property depends the decomposition of silicates, the etching of glass, and its detection. All metallic fluorides are decomposed by conc. sulphuric acid with evolution of hydrofluoric acid, *e. g.*, $CaFl_2 + SO_4H_2 = SO_4Ca + 2HFl$. Hydrofluoric acid imparts to Brazil-wood paper a straw-yellow color. Silicates containing even a small quantity of fluorine, when heated in the closed tube, give off hydrofluosilicic acid; this is decomposed into *silicic* acid, which is separated near the assay, and *hydrofluoric* acid, which passes off; but the latter may be detected by inserting a strip of moistened Brazil-wood paper as just mentioned.

When fluorides are heated in a glass tube with bisulphate of potash, hydrofluoric acid is given off. This etches the tube immediately above the assay, and gives the reaction with Brazil-wood paper.

20. Glucina.—(Beryllia, oxide of beryllium), BeO, is found in a few minerals, viz., *phenakite*, *beryl*, *euclase.* It gives no characteristic reaction B. B. With borax on platinum wire it is soluble in large quantities in a clear glass, that becomes milk-white by flaming, or when saturated by simple cooling. With salt of phosphorus it behaves as with borax. With solution of cobalt in O. F. it acquires a pale bluish-green color.

The wet reactions bear a close resemblance to those of alumina; it differs, however, from the latter by its solubility in carbonated alkalies and in boiling sal-ammoniac solution with evolution of ammonia; by its salts affording no precipitate of glucina alum with sulphate of potassium, and by the fact that

---

* Free fluorine gas is affirmed to have been found by Oscar Löw, at Munich, in fluor-spar from Wölsendorf. See Berichte der Deutschen Gesellschaft. Berlin, 1881, pp. 1144–1146. 14 Jahrgang, 9.

its dilute solution in the caustic alkalies is decomposed by long boiling, the earth being precipitated. Alkaline carbonates throw down in solutions of its salts $BeCO_3$, soluble only in considerable excess of the precipitant. A concentrated solution of carbonate of ammonia dissolves the precipitate more readily than either the carbonate of sodium or potassium; but by boiling the earth is again precipitated in such a solution. Native minerals containing glucina are fused with 4 parts of carbonated alkali. The mass is evaporated with a slight excess of sulphuric acid to dryness, and the SiO_2 separated by the addition of water. From the concentrated filtrate nearly the whole amount of alumina may be removed in the form of *alum*, while the BeO remains all dissolved in the mother-liquor. This solution is poured into a warm concentrated solution of carbonate of ammonium. After remaining in contact for several days the solution, containing $BeCO_3$, is filtered off and boiled for a long time to precipitate the $BeCO_3$; or it may, after being acidulated with HCl, be thrown down by ammonia as glucinum hydroxide $Be(OH)_2$.

Glucina occurs usually in combination with *silica* and *alumina* in minerals.

21. Gold may generally be recognized by its physical characters: color, lustre, malleability, spec. grav. When a gold compound is heated on a carbonized match in R. F., a yellow malleable bead is obtained, which dissolves in aqua regia. If this solution be dropped on to filter paper and one drop of stannous chloride added, a purple-red color is observed. Gold can be readily detected in its solutions, inasmuch as it is obtained in the metallic state by reducing agents, the well-washed precipitate being dissolved and tested with stannous chloride. It is separated from the easily volatile metals by simple heating on charcoal in O. F. If associated with copper or silver, it must be fused with a large excess of pure metallic lead and subjected to cupellation. The copper is absorbed into the cupel with the lead, while the silver remains alloyed with

the gold. If the globule is quite yellow, it is a proof that but little silver is present, it is then to be tested with salt of phosphorus, to prove the presence of silver, which, after fusion on charcoal in O. F., will impart an *opaline* character to the *cool bead.* If it be more of a silver-white color, the amount of gold will be small, and in order to prove its presence and approximate quantity the globule must be digested in a porcelain capsule with nitric acid, by application of heat. The silver is thus dissolved, and the gold remains as a dark powder, or as a spongy mass. If this powder be washed and fused with borax on charcoal, it will yield a globule of metallic gold.

22. IODINE.—Iodides added to a bead of salt of phosphorus previously saturated with oxide of copper, tinge the O. F. intensely emerald-green. Compare chlorine and bromine, pages 152 and 156.

Iodides, like bromides, are decomposed and yield, by fusion with bisulphate of potassium, free iodine, which may be recognized by its purple-colored vapor and disagreeable odor.

When an emulsion of starch-paste is mixed with a little iodide of potassium, and some HCl is added, *iodine* is liberated, which colors the starch *blue.*

The *iodide of silver*, and the iodides of the alkalies, are distinguished, in the presence of other halogen compounds, by the fine scarlet coating they produce, B. B., on coal, when fused with *sulphide of bismuth* (obtained by heating flowers of sulphur and bismuth).

23. IRIDIUM, Ir.—The metal itself is easily distinguished from all others, excepting rhodium and ruthenium, by its insolubility in acids, not being attacked in the compact state by any acid whatever, and in a state of fine division, only very slowly by nitro-muriatic acid. Its infusibility, even in an ordinary oxyhydrogen blowpipe flame, serves also to distinguish it from all other metals, except rhodium, ruthenium, and osmium. It may be distinguished from rhodium by fusing it, in the finely divided state, with acid (bi) sulphate of potassium. The

iridium is then converted into sesquioxide, but does not dissolve in the acid sulphate or color it pink-red as rhodium does.

Another method of distinguishing iridium from rhodium, and likewise from ruthenium, is to mix it intimately with potassium or sodium chloride, heat the mixture in a stream of chlorine, and dissolve the resulting double chlorides in water. Iridium thus treated yields a blackish-brown solution, rhodium a rose-red, and ruthenium an orange-yellow solution. All compounds of Ir are easily reduced to the metallic state by ignition in an atmosphere of hydrogen; the reduced metal may then be tested in the manner just described.

24. IRON.—The oxides of iron impart a brownish or yellowish-red color to Bx. or S. Ph. in the O. F., and a green one in the R. F., which color nearly disappears on cooling.

In order to ascertain whether a substance contains protoxide or sesquioxide of iron, some of it is dissolved B. B. in a bead of Bx. previously saturated with some black oxide of copper. If sesquioxide be present the bead turns bluish-green; if protoxide, red opaque spots and streaks are visible on the bead from separated cuprous oxide (Cu_2O).

Ferrous oxide, FeO. The salts of this oxide are formed by dissolving iron in dilute HCl or H_2SO_4, with evolution of hydrogen gas. In warm HNO_3 iron is oxidized to a *ferric* salt. The *ferrous* salts are white when anhydrous; bluish-green as hydrates. They oxidize gradually on exposure to the air, forming a yellow basic ferric oxide, which is deposited in a neutral solution. They give up their acids at a red heat, when red sesquioxide is left behind.

Caustic alkalies and ammonia precipitate from ferrous salts white hydrated ferrous oxide, $Fe(OH)_2$, which turns green, and finally brown in the air. In the presence of ammonia-salts, or organic acids, the precipitation is incomplete.

Sulphydric acid gives no precipitate in acid solutions of ferrous salts.*

---

* Except the *ferrous acetate*, which is partially precipitated, even in the presence of *free acetic acid*.

Sulphide of ammonium throws down the iron completely as black sulphide, FeS, slightly soluble in an excess only, when much carbonate of soda is present. FeS is easily soluble in HCl, being converted into $FeCl_2$ with evolution of SH_2.

Ferrocyanide of potassium gives with ferrous salts a white precipitate, or with solutions containing small quantities of ferric oxide a bluish-white one, $FeCy_2 + KCy$, which, on exposure to the air, changes quickly into Prussian blue.

Ferricyanide of potassium gives at once a fine blue precipitate (Turnbull's blue), $3FeCy_2 + FeCy_6$ (characteristic distinction of the two oxides).

Tincture of galls produces no change unless the ferrous salts contain some sesquioxide.

Ferrous salts reduce chloride of gold and nitrate of silver to the metallic condition.

Ferric oxide (sesquioxide) of iron, Fe_2O_3. This reddish-brown powder remains unchanged when ignited by itself. In this form iron is always determined quantitatively. Fe_2O_3 is completely soluble in HCl. The native oxide, or that which has been previously ignited, being only slowly soluble. The salts of the sesquioxide in dilute, and as nearly as possible neutral solution, or when the solution is previously treated with acetate of sodium, are decomposed at a boiling heat, sesquioxide of iron being precipitated; if phosphoric or arsenic acid be present these acids will be contained in the precipitate. By warming a solution of ferric salts with metallic iron, zinc, or with sulphurous acid, or by passing H_2S through it, they are reduced to ferrous salts. On the contrary, solutions of ferrous salts are converted into ferric salts if at a boiling heat some nitric acid is added. The presence of another free acid (*e. g.*, HCl or H_2SO_4) is advantageous. The nitric acid is thereby decomposed, and nitric oxide gas, NO (turning to red nitrous acid fumes in the air) is given off, viz.:

$$6FeCl_2 + 6HCl + 2NHO_3 = 3(Fe_2)Cl_6 + 2NO + 4H_2O.$$

If no free acid is present, there are partly basic and usually insoluble ferric salts produced. Chlorine gas likewise causes an analogous oxidation of ferrous salts. Thus, if one of the latter, after being acidulated with HCl, is warmed and some chlorate of potassium, $KClO_3$, is added (not more than 2 or 3 crystals), the HCl is decomposed into water and chlorine, which latter, indicated by its odor, accomplishes the oxidation thus:

$$2FeCl_2 + Cl_2 = (Fe_2)Cl_6.$$

The following equation expresses the action of chlorate of potassium:—

$$6FeCl_2 + 6HCl + KClO_3 = 3(Fe_2)Cl_6 + 3H_2O + KCl.$$

Free chlorine gas, or chlorine water, may be thus employed, or chlorides, such as the perchloride of tin, $SnCl_4$ (which yields chlorine). In the separation of Fe_2O_3 from FeO, MnO, etc., we precipitate the Fe_2O_3 with carbonate of barium, which precipitates the Fe_2O_3 completely, even in the cold, while ferrous oxide remains unaltered in the solution (if free from access of air).

The two oxides, when both are present at the same time, are found by two experiments: 1st, with ferricyanide of potassium (red prussiate of potassium) we test for *ferrous* oxide (blue precipitate); and 2d, with ferrocyanide of potassium (yellow prussiate of potassium) we test for *ferric* oxide (blue precipitate). From the alkalies sesquioxide of iron is separated by ammonia; from the alkaline earths and magnesia, by precipitating with ammonia, in the presence of sal ammoniac, and boiling until the odor of ammonia disappears. Oxides of the formula MO, that were likewise partially thrown down, pass thus again in solution. From manganese, nickel, $Ni(HO)_2$, cobalt, $Co(HO)_2$, it is more readily separated if the dilute solution, containing ferric oxide, is heated with carbonate of sodium until it turns brownish-red, then acetate of sodium added and heated to boiling, when only Fe_2O_3 is thrown down.

Tincture of galls precipitates the sesqui salts of iron bluish-black (ink).

Sulphocyanide of potassium (CNKS) produces a blood-red color, which is not destroyed by HCl, but disappears in the presence of acetate of sodium.

Ferric acid, FeO_3, is only known in combination with alkalies, forming fine, amethystine-red solutions.

25. LEAD.—B. B. with Sd. on Ch, a malleable globule of metallic lead is obtained from lead compounds; the coating has a yellow color near the assay, and further off a white color (carbonate); on being touched with the R. F. both of these disappear, tinging the flame azure-blue. In solutions, dilute sulphuric acid gives a white precipitate of lead sulphate, nearly insoluble in water and in dilute acids. The acid mixture is then best evaporated on a water-bath, water added to the residue, when the lead sulphate, if present, may further be experimented with. This precipitate, SO_4Pb, is decomposable by hot concentrated HCl, is soluble in caustic potassa, also in tartrate of ammonium, containing an excess of ammonia, from which latter solutions it can be precipitated by *sulphide of ammonium* (*black*) or *chromate of potassium* (*yellow*); by being boiled with carbonate of sodium, SO_4Pb is completely converted into carbonate of lead. Salts of lead are precipitated both by sulphide of hydrogen and sulphide of ammonium, the black precipitate, PbS, being insoluble in dilute acids, potassa, and sulphide of ammonium. In the presence of much free HCl, the precipitated sulphide of lead looks brown or almost red. When in thick masses, such as the common sheets and pipes of commerce, lead is scarcely at all acted upon by cold sulphuric acid, and is but slowly corroded by hydrochloric acid. Both these acids form, by their action on the lead, nearly insoluble salts, and as soon as a layer of the salt has once been deposited upon the surface of the metal, the latter is thereby protected from further corrosion. On exposure to the air lead soon tarnishes, owing to the formation of a thin coating of *lead suboxide.* By the simultaneous or alternate action of water and air, lead is very rapidly corroded in consequence of the formation of a *lead hydrate*, which is converted by the carbonic acid in the air into lead carbonate. All natural waters act more or less on lead.

In some cases the action is so slight that lead pipes are used with safety for conveying the water; in other cases, the use of lead pipes is very dangerous on account of the poisonous character of the salts of lead. The author of this book has had frequently occasion to test water, which passed through lead pipes, for this injurious ingredient. Even very minute quantities of lead may be traced thus: A measured quantity of suspected water is evaporated nearly to dryness, and the thus concentrated liquid placed in a small, bright, new porcelain dish, where it is first acidulated with pure acetic acid, and next sulphide of hydrogen passed into it, when, if lead is present, either a black or brown precipitate of PbS is thrown down. Owing to the presence of free acetic acid, ordinary metals like iron do not interfere with the reaction.

26. LIME, B. B.—It imparts a yellowish-red color to the flame. When observed through copper-green glass the lime-flame appears siskin-green; with cobalt-blue glass it is pale greenish-gray.

Many calcium salts give an alkaline reaction with test papers after ignition (caustic lime).

Calcium hydroxide $Ca(HO)_2$ is soluble in 600–700 parts of cold water (lime-water), which reacts alkaline and becomes turbid in the air ($CaCO_3$). Sulphate of calcium, $CaSO_4 + 2H_2O$, is soluble in 500 parts of water, more readily in acids, but insoluble in alcohol. When sulphate of calcium is digested, even in the cold, with carbonate of potassa or carbonate of ammonium, it is entirely converted into carbonate of calcium. Oxalic acid, or soluble oxalates, precipitate lime completely, even from very dilute solutions, as *calcium oxalate*, $C_2O_4Ca + H_2O$. Ammonia promotes the formation of the precipitate, which is insoluble in water, acetic, and oxalic acid, but easily soluble in mineral acids, and in neutral *magnesia salts*. From solutions previously warmed, we precipitate lime generally by oxalate of ammonium and free ammonium (the liquid must smell of free ammonia), and let it rest for twelve hours in a covered glass beaker, decant the clear supernatant liquid, and bring the rest upon a filter and wash with hot water. For quantitative determinations the dried precipitate, with filter, is brought into a platinum crucible and heated, at first gently, and then for ten minutes to a light red heat. The crucible is brought into a drier, and, when cold, weighed. The oxalate has thus been converted into carbonate of calcium. If the heat be too great, some caustic lime may be formed (indicated by moist turmeric paper); in that case, a piece of carbonate of ammonium is thrown into the crucible and heat again applied with great care. It is simpler and safer to convert all into caustic lime by heating the crucible over a *blast-lamp* for twenty minutes. Limestones are tested for strontia by calcining, then adding water and boiling, when all the strontia and some little lime will be found in the filtrate. Compare the whole group of *alkaline earths* (Ba, Sr, Ca, Mg) and note the distinctive reactions.

27. LITHIA (LiO).—Lithia is found in small quantities in petalite, spodumene, amblygonite, lepidolite, tryphylite, and also in the waters of mineral springs.

B. B. Salts of lithium impart a carmine color to the gas flame or to that of alcohol, which is not prevented by the presence of potassa but is concealed by the intensely yellow color of the salts of sodium. Silicates containing but little lithium scarcely tinge the flame, but if the fine mineral powder is mixed with one part of finely pulverized fluor-spar, and one and a half part of bisulphate of potassium, the whole kneaded with some water into a paste, and this exposed on platinum wire to the point of the blue cone of the flame, the outer flame will be colored distinctly red; if no lithium be present, the mixture gives a faint violet flame. Chapman has shown that the lithium flame, unlike strontium, is not obscured by the presence of barium. He suggests fusing lithium minerals with chloride of barium. Thus, if tryphylite (an iron-manganese-lithium phosphate) is treated in this manner, it yields a beautiful crimson color. (*See flame reactions.*)

The salts of *lithium* are all soluble in water, but the oxide, carbonate, and phosphate of lithium are nearly *insoluble* in water, hence salts of lithium, in concentrated solution, will give precipitates with carbonate or phosphate of sodium, especially when they are heated and somewhat evaporated. Lithium-platinic chloride is soluble in water, alcohol, and ether.

28. MAGNESIA, B. B.—Magnesia, and many magnesian silicates, afford a clear rose-red color with cobalt solution after a long heating. A fragment after heating should be moistened with the solution and then heated again, the color deepens on cooling. It is distinguished from baryta and strontia in the wet way, by the fact that sulphuric acid gives no precipitate in dilute HCl solutions, but gives a precipitate in concentrated solutions of calcium salts, which fact again distinguishes lime from magnesia, the sulphate of which (Epsom salts) is soluble in water. The calcium sulphate differs from barium and strontium sulphates by being soluble in a *concentrated solution of ammonium sulphate.*

The whole group of the metals of the alkaline earths, like that of the alkalies, occurs only in the form of *salts.* Their oxides, the alkaline earths (BaO, SrO, CaO), are soluble in water, taking up first a portion thereof and forming, with evolution of heat, *oxyhydrates* (hydroxides) of the general formula $MO, H_2O = M(OH)_2$. *Magnesia*, MgO, is insoluble in water, though with difficulty soluble as a *hydrate.* Their carbonates, CO_3M, and phosphates, $(PO_4)_2M_3$, are insoluble in water but soluble in acids, the soluble salts of the alkaline earths are hence precipitated by *soluble* and *neutral* carbonate and phosphate salts.

Owing to the possibility that the precipitated carbonates of Ba, Sr, and Ca may be partly retained (dissolved), by the free carbonic acid, the precipitation with carbonate of ammonium should take place with the slightly warmed liquid and in the presence of *free* ammonia. The precipitation is somewhat slow, but complete in the absence of *ammonium salts*, especially *chloride of ammonium.*

For qualitative analysis the following reactions are not without some importance. The phosphates of the alkaline earths, viz., $Ba_3(PO_4)_2$, $Sr_3(PO_4)_2$, $Ca_3(PO_4)_2$, are obtained by precipitating the earthy salt solution with a *soluble phosphate.* The precipitates are white, amorphous, soluble in mineral and acetic acids, but insoluble in water. Consult *Magnesia*, p. 173.

Solubility of the *chlorides* and *nitrates* of the alkaline earths in alcohol—

$$\left.\begin{matrix}BaCl_2\\ Ba(NO_3)_2\end{matrix}\right\}\text{insoluble.}\quad \left.\begin{matrix}SrCl_2\\ Sr(NO_3)_2\end{matrix}\right\}\begin{matrix}\text{soluble.}\\ \text{insoluble.}\end{matrix}\quad \left.\begin{matrix}CaCl_2\\ Ca(NO_3)_2\end{matrix}\right\}\text{soluble.}$$

These reactions can be used for the separation of the group mentioned (also quantitative) in the absence of water, *i. e.*, the salt must be completely dry, and the alcohol must be anhydrous (100 p. c.).

Deportment of the Alkaline Carbonates with the Alkaline Earths.

When the *sulphates of barium*, *strontium*, and *calcium* are fused in a crucible with carbonate of potassium or sodium, they are quickly and completely converted into carbonates. By merely boiling these earthy salts with a concentrated solution of carbonate of sodium, the sulphates of strontium and of calcium pass readily into carbonates, whilst the sulphate of barium decomposes very slowly, and the solution of the carbonate of sodium must be repeatedly poured off, and be replaced by a new portion and heat applied.

Separation of *sulphate of strontium* from *sulphate of calcium* by *sulphate of ammonium.*

A solution of *sulphate of ammonium* in large excess (1 part of dry salt and 4 parts of water) after boiling for one hour, or in contact for twelve hours at a common temperature, dissolves *sulphate of calcium* completely, whilst *sulphate of strontium* (and sulphate of barium) are not altered. From the solution of the sulphate of ammonium the lime is precipitated as *oxalate of calcium*, which, on ignition, forms carbonate of calcium.

Sulphuric acid and soluble sulphates produce no precipitate in a solution of a magnesium salt, but the fixed caustic alkalies, and also baryta, and lime-water, especially at a slightly elevated temperature, throw down all the magnesium in form of a hydrate, $Mg(OH)_2$, which, however, upon addition of an ammonium salt, in sufficient quantity, disappears again, or when ammonium salts are present, is not precipited at all.* An excess of neutral carbonate of ammonium precipitates from neutral magnesium salts, when the solution is not too diluted, all the magnesium in the form of an insoluble *double salt*, *e. g.*, $CO_3MgCO_3(NH_4)_2 + 4H_2O$, by which process magnesium may be separated from the fixed alkalies. The fixed carbonates of the alkalies throw down at a boiling heat all the magnesia in the form of gelatinous basic carbonate of magnesium (magnesia alba), $3CO_3Mg + Mg(OH)_2 + 4H_2O$, but only in the absence of ammonium salts.

Phosphate of sodium, (PO_4HNa_2), produces even in dilute solutions of magnesium salts, in the presence of sal-ammoniac and free ammonia, a white crystalline precipitate ($PO_4HNa(NH_4) + 6H_2O$), soluble in acids, even acetic acid, but entirely insoluble in dilute ammonia, with which it is washed when filtered off. When ignited it passes into *pyrophosphate of magnesium* (P_2O_7,Mg_2).

29. MANGANESE.—The oxide (Mn_2O_3) gives with borax in the O. F. an amethystine bead (very dark with excess), which becomes colorless in the R. F. (protoxide). The soda test when executed on platinum foil is the most sensitive. The deep green color is more quickly obtained when a small fragment of nitre or chlorate of potassium be added to the assay before fusion. When testing substances which do not dissolve readily in soda, it is well to add a little borax to the bead, and this also makes the test much more delicate (Chapman). By this operation the manganese is oxidized to manganic acid, which forms with soda green *manganate of sodium*, MnO_4Na_2.

Manganese forms with oxygen a series of compounds, viz., *Manganous oxide*, MnO, *Manganic oxide* (sesquioxide) Mn_2O_3

---

* For 1 mol. of magnesium salt at least 4 mol. of carbonate of ammonium are required.

Manganese dioxide (pyrolusite), MnO_2. Manganic acid, MnO_3 forming manganates, but not used as an acid. Permanganic acid, Mn_2O_7, only known and in use as *permanganate salt*, as a powerful oxidizing agent. The *manganous salts* are either of a rose color or colorless, mostly soluble in water, the solution undergoing no higher oxidation in the air; the sulphate is permanent even when ignited. All the oxygen compounds of manganese (and carbonates) form, when ignited, *manganous-manganic oxide* (Mn_3O_4). All the higher oxides, on being heated with HCl, pass into the condition of manganous chloride ($MnCl_2$), corresponding with manganous oxide (MnO), *e. g.*,

$$MnO_2 + 4HCl = MnCl_2 + 2Cl + 2H_2O.$$

Manganic oxide is not decomposed by HCl in the cold. Heated with conc. sulphuric acid all the higher oxides evolve oxygen with formation of SO_4Mn.

Sulphydric acid occasions no precipitate in solutions of *manganous salts*, not even with the acetate.

Sulphide of ammonium gives a flesh-colored precipitate of manganous sulphide, MnS. Acetic acid acting on the precipitated sulphides, separates manganese from cobalt and nickel and from a part of zinc (separation of zinc from manganese and other metals).

We may also proceed thus: To the examining solution we add acetate of sodium, and precipitate with H_2S, which throws down sulphide of zinc, and leaves in solution manganese and iron. Acid solutions must previously be neutralized with carbonate of sodium until they become slightly turbid, and next be acidulated with *acetic acid.*

MnS when dissolved in acetic acid in the air gives off H_2S, takes up oxygen, and turns *brownish-black.*

Caustic potash or soda precipitates white manganous hydrate, $Mn(OH)_2$, insoluble in excess, and becoming quickly brown in the air, and is then no longer *completely* soluble in *chloride of ammonium.*

Ammonia gives in acid solutions of the manganous salts, or in those which contain ammoniacal salts, no precipitate at first, but the solution becomes turbid on exposure to the air, and deposits (if sufficient ammonia be used) all the metal as brown hydroxide of manganese, $Mn_2(OH)_6$.

Alkaline carbonates, phosphates, arseniates, and oxalates occasion white precipitates.

Ferrocyanide of potassium gives a white precipitate with manganous salt, and ferricyanide of potassium a brownish-yellow one. If lead dioxide or superoxide (PbO_2), or minium ($2PbO, PbO_2$) be heated with an excess of nitric acid, and a trace of a manganous salt be added (or the solution to be tested for manganese free from sal-ammoniac), the fluid assumes the intense *purple color* of *permanganic acid*, which is very perceptible after the separation of the excess of dioxide of lead (a delicate test for manganese).

Manganic oxide (sesquioxide), Mn_2O_3, as well as the corresponding hydroxide, $Mn_2(OH)_6$, form brownish-black powders. The solution in cold sulphuric acid is cherry-red or crimson, and passes, like other manganic salts, into *manganous salts*, with a loss of color when in contact with reducing agents (hydrochloric, sulphurous, and nitrous acid, organic matters, etc.), or when heated by themselves. Dioxide of manganese (peroxide), MnO_2, is the most important native mineral (pyrolusite).

By ignition it yields one-third part of oxygen gas, and when treated with conc. sulphuric acid half its contents of oxygen.

Permanganic acid.—Its salt dissolves in water with an intense purple color, which is immediately decolorized by organic materials (analysis of water), and all the following reducing agents (HCl, SO_2, As_2O_3, H_2S, ferrous salts, etc.).

30. MERCURY and AMALGAMS yield a sublimate of finely divided metallic mercury, when heated in the closed tube. Compounds of mercury heated in the closed tube together with soda, yield also metallic mercury which condenses above the assay. When a gray sublimate is obtained, without exhibiting distinct metallic globules, these may be made to coalesce by

means of a feather, or the part of the tube containing the sublimate is cut off with a file, brought into a test-tube, and boiled with some dilute HCl, by which treatment the mercury unites in shining globules. In cases where mercury is present in such small quantities that no distinct sublimate is formed, it may be detected by inserting into the tube a piece of gold-leaf wrapped around the end of an iron wire and held just above the assay. On heating, the mercury is volatilized, and combining with the gold forms a grayish-white amalgam.

Mercurous compounds of ordinary occurrence are insoluble in water, except the normal nitrate, the sulphate, and the acetate, which are sparingly soluble (300 to 600 parts of water). All these require acidulated water for their solution, becoming decomposed by *water* at a certain degree of dilution, and yielding precipitation of *basic salts.*

Solutions of *mercurous salts* are precipitated by HCl and by soluble chlorides, the precipitate being white *mercurous chlorides* or *calomel*, Hg_2Cl_2, which turns black with caustic potash or ammonia.

Solutions of mercuric oxide, Hg_2O_2 are not precipitated by HCl, since the *mercuric chloride* (corrosive sublimate) is soluble in about twelve parts of cold, or two to three parts of boiling water, and freely soluble in alcohol and ether.

Stannous chloride ($SnCl_2$) throws down calomel from mercuric chloride ($HgCl_2$) solutions. A clean strip of copper, placed in a slightly acid solution of a salt of mercury, become coated with *metallic mercury*, and when gently rubbed with cloth or paper, presents the tin-white lustre of the metal, the coating being driven off by heat.

31. MOLYBDENUM.—B. B., on charcoal, gives a copper-red stain in the O. F. on cooling, which becomes azure blue when touched for a moment with the R. F.

When it is present in small quantity, particularly when associated with copper or tin, as in some furnace products, it is necessary to have recourse to the wet way. The silver-white molybdenum is not oxidized in the air at an ordinary temperature, but when slowly heated it assumes a brownish-yellow, then a blue tarnish, and at a higher temperature it burns off to MoO_3. It is speedily dissolved by nitric acid as molybdic anhydride (MoO_3), with evolution of nitrous fumes; slowly by hot sulphuric acid, with evolution of SO_2. Molybdenum forms three classes of compounds, viz., *molybdous oxide*, MoO; chloride, $MoCl_2$, and other molybdous salts; *molybdic oxide*, MoO_2; chloride, $MoCl_4$, and corresponding salts; the two kinds of bases are converted into molybdic acid, or molybdates, by strong oxidizing agents, while molybdates are reducible to one or the other of the bases by *deoxidizing agents*. From *molybdous salts*, as $Mo(NO_3)_2$, alkaline hydrates or carbonate precipitate dark-brown *molybdous hydrate*, becoming blue in the air by oxidation to *molybdic-molybdate*, $Mo(MoO_4)_2$ and Mo_2O_5. The hydrate is insoluble in alkalies, sparingly soluble in alkaline carbonates, but easily soluble in bicarbonates. For analytical purposes the most important is *molybdic anhydride*, MoO_3. It is white, lemon-yellow when heated, fuses at a red heat, and sublimes. Hydrochloric acid separates from alkaline molybdates, *e.g.*, K_2MoO_4 white crystalline molybdic acid, soluble again in an excess of the acid. This latter acid solution, or the HCl solution, assumes, in contact with zinc, at first a blue, then a green and brown color. The addition of sulphocyanide of potassium changes the brown solution to red. The same red tint is obtained when the hydrochloric acid solution of a molybdate is treated with sulphocyanide of potassium. Ether withdraws this color from the liquid and assumes an orange tint, which, exposed to the air, turns crimson (the most sensitive reaction for molybdenum). H_2S produces in acid solutions of molybdic acid gradually a brown precipitate, MoS_3, soluble in $(NH_4)_2S$, forming $(NH_4)_2MoS_4$, while the supernatant liquid appears blue or green. The same precipitate is formed when the aqueous solution of an alkaline molybdate, after being saturated with H_2S, or after the addition of $(NH_4)_2S$, is acidulated with HCl. When the powdered compound of molybdic acid is mixed with a drop of strong sulphuric acid on platinum foil, a blue color is obtained, or it is still better to heat the pulverized substance in a small porcelain dish with a little conc. sulphuric acid, and then add alcohol, when the liquid assumes a sky-blue color if molybdic acid is present. For the reaction of molybdate of ammonium with phosphoric acid see "Phosphates," page 183.

32. NICKEL, B. B.—Oxide of nickel gives, if cobalt is not present, in the O. F. a reddish-brown bead when hot and pale-yellow on cooling. With larger quantities of oxide these colors are darker. In the R. F. the bead becomes gray and opaque from the separation of metallic nickel, and on long continued blowing colorless. Upon Ch. in the R. F., especially upon addition of granulated tin, the reduction is quickened and the reduced nickel unites with tin to a metallic globule.

All the salts of the protoxide, or nickelous oxide, NiO, are *yellow* when anhydrous; as hydrates, or in solution, *green;* they redden litmus paper, and are decomposed on ignition. The neutral salts (containing *no free* acid) are only partially decomposed by H_2S; and, when acidulated with HCl, not at all; acetate of protoxide of nickel or any nickel salt, previously treated with acetate of sodium, is completely precipitated by H_2S when the solution is warmed, and contains not too much free *acetic acid.* The precipitated black sulphide of nickel (NiS) is with difficulty soluble in dilute hydrochloric, and in acetic acid, though very soluble in nitric, and nitro-hydrochloric acid. $(NH_4)_2S$, likewise throws down from a neutral solution sulphide of nickel, of which only a very small quantity remains soluble in an excess, giving it a brown color. On this account a brown color of the liquid (which is poured off from the precipitate produced by $(NH_4)_2S$) indicates *nickel.*

Potassa throws down apple-green *nickel* hydroxide $= Ni(OH)_2$, insoluble in excess, soluble in ammonia salts. Acid salts, or such containing sal-ammoniac, are not precipitated by NH_3; neutral salts only partially; the precipitate is soluble in an excess of ammonia with a blue color. Caustic potash throws down gradually from this solution $Ni(OH)_2$. Carbonates of the alkalies precipitate basic carbonates; the precipitate being soluble in an excess of the precipitant.

Nitrite of potassium produces in very concentrated nickel solutions only a brownish-red precipitate of potassio-nickelous nitrite $= (NO_2)_2Ni + 4NO_2K$, soluble upon addition of water. In the presence of carbonates of the alkaline earths (Ba, Sr, Ca), CO_3, said reagent throws down, even in dilute nickel solutions, nearly all the metal in the form of yellow crystalline salt $(NO_2)_6NiMK_2$, (M=Ba, Sr, or Ca), which in cold water is with great difficulty, in boiling water easily, soluble, with a green color, decomposition taking place.

Ferrocyanide of potassium yields a greenish-white, ferricyanide of potassium a yellowish-green precipitate.

Cyanide of potassium precipitates nickelous cyanide, soluble in excess, the solution contains potassio-nickelous cyanide $=$ ($NiCy_2$, 2KCy), from which dilute HCl, or H_2SO_4, again throws down $NiCy_2$, with evolution of hydrocyanic acid.

If the solution of $NiCy_2$, 2KCy, is treated with an alkaline solution of hypochlorite of sodium, and heat applied, blackish-brown nickelic oxide (peroxide) $= Ni_2O_3$, is thrown down as *hydroxide*. The same happens, when the hydrated *protoxide of nickel*, diffused in water (or better in dilute alkali) or a solution of cyanide of nickel, is treated with chlorine. Free acids, even acetic acid, prevent its formation. HCl converts it into chlorine and chloride of nickel. On this reaction rests a method of *separating nickel* from *cobalt*.

33. NITRIC ACID (NITRATES).—When nitrates are fused in a glass tube with bisulphate of potasium, reddish-brown fumes are evolved (N_2O_3), which become readily visible when the tube is held against a white background. All nitrates detonate when heated on charcoal; those of the alkalies and alkaline earths (calcium nitrate) deflagrate with violence, being converted into carbonates.

Osmium. See page 123.

Oxygen.—All combustible substances burn in oxygen gas with great brilliancy, hence if this element is given off from some compound heated in a reagent tube, and an ignited splinter of charcoal be brought into the gas, it will burn with greatly increased brilliancy.

34. PALLADIUM.—Oxide of palladium, PdO, is reduced on ignition by B. B., but the metallic particles cannot be fused together. With borax on platinum wire in O. F. it is reduced without dissolving in the flux. The metallic particles cannot be united together to a globule even on charcoal in R. F. as in O. F. With salt of phosphorus it gives the same reaction. With soda on coal insoluble. The soda is absorbed by the coal, leaving the Pd behind as infusible powder.

Palladium occurs in a tolerably pure state with Brazilian platinum ore, also together with gold. It is darker than platinum; heated in the air, it oxidizes and turns blue; at a higher temperature the oxide is again destroyed. In the alcohol flame the metal becomes covered with soot; it is capable of condensing enormous quantities of hydrogen gas.* In nitric acid it is with difficulty dissolved. In hot hydrochloric and sulphuric acid scarcely soluble; in aqua regia readily soluble. With oxygen it forms two oxides, PdO and PdO_2, like platinum. PdO is the common compound. $PdCl_4$ is produced with aqua regia, and combines with other chlorides, viz., K_2PdCl_6. Palladic chloride loses chlorine easily, passing into palladious chloride, $PdCl_2$, and to this correspond the other palladious salts. From solutions of these caustic alkalies produce a dark-brown precipitate, PdO, soluble in excess; ammonia gives a flesh-red precipitate, $PdCl_2NH_3$, soluble in excess. By the action of HCl on this solution, a yellow precipitate is formed, $Pd(NH_3Cl)_2$. Iron vitriol reduces palladium salt slowly to metallic palladium (black). Stannous chloride induces a black precipitate, and gives a green solution. Iodide of potassium produces, even in dilute solutions, a black precipitate of palladious iodide, PdI_2,

---

* Palladium hydrate, Pd_2H_4, is formed by passing hydrogen over metallic palladium heated to redness. It possesses all the properties of a metal; it has metallic lustre, is tough, conducts electricity, and is distinctly magnetic. (Graham.)

quite insoluble in water, and suitable for the quantitative determination of iodine.

35. PHOSPHORIC ACID OR PHOSPHATES.—The green color (see flame reactions) which phosphates impart B. B. to the flame, especially upon the addition of a drop of concentrated sulphuric acid serves often for their detection.

If a previously pulverized and well-dried phosphate is heated to a red heat in a closed tube with a piece of magnesium-wire or metallic sodium, the phosphoric acid will be reduced. If the tube is then broken, and the piece containing the fused assay is, after cooling, moistened with a little water, phosphoretted hydrogen PH_3 is given off, having the characteristic disagreeable odor of decaying fish.

If a phosphate salt is dissolved B. B. in a borax bead to which some carbonate of sodium has been added, and tungstate of sodium is introduced, the bead upon being heated in the R. F. turns blue, while tungstic acid alone colors a borax bead in the R. F. yellow.

In the wet way it is traced, even in very minute quantities, thus, a few drops of a neutral or acid solution containing phosphoric acid are poured into a test-tube which is then filled to the depth of an inch with a solution of *molybdate of ammonium* containing much *free nitric acid*, there is formed a pale yellow precipitate termed *ammonium phosphomolybdate*. For the full delicacy of the test, especially if mere traces of phosphoric acid are present, the mixture should be set aside for several hours at a temperature of 30° to 40° C.

Silicic acid, with which phosphoric acid might be confounded, produces a strongly yellow coloration, but does not yield a precipitate, whilst arsenic compounds in solution furnish a yellow precipitate of ammonium arsenio-molybdate of variable composition.

36. PLATINUM.—This metal is insoluble in HCl, HFl, H_2SO_4, and HNO_3, but soluble in aqua regia to platinic chloride, $PtCl_4$. From this reddish-yellow solution H_2S throws down dark-brown platinum sulphide PtS_2, soluble in an excess

of yellow ammonium sulphide. Stannous chloride colors the solution of platinum dark brownish-red. For the reactions of $PtCl_4$ with KCl and NH_4Cl, consult potassium (below) and ammonium, page 140.

37. POTASSIUM.—For flame reactions, see B. B. A glass of borax containing potassa becomes blue when a little oxide of nickel* is carefully added, with soda alone a brown bead is obtained on cooling.

For the detection of potassium in compounds in the wet way, platinic chloride ($PtCl_4$) is added to neutral and acid solutions of the compound substance (not too dilute), together with HCl, (if the compound be not a chloride), when a yellow crystalline precipitate of potassium platinic chloride $(KCl)_2PtCl_4$ is thrown down. Since ammonium salts are also precipitated by this reagent with closely resembling color and form, these, if present, must first be removed (volatilized). Minute portions of potassa are detected by evaporating the solution with the reagent nearly to dryness on the water-bath, and then dissolving the mass in alcohol; the yellow crystalline precipitate, *octahedral*, remains undissolved, and may be identified under the microscope.

38. RHODIUM.—Rhodium is contained in platinum ores (0.4 to 1.0 p. c.). It is soluble in aqua regia only when in an alloyed condition (with Pt or Cu). It is soluble on fusion with bisulphate of potassium; it is oxidized at a red heat when mixed with potassa and nitre, forming brown RhO_2. When Rh is mixed with common salt, and a current of chlorine passed through the mixture, a red double salt is formed, $Rh_2Cl_6 + 6NaCl$, soluble in water. From the warm solution, H_2S precipitates slowly. Rh_2S_3 insoluble in $(NH_4)_2S$. When the solution is treated with some caustic potassa solution, and a few drops of alcohol added,

---

* Oxalate or carbonate of nickel may also be employed. It must be free from cobalt (must not furnish a blue glass with borax). Admixtures of soda and lithia do not interfere with the reaction if the potassa is present in sufficient quantity.

a black precipitate of metallic rhodium falls at ordinary temperature.

39. RUBIDIUM.—The oxide rubidia, a very rare alkali, gives B. B. a violet flame, and when mixed with cæsia and potassa, can only be distinguished by spectroscopic examination.

40. RUTHENIUM is alloyed with platinum, and found as laurite, Ru_2S_3, in the platinum ore of Borneo. Insoluble in acids. By fusion with caustic potassa and chlorate of potassium, or saltpetre, an orange colored RuO_4K_2 is formed, from the solution of which nitric acid separates black sesquioxide. Chlorine throws down anhydrous RuO_4. From the orange solution of the sesquioxide in HCl, hydrosulphuric acid (which colors it at first blue), throws down after a while brown sulpho-metal. Sulphocyanide of potassium (in the absence of other platinum alloys) causes a purple-red, and, when heated, a violet coloration.

41. SELENIUM and SELENIURETS yield in the closed tube at a high temperature, a sublimate which is reddish or black, and producing a red powder, give off at the same time the odor of decaying horse-radish. In the open tube they evolve the same characteristic odor, and yield a sublimate of selenium, which near the assay is steel gray, and further off red.

Selenites and selenates are reduced to selenides B. B. on charcoal in R. F. with the characteristic odor of selenium.

Selenium is steel-gray with a faint metallic lustre; it fuses very easily; volatilizes with brown fumes, giving the odor of decaying horse-radish; is soluble in bisulphide of carbon, and imparts B. B. a blue color to the O. F. Consult flame reactions, page 105.

42. SILICIUM, SILICON, or the oxide, SILICA, when heated with soda gives a clear glass, if the soda be not in excess. This reaction distinguishes silica from the earths; silica may, however, contain alumina, and still fuse with soda to a clear glass.

In most silicates the silica may be detected by the help of salt of phosphorus. Most silicates, when added to a bead of that salt and heated, are decomposed; the bases dissolve in the free phosphoric acid without interfering with its transparency (unless the substance is present in too large a quantity), while the silica, being almost insoluble, floats as a translucent spongy mass* in the bead. The latter must be observed carefully while hot, since many silicates form a glass, which, on cooling, becomes opalescent or turbid. The spongy mass (Kieselskelett) consists of an aggregate of most minute crystals which almost defy a microscopical determination. According to a great many experiments, however, they possess the crystalline form of *tridymite*, which is hexagonal, the crystals being tabular, formed by the prism and basal plane. They consist of pure silica, like quartz.†

When a finely powdered silicate is fused with an excess of carbonate of sodium, the resulting mass dissolved in dilute HCl, and evaporated to dryness, the silica is rendered insoluble; and on moistening the residue with strong HCl, and dissolving it in hot water, all the silica will remain behind; and can be separated from the bases by filtration and washing.

Most of the hydrous silicates, and many which are anhydrous, but which contain an excess of base, are decomposed by strong HCl, the bases uniting with the HCl, while the silica separates, either as a *gelatinous hydrate*, or as a *non-gelatinous powder.*

43. SILVER.—This metal is easily recognized by its physical characters, as also by the brown coating it gives when heated in O. F. on charcoal. When combined with easily oxidizable metals, it may be separated by heating on charcoal in O. F. If silver be associated with a large quantity of lead or bismuth, it is best to subject it to cupellation. The following process serves for its complete separation from most argentiferous ores. The finely powdered substance is mixed with an equal bulk of borax glass, and an excess of pure granulated lead (except in

---

* Kieselskelett, Germ.

† J. Landauer's Löthrohranalyse, 2d ed. Berlin, 1881, p. 95. See also "Tridymite," p. 260, in E. S. Dana's Text-book of Mineralogy, New York, 1877.

cases where lead or its oxide already exists, as in litharge, minium, cerussite). The mixture is placed in a cylindrical cavity of the coal, and fused in R. F. with Fletcher's blowpipe, Fig. 91, after the earthy matters have been dissolved, and the metallic particles united into one globule; this latter is subjected for a short time to the O. F., thereby separating volatile and easily oxidizable substances that may be present. The remaining globule, containing a large excess of lead and all the silver, together with the larger portion of the nickel and copper, is then separated from the flux mechanically, and subjected to cupellation.

For this purpose finely pulverized bone-ash is mixed with a small quantity of soda and made into a stiff paste with water. This paste is placed in a circular cavity in charcoal, half an inch in diameter, and one quarter inch deep, and the surface of it made concave and smooth by pressing it with an agate pestle, or any other suitable convex surface. This cupel is now carefully exposed to a gentle heat till perfectly dry. These capsules may be bought ready-made. The lead globule freed from adhering flux is then placed upon the cupel and exposed to O. F. Should much nickel and copper be present an infusible coating is formed which prevents the desired oxidation; this may be counteracted by the addition of a small quantity of lead. The blast is kept up until all traces of lead have become oxidized; this is indicated by the cessation of the rainbow colors of the oxide of lead which play over the surface of the globule. When the quantity of litharge that is formed in the process of cupellation is large, the globule of silver, still containing lead, may be removed to a fresh cupel and there finally refined. The instant when the last traces of lead disappear is then readily perceived by the sudden brightening of the globule. The remaining metal, when freed from gold, has a silver-white color. It may be tested for gold as described under that metal. See, also, cupellation of silver and gold, page 165.

In the wet way silver is determined, in almost all cases, as chloride of silver, $AgCl$, and separated from other metals; its insolubility in acids and solubility in ammonia distinguish it readily from all the other chlorides which are insoluble, or with difficulty soluble. Some metals, such as zinc, iron, and copper, the protosulphate of iron (or, perhaps better, the prot-acetate of iron), stannous chloride, sulphurous acid, and many *organic compounds*, precipitate metallic silver from its solutions.

44. SODIUM.—It is readily distinguished, even in compound substances, by the intense yellow color it imparts to the outer blowpipe flame. The sodium flame is invisible when observed through cobalt-blue glass, and red glass; with green glass it is orange colored (sensitive reaction). Sodium is not precipitated by platinic chloride, since it forms a compound soluble in water, alcohol, and ether. Indeed, nearly all its salts are soluble, except pyroantimoniate of sodium, $Na_2H_2Sb_2O_7 + 6H_2O$.* Pyroantimoniate of potassium, which is soluble, is hence the only reagent that precipitates soda from its solutions, as a white compound, of the above-mentioned composition, viz:—

$$K_2H_2Sb_2O_7 + 2NaCl = Na_2H_2Sb_2O_7 + 2KCl.$$

It must be precipitated from a neutral, or feebly alkaline solution. Alkaline solutions must be neutralized with dilute hydrochloric or acetic acid; acid solutions with caustic potassa (not ammonia).

Compare flame reactions.

---

* Prof. N. Menschutkin's Analytische Chemie. German edition of Dr. O. Bach, page 32. Fremy, the discoverer of this salt, calls it *metantimoniate of sodium*, which, according to Menschutkin, is not correct. This author considers antimonic acid in some respects analogous to phosphoric acid, viz:—

Phosphoric acid $= PH_3O_4$.
Pyrophosphoric acid $= 2PH_3O_4 - H_2O = P_2H_4O_7$.
Metaphosphoric acid $= PH_3O_4 - H_2O = PHO_3$.
Antimonic acid $= SbH_3O_4$
Pyroantimonic acid $= 2SbH_3O_4 - H_2O = Sb_2H_4O_7$.
Metantimonic acid $= SbH_3O_4 - H_2O = SbHO_3$.

45. STRONTIUM.—Strontium compounds color the flame *crimson.* In the presence of barium the crimson color appears at the moment when the substance, moistened with HCl, is first brought into the flame. The paler, yellowish-red flame of calcium is liable to be mistaken for the strontium flame. Consult flame-colors, p. 104 *et seq.*

In *solubility*, most compounds of strontium closely resemble those of barium, the hydrate being a little less soluble, and the sulphate and chromate more soluble in water than the corresponding barium compounds, and the silico-fluoride quite soluble. The chloride is soluble, the nitrate insoluble, in absolute alcohol (100 per cent.).

Strontium sulphate ($SrSO_4$), like barium sulphate, is almost insoluble in concentrated solution of ammonium sulphate, while sulphate of calcium is soluble, and may thus be separated. A saturated solution of calcium sulphate ($CaSO_4$) slowly produces a faint precipitate of $SrSO_4$ (prevented, or dissolved, by the presence of HCl, and HNO_3), but quite insoluble in alcohol.

An aqueous solution of calcium sulphate (gypsum) may be the simple means to distinguish calcium, barium, and strontium salts, when soluble in water. No precipitate will be formed if lime is present, while a *baryta* solution will at once be rendered turbid, or afford a precipitate, and *strontia* gives a faint precipitate after some time only. An addition of alcohol, however, throws down completely sulphate of strontium and sulphate of calcium.

46. SULPHUR.—Free sulphur fuses and forms a yellow sublimate in the closed tube. In an open tube, or on charcoal, it burns, yielding sulphurous acid, SO_2. The higher sulphides (sulphurets) give off sulphur in the closed tube; the neutral sulphides and subsulphides give off sulphurous acid gas when heated in the open tube, recognizable by its odor and the reddening of moist blue litmus paper. Sulphur is soluble in bisulphide of carbon, benzine, and turpentine.

In the investigation B. B. of sulphur-compounds, a lamp or candle-flame should be employed, since ordinary coal gas often contains considerable quantities of sulphur. The sulphur in sulphides and sulphates may be detected B. B. by fusing small quantities on coal with two or three parts of soda in the R. F. The sulphur is hereby converted into sulphide of sodium, which when placed on blank silver-foil, or on a bright silver coin, and moistened with a drop of water, yields sulphuretted hydrogen, which blackens the silver, and also test-paper containing acetate of lead. If selenium is present, the reaction cannot be used.

The following delicate test in the wet way, given by von Kobell, answers well in most cases: A small quantity of the powdered mineral sample, and an equal volume of iron powder* (Ferrum pulveratum, or alcoholizatum of the druggist) are put with a spatula into a glass cylinder 2½ inches high and 1 inch in diameter, and barely covered with hydrochloric acid (1 vol. conc. acid and 1 vol. of water). A strip of filtering paper, previously dipped into sugar-of-lead solution and dried, is fastened to a cork, and the mouth of the cylinder closed with it. In about one minute the paper appears blackened by the sulphide of lead thus formed, if any sulphur is present. All those compounds giving any distinct sulphur reactions, react also hepatic with *iron powder*. A dilute solution of ammonium molybdate with an excess of hydrochloric acid is colored fine blue by a small quantity of sulphuretted hydrogen or of sulphides dissolved in water. One of the most sensitive tests for sulphur (in the presence of an alkaline hydrate) is that of Prof. J. D. Dana. Heat B. B. in the R. F. any sulphide or sulphate, or any powdered mineral assay containing sulphur, upon charcoal with Sd. Put the fused mass into a watch-glass, moisten with a drop of water, and add a particle of a crystal, not larger than a pin's head, of the sodium nitroprusside (or of the corresponding potassium salt); there will be a magnificent purple color displayed at once, but disappearing after some time. Vapors

---

* Iron filings, free from rust, are pounded in an iron mortar; first sifted through a fine sieve, and afterwards through linen.

are tested for hydrosulphuric acid (H_2S) by conducting them into an ammoniacal solution of sodium nitroprusside.*

A glass made B. B. of soda and silica becomes red, or orange, when sulphur is present.

When soda is fused on charcoal in the R. F. with any compound of sulphur (sulphide or sulphate), *sulphide of sodium* is produced, and, if much sulphur is present in the sample, the fused mass will show the characteristic color of "*hepar*" (*Hepar sulphuris*, or liver of sulphur), being an old term for the higher sulphides of the alkalies, having a liver-brown color.

47. TANTALUM.—See Columbium (Niobium), § 72, p. 144.

48. TELLURIUM.—1. Tellurides, heated in the open glass tube, give a white or gray sublimate, fusible B. B. into colorless, or nearly colorless, drops. On charcoal, they give a white coating, and color the R. F. green-blue.

2. When a compound containing tellurium is triturated with soda and charcoal dust and fused in a closed tube, then allowed to cool, and a little hot water dropped into the tube, the water assumes a beautiful purple color, owing to the dissolved telluride of sodium.

3. Tellurium compounds, when gently heated in a mattrass with an excess of conc. sulphuric acid, impart to it a purple

---

* If this test for sulphur is made with any organic substance, as pairings of nails, hair, albumen, etc., the carbonate of sodium should be mixed with a little starch-powder, which appears to prevent the loss of any of the sulphur by oxidation. On winding up a hair four inches long, by coiling it around one point of a platinum support, moistening it and dipping it into the mixture of carbonate of soda with starch, and then heating by the blowpipe, the fused mass will give with the nitro-prusside an unmistakable action indicative of sulphur. By careful management perfectly satisfactory results may be obtained from a piece of hair less than an inch long. For theoretical deductions concerning *nitro-ferricyanides* or *nitro-prussides*, consult Qualitative Chemical Analysis, by Professors Douglass and Prescott, 3d edition, 1880, pp. 187 and 196.

color, which disappears on the addition of water, when a blackish-gray precipitate is formed.

Consult Bunsen's flame reactions, p. 111 *et seq.*

49. Tin.—In the metallic state, tin is recognized by its peculiar physical properties. In nature it is found only as an oxide, SnO_2 (cassiterite). B. B. oxide of tin is slowly dissolved by borax to a transparent glass, which is transparent on cooling. With soda or cyanide of potassium on charcoal it is easily reduced; and if borax also be added, a very minute quantity of tin may be detected when present in other minerals.

Sulphides containing tin must first be roasted, and the roasted mass treated with a mixture of soda and borax in R. F., the product is bright metallic tin, which can be further tested. On Ch. in the O. F. it forms oxide, that "glows" strongly, appears yellowish while hot, but becoming, on cooling, dirty yellowish-white. Exposed to the R. F. the molten metal retains it bright aspect.

Tin dissolves in conc. HCl with evolution of hydrogen, forming stannous chloride, $SnCl_2$, corresponding to stannous oxide SnO; in conc. aqua regia it is easily dissolved to stannic chloride, $SnCl_4$; in cold nitric acid, or dilute aqua regia, without evolution of gas, but with formation of ammonium salts, to stannous oxide or stannous chloride, viz., $Sn + 4NO_3H = Sn(OH)_4 + 4NO_2$, or $Sn + 9HCl + NO_3H = 4SnCl_2 + NH_4Cl + 3H_2O$. Conc. sulphuric acid dissolves it with evolution of SO_2, to stannous sulphate, SO_4Sn. Of the stannous salts, the chloride, $SnCl_2$, is the most in use, soluble in water and HCl, absorbing oxygen in the air, and separating oxide, or oxy-chloride. H_2S precipitates, from neutral and acid solutions, brown stannous sulphide, SnS, scarcely soluble in ordinary $(NH_4)_2S$, but more readily soluble in yellow sulphide of ammonium. Alkaline supersulphides, whereby ammonio—stannic sulphide—$SnS_3(NH_4)_2$ is formed, from the solutions of which acids throw down yellow stannic sulphide, viz:—

1. $SnS + (NH_4)_2S_2 = SnS_3(NH_4)_2$.
2. $SnS_3(NH_4)_2 + 2HCl = SnS_2 + 2NH_4Cl + H_2S$.

Stannous salts are oxidized to *stannic* salts by many oxidizing reagents. They are themselves powerful reducing agents.

Stannic oxide, or anhydride, forms two well-marked hydrates or acids: *stannic acid*, H_2SnO_3, and *metastannic* acid, $H_{10}Sn_5O_{15}$ (variable). *Stannic acid* is formed by precipitating *stannic* salts with alkalies; *metastannic* acid, by the action of nitric acid on tin. Stannic acid is insoluble in water, but it readily forms soluble stannic salts with HCl, H_2SO_4, and HNO_3; and also soluble alkaline stannates with the alkaline hydrates; other stannates being insoluble. Metastannic acid is insoluble in acids, and does not form metastannates.

The stannic oxide, hydrate, sulphide, and phosphate are insoluble in water.

The alkaline hydrates, carbonates, and barium carbonate, precipitate, from solutions of stannic salts, stannic acid, H_2SnO_3, which is white, and soluble in an excess of fixed alkaline hydrates and carbonates, but insoluble in ammonium hydrate and carbonate (distinctive from antimony), *e. g.*, $SnCl_4 + 4KOH = H_2SnO_3 + 4KCl + H_2O$.

Copper and tin are separated by strong nitric acid until all the metal is oxidized, the whole evaporated, to get rid of most of the acid, hot water added, when all the stannic oxide (and a trace of copper) can be filtered off; from the filtrate *copper* can be thrown down with caustic potassa at a boiling heat as *black oxide*. Should lead, zinc, and iron be present at the same time, we proceed as follows: after the stannic oxide has been removed, we separate the lead with sulphuric acid; the copper is precipitated from the acid solution by H_2S; zinc and iron are separated by boiling with acetate of soda, or by adding an excess of ammonia, when the iron is precipitated. From the solution zinc is thrown down by $(NH_4)_2S$, or in the absence of ammoniacal salts by carbonate of sodium at a boiling temperature.

Tin from Bismuth.—To a strong HCl solution of the two metals, add an excess of water, when an insoluble white precipitate of oxychloride of bismuth is produced. The tin will remain in solution.

Tin from Antimony.—Advantage is taken of the solubility of the sulphides of tin in oxalic acid. From the solution of the two metals the sulphides are precipitated in the usual manner, oxalic acid added in great excess, *i. e.*, 20 grammes of the reagent for every gramme of tin, so that the acid will crystallize out in the cold. Then heat to boiling, and pass in H_2S for about twenty minutes. No precipitate appears at first; but as soon as the liquid is saturated with the gas the sulphide of antimony begins to fall, and, in a very few moments, is completely thrown down.

When a neutral solution of salts of tin acidulated with some HCl is brought in contact with metallic zinc, metallic tin is thrown down in the form of scales, or as a gray spongy mass. When this reaction is carried on upon platinum foil, no black spot is produced, which is the case when a salt of antimony is thus treated.

50. SEPARATION OF As, Sb, Sn.—The metals are precipitated as sulphides from an acid solution and redissolved in $(NH_4)_2S$ (to separate them from metals not precipitated from acid solutions and not soluble in $(NH_4)_2S$ if present), then HCl is added, when a yellow precipitate falls; the mixture is slightly heated, the sulphides filtered off and washed. The mixture of sulphides is gradually and slightly heated with conc. HCl; the yellow residue is sulphide of arsenic, the filtered solution contains Sn and Sb.

The yellow As_2S_3* is dissolved in conc. HCl with addition of $KClO_3$, the solution saturated with NH_3 in excess, NH_4Cl and $MgSO_4$ added; precipitate $Mg(NH_4)AsO_4$. For further confirmation the precipitate is filtered off, and, after washing, a portion of it is dissolved in nitric acid, neutralized with ammonia, and treated with $AgNO_3$, forming brownish-red Ag_3AsO_4, which is soluble in ammonia and nitric acid.

---

* H_2S precipitates the arsenic from an acid solution always as As_2S_3; but by the treatment with yellow $(NH_4)_2S$ it passes into As_2S_5.

51. **TITANIUM.**—Compounds of titanic acid treated with S. Ph. B. B. dissolve in the O. F. to a clear bead, pale-yellow when hot, and colorless when cold. The strong R. F. now turns the bead yellow while hot, reddish when cooling, and violet when cold (titanous oxide). If iron is present, the cold bead is brownish-yellow to brownish-red, and the violet color only appears when the bead is acted upon with tin, in the R. F. on charcoal. An excess of iron interferes with the reaction.

2. Ignition in the O. F. on charcoal with soda does not reduce titanic acid to the metallic state (distinction from tin).

3. If a substance containing titanium is fused with carbonate of sodium, and the product obtained is dissolved in HCl, and then heated with metallic tin or zinc, the titanic acid is reduced to sesquioxide of titanium, coloring the liquid blue or violet, and finally the violet hydrated sesquioxide separates as a powder, retaining its color.

4. When the powdered mineral containing titanic acid is fused with 6 to 8 parts of the bisulphate of potassium, and the mass dissolved in very little water, then a few drops of water added, and next 5 or 6 volumes more of water, and the mixture is then boiled, a white precipitate results (titanic acid) which may be further examined with salt of phosphorus, etc.

Native titanic acid (Rutile) is finely pulverized and fused with 4 parts of its weight of alkaline carbonate. The mass, when treated with water deposits crystalline acid, titanate of the alkali remaining along with the iron. This should be digested with conc. HCl, and the diluted solution boiled with sulphite of sodium, when the titanic acid will be precipitated; or we may precipitate with sulphide of ammonium, and pour sulphurous acid solution over the precipitated mixture, when the sulphide of iron is dissolved out, and the titanic acid left as a white powder.

52. **TUNGSTEN** (*Wolframium*).—This is found in the minerals Wolframite $(Fe,Mn)WO_4$; in Scheelite, $CaWO_4$; Cuprotungstite, Cu_2WO_5+aq; Stolzite $PbWO_4$. B. B. the oxides of tungsten impart to the bead of salt of phosphorus in the R. F.

at first a dirty green, and then a blue color when cold (if iron is present the bead appears blood-red). With tin the bead, in the presence of iron, turns also blue or green.

The metal resembles iron, is brittle, and with difficulty fusible. Treated with nitric acid, or aqua regia, it is converted into anhydrous tungstic trioxide, WO_3, which is a yellow powder, insoluble in water and acids, but soluble in caustic alkalies; when it is feebly heated (to 250° C.) and a current of hydrogen gas passed over it, it turns to blue oxide, *i. e.*, tungstic trioxide combined with tungstic dioxide, $2WO_3+WO_2$, at a dull-red heat it forms brown tungstic dioxide, WO_2.

When a tungstate is fused with carbonate of sodium, and treated with hydrochloric acid and zinc, a beautiful blue color is obtained (reduction to $W_2O_5=WO_3+WO_2$). When a tungstate is fused with bisulphate of potassium, and the fused mass, consisting of tungstate of potassium, K_2WO_4, and free tungstic acid, is treated with water, some of it is dissolved, especially in the presence of carbonate of ammonium (distinction from silicic acid). When a finely powdered tungstate is treated with conc. hydrochloric acid, and a little nitric acid is added, yellow tungstic acid remains undissolved, but this is readily taken up by ammonia, and this solution, mixed with hydrochloric acid and zinc, assumes a blue color.

Tungstic acid and *tungstates.* Two modifications of *tungstic acid* exist, termed *normal* and *metatungstic acid;* and the tungstates may likewise be divided into two corresponding classes, the ordinary or *normal tungstates* and the *metatungstates.*

Tungstic acid, H_2WO_4. When a solution of a tungstate is precipitated in the cold, a white precipitate is thrown down, consisting of hydrated tungstic acid, $H_2WO_4 + H_2O$. This is soluble in water, has a bitter taste, and reddens blue litmus paper.

Metatungstic acid, $H_2W_4O_{13}+7H_2O$. For this purpose the barium salt is decomposed by dilute sulphuric acid, or the lead salt with hydrosulphuric acid. The acid crystallizes in small yellow octohedrons. The salts are readily soluble in water. When the solution is concentrated by boiling, a white hydrate is deposited, and afterwards the trioxide separates.

With chlorine, tungsten forms four compounds, viz:—

Tungsten dichloride,	WCl_2.
Tungsten tetrachloride,	WCl_4.
Tungsten pentachloride,	WCl_5.
Tungsten hexachloride,	WCl_6.

A characteristic reaction is the following: When a tungstate is fused with carbonate of sodium, the mass dissolved in HCl, and the solution boiled with metallic zinc, it becomes intensely blue, but fades entirely on dilution with water. A small amount of tungstic acid is detected thus: The assay is fused with five parts of soda, the mass extracted with water, and HCl added, when the tungstic acid, insoluble in acid, falls in the form of a white powder. The precipitate turns yellow by boiling, is insoluble in an excess of acid (distinction from molybdic acid), but soluble in ammonia. This solution, previously acidified, yields with ferrocyanide of potassium a deep-brown solution, and after some time a precipitate of the same color falls. With nitrate of silver it gives a white, with stannous chloride ($SnCl_2$), a yellow precipitate, which appears fine blue when the solution was previously acidulated wtih HCl. (Laudauer.)

The mineral wolfram (tungstic acid, iron, and manganese), the author found (confirming Dana's experience) to be sufficiently decomposable by boiling conc. sulphuric acid to give a colorless solution, which, treated with metallic zinc, becomes intensely blue, like Prussian blue, the color lasting several hours.

53. URANIUM.—The reactions B. B. with borax and salt of phosphorus lead to its detection. With salt of phosphorus it dissolves to a clear yellow glass, turning to a greenish-yellow when cold. In R. F. acted upon, this glass assumes a dirty-green color when hot, but a beautiful green when cold.

Treated upon charcoal with tin, this color becomes a darker green. Uranium occurs chiefly in the minerals pitchblende and uranite. It combines with oxygen in several proportions,* viz., Uranium dioxide UrO_2, and trioxide UrO_3, and these combine to form intermediate oxides, *e. g.*, $Ur_3O_8 = UrO_2 + 2UrO_3$.—UrO_2 is basic, while UrO_3 is an acid-forming oxide.

Uranous dioxide, UrO_2, is obtained by heating the uranosuranic oxide or uranic oxalate in a current of hydrogen. It forms a brown or brick-red pyrophoric powder. When heated in the air it takes fire and is converted into Ur_3O_8. It dissolves in strong acids, forming green uranous salts. Uranous hydroxide is precipitated in reddish-brown flakes, which become black on ebullition, by adding an alkali to a uranous solution. It dissolves easily in dilute acids, while the calcined oxide is soluble only with difficulty.

Uranium tetrachloride, or uranous chloride, $UrCl_4$. It is best prepared by passing chlorine over an intimate mixture of charcoal and any of the oxides of uranium, strongly heated in a tube of hard glass. It crystalizes in fine dark-green regular octachedrons, volatilizing in red vapors. Dissolves in water, forming an emerald-green solution. Caustic alkali throws down uranous hydrate.

Uranic trioxide, UrO_3 or uranyl oxide† $(UrO_2)O$. As an anhydride it is brick-red; as hydroxide, yellow. Reactions of the trioxide salts dissolve in water with a yellow color.

Uranic sulphate, $UrO_2SO_4 + 3Aq$, is obtained by heating the nitrate with sulphuric acid.

Uranic nitrate, $UrO_2(NO_3)_2 + 6Aq$, is prepared by dissolving any of the oxides in nitric acid.

---

* The atomic weight of uranium is, according to the recent investigations of D. J. Mendelejeff, 240, while hitherto it was assumed to be 120, and, accordingly, the formulæ of the oxygen compounds were noted protoxide, UrO, sesquioxide Ur_2O_3, and the proto-sesquioxide, Ur_3O_4.

† Péligot regards UrO_2 as a compound radical. Uranyl, the trioxide being the oxide of this radical, and the hydroxide has the formula $UrO_2(HO)_2$.

Hydrogen sulphide, in solutions acidulated with HCl, produces no precipitate; sulphide of ammonium produces a dark-brown one of *oxysulphide*, UrO_2S+H_2O somewhat soluble in an excess, but quite insoluble in yellow sulphide of ammonium (containing more S).

54. URANATES.—Uranyloxide not only forms the uranyl salts, but also unites with basic metallic oxides to form the *uranates*. Potassium uranate $= K_2Ur_2O_7$. This orange powder is obtained by precipitating an uranic salt with an excess of potash.

Ammonium uranate, $(NH_4)_2Ur_2O_7$, a yellow precipitate, obtained with NH_3. Carbonate and bicarbonate of potassium give a yellow precipitate of the double carbonate, $UrO_2K_4(CO_3)_3$, soluble in excess, and likewise soluble in carbonate of sodium and carbonate of ammonium. Carbonate of barium precipitates uranium salts completely in the cold.

For a process for the extraction of uranium from pitchblende, by Wöhler, consult Roscoe and Schorlemmer, *Treatise on Chemistry*, vol. ii. pt. ii. p. 218.

For reactions with borax see table, page 94.

55. VANADIUM.—Vanadates, in the absence of other colored metallic compounds, may be detected by their reactions with borax and salt of phosphorus before B. B.

In the O. F. with S. Ph. the bead is soluble to a clear glass which is dark yellow while hot, light yellow when cold. This bead, when brought in the R. F., assumes a brownish color when hot, and a beautiful chrome green color when cold. Distinguished from chromium by its reaction in O. F.

Vanadium forms with oxygen a series of compounds, viz., the monoxide V_2O, the dioxide V_2O_2, the trioxide V_2O_3, the tetroxide V_2O_4, the pentoxide (vanadic acid) V_2O_5. Corresponding with these a series of chlorides are known. The most important compound, from an analytical point of view, is vanadic acid. It forms a reddish-yellow powder, fusible at a red heat, forming, when cold, a crystalline mass scarcely soluble in water, but easily soluble in stronger acids and in alkalies.

The vanadiates of the alkalies are all soluble in pure water, but much less so in the presence of other alkaline salts. Vanadiate of barium is insoluble; hydro-sulphuric acid H_2S, or sulphurous acid (SO_2), reduces an acidulated solution of V_2O_5 to dioxide (V_2O_2), which latter remains dissolved with a blue color. Sulphide of ammonium throws down a brown precipitate, soluble in an excess with a brown color; soluble in colorless sulphide of ammonium or in sulphide of potassium with an intense cherry-red color (the reaction is very characteristic, but evanescent). Ferrocyanide of potassium produces a yellow precipitate, which becomes green on exposure to the atmosphere. The acidulated solution of a vanadiate of alkali, when shaken with ether containing hydrogen dioxide, H_2O_2, turns red. V_2O_5, when heated in a current of hydrogen gas, is reduced to V_2O_3. This same oxide is formed, as a soluble salt, if a solution of the pentoxide in sulphuric acid is reduced by metallic magnesium. The neutral solutions are brown, the acid ones green. All the lower oxides of vanadium in an acid solution are with permanganate of potassium oxidized to vanadic acid, exhibiting with sulphide of ammonium the same deportment as that acid itself. Compounds of vanadium can be fused with soda and saltpetre in a platinum crucible. The fused mass, when extracted with water and acidulated with conc. acetic acid, forms, when filtered, upon addition of nitrate of silver, a yellow precipitate. When the fusion is evaporated with HCl, a yellow or brownish-yellow solution is obtained, turning upon addition of protochloride of tin (stannous chloride) blue.

56. YTTRIUM.—Yttria, its oxide, is found in the minerals gadolinite,* orthite, yttrotantalite, etc. B. B. the reactions

---

* Gadolinite contains, according to an analysis of Bahr and Bunsen (Anal. d. Chem. und Phys., Jan. 1866), silica 22.61, glucina 6.96, sesquioxide of iron 4.73, protoxide of iron 9.76, yttria 34.64, erbia 2.93, protoxide of cerium (CeO) 2.86, oxide of didymium (DiO) 8.38, lanthanoxide (LaO) 3.21, magnesia 0.15, lime 0.83, soda 0.38, water 1.93 = 99.37.

of yttria (YO) are identical with those of the oxide of glucinum, or BeO (oxide of berryllium). From its salts caustic potash, ammonia, and sulphide of ammonium precipitate white hydrated oxide $Y(HO)_3$ not soluble in excess. Sal-ammoniac prevents the reaction. YO is a strong base, decomposes salts of ammonia, and attracts greedily carbonic acid from the atmosphere. Carbonate of baryta does not precipitate it.

Analysis of the gadolinite (silicate of Y, Be, Fe, Mn, Ce, La). After the removal of the silica, oxalate of ammonium removes from the neutral solution, in the presence of ammonia and sal-ammoniac, the insoluble oxalate salts of Y, Ce, La, while Be, Fe, Mn remain in solution as oxalates. The separation of Y from Ce and La is executed with conc. neutral sulphate of potassium solution. The double sulphate, $K_3Ce(SO_4)_3$ is but slightly soluble in water, and quite insoluble in sulphate of potassium solution, and the same is the case with the double sulphate, $K_8La_2(SO_4)_7$. Hence these are precipitated, while from the solution the yttrium oxide, YO, is thrown down by ammonia and is determined as such.

57. Zinc.—Oxide of zinc with borax gives a clear glass, which is milk-white on flaming; or, with more assay, is enamel-white on cooling. In the inner flame, on charcoal, fumes are given off and a white coating surrounds the assay. With soda on charcoal the ores, even when containing little zinc, afford the peculiar bluish flame of burning zinc, and white oxide is deposited on the coal. With cobalt solution a green color, while tin gives a bluish-green.

From solutions of zinc all the alkali hydrates, including ammonia, precipitate white hydrate of zinc, $Zn(OH)_2$ soluble in an excess.

Hydrosulphuric acid precipitates a part of the zinc from neutral solution of its salts with mineral acids, and the whole from the acetate (*i. e.*, sulphide of zinc is not soluble in acetic acid). Alkali sulphides—as sulphide of ammonium $(NH_4)_2S$—throw down all the zinc as sulphide, both from its salts with acids, and from its soluble combinations with alkalies. Pure sulphide of zinc is white.

58. ZIRCONIA occurs in nature in the zircons or jargons. B. B. infusible, when strongly heated a very brilliant light is given out.

It forms only one compound with oxygen, viz., ZrO_2, which yields salts with acids, the sulphate is with difficulty soluble; the chloride, $ZrCl_4$, is volatile. Fluoride of zirconium is soluble in water (distinctive from thorium) and yields with fluoride of potassium a double salt, K_2ZrFl_6, with difficulty soluble in water. ZrO_2, fused with soda, liberates CO_2, forming a scarcely soluble sodium compound, the composition of which differs. The simplest Na_4ZrO_4 is produced by the action of an excess of soda.

Reactions of zirconium salts:—

Caustic alkalies, ammonia, and sulphide of ammonium, throw down hydroxide, $Zr(OH)_4$, not soluble in an excess of caustic alkalies and in sal-ammoniac (distinction from alumina and glucina), but soluble in carbonate of ammonium. $Zr(OH)_4$ obtained in the cold is easily soluble in acids, that produced at a higher temperature, or the ignited oxide, is with difficulty soluble (requiring two parts of conc. sulphuric acid to one of water).

The carbonate of zirconium is soluble in carbonate of ammonium, separating again by boiling. Neutral sulphate of potassium precipitates white $K_4Zr(SO_4)_4$, insoluble in an excess, but soluble in cold HCl (difference from Th, Ce). The precipitated salt furnished at a higher temperature is insoluble in HCl.

Oxalic acid yields an oxalate insoluble in an excess but soluble in HCl and in oxalate of ammonium (difference from thorium). Analysis of zircon: SiO_4Zr, is fused with soda. The mass is treated with water, which dissolves silicate of sodium, and leaves behind a crystalline powder of zirconia-sodium, which, after washing with more water, is dissolved in HCl, from which solution NH_3 throws down $Zr(OH)_4$. From oxide of iron, zirconia is separated with oxalic acid or sulphite of sodium.

CHAPTER VIII.

FUSION AND FLUXING.

THE term "fusion" is applied to the conversion of a solid substance into the fluid form by the application of heat; fusion is most frequently resorted to for the purpose of effecting the combination or the decomposition of bodies. The term "fluxing" is applied to the process in cases where substances insoluble, or difficult of solution, in water and acids, are, by fusion, in conjunction with some other body, modified or decomposed in such a manner that the new-formed compounds will subsequently dissolve in water or acids. Fusion and fluxing are conducted either in porcelain, silver, or platinum crucibles, according to the nature of the compound. The crucible is supported on a triangle of medium stout platinum-wire, resting on the ring of a blast lamp. (See Fig. 46, p. 53.)

Resort to fluxing is especially required for the analysis of the *sulphates of the alkaline earths*, and also for that of many silicates. The flux most commonly used is carbonate of sodium or carbonate of potassium, or, better still, a mixture of both in equal atomic proportions, *i. e.*, 13 parts of pure carbonate of sodium are mixed with 10 parts of pure *anhydrous* carbonate of sodium.*

Silicates are fused with about 4 to 5 parts of the alkaline mixture mentioned, or, still better, with carbonate of sodium alone, provided the operation is carried on with Bunsen's blast lamp, or a wind furnace. A basic alkaline silicate is formed, which, being soluble in water, may be readily separated from such metallic oxides as it may contain in admixture.

---

* The mixture is kept in a well-stoppered bottle.

From this basic alkaline silicate, hydrochloric acid separates *the silicic acid as hydrate.* If a fixed alkaline carbonate is fused together with sulphate of barium, strontium, or calcium, there are formed carbonates of the alkaline earths and sulphates of the alkalies. In the new compounds both the base and the acid of the originally insoluble salt may now be readily detected. However, we do not employ carbonate of potassium separately, nor carbonate of sodium, to effect the decomposition of the insoluble silicates and sulphates; but we employ for this purpose the above described mixture of both, because this mixture requires a far lower degree of heat than either of its components alone, and hence the operation may be conducted over an alcohol lamp with an argand burner, or a Bunsen gas burner. The fusion with alkaline carbonates is always effected in a platinum crucible provided no reducible metallic oxides be present, which would ruin it.

In cases where alkalies are present in the mineral submitted to analysis, we employ hydrate of baryta* for its fusion. Upon fusing silicates together with about four parts of hydrate of baryta, a basic silicate of barium is formed, and the oxides are liberated. If the fused mass is treated with hydrochloric acid, the solution evaporated to dryness, and the residue digested with hydrochloric acid, the silicic acid is left behind, and the oxides are obtained in solution in the form of chlorides. Hydrate of baryta is preferable as a flux to test silicates for alkalies, to carbonate or nitrate of barium, since it does not require a very high temperature for its fusion, nor does it cause any spurting in the fusing mass from the disengagement of gas, as in the case with the nitrate. The operation is conducted in a silver or platinum crucible. The mineral subjected to fusion must in every case be very finely pulverized in an agate mortar and sifted through the finest hair sieve.

---

* Hydrate of baryta fuses at a gentle red heat without losing its water.

DEFLAGRATION.

In a very general sense "*deflagration*" signifies a process of chemical decomposition attended with a detonation or explosion. It is here used in a more restricted sense to designate the deoxidation of a substance in the dry way at the expense of the oxygen of another substance mixed with it, usually a nitrate or a chlorate, viz., saltpetre, potassium chlorate. Connected with this process is a sudden or violent combustion, attended with a very lively incandescence. Deflagration is resorted to, either to produce the desired oxide—*e. g.*, tersulphide of arsenic is deflagrated with nitrate of potassium to obtain arsenate of potassium—or it is applied as a means to prove the presence or absence of a certain substance. Thus salts are tested for nitric or chloric acids by fusing them with cyanide of potassium, and observing whether this process will cause deflagration* or not.

To attain the former object, the perfectly dry mixture of the substance under investigation, and of the deflagrating agent is projected in small proportions into a red-hot porcelain crucible With very small quantities the process is best conducted on piece of platinum foil, or on a small platinum spoon.

ON THE USE AND PRESERVATION OF PLATINUM VESSELS.

Platinum apparatus being very expensive, should be handled with great care and kept polished, *i. e.*, by gently rubbing with moist sea-sand (the rounded grains of which do not *scratch* the metal); by fusing borax upon the coated surface, or by digestion with nitric acid, and lastly polishing again with sea-sand.

1. *Platinum* is not attacked at any temperature by nitric,

---

* B. B. deflagrations of minute quantities, viz., common and Chili saltpetre, chlorate of potassium, are executed on charcoal. If we place upon the fused mass a moistened red litmus paper it turns blue (alkaline carbonates), and a drop of HCl causes effervescence (CO_2).

hydrochloric, or sulphuric acid, but dissolves in nitro-hydrochloric acid, though less readily than gold.

2. *Free chlorine* and *bromine* attack platinum at an ordinary temperature; also free sulphur, phosphorus, arsenic, selenium, and iodine attack ignited platinum. Hence the fusion of sulphides, sulphates, and phosphates with reducing agents (carbon, etc.) is injurious or fatal to platinum vessels. The ignition of organic material containing phosphates acts in a slight degree as free phosphorus.

3. *The heating* of ferric chloride, and the fusion of bromides, and iodides affect platinum to some extent.

4. *The alkali hydrates** (not their carbonates) and the *alkaline* earths, especially baryta and lithia when ignited with platinum in the air, gradually corrode platinum vessels. The nitrates of the alkalies or alkaline earths are also detrimental.

5. All *metals* which may be reduced by fusion, especially salts of bismuth, lead, tin, and all metallic compounds mixed with reducing agents (cyanide of potassium, etc.), including the alkalies and earths, form fusible alloys at a high temperature with platinum. Oxides of mercury, lead, bismuth, tin, antimony, zinc, copper, nickel, are, at a white heat, rapidly reduced, unite with the platinum, and corrode it.

6. Silica with charcoal slowly corrodes ignited platinum. Hence platinum crucibles should not be supported on charcoal in the furnace, but packed in magnesia in an outer crucible of clay.

Cracks and holes in platinum crucibles may be repaired with gold solder, but such vessels cannot afterwards be exposed to a high heat.

---

* Caustic alkalies must be fused, or evaporated in silver crucibles. These can only be used at temperatures below full redness, and must not come in contact with sulphur or be heated over coke, coal, or gas, or other fuel containing sulphur.

PART II.

DETERMINATIVE MINERALOGY.

CHAPTER IX.

ON THE DETERMINATION OF MINERALS BY MEANS OF SIMPLE EXPERIMENTS WITH THE BLOWPIPE, AIDED BY HUMID ANALYSIS.

A FREE translation from the twelfth edition of Professor Franz von Kobell's "Tafeln zur Bestimmung der Mineralien."*

INTRODUCTION TO THE TABLES.

The following tables are intended to assist in the discovery and facilitate the determination of minerals by the most plain and reliable methods of examination. They are based upon a few simple experiments with the blowpipe or with chemicals in the wet way, *i. e.*, the substance, if not already fluid, is first brought into the liquid state and is then operated upon by chemical reagents in the form of a solution. These experiments soon lead to a group containing a few species, among which is the mineral sought—its name and usual composition. The species under examination can generally be distinguished from others in the same group by some of its chemical characters. In any case where uncertainty or doubt might arise on

---

* Before the last edition was fully prepared for printing, the celebrated author von Kobell died (Nov. 11, 1882); hence this twelfth, improved, and augmented edition has been issued by K. Oebbeke, München, 1884. J. Lindauer's Buchhandlung.

account of similarity in the chemical reactions of two species, we may be convinced of the correctness of our determination by referring to any work on mineralogy, and comparing the physical properties of the species. The correctness and advantage of this method of determining minerals have been sufficiently demonstrated by practical exercises carefully conducted for many years.

In order to perform successfully all the manipulations here required, it is only necessary to be acquainted with the use of the blowpipe, and also with the manner of making some simple solutions and precipitations.

It is expected that these pages will be especially useful to those who have neither time nor the inclination to devote themselves to the study of larger works on mineralogy, but to whom the determination of some few minerals is often a matter of interest. For that reason it may be acceptable to the chemist, the miner, the farmer, and the mechanic.

When an individual wishes to determine any mineral, the arrangement is such that he will be constantly directed by the divisions to the tests which he must make. After noting the

"*Lustre of the Mineral*,"

there is generally required a *single fusion of the sample*, either alone or *with soda;* then one trial by solution, and a few precipitations, when the object sought is attained. Any one who will follow the directions here given, and execute the tests with accuracy, will soon become acquainted with many reactions, and by a short practice he may acquire the ability to determine minerals with facility and certainty. Where errors would be most likely to occur in the examination, they are avoided by the arrangement of the divisions, *i. e.*, some minerals have both a *metallic* and *non-metallic* lustre; some fuse *under* or *above* 5, according to the skill of the operator. As these minerals might appear of doubtful limit, they are mentioned in both divisions.

PHYSICAL PROPERTIES OF MINERALS.

I. LUSTRE. In the group of minerals with metallic lustre are placed only those which are perfectly opaque. A thin splinter held between the eye and the light must show no translucency when it is considered as having *metallic lustre;* otherwise as without it.

II. FUSIBILITY.

The following is the scale of fusibility:—

1. Stibnite (antimony glance).
2. Natrolite.

These in coarse or fine splinters fuse in the mantle of a candle flame (without the blowpipe).

3. Almandite. Alumina-iron garnet, does not fuse in a candle flame like the preceding; but B.B. easily, even in somewhat larger pieces.

4. Actinolite. B. B., fusible in rather fine splinters.

5. Orthoclase. B. B., fusible in finer splinters.

6. Bronzite. (B. B. becomes rounded only on the finest points and the sharpest edges.) Splinters or fragments of these minerals are kept on hand, and their fusibility compared with that of samples similar to them in size and edges.

Trials of fusibility should be made in the forceps, and minerals difficult of fusion should be employed in thin splinters since these might fuse on the edges, while an obtuse piece might lead to the conclusion that the mineral is infusible. Nor should the sample be regarded as infusible until it has been heated just beyond the extremity of the blue flame where the heat is most intense.

Minerals which decrepitate strongly (like common salt) are finely pulverized, moistened with water and placed on charcoal; by heating the particles become sintered (if the sample be fusible), so that the mass may be taken in the forceps and further heated in the flame.

III. Hardness. For the scale of hardness that of Mohs is adopted, which is as follows, viz:—

1. Talc, common foliated, light-green variety.
2. Gypsum, the crystallized variety (or rock-salt, Dana).
3. Calcite (calc-spar), transparent variety.
4. Fluor-spar, crystallized variety.
5. Apatite, transparent variety.
5.5. Scapolite, crystalline variety.
6. Orthoclase, white, cleavable variety.
7. Quartz, transparent variety.
8. Topaz, transparent crystal.
9. Corundum (sapphire), cleavable variety.
10. Diamond.

Trials of hardness are made by taking individuals of the scale and attempting to scratch the mineral under examination, or by using a file on similar edges of each; both methods may be employed. A few trials will give sufficient experience in the use of this scale.

Sharp corners must be used in scratching, and particular care should be taken in this, as in all other cases, that *impurities* do not come in to modify the result; thus a grain of quartz in some of the impure varieties of Galena, if it happened to come upon the corner which is used, would make the mineral appear quite hard, and without proper precautions many such errors may occur.

IV. Color. Great care must be taken in forming any conclusions from the color of minerals. In minerals of metallic lustre the color is generally constant and often very characteristic in some of the non-metallic species the same is true, but experience will teach how greatly the colors of non-metallic minerals vary, and varieties are constantly found differing in color from all that were previously known. Hence, especially in non-metallic minerals, the color which is given should only be regarded as an aid, or unimportant suggestion in the determination.

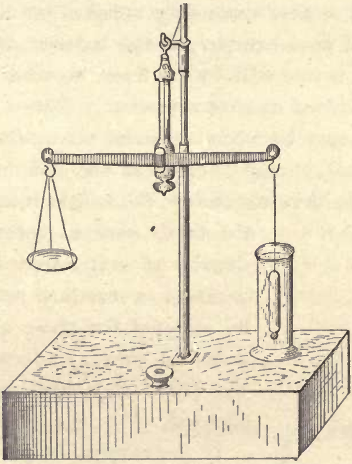
V. **Streak.** The *streak* of a mineral is the color of the powder obtained by scratching it with a knife or file, or better, if not too hard, by drawing it across a piece of unglazed porcelain.

Specific Gravity.

Determination of the specific gravity by an ordinary good balance and weights. The specific gravity of a mineral is its weight compared with that of an equal volume of water, which is taken as a unit of comparison.

The direct comparison by weight of a certain volume of water with an equal volume of a given solid is not often practicable. By making use, however, of a familiar principle in hydrostatics, viz., that the weight lost by a solid, immersed in water, is equal to the weight of an equal volume of water, that is, the volume of water it displaces—the determination of the specific gravity becomes a very simple process.

Fig. 118.*



---

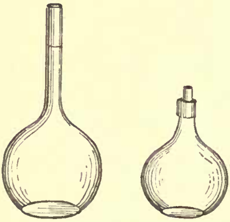
* Mohr's hydrostatic balance for determining the specific gravity of liquids and solid objects.

The weight of the mineral in the air (w) is determined by weighing with the balance in the usual manner, then the weight in water is found (w'), when the loss by immersion, or the difference of the two weights ($w-w'$) is the weight of a volume of water equal to that of the mineral. Finally, the quotient found by dividing the first weight (w) by that of the equal volume of water as determined ($w-w'$), gives the specific gravity (G.) That is to say: $G. = \frac{w}{w-w'}$.

For example, the weight of a fragment of *quartz* is found to be 4.534 grammes. Its weight in water = 2.817 grammes, and therefore the loss of weight, or the weight of an equal volume of water = 1.717. Consequently the specific gravity $= \frac{4\ 534}{1.717}$ or 2.641.

The mineral is first accurately weighed on a good balance, then suspended from one pan of the balance by a horse-hair, silk thread, or, better still, by the finest possible platinum wire, in a glass of distilled water conveniently placed beneath. The platinum wire may be wound around the specimen, or, where the latter is small, it may be made at one end into a little spiral support. While thus suspended, the weight is again taken with the same care as before. Since the density of water varies with its temperature, a standard temperature must be selected for these experiments, in order to obtain uniform results: 60° F. (15° C.) has been generally adopted.

Fig. 119.



If the mineral is not solid, but pulverulent or porous, it is best to reduce it to a powder and weigh it in a little glass bottle, shown above (Fig. 119).* This bottle has a stopper which fits tightly, and the neck of which is drawn out

---

* These glass bottles are capable of holding exactly a thousand grains, or two hundred grains, or any known weight, of distilled water.

to a fine tube, with a very fine opening. The bottle is filled with distilled water, the stopper inserted, and the overflowing water carefully removed with a soft cloth. It is now weighed, and also the mineral whose density is to be determined. The stopper is then removed; and the mineral in powder form or in small fragments inserted with care, so as not to introduce air-bubbles. The water which overflows on replacing the stopper is the amount of water displaced by the mineral. The weight of the bottle with the inclosed mineral is determined, and the weight of the water lost is obviously the difference between this last weight and that of the filled bottle and the mineral together, as first determined. The specific gravity of the mineral is equal to its weight in air, divided by the weight of the equal volume of water thus determined.

Where this method is followed with sufficient care, especially avoiding any change of temperature in the water, the results are quite accurate.

If a mineral is soluble in water, it is weighed in a liquid in which it is insoluble, and of which the specific gravity is known. The specific gravity is then readily calculated.

Example 1.—50 parts of rock-salt (w), when weighed in spirits of turpentine, displace an amount the weight of which is equal to 19.53 parts. The specific gravity of spirits of turpentine is to that of water as $0.872:1$; hence, we find that $0.872:1=19.53:w-w'$, and hence $w-w'=\frac{19.53}{0.872}=22.396$, *i. e.*, the weight of an equal volume of water.

Since $G=\frac{w}{w-w'}=\frac{50}{22.396}=2.232$, the latter number, 2.23, expresses the specific gravity of rock-salt.

Example 2.—A substance soluble in water was weighed in oil, and its specific gravity, compared with the oil, was 2.6, the specific gravity of the oil was 0.87: then $2.6\times0.87=2.262$, the specific gravity of the substance.

The specific gravity of a substance lighter than water, for instance that of elmwood, is found as follows:—

The elmwood by itself weighs in the air =	2 oz.
The wood is attached to a piece of lead which weighs =	4 oz.
Total weight of both in air =	6 oz.
In water both together weigh =	3 15 oz.
Loss of both united =	2.85 oz.
The lead alone weighs in the air =	4.00 oz.
When submerged in water =	3.65 oz.
Loss of the lead alone in water	0.35 oz.
By substracting from the loss of *both solids* in water =	2.85 oz.
The loss of lead alone in water =	0.35 oz.
We obtain hence for the loss of the wood =	2.50 oz.

Hence the specific gravity of elmwood is = 0.8.

Since: $\frac{2.00 \text{ (absolute weight in air)}}{2.50 \text{ (weight of an equal bulk of water)}} = 0.8$ (*i. e.*, the spec. grav. of the wood mentioned).

The specific gravity of minerals is most easily taken by means of Prof. Jolly's spring-balance.* (Fig. 120). A wire wound in a spiral form is suspended at *a*, and has attached at its lower end, *b*, two pans *c* and *d*. The pan, *d*, dips into water. The vessel containing the water in which the pan is suspended is placed upon a shelf, which may be moved up or down on the standard of the balance. A mark at *m* shows the extension of the spiral on the mirror scale, which is also attached to the standard. In reading, the mark is made to cover the reflection on the mirror.

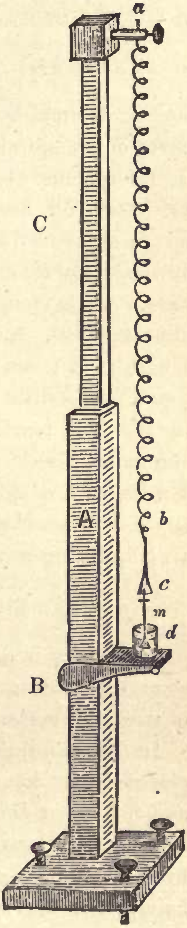
If weights increasing a tenth of a gramme are added succes-

---

* This spring-balance (Federwage) is furnished by Mechaniker Berberich, in München, for 27 marks, about $6.75.

sively to the pan in the air, it is found that the extension of the wire is in proportion to the weight added. Conically wound wire, with its greatest diameter at *a*, and its smallest at *b*, shows precisely the relation between the size of the load and the extension of the spiral.

Fig. 120.



The manner of using the balance is extremely simple. Before the substance is placed on the pan, the place of the mark is observed on the scale. A known weight is then placed on the upper pan, and the shelf, B, moved down as far as necessary; so far, that with the consequent extension of the spiral, the pan, *d*, will again sink into the water, when a second reading is made. The difference in these figures gives the number of divisions on the scale over which the spiral has been made to pass by the weight. If it is found, for example, that with a weight of 1 gramme the extension of the spiral is 122.2 divisions, while with some substance, as a piece of mineral, the extension is only 54.4, the absolute weight of the substance will be $\frac{54.4}{122.2} = 0.445$. If, however, the absolute weight is not required, only the specific, it is not necessary to express the absolute weight in grammes. *Three* readings are made: first, with empty pan; second, with substance placed on the upper pan; and the third, after placing the same substance on the pan under water. The difference between the first two gives the absolute weight expressed in divisions of the scale, and the difference in the last two gives the weight of the displaced water. The quotient of these differences is, therefore, the *specific weight.* If the mark with the empty pans stands at 64.2, and with the substance placed in the upper pan at 275.3, and with the same substance in the lower pan at 220.8, then the absolute weight is $275.3 - 64.2 = 211.1$, and loss of weight in water is $275.3 - 220.8 = 54.5$. Specific weight will be $\frac{211.1}{54.5} = 3.85$. The second decimal is not always certain, but, by proper arrangement of the spiral, is found as reliable as the ordinary balance. If the specific weight of a fluid is to be determined, both pans are taken off, and in place of them a glass of about 1 c.c. in size is suspended by a fine platinum wire. The loss of weight in water and other liquids is shown by the scale as in the former case. As is shown in the drawing, the shelf, B, is attached to the standard, A. The movable standard, C, has the same length as A; can be raised or lowered, and made fast at any point. C is drawn out according to the length of the spiral, so far that the mark with the pans empty stands opposite one of the upper divisions of the scale, which, to show the whole extension of the spiral, must be at least 600 mm. long. Every spiral at first shows a little elasticity, which grows less, and which, during any one experiment, amounts to really nothing.

PYRO-ELECTRICITY.

Electricity is developed in some minerals by heat, whereby some light substances are attracted, such as deer's hair or fibres of wool and cotton.

In determining whether a crystal be positively or negatively electric, mistakes may easily happen, which may, however, be avoided, according to von Kobell, by employing "chamois beard" hair electroscope (*i. e.*, the long hair, hanging down the back of a four year old chamois, is called its "beard.") These hairs, when rubbed from the root toward the end point, become strongly positive electric; on the contrary, rubbed from the point toward the root they become negative electric, though less so.

OPTICAL INVESTIGATION OF MINERALS.

When a mineral is transparent, a *Nicol* prism, and von Kobell's Stauroscope* will be useful in determining the optical properties of minerals.

Altered reactions of impure minerals. It is scarcely necessary to remark that the reactions usually mentioned relate only to pure or homogeneous specimens. When a mineral is presumed to be impure we must take into consideration its adulterations and judge of the reactions accordingly. Some varieties of wollastonite, for example, effervesce with acids, and also react alkaline after fusion; neither of which reactions belongs properly to this material, but is caused by an admixture of calcite or other carbonate.

CRYSTALLIZATION.

Crytallization,† if distinct, will often aid very materially in determining the identity of a mineral.

The forms of crystals are exceedingly various, while the systems of crystallization based on their mathematical distinctions are only *six* in number.

---

* See von Kobell's Mineralogie, 5te Auflage, Leipzig, 1878, page 65, "Stauroscope;" also, The Study of Rocks, by Frank Rutley, F.G.S., London; Longmans, Green & Co., 1879, page 81, giving a description of the instrument devised by von Kobell, and an improvement made by Brezina.

† For the study of Crystallography and the Physical Characters of Minerals, E. S. Dana's "Text-book of Mineralogy" is recommended, 3d ed., New York, 1880.

SYSTEMS OF CRYSTALLIZATION.

No.	Some typical simple forms.	Axes.
1	Cube and octahedron.	3 axes, rectangular and equal.
2	Right prism with square base.	3 axes, rectangular, 2 equal.
3	Right prism with rectangular or rhombic base.	3 axes, rectangular and unequal.
4	Right rhomboidal and oblique rhombic prisms.	3 axes, unequal, 2 rectangular.
5	Oblique disymetric rhomboidal prism.	3 axes, unequal, and unequally inclined.
6	Rhombohedron and hexagonal prism.	4 axes, 3 equal and equally inclined, 1, unequal at right angles to the other three.

NAMES USED BY DIFFERENT AUTHORS.

No.	Naumann.	Mohs.	Weiss & Rose	Phillips.	Delafosse.	Dana.
1	Tesseral.	Tessular.	Regular.	Cubic.	Cubic.	Isometric.
2	Tetragonal.	Pyramidal.	2 and 1 axial.	Pyramidal.	Tetragonal.	Dimetric, or Tetragonal.
3	Rhombic.	Orthotype.	1 and 1 axial.	Prismatic.	Orthorhombic.	Trimetric, or Orthorhombic.
4	Monoclinohedric	Hemiorthotype.	2 and 1 membered.	Oblique.	Clinorhombic.	Monoclinic.
5	Triclinohedric.	Anorthotype.	1 and 1 membered.	Anorthic.	Clinohedric.	Triclinic.
6	Hexagonal.	Rhombohedral.	3 and 1 axial.	Rhombohedral.	Hexagonal.	Hexagonal.

CHEMICAL PROPERTIES OF MINERALS.

Preliminary proceedings for testing and properly classifying them. In commencing examinations for ascertaining the species and name of a mineral, it is always important to begin with the first group, and pass on to those following, since a mineral which is contained in a former group may also possess the character of a succeeding group, but never the reverse.

For convenience of those making examinations, a SYNOPSIS OF THE DIVISIONS AND GROUPS IS PREFIXED. Instead of further explanation, two examples will sufficiently illustrate the method of determination.

1. EXAMPLE. Suppose we have a specimen of "ALUMINITE" before us and are unacquainted with the mineral. It *has no metallic lustre*, and therefore belongs to the Division II., viz: *Minerals without metallic lustre.*

It is infusible, and therefore falls under subdivision C. *Minerals infusible or fusible above* 5. The first group of the subdivisions is characterized by its behavior before the blowpipe, "*turning blue*" *when moistened with cobalt solution.* One trial shows that it belongs to this group, and since it yields *much water* in a matrass, it must be looked for under section i, page 289. Among the minerals here mentioned, only *alunite* and *aluminite* yield *hepar* with soda; the specimen under examination shows this deportment, and must be one or the other; *aluminite* is described as being *easily soluble* in *muriatic acid*, while *alunite* is *scarcely attacked.* A single trial with muriatic acid determines the mineral to be "*aluminite*," and its white color distinguishes it further from the similar mineral, "*pissophanite*," which is olive-green, and has a vitreous lustre.

To each species is added its chemical formula, for the purpose of affording to those who are acquainted with chemistry a ready means of obtaining a more intimate knowledge of its composition than is developed in the characters mentioned. For example, the formula of aluminite is $AlSO_6 + 9Aq$, from which we see that the essential constituents of this mineral are *alumina*, *sulphuric acid*, and *water;* other trials, therefore, could be made in addition to those just described, to verify its composition.

TESTING FOR WATER.

For the determination of water, a number of small fragments of crystals, or compact mineral should be selected. Instead of a matrass, an open glass tube about 5 inches in length is used; the sample is placed within it, and we can blow gently on the outside, so as not to fuse the glass; the water, if present, collects in small drops on the cooler parts of the tube.

A trace of moisture may be found in almost any mineral, but a very little practice will show whether a mineral is really hydrous or not. Decrepitating minerals may be enveloped in a piece of copper-foil, and thus placed in the tube and heated. In order to determine the loss of water by ignition, quantitatively, we choose a small platinum crucible, holding some 2 grammes of the hydrated mineral. The heating is done over a *Bunsen burner*, or blast-lamp, the flame of which envelops the apparatus completely. In this manner some silicates of magnesia, like chlorite, ripidolite, etc., will lose their water completely, but which could not have been expelled by a *common alcohol lamp*.

SOLUTION is the liquefaction of a solid, or a gas, by mixture with a liquid. The most universal solvent is water; it is always understood to be present in definite proportions, in operations in the wet way. Other solvents are alcohol, ether, disulphide of carbon, benzine, glycerine, and others less important. It must never be forgotten that there are *degrees* of solubility, but there is hardly such a fact as *absolute solubility*, or *insolubility*, regardless of the proportion of the solvent.

Substances are said to dissolve in acids, or in alkalies, and this is termed a chemical solution; or, more definitely, it is both a chemical action and solution; the solution being always a mere physical change. We say that lime dissolves (chemically) in hydrochloric acid, *i. e.*, in the reagent thus called, which is a mixture of that acid in water. The acid unites with the lime, forming a soluble solid, which the water dissolves.

DECOMPOSITION BY ACIDS.

To test whether a mineral is decomposable (soluble) in acids or not, the sample should be as finely pulverized as possible in an agate mortar. It is then treated with tolerably strong acid, and, if necessary, heat is applied. The digestion is carried on in a small glass flask, a large test-tube, or a small porcelain dish for a quarter of an hour. In order to see whether *silicates* or many *compounds of the earths*, and the allied *metallic oxides*, have been partially dissolved, we separate the acid by decantation or filtration from the residue, and add *ammonia* in excess, and then a few drops of *phosphate of sodium*. In case these two reagents produce a decided precipitate, it is a sign that decomposition has taken place, but when no precipitate is formed, or but a few flakes appear, the mineral may be pronounced nearly or quite insoluble.

If silicates in fine powder form are heated with conc. phosphoric acid (until the latter begins to volatilize, forming thereby dense vapors), and the cold mass is treated with water and boiled, gelatinous lumps of *silica* separate. Many silicates "gelatinize" when previously fused, viz., garnet, vesuvianite, etc. For this purpose several splinters, or small pieces of the sample are fused B. B., then wrapped in paper and crushed to powder on a steel anvil, and then still finer ground in an agate mortar. This fine powder is brought into a reagent tube or porcelain dish, some hydrochloric acid added, and the whole boiled until the acid is evaporated, when gelatinous lumps remain behind; or, after the lapse of about twelve hours a distinct immovable "gelatinous" mass is produced in the vessel. If this is stirred up with water, it may be filtered off, and the filtrate be further tested with ammonia, oxalate of ammonium, etc., for alumina, lime, etc., that might be present.

2. Example. Let us suppose that we have bornite, or variegated copper pyrites to determine upon.

The mineral has metallic lustre; B. B. it fuses without giving off perceptible fumes. In the oxidizing flame we can perceive the odor of sulphurous acid, and the sample would, of course, when heated with carbonate of sodium, form hepar (sulphide of sodium) which an experiment confirms. From this it follows that the mineral must be looked for under I—A.—5. A single trial with soda shows that it cannot be one of the first four minerals of this (5) group, and that it must belong to the group Chalcocite, etc., whose solutions in nitric acid, treated with an access of ammonia, give an azure-blue color, and which, when fused on coal and moistened with muriatic acid, tinge the blowpipe flame blue. Among minerals of metallic lustre the color is usually characteristic; it is therefore mentioned when applicable for the purpose of shortening the process of determination. The color of the specimen under examination is copper-red, inclining to yellow; this sufficiently distinguishes it from the others of the same group, and we must call the mineral bornite, or *variegated copper pyrites.*

On beginning the delightful study of determinative mineralogy, the student ought to exercise great patience and proceed slowly, but surely. It is by far the best way to examine at first well-known species.

Mineral species selected for the study of determinative mineralogy. Von Kobell advises his own students to determine successively the following list of minerals according to the method before us:—

Aluminite,
Alunite,
Anhydrite,
Antimony-glance,
Apophyllite,
Argentite,
Arsenopyrite,
Atacamite,
Barite,
Borax,
Bornite,
Bournonite,
Calamine,
Calcite,
Cassiterite,
Celestite,
Cerussite,
Chalcopyrite,
Chalcocite,
Cinnabar,
Cryolite,
Cuprite,
Datolite,
Diallogite,
Dolomite,
Lapis-lazuli,
Lievrite,
Lepidolite,
Pectolite,
Siderite,

Limonite,
Magnesite,
Magnetite,
Malachite,
Manganite,
Molybdenite,
Natrolite,
Niccolite,
Orpiment,
Psilomelane,
Pyrite,
Pyrolusite,
Pyromorphite,
Pyrrhotite,
Realgar,
Scheelite,
Smaltite,
Smithsonite,
Sphalerite,
Strontianite,
Talc,
Witherite,
Wolfram,
Wollastonite,
Wulfenite.

French Weights and Measures.

French.		*English.*	
One Milligramme	=	.0154	grains Troy.
" Centigamme	=	.1543	" "
" Decigramme	=	1.5434	" "
" Gramme	=	15.4336	" "
" Decagramme	=	154.336	" "
" Hectogramme	=	1543.36	" "
" Kilogramme	=	15433.6	" "
	=	2.679	lbs. Troy.
	=	2.205	" avoirdupois.

French.		*English.*	
One Millimetre	=	.0394	inches.
" Centimetre.	=	.394	"
" Decimetre	=	3.937	"
" Metre	=	39.37	"
" Decametre	=	393.71	"
" Hectometre	=	3937.1	"
" Kilometre	=	39371.	"
" Myriametre	=	393710.	"

1 pound avoirdupois = 7000 grains Troy, or 16 ounces. 1 ounce avoirdupois = 437½ grains Troy. 1 gramme = 15.43 grains. 28.35 grammes = 1 ounce avoirdupois. 453.60 grammes = 1 pound avoirdupois. 31.1 grammes = 1 ounce Troy. 1 pound Troy = 5760 grains Troy. 1 kilogramme = 1000 grammes, or = 35.30 ounces avoirdupois, or = 32.48 ounces Troy. 100 grammes = 3.53 ounces avoirdupois, or 3.2 ounces Troy. 1 inch English = 25.4 millimetres, or 2.54 centimetres. 1 foot English = 30.48 centimetres, or 304.8 millimetres.

The imperial gallon contains of water at (62° F. 16⅔° C.) 70,000 grains.
The pint ($\frac{1}{8}$ of gallon) " " " " 8,750 "
The fluidounce ($\frac{1}{20}$ of pint) " " " 437.5 "

Relations of the Scales of the Thermometers of Celsius (Centigrade), Reaumur, and Fahrenheit.

Rules to find the relative value of the three scales.

Since, $180^\circ \text{ F.} = 100^\circ \text{ C.} = 80^\circ \text{ R.},$

Therefore, $9^\circ \text{ F.} = 5^\circ \text{ C.} = 4^\circ \text{ R.}$

Consequently, $1^\circ \text{ F.} = \frac{5^\circ}{9} \text{ C.} = \frac{4^\circ}{9} \text{ R.}$

Also $1^\circ \text{ C.} = \frac{9^\circ}{5} \text{ F.} = \frac{4^\circ}{5} \text{ R.}$

And $1^\circ \text{ R.} = \frac{9^\circ}{4} \text{ F.} = \frac{5^\circ}{4} \text{ C.}$

From this and the fact that the temperature denoted by 32° on the Fahrenheit scale, corresponds to that denoted by 0° on the other two scales, the following rules are derived :—

1. To convert F. degrees into C. degrees.

Subtract 32 from the number of F. degrees, and multiply the remainder by $\frac{5}{9}$, according to the formula

$$x^\circ \text{ F.} = \left(x - 32^\circ \times \frac{5^\circ}{9}\right) \text{ C.} \quad \text{Thus}$$

$$212^\circ \text{ F.} = (212-32)\,\frac{5}{9} = 180 \times \frac{5}{9} = 100^\circ \text{ C.}$$

2. To convert C. degrees into F. degrees.

Multiply the number of C. degrees by $\frac{9}{5}$ and add 32 to the product, according to the formula :—

$$x^\circ \text{ C.} = \left(x \times \frac{9}{5} + 32^\circ\right) \text{ F.} \quad \text{Thus}$$

$$100^\circ \text{ C.} = 100 \times \frac{9}{5} + 32 = 180 + 32 = 212^\circ \text{ F.}$$

3. To convert F. degrees into R.

Subtract 32 from the number of F. degrees, and multiply the remainder by $\frac{4}{9}$ according to the formula:—

$$x^\circ \text{ F.} = (x - 32 \times \frac{4^\circ}{9})\text{ R.} \quad \text{Thus}$$

$$212^\circ \text{ F.} = (212 - 32) = 180^\circ \times \frac{4}{9} = 80^\circ \text{ R.}$$

4. To convert R. degrees into F.

Multiply the number of R. degrees by $\frac{9}{4}$ and add 32 to the product, according to the formula:—

$$x^\circ \text{ R.} = \left(x \times \frac{9}{4} + 32^\circ\right)\text{F.} \quad \text{Thus}$$

$$80^\circ \text{ R.} = 80 \times \frac{9}{4} + 32 = 180 + 32 = 212^\circ \text{ F.}$$

5. To convert C. degrees into R.

Multiply the number of C. degrees by $\frac{4}{5}$, according to the formula:—

$$x^\circ \text{ C.} = x \times \frac{4}{5}\text{ R.}$$

$$100^\circ \text{ C.} = 100 \times \frac{4}{5} = 80^\circ \text{ R.}$$

6. To convert R. degrees into C.

Multiply by $\frac{5}{4}$, according to the formula:—

$$x^\circ \text{ R.} = x \times \frac{5^\circ}{4}\text{ C.} \quad \text{Thus}$$

$$80^\circ \text{ R.} = 80 \times \frac{5}{4} = 100^\circ \text{ C.}$$

The table on next page will give the comparative values of degrees of Reaumur, Celsius, and Fahrenheit.

Reaumur.	Centigrade.	Fahrenheit.
Above freezing-point.		
+80	+100	+212
76	95	203
72	90	194
68	85	185
64	80	176
60	75	167
56	70	158
52	65	149
48	60	140
44	55	131
40	50	122
36	45	113
32	40	104
28	35	95
24	30	86
20	25	77
16	20	68
+12	+15	+59
8	10	50
4	5	41
0	0	32
Below freezing-point.		
— 4	— 5	23
8	10	14
12	15	5
16	20	— 4
20	25	13
24	30	22
28	35	31
32	40	40
36	45	49

KEY TO THE GENERAL CLASSIFICATION OR SYNOPSIS OF THE TABLES.

Group I.—Minerals with metallic lustre. (Of those minerals whose lustre may be doubtful, only such are here included as are perfectly opaque, even on the thinnest edges.)

Class I.—Native malleable metals and mercury (are easily distinguished from others), see page 230. The remaining minerals form the following groups:—

Class II.—Fusible from 1–5, or readily volatile.

Division 1.—B. B., on charcoal evolve the strong garlic odor of arsenic, page 232.

Division 2.—B. B., on charcoal, or heated in an open glass tube, give the horseradish odor of selenium, page 236.

Division 3.—B. B., on charcoal, a whitish deposit is obtained which tinges the R. F. green; in presence of selenium, greenish-blue. Heated gently in a small flask or a test-tube with an excess of concentrated sulphuric acid, the latter assumes a purple-red or hyacinth-red color, which upon the addition of water disappears, while a grayish-black precipitate of tellurium is thrown down, page 238.

Division 4.—B. B., on charcoal, or in an open glass tube, evolve copious fumes of antimony, page 240.

Division 5.—Heated in an open glass tube give off sulphurous acid, which reddens moistened blue litmus paper. B. B., with soda on charcoal, yield hepar, but do not give reactions of the preceding divisions, page 243.

Division 6.—Not belonging to the preceding divisions, page 248.

Class III.—Infusible, or fusibility above 5, and not volatile, page 251.

Division 1.—B. B., impart, even in small quantities, to the borax bead in the O. F., the amethystine color of manganese, page 251.

Division 2.—Are magnetic, or B. B., on charcoal become so if perseveringly heated in the R. F., page 252.

Division 3.—Not included, but in some respects related to the preceding divisions, page 254.

Group **II**.—Minerals without metallic lustre.

Class I.—B. B., volatilize easily or are combustible, page 256.

Class II.—B. B., fuse easily between 1–5, and volatilize only partially or not at all, page 258.

Part **A**.—B. B., fused with soda on charcoal yield a metallic globule, or when fused alone, in the R. F., form a mass which acts upon the magnetic needle.

Division 1.—B. B., yield with soda alone, or with soda and borax together, a silver globule.

Those decomposable by nitric acid yield, when their solution is treated with hydrochloric acid, a white precipitate of chloride of silver, which B. B. on charcoal is easily reduced to metallic silver, page 258.

Division 2.—B. B., with soda, yield a lead globule.

The nitric acid solution gives, upon the addition of sulphuric acid, a white precipitate of sulphate of lead, which B. B. with soda on charcoal furnishes metallic lead, page 260.

Division 3.—Moistened with hydrochloric acid, communicate to the blowpipe flame a transient blue color, and produce with nitric acid a solution which, upon addition of an excess of caustic ammonia, turns azure blue, page 263.

Section i.—B. B., fused on charcoal, evolve a strong arsenical odor, page 264.

Section ii —B B., on charcoal, evolve no arsenical odor, page 265.

Division 4.—B. B., impart to the borax bead a sapphire-blue color (cobalt), page 268.

Division 5.—B. B., fused in forceps, or melted on charcoal in the R. F., give a black or gray metallic mass, acting upon the magnetic needle, but do not belong to the preceding divisions, page 268.

Section i.—Evolve, when fused, a strong arsenical odor, page 268.

Section ii.—Soluble in hydrochloric acid without leaving a perceptible residue, and without gelatinizing, page 269.

Section iii.—With hydrochloric acid form a jelly, or decompose with separation of silica, page 272.

Section iv.—Only slightly attacked by hydrochloric acid, page 275.

Division 6.—Not included in the foregoing divisions, page 276.

Part **B.**—B. B., fused with soda on charcoal give no metallic globule, or fused alone in R. F. do not become magnetic.

Division 1.—B. B., after fusion and continued heating on charcoal or in the forceps (or when easily fusible, in a platinum spoon), have an alkaline reaction, turning the moistened yellow turmeric paper brown,* or rendering red litmus paper blue, page 277.

Section i.—In water easily and perfectly soluble, page 277.

Section ii.—Insoluble or very slightly soluble in water, page 279.

Division 2.—Soluble in hydrochloric acid, some also in water, without perceptible residue; the solution does not form a gelatinous mass upon evaporation, page 282.

Division 3.—Entirely soluble in hydrochloric acid, forming a stiff jelly upon evaporation, page 286.

---

* Prof. Kenngott has shown that many silicates and other compounds, before and after fusion, have an alkaline reaction when they are placed on turmeric paper in the form of powder moistened with water, but they do not show this reaction when in fragments.

Section i.—B. B., in the closed tube give water, page 286.

Section ii.—B. B., in the closed tube, give none or only traces of water, page 287.

Division 4.—Soluble in hydrochloric acid, the silica separating without forming a perfect jelly, page 289.

Section i.—B. B., in the closed tube give water, page 289.

Section ii.—B. B., in the closed tube yield no water or only a trace, page 292.

Division 5.—Are only slightly attacked by hydrochloric acid, and B. B. impart to borax glass a deep amethystine color of manganese, page 294.

Division 6.—Not included in the preceding divisions, page 295.

Class III.—Infusible, or fusible above 5.

Division 1.—B. B., after previous ignition, assume a fine-blue color when moistened with cobalt solution and again ignited (alumina), page 303.

Section i.—B. B., yield much water in the closed tube, page 303.

Section ii.—B. B., in the closed tube yield little or no water, page 306.

Division 2.—Moistened with cobalt solution and ignited, assume a green color (zinc), page 309.

Division 3.—After ignition, B. B. have an alkaline reaction, and change the color of moistened turmeric paper to reddish-brown, or red litmus paper to blue, page 309.

Division 4.—Completely soluble in hydrochloric acid, or when this has no effect, in nitric acid, without gelatinizing by evaporation or leaving a considerable residue of silica, page 311.

Division 5.—Gelatinize with hydrochloric acid, or are decomposed with separation of silica, page 316.

Section i.—B. B., in the closed tube yield water, page 316.

Section ii.—B. B., in the closed tube yield no water or but traces, page 320.

Division 6.—Not included in either the foregoing divisions, page 321.

Section i.—Hardness under 7, page 321.

Section ii.—Hardness 7 or above, page 325.

GROUP I.—MINERALS WITH METALLIC LUSTRE.

Of the minerals which show an imperfect metallic lustre, only such are included in this division which are also opaque, as wolframite (tungstate of iron), chrome iron ore, etc. The following are ductile and malleable, and are easily distinguished from others by their physical properties:—

Class I.—Native Malleable Metals and Mercury.

MALDONITE, Au_2Bi. Color, silver-white (tarnishing black). B. B. upon coal readily fusible, producing inodorous bismuth fumes (covering the coal with dark-brown oxide, which turns pale-yellow on cooling); at the same time the gold collects in a globular mass on the coal. By fusing the mineral together with sulphur and iodide of potassium, the coal becomes coated with red iodide of bismuth. G. 8.2–9.7.

NATIVE SILVER, Ag. Color, silver-white; is easily soluble in nitric acid; the solution even when much diluted gives with muriatic acid a white curdy precipitate of chloride of silver, which, exposed to the light, changes color, becoming bluish-gray. It is easily soluble in ammonia from which copper foil precipitates it in the form of metallic, spongy silver, assuming its natural white color and lustre when rubbed in an agate mortar. H. 2.5–3. G. 10–11. Moistened with sulphide of ammonium, bright silver at once becomes yellowish-brown to gray. (Compare *Amalgam.*)

NATIVE GOLD, Au and Electrum (gold alloyed with silver, $Ag + x\,Au$, more or less of a gold-yellow color). Native gold is soluble only in nitro-muriatic acid (aqua regia), without perceptible residue. The alloy with silver is partly or entirely decomposed by nitro-muriatic acid with the formation of chloride of silver, which remains undissolved. If we dilute a few drops of the gold solution, concentrated by evaporation with much water until the yellow color has almost disappeared, and then heat this liquid in a porcelain dish, together with tin-foil (stanniol), a beautiful purple color is produced, yielding, when left standing, a purple-red deposit of stannate of protoxide of gold, the so-called "*purple of Cassius.*" Heated to boiling with some crystals of oxalic acid, the metallic gold is precipitated as a brown powder, which by rubbing assumes metallic lustre. The solution gives with proto-sulphate of iron (copperas) the same reddish-brown precipitate of gold, which, by rubbing, assumes the color and metallic lustre of gold. H. 2.5–3. G. 15.6–19.5.

NATIVE COPPER, Cu, is of a copper-red color; dissolves in nitric acid, forming a sky-blue solution which yields with caustic ammonia a blue precipitate, soluble in excess to a deep azure-blue liquid. H. 2.75. G. 8.5–8.9.

NATIVE LEAD, Pb. Of a lead-gray color; B. B. easily fused, fuming and coating the coal with a greenish-yellow oxide. Dissolves easily in nitric acid, and the solution gives, with muriatic acid, if much diluted, no precipitate,* but, on the addition of sulphuric acid, a heavy white precipitate of sulphate of lead. H. 1.5. G. 11.3.

NATIVE PLATINUM, Pt (H. 4.5–5. G. 17–18), and

PALLADIUM, Pd. Both are infusible. Platinum is of a steel-gray color, soluble in nitro-muriatic acid, but not in nitric. Palladium is between a steel-gray and silver-white; soluble in nitric, but more easily in nitro-muriatic acid. The solution of platinum gives with carbonate of potassium a yellow precipitate, insoluble in excess. That of palladium gives a brownish precipitate soluble in excess of the reagent. H. 4.5–5. G. 11.8–12.2.

NATIVE IRON, Fe; color steel-gray; attracted by the magnet; infusible; soluble in muriatic acid. H. 4.5. G. 7–7.8.

Argentite (sulphuret of silver), is malleable. (Compare, also, *Hessite.*)

NATIVE MERCURY, Hg; is easily recognized, since it is fluid at common temperature; color, tin-white. G. 13.5–13.6.

---

* In a concentrated solution a white precipitate of chloride of lead is formed, soluble in much water.

The other minerals with metallic lustre may be divided into the following groups:—

Class II.—**Fusibility from 1—5, or easily volatilized.**

Division 1.—*B. B. on coal evolve the strong garlic odor of arsenic.*

Native Arsenic, As; volatilizes B. B. without fusing, and sublimes in a bolt-head as a grayish-white crystalline coating. In some varieties the last portion fuses before volatilizing. Streak and fracture, tin-white. H. 3.5. G. 5.7–5.8.

Binnite.[*] Composition probably $Cu_6As_4S_9$. B. B. fused and then moistened with HCl colors the flame blue (chloride of copper). A nitric acid solution is rendered blue. Ammonia and this reagent give no precipitate (iron). In the closed tube gives a sublimate of arsenic sulphide; in the open tube, a crystalline sublimate of arsenic trioxide (As_2O_3) with vapor of sulphur dioxide (SO_2). B. B. on coal gives a faint, white coating and odor of arsenic; with soda fuses to a globule, giving metallic copper. Lustre, metallic; color, black on fresh fracture; streak, cherry-red; brittle, H. 4.5. G. 4.4. A similar deportment is exhibited by—

Arsenomelane and

Jordanite ($Pb_3As_4S_9$). The latter exhibits a lead-gray color and a black streak.

Dufrênoysite,[†] $Pb_2As_2S_5$.

Tennantite, Graukupfererz, $Cu_8As_2S_7$ (or $4Cu_2S+As_2S_3$).

Polybasite $(Ag,Cu)_9(Sb,As)S_6$.

Enargite, Cu_3AsS_4,

Rionite $(Cu,Fe)_6(As,Bi)_2S_8$.

Domeykite, Cu_3As. B. B. when fused on coal, and then

---

[*] According to von Kobell this species, found in the valley of "Binnen," Switzerland, consists of arsenite of lead, containing no copper. Consult Dana's Syst. of Min., p. 90.

[†] According to the nomenclature of Prof. Kenngott.

moistened with HCl, give to the flame a blue color. The solution in nitric acid yields, with caustic ammonia in excess, a sky-blue liquid. The solution of polybasite in nitric acid, yields, with HCl, a heavy precipitate of chloride of silver, while the others give only a slight one or none at all. A strong solution of caustic potassa extracts on long boiling from all, except domeykite, sulphuret of arsenic (and sulphuret of antimony), which, when the previously diluted solution is treated with HCl, is precipitated in lemon-yellow flakes (if the sulphuret of antimony predominates, the flakes are of a yellowish-red color).

Rionite, when fused B. B. on coal with sulphur and iodide of potassium, produces a red deposit of iodide of bismuth on the coal, while the others do not.

Enargite is plainly cleavable at an angle of 98° ; the others show no cleavage at all.

Dufrénoysite has a dark steel-gray color and a reddish-brown streak.

Tennantite is of a light steel-gray color,

Domeykite is silver-white, with a yellow tarnish. The nitric acid solution of most varieties of tennantite yields with ammonia a reddish-brown precipitate of hydrated sesquioxide of iron. The solution of dufrénoysite does not. Similar to that of tennantite is the deportment of epigenite. The latter, however, crystallizes in the orthorhombic; the former in the isometric system. In the neighborhood of domeykite (G. 7 to 7.5) belong—

Algodonite (of Chile), Cu_6As (with 83.5 per cent. of Cu). H. 4; G. 7.6.

Whitneyite, Cu_9As (88.4 per cent. Cu), color bronze to reddish-white, becoming brown on exposure. Malleable. H. 3.5; G. 8.3. Less fusible than algodonite.

Smaltite (Speisskobalt), Co (Fe,Ni)As_2. H. 5.5 ; G. 6.37–7.3

Skutterudite (Tesseralkies), $CoAs_3$.

Cobaltite (glance-cobalt, arsenio-sulphuret of cobalt), Co, AsS. H. 5.5 ; G. 6–6.1.

Glaucodot $(Co,Fe),AsS$, and

Alloclasite $(Co,Fe,Zn)\ 4(As,Bi_7S_9)$. B. B. in small quantities all impart to a borax bead a fine sapphire-blue color. By concentrated nitric acid they are dissolved, with separation of arsenious acid. The solutions have a red color. The concentrated solution of alloclasite becomes turbid upon the addition of water (bismuth); the others give no such reaction. The solution yields with soluble glass (silicate of potassium solution) a blue precipitate.

Smaltite (smaltine), skutterudite, and glaucodot yield B. B. in a bolt-head, heated until the glass begins to melt, a gray sublimate of metallic arsenic. Cobaltite gives no sublimate at all. The much diluted nitric acid solution of cobaltite (cobaltine) and glaucodot give, with chloride of barium, a heavy deposit of sulphate of barium.

Cobaltite crystallizes in the isometric system, and has octahedral cleavage; skutterudite a cubical one. Glaucodot* crystallizes in the orthorhombic system; cleavage, basal perfect; prismatic less so. The nitric acid solutions of smaltite and skutterudite yield, when *pure*, no precipitate with chloride of barium, otherwise a slight one of sulphate of barium. Smaltite shows no cleavage, while skutterudite cleaves in distinct cubes.

Some varieties of smaltite contain much nickel, approaching chloanthite; in which case their solutions in nitric acid exhibit a greenish color. The nickel is recognized distinctly as follows: The mineral powder is decomposed with a small quantity of concentrated nitric acid, and, without filtration, ammonia gradually added, until the last few drops of that reagent produces a distinctly alkaline reaction, when the mixture, without further dilution with water, is filtered. The filtrate is sky-blue if nickel is present.

Compare the following (also native bismuth, which is often contaminated with cobalt ores). Bismuth is, however, readily recognized from the fact that water precipitates it *white* from

---

* A similar behavior like glaucodote is exhibited by glaucopyrite, Fe, Co, Cu, Sb, As, S.

its concentrated nitric acid solution, the same as alloclasite, whose color is, however, steel-gray, while that of metallic bismuth is reddish silver-white.

NICCOLITE (nickeline or copper nickel, or rothnickelkies), Ni_2As. H. 5.25. G. 7.5.

Cloanthite,* or weissnickelkies $(Co,Ni)As_2$, and

Gersdorffite, or nickel glance, or arsenio-sulphuret of nickel, NiSAs. H. 5. G. 6.

These give, when boiled with nitro-muriatic acid, an apple-green solution. Caustic ammonia in excess produces a sapphire-blue liquid. Potassa and silicate of potassium (soluble glass) added to the solutions give greenish precipitates. Chloride of barium produces in the dilute acid solution of gersdorffite a heavy precipitate; in the other two none, or only a feeble one.

Niccolite and gersdorffite, when heated in closed glass tube, give no sublimate of metallic arsenic, but cloanthite* does. A similar deportment is shown by chatamite, whose solution yields, however, with an excess of ammonia, a reddish-brown precipitate (hydrated ferric oxide). Further,

Corynite†, Ni(As,Sb)S, and

Wolfachite, Ni(As,Sb)S, B. B. on coal yield arsenic and antimony fumes, and produce with soda hepar.† These minerals usually show the reaction for cobalt.

The color of *niccolite* is light copper-red; of *chloanthite* and *chatamite*, tin-white; that of *gersdorffite*, light lead-gray, inclining to tin-white. *Corynite*, is silver-white to steel-gray; *wolfachite*, silver-white. Compare ulmannite (nickeliferous gray antimony) which contains arsenic, and in that case resembles *gersdorffite* in its behavior.

ARSENOPYRITE, or *arsenio-sulphuret of iron*, or *mispickel*, FeS_2+FeAs. B. B. in a bolt-head yields a sublimate of metal-

---

* Chloanthite is, according to Dana, only a variety of smaltite; it crystallizes in the isometric system, whilst rammelsbergite, NiAs, of like composition, crystallizes in the orthorhombic system.

† Corynite is isometric; wolfachite, orthorhombic.

lic arsenic; on coal it fuses to a black, and, after long blowing, to a magnetic globule,* thereby covering the coal with white arsenious acid. In nitric acid it is soluble with separation of sulphur and arsenious acid. The solution gives, with caustic ammonia, a reddish-yellow precipitate. Fracture, silver-white, inclining to gray. H. 5–5.5 G. 6–6.2.

Compare native bismuth and native antimony, which often contain arsenic, but are easily recognized by their fusibility at a low temperature, and the white or yellow coating which they give to coal. Some proustite and pyrargyrite show often a submetallic lustre, but are readily distinguished by their cochineal-red streak.

Division 2.—*B. B. on coal, or in open glass tube, evolve the strong horseradish odor of selenium.*

GUANAJUATITE† (*Frenzelite*), selenide of bismuth (Bi_2Se_3). B. B. fuses readily, colors the flame blue, and gives when fused with sulphur and iodide of potassium upon charcoal a red coating of iodide of bismuth. H. 2.5–3.5. G. 6.25.

Tiemannite (selenide of mercury) (HgSe,) and *Lehrbachite* (selenide of mercury and lead) (P,Hg)Se. B. B. yield with soda, in a bolt-head, metallic mercury; this is likewise the case when the mineral powder is mixed with iron powder, and the mixture wrapped in copper foil is heated in a glass tube. *Lehrbachite* gives with soda on coal, globules of lead; *tiemannite* does not. Both volatilize readily, tiemannite while fusing, lehrbachite before fusing. Color of the former is steel-gray to blackish lead-gray, that of the latter lead-gray.

Guadalcazarite (Hg,Zn), (S,Se). Gives the reaction of mercury and also of sulphur. Hence, when the mineral powder

---

* A similar behavior is exhibited by löllingite, leucopyrite, arseniuret of iron, $FeAs_2$, which, after the expulsion of arsenic, fuses imperfectly and with difficulty on its edges. Specific gravity 7.2. With iron it producces no hepar, or the reaction is but feeble.

† See E. S. Dana's Text-book, 1880, page 211.

is heated together with iron-powder and the mass treated with muriatic acid, sulphide of hydrogen is evolved. Color is iron-gray, streak black. H. 2. G. 7.15.

CLAUSTHALITE (seleniuret of lead, Selenblei, $PbSe$). B.B. volatilizes chiefly without fusion, and coats the coal with a feeble metallic gray, and then with a white and greenish-yellow color. It yields with some difficulty, by means of soda, a globule of lead. Dissolved in nitric acid it is precipitated by sulphuric acid, sulphate of lead being formed. Heated with concentrated sulphuric acid until the latter commences to escape in vapor form, it yields a fine green solution, from which water throws down a fine red precipitate, or produces cloudiness of the same color (selenium). Color, lead-gray. H. 2.5–3. G. 8.2–8.8.

NAUMANNITE (seleniuret or silver, Selensilber $(Ag,Pb)_5Se_3$). B. B. fuses easily, and in the O. F. quietly; in the R. F. with intumescence; with soda and borax it yields a globule of silver. Dissolves in concentrated nitric acid; the solution throws down with muriatic acid a strong precipitate of chloride of silver. Color, iron-black. H. 2.5. G. 8.

Berzelianite (*seleniuret of copper*, Selenkupfer), Cu_2Se.

Raphanosmite (*seleniuret of copper and lead*), Selenbleikupfer, $(Pb,Cu_2)Se$, and

Eucairite (*seleniuret of silver and copper*), $(Cu,Ag)_2,Se$. B. B. on coal fuse to a metallic globule, which, moistened with muriatic acid, imparts to the flame a blue color. They are soluble in concentrated nitric acid, and the solutions treated with caustic ammonia in excess assume an azure-blue color. The solution of eucairite gives, with muriatic acid, a heavy precipitate of chloride of silver; that of raphanosmite with sulphuric acid, a precipitate of sulphate of lead; that of berzelianite affords no precipitate with either of the acids. Color of berzelianite is silver-white; that of eucairite and raphanosmite, lead-gray.

Crookesite $(Cu_2Tl,Ag)Se$ is similar to berzelianite, containing 17.25 per cent. of thallium, and coloring the flame vivid green.

Division 3.—*B. B. on coal yield a whitish deposit, which colors the reducing flame greenish or greenish-blue.* Impart to concentrated sulphuric acid, when gently heated with it in a test-tube, a purple-red or hyacinthine color, which, upon the addition of water disappears, while a blackish-gray precipitate forms (tellurium).*

Collecting the precipitate upon a filter and drying it, it imparts to concentrated sulphuric acid, when heat is first applied, a purple color, which again disappears upon continued heating. B. B. most compounds of tellurium evolve on charcoal the horseradish odor of selenium, caused by an accidental trace of this element.

The ores of tellurium may, by their color, be divided into two groups.

(*a*) Those of a tin or silver-white color.

NATIVE TELLURIUM, Te. B. B. fuses easily; can be entirely volatilized; fumes strongly, and burns with a greenish flame. In nitric acid it is soluble without residue; the solution gives with potassa a white precipitate mostly soluble in excess; muriatic or sulphuric acid causes no perceptible precipitate. Color, tin-white to silver-white. H. 2–2.5. G. 6.1–6.3.

MELONITE, Ni_2Te_2. Hexagonal, reddish-white, dark-gray streak.

HESSITE (*telluret of silver*, Tellursilber), Ag_2Te (sectile) and

ALTAITE (*telluret of lead*, Tellurblei), PbTe, are soluble in nitric acid without residue. The solution of the first in excess of nitric acid forms *no* precipitate with sulphuric acid, while the second gives a heavy deposit of sulphate of lead. B. B. the first mineral gives, with soda, a globule of silver,

---

* If the incrusted coal is held over a watch glass containing *sulphide of ammonium*, the vapors of the latter render the coat *brownish*, while, under the same circumstances, a coat of antimony would turn *orange-red.*

containing sometimes gold. Hessite is malleable. Altaite is only sectile. Color, tin-white.

MUELLERITE (*aurotellurite*, Weisstellur), (Au,Ag,Pb),Te_3, Sb. Is chiefly soluble in nitric acid with separation of the gold; with muriatic acid the solution affords a precipitate of sulphate of lead. Color, silver-white, inclining to brass-yellow. Brittle. (Belongs probably to Sylvanite.)

Compare the following:—

(*b*) Those which have a lead-gray or steel-gray color.

TETRADYMITE (*telluret of bismuth*), Bi,$(Te,S)_3$. B. B. fuses to a silver-white, brittle, metallic globule; yields, when fused upon coal with iodide of potassium, a red precipitate. Dissolves easily in nitric acid, with separation of sulphur; the solution yields with sulphuric or muriatic acid, *no precipitate;* with potassa, a white precipitate insoluble in excess. Color, light lead-gray. The thin laminæ somewhat elastic. A similar compound is Joseïte, $Bi_{12}Te_4SeS_3$. H. 1g2. G. 7.5.

SYLVANITE (graphic tellurium$_8$ Schrifterz), $(Au,Ag)Te_3$.* B. B. soon fuses, and after long blowing is reduced to a ductile, metallic globule. In nitric acid it is imperfectly soluble, in nitro-muriatic acid entirely so, with precipitation of chloride of silver. The solution gives no precipitate on the addition of sulphuric acid. Color, light steel-gray.

Nagyagite (telluret of gold and lead, Blättererz), Pb,Au, Te,S. B. B. fuses easily, and after long blowing, to a malleable, metallic globule. In nitric acid it is easily and chiefly soluble; the solution yields, with sulphuric acid, a heavy precipitate of sulphate of lead. When heated with concentrated sulphuric acid, a solution is obtained of a hyacinthine or brownish-yellow color, *not* exhibiting, as in the previous cases, a fine red hue. Water discolors the liquid with separation of tellurium. Color, blackish lead-gray. H. 1–1.5. G. 6.8–7.2.

(Compare, also, belonite.)

---

* Petzite $(Ag,Au)_2Te$, shows a similar composition, but contains more silver.

Division 4.—*B. B. on charcoal evolve copious fumes of antimony.*

The fumes are nearly inodorous, or smell of sulphurous acid, or have a feeble, arsenical odor caused by the sulphur in the ores, or an accidental trace of arsenic.

By the first action of the flame, the vapor coats the coal white (oxide of antimony), which coating submitted to the R. F. does not alter the color of the flame. When this coating is collected in a glass tube, and exposed to the vapors of sulphide of ammonium, it turns orange, sulphide of antimony being produced.

Native Antimony, Sb. H. 3.3–5. G. 6.6–6.8.

Stibnite (sulphuret of antimony, Antimonglanz), SbS_3.

Zinkenite (antimonial sulphuret of lead), $PbSbS_4$.

Jamesonite (sulphuret of antimony and lead), Pb_2SbS_5.

Bournonite (antimonial sulphuret of lead and copper), $3(Cu,Pb)SSbS_3$. B. B. volatilizes entirely or principally. Native antimony is distinguished by its tin-white color. Heated B. B. it continues to burn without further blowing, and covers the globule of metal with white, needle-shaped crystals of oxide.* Stibnite (antimonite, antimony glance), in powder form, it is soon changed to an ochre-yellow by a strong solution of potassa, in which it is also chiefly soluble ; hydrochloric acid precipitates it in yellowish-red flakes. Color of this mineral is lead-gray, inclining to steel-gray.

Zinkenite, *jamesonite*, and *bournonite* are of a steel-gray color. Digested in powder form with potassa solution they do not change their color ; the potassa, however, when boiled down nearly to dryness, extracts the sulphuret of antimony, which may be precipitated by hydrochloric acid in yellowish-red or orange flakes. *Zinkenite* and *jamesonite* are converted by nitric acid into a white pulverulent oxide without changing the color of the acid, which dissolves only a small portion. *Bour-*

---

* Compare native bismuth and bismuthinite.

nonite partially dissolves to a sky-blue solution, yielding, with sulphuric acid, a white precipitate of sulphate of lead, and with caustic ammonia in excess an azure-blue liquid (copper).

Stylotypite $(Cu_2,Ag,Fe)_3SbS_6$, shows a similar deportment to bournonite, but its solution in aqua regia yields no precipitate with sulphuric acid. H. 3. G. 4.8.

Zinkenite is not cleavable. Hardness, 3.5. *Jamesonite* is generally cleavable in one direction. Hardness, 2.5. These minerals are related in their chemical characters to the following rare compounds, which are all sulphurets of lead and antimony, viz:—

Boulangerite, Pb_3SbS_6.
{ *Geocronite*, Pb_5SbS_8.
{ *Kilbrickenite.*[*]
Plagionite, PbSbS.
Meneghinite, Pb_4SbS_7.

Some antimonites mixed with *galenite* (galena) behave similarly, likewise *kobellite* $= Pb_3BiSbS_6$ (or $3PbS + (Bi.Sb)_2S_3$), which contains 35 per cent. of sulphide of bismuth. B. B. when fused together with sulphur and iodide of potassium on charcoal, it affords a red and yellow coating. When the nitric acid solution is treated with sulphuric acid, white sulphate of lead is precipitated.

DYSCRASITE (antimonial silver, Antimonsilber $= Ag_3Sb$).

STEPHANITE (antimonial sulphuret of silver), Ag_5SbS_8 (or $5AgS + SbS_3$). H. 2–5.5. G. 6.2.

TETRAHEDRITE[†] (gray copper ore, Fahlerz.)

Antimonfahlerz, $Cu_8Sb_2S_7$, with (Cu_2) replaced by (Fe), (Zn), (Ag_2) or (Hg).

---

[*] According to Dana and Brush identical with Geocronite.

[†] *Polytelite*, v. Kobell. Varieties of Antimonfahlerz, when poor in silver, are distinguished from those rich in silver, by yielding from their nitric acid solution a slight precipitate with HCl. All the varieties containing copper furnish nitric acid solutions, which turn azure blue by an excess of ammonia. (See Polytelite, Dana's Syst. of Min., pp. 101, 104, 804.)

Miarygyrite (sulphuret of antimony and silver), $AgSbS_4$. B. B. yields with soda, or soda and borax, a malleable silver globule, and the nitric acid solution yields, with muriatic acid, a precipitate of chloride of silver. Dyscrasite has a silver-white color, and gives with soda no hepar. Is not attacked by potassa. All the others give, with soda, hepar, and potassa solution extracts sulphuret of antimony, which is precipitated in orange-colored flakes by muriatic acid. Stephanite and miargyrite are partially soluble in nitric acid, oxide of antimony being deposited; the solution treated with caustic ammonia in excess acquires none or only a feeble bluish tint; that of tetrahedrite (polytelite, v. Kobell) assumes a sky-blue color. The color of stephanite is between an iron-black and a blackish lead-gray. Streak, black. Hardness, 2.5. Miargyrite is iron-black, inclining to light steel-gray. Streak, dark cherry-red. Hardness, 2.5. Tetrahedrite (polytelite) is between steel-gray and iron-black. Hardness, 3.5. Streak, grayish-black.

Brogniardite $(Pb,Ag)_2SbS_5$, is an ore which shows a similar deportment like the preceding. It crystallizes in the isometric system (octahedrons). When decomposed by nitric acid, sulphate of lead separates.

Freieslebenite $(Pb,Ag)_5,Sb_2,S_{11}$, and

Diaphorite, Ag_3SbS_3.

The former crystallizes in the monoclinic and the latter in the trimetric (orthorhombic) system.

(Compare also pyrargyrite (ruby silver ore), Ag_3SbS_6.)

SPANIOLITE (gray copper, Quecksilberfahlerz), $(Cu,Hg)SbS$. The nitric acid solution is colored azure-blue by an excess of ammonia. It affords mercury when ground together with iron-powder and soda, then the whole wrapped in copper-foil and heated in a glass tube. H. 3.5. G. 8.1.

CHALCOSTIBITE (sulphuret of copper and antimony, Kupferantimonglanz), Cu_2SbS_4. B. B. roasted on coal with soda for some time yields a copper globule. HCl (hydrochloric acid) produces no precipitate in the nitric acid solution. An excess of ammonia renders the solution azure-blue. Color, lead-gray to iron-black. H. 3.5. G. 4.8.

ULLMANNITE (nickeliferous gray antimony, Nickelantimonglanz), Ni_2SbS_2. H. 5.5. G. 6.3.

BREITHAUPTITE (antimonial-nickel, Antimonnickel), Ni_2, Sb, and

BERTHIERITE (sulphuret of antimony and iron), $FeSbS_4$. B. B. on coal yield, after long blowing, a magnetic globule. Breithauptite fuses with difficulty; muriatic acid attacks it with difficulty; aqua regia readily and completely dissolves it. Color, between copper-red and violet. Ullmannite fuses readily; muriatic acid attacks it with difficulty; aqua regia dissolves it with separation of sulphur.* Color, between lead-gray and steel-gray. *Berthierite* fuses without difficulty; and is easily dissolved in muriatic acid with evolution of sulphuretted hydrogen. Color, steel-gray inclined to brown.

Division 5.—*Heated in an open glass-tube give sulphurous acid, which reddens a strip of moistened blue litmus paper placed in the end. B. B. with soda give hepar, without presenting the general characters mentioned in the preceding numbers.*

ARGENTITE (sulphuret of silver, silverglance, Glaserz), AgS and *Jalpaite* $(Ag,Cu_2)S$ can easily be distinguished from the following by being malleable and sectile like lead.

The nitric acid solution yields with hydrochloric acid, a heavy precipitate of chloride of silver. The addition of ammonia colors the solution of *Jalpaite* blue, that of Argentite remains colorless. B. B. on charcoal, heated with cyanide of potassium, *Jalpaite* yields a silver globule containing copper.

Acanthite, AgS, is distinguished from *argentite* only by the crystalline form. The former crystallizes in the trimetric, the latter in the isometric system.

---

* In other respects the solutions of the first two show, with ammonia, the same deportment that is mentioned in (1) of nickeline.

Alabandite, MnS, and

Hauerite, MnS_2, can be distinguished by the color of their powders. That of the first is leek-green, that of the second brownish-red. Both yield, when boiled down with a mixture of phosphoric and nitric acid, a handsome violet liquid.

Cinnabar, HgS, usually of a red, in many varieties of a lead-gray color, is characterized by the red streak. When mixed with iron-powder, wrapped in copper-foil, and heated in a glass-tube, metallic mercury is produced.

(Compare *proustite* and *pyrargyrite.*)

GALENITE (sulphuret of lead, galena, Bleiglanz), PbS. B. B. with soda is easily reduced to metallic lead, coating the coal with a greenish-yellow oxide. In concentrated nitric acid it readily dissolves with separation of sulphur and sulphate of lead. Color, lead-gray. Cleavable in cubes. The nitric acid solution of galenite is not colored blue with an excess of ammonia, which is, however, the case with the next. H. 2.5. G. 7.5.

CUPROPLUMBITE (Kupferbleiglanz), $Cu_2S,2PbS$. B. B. the latter exhibits otherwise a deportment similar to that of galenite.

HUASCOLITE is a zinciferous variety of the preceding, and very similar in its behavior.

CHALCOCITE (suphuret of copper, Kupferglanz), Cu_2S. H. 2.5–3. G. 7.5.

STROMEYERITE (sulphuret of silver and copper, Silberküpforglanz), $AgCu_2S$.

WITTICHENITE (sulpuhuret of copper and bismuth, Kupferwismutherz), Cu_3BiS_3.

STANNINE (tin pyrites, sulphuret of tin, Zinnkies), (Cu,Sn, Fe, Zn,) S.

CHALCOPYRITE (copper pyrites, sulphuret of copper and iron, Kupferkies), $Cu_2Fe_2S_4$. H. 3.5. G. 4.3.

CUBAN (Cubanite), $Cu_2Fe_4S_4$.

BORNITE (erubescite, variegated copper, Buntkupfererz),* $(Cu_2Fe)S$. H. 3. G. 5.

---

* A copper ore of similar color and tarnishing like *bornite*, is *castillite* $= (CuAg)_2 + 2(Cu,Pb,Zn,Fe)S$. It is considered to be an

BELONITE, aikinite (acicular bismuth, Nadelerz), CuPb BiS_3.

SAYNITE grünanite (bismuth nickel, Nickelwismuthglanz), Ni,Bi,Fe,Cu,S.

CUPROPLUMBITE, $Cu_2S,2PbS$, and

PENTLANDITE (sulphuret of iron and nickel, Eisennickelkies), (Fe,Ni)S, are partially soluble in nitric acid to a sky-blue or greenish liquor, which, with ammonia in excess, assumes an azure-blue or a deep blue color. If the blue ammoniacal liquor is strongly acidulated with sulphuric acid, and a strip of blank sheet-iron put into it, all the previously mentioned minerals, with exception of *saynite* and pentlandite (provided these two are free from an admixture of chalcopyrite), throw down metallic copper. The color of chalcopyrite* and cubanite is brassy-yellow, the latter cleavable in hexadrons, the former not. The color of bornite is between copper-red and pinchbeck-brown. That of pentlandite, light bronze yellow. B B. these ores melt to a steel-gray, brittle globule which is attracted by the magnet. Pentlandite acts upon the magnetic needle. H. 3.5–4. G. 4.6.

In order to distinguish the others (the colors of which are gray), we proceed as follows:—

a. The saturated nitric acid solution gives, upon the addition of water, a white precipitate with *wittichite*, *saynite*, and *belonite*. B. B. all three yield, when mixed in powder form with sulphur and iodide of potassium and then fused on charcoal (by continuous blowing), a red coat of iodide of bismuth. In the acid solution of *belonite*, sulphuric acid produces a white precipitate of sulphate of lead, which does not take place with the others. (Compare chiviatite.)

---

argentiferous *bornite*. When decomposed by nitric acid, a residue of sulphate of lead remains behind.

* A mineral much resembling *chalcopyrite* is barnhardtite (homichline) $Cu_4Fe_2S_5$. Color, brass-yellow ; the fresh fracture tarnishes to a golden-yellow in twenty-four hours.

B. B. on coal, *wittichite* yields with soda a copper globule ;* saynite, a gray, nickeliferous, strongly magnetic globule.

b. The saturated nitric acid solution furnishes with water no precipitate, but with sulphuric acid a white one of sulphate of lead ; the mineral is *cuproplumbite.*

c. The nitric acid solution produces neither with water nor sulphuric acid, any precipitate, but if muriatic acid throws down white chloride of silver—the mineral is *stromeyerite.*

d. Neither of the reagents alluded to having any effect, or producing but a very slight precipitation, we arrive at *chalcosite* and *stannite.*

(Compare *tetrahedrite.*)

Chalcosite on coal B. B. gives, after long blowing, a malleable copper globule ; is soluble in nitric acid with separation of sulphur; color, between blackish lead-gray and steel-gray. But stannite alone gives no malleable or metallic globule ; is dissolved by nitric acid with separation of sulphur and oxide of tin ; color, between steel-gray and brass-yellow.

Chalcosite crystallizes in the trimetric system. Other similar sulphides of copper are :—

Carmenite.†

Digenite.

Cupreine (hexagonal).

Millerite (sulphuret of nickel, Haarkies), NiS.

Linnéite, *linnæite* (cobalt pyrites, Schwefelkobalt), CO_3S_4 (or $2CoS+CoS_2$). A variety is called *siegenite*, carrollite, $=Co_2CuS_4$.

PYRITE (iron pyrites, bisulphuret of iron, Eisenkies), FeS_2. H. 6–6.5. G. 4.9.

---

* A deportment similar to wittichite is exhibited by *tannenite* and *klaprothite.*

† According to Dana (System of Min. 1872, p. 53), carmenite is a mixture of chalcocite and covellite. Digenite and cupreine result also probably from alterations according to him, see p. 53.

PYRROTHITE (*Pyrrhotine*, magnetic pyrites, Magnetkies), Fe_7S_8, and

STERNBERGITE (sulphuret of silver and iron), (AgFe)S. B. B. are reduced to a magnetic globule which, moistened with muriatic acid, imparts to the flame no perceptible change of color except carrollite which, under these circumstances, colors the flame blue; the partial nitric acid solution is not blue. B. B. linnæite and carrollite render a borax bead sapphire-blue; in nitric acid both dissolve perfectly and easily, forming a rose-red solution which gives, with chloride of barium, a white precipitate. From the solution of carrollite, iron wire precipitates metallic copper. Color, between tin-white and light steel-gray. Sternbergite B. B. is partly reducible to silver; the partial nitric acid solution gives, with muriatic acid, a heavy precipitate of chloride of silver. Color, dark tombac-brown. Pyrite and pyrrhotite B. B. give only the reaction of iron and sulphur.

Pyrite* before fusion does not act on the magnetic needle; is only slightly attacked by muriatic acid. Aqua regia forms a solution which with ammonia yields a brownish red precipitate insoluble in an excess and not rendering the solution blue. Color, pale yellow.

Pyrrhotite acts upon the needle; is principally soluble in muriatic acid with evolution of sulphuretted hydrogen. Color, between brown-yellow and copper-red (usually tarnished tombac-brown).

Millerite is scarcely affected by nitric acid; with nitro-muriatic acid it forms a greenish solution, in which potassa causes a greenish precipitate. Ammonia produces a precipitate which dissolves in an excess with a blue color. Color, between a brass-yellow and bronze-yellow. Has been heretofore found only in hair-like crystals.

Closely related to the preceding is beyrichite Ni_5S_7.

---

* Marcasite (ortho-rhombic iron pyrite) and pyrite (isometric iron pyrite) are only distinguishable by their crystalline form. Are decomposed by nitric acid.

Color, lead-gray. B. B. in a closed tube affords a sublimate of sulphur. Millerite does not.

BISMUTHINITE (sulphuret of bismuth, Wismuthglanz), BiS_3. B. B. in the reduction flame fuses with boiling and spirting. Yields a globule of bismuth, and coats the coal yellow. Dissolves in nitric acid with separation of sulphur. The concentrated solution diluted with water becomes turbid, and then yields a white precipitate of bismuth. Color, light lead-gray, inclining to steel-gray. H.2. G. 6.4.

A similar behavior is shown by *chiviatite* $(Pb_2,Cu_2)Bi_8S_{11}$. It is decomposed by nitric acid with separation of sulphate of lead. Emplectite $CuBiS_2$ affords with nitric acid a bluish-green solution, which turns, with an excess of ammonia, azure-blue. Behaves otherwise like bismuthite. (Compare native bismuth.)

Division 6.—*Not belonging to the preceding divisions.*

AMALGAM (native), $AgHg_2$ and $AgHg_3$. B. B. gives off quicksilver in a matrass, with boiling and spirting, and leaves a swollen mass of silver. Dissolves easily in nitric acid. Color, silver-white. The amalgam richest in silver is arquerite, $Ag_{12}Hg$.

Metacinnabarite, HgS. Mixed with iron powder, it affords, in a matrass, mercury and sulphide of iron, which latter evolves sulphide of hydrogen when treated with hydrochloric acid. Rarely crystallized, constituting amorphous cinnabar. Color, grayish-black. Streak, black.

BISMUTH (native), Bi. B. B. fuses easily, and does not continue to burn after removal from the flame ; evaporates after long blowing, and imparts to the coal, at first, a white coating, which becomes partly yellow and partly orange. The color slightly fades on cooling. B. B. The mineral powder when fused together with sulphur and iodide of potassium on charcoal affords, after continuous blowing, a cinnabar-red coating. It is easily soluble in nitric acid. The concentrated solution yields with much water a white precipitate. Color, reddish silver-white. Brittle. H. 2.5. G. 9.7.

Rabdionite (Cu,Mn,Co,Fe). Colors the borax bead cobalt-blue. Heated with phosphoric acid, gives a violet solution (manganese). Is dull, but gives a metallic greasy streak. Color, black. H. 1. G. 2.8.

HÆMATITE (specular iron, red iron ore, Rotheisenerz), Fe_2O_3. Difficult of fusion; in the reduction flame becomes magnetic. Streak, cherry-red. H. 5.5–6. G. 5.

Cuprite (red copper ore), Cu_2O; has sometimes a metallic lustre; easily reducible to a copper globule B. B.

Magnetite (magnetic iron, Magneteisenerz), Fe_3O_4. B. B. fuses with great difficulty, usually above 5. It may be easily recognized by its action on the needle, and its black streak.

Hortonolite $(Fe,Mg)_2SiO_4$. Fuses at 4. Color, yellow to dark yellow-green. It has partly a metallic lustre and with an admixture of *magnetite* is magnetic.

Roepperite $(Fe,Mn,Zn,Mg)_2SiO_4$. Color, dark-green to black.

Fayalite, Fe_2SiO_4. Fuses at 3. Color, dark-green, brown to black.

The three latter minerals gelatinize with hydrochloric acid.

WOLFRAMITE (*Wolfram*, tungstate of iron and manganese), $(Fe,Mn,)\ WO_4 = \dddot{W}$ 75.56, $\dot{F}e$ 20.17, $\dot{M}n$ 3.54 ($\dot{F}e$ and $\dot{M}n$ varying greatly). B. B. fuses at 3 to a gray and often crystalline globule; with borax it yields an amethystine colored bead. Boiled with phosphoric acid and strongly concentrated it yields a fine blue liquid, whose color is heightened on cooling. When diluted with water a reddish-yellow, and later a colorless liquid is obtained. Upon the addition of iron powder and sulphuric acid it turns, when shaken, intensely sapphire blue. This liquid, when diluted with much water, loses in a few minutes its blue color. If we add to the blue solution with phosphoric acid, a little nitric acid, the color is changed to violet (manganese reaction). Color, grayish-black to iron black. Streak, dark reddish-brown to black. H. 5.5. G. 7.3.

Black Silicate of Manganese (Schwarzer Mangankiesel)* $MnSiO_3 + 2H_2O$. B. B. fuses with intumescence, and in a bolt-head yields much water; imparts to a borax bead in the oxidizing flame a strongly amethystine color. It is dissolved by muriatic acid with separation of silicic acid, without gelatinizing. Color, between lead-gray and iron-black.

(Compare Klipsteinite, $Mn_2O_3,MnOSiO_2,H_2O$.)

Psilomelane (name alludes to its smooth botryoidal form and black color). General formula $= RO + 4MnO_2$. Many varieties; compact; amorphous. B. B. fusible; reacts strongly of manganese with borax. Boiled with muriatic acid it gives off chlorine. Color, dark bluish-gray. H. 5–6. G. 3.7–4.7.

Lievrite (Ilvaite, Yenite), $H_2Ca_2Fe_4\cancel{F}eSi_4O_{18}$.

Allanite $(Ce,La,Di,Fe,Ca)_3(\cancel{A}l,\cancel{F}e)Si_3O_{12}$.

Both gelatinize completely with hydrochloric acid. *Allanite* fuses easily and swells up. *Lievrite* fuses easily and quietly.

Plattnerite (superoxide of lead, Schwerbleierz), PbO_2. Of adamantine lustre; spec. gravity, 9.3. Color, iron-black. Streak, brown. B. B. with soda on charcoal yields a globule of lead.

Samarskite (uranotantalite), $(Fe,Y,UO_2)_5(Cb,Ta)_4O_{15}$. Fuses at 4–5 to a steel-gray mass. Lustre of surface of fracture shining and submetallic. Color, velvet-black. Streak, dark red-brown.

When the powdered mineral is fused with caustic potassa in a silver crucible, and the mass afterwards extracted with water and filtered, a green solution is obtained, which, when neutralized with hydrochloric acid, yields a whitish precipitate. If the latter is boiled with a sufficient quantity of fuming hydro-

---

* A name given by v. Leonhard to a mineral as yet imperfectly known, and containing 14.9 per cent. of water. The analysis is by Klaproth. It is mentioned by v. Kobell, and in Naumann's Mineralogie, Leipzig, 1871. Is not described in Dana's Syst. of Min., 5th edit.; but the closely related mineral Klipsteinite, which gives 9 per cent. of water on ignition.

chloric acid and tinfoil for some minutes, and then diluted with an equal volume of water, a sapphire-blue solution results.

Class III.—**Infusible, or Fusibility above 5, and Non-volatile.**

Division 1.—*B. B. impart, in ever so small quantity, to the borax bead in the oxidizing flame an amethystine color of manganese.*

The oxides of manganese belonging to this group dissolve more or less easily in muriatic acid with evolution of chlorine gas. They yield, when the powdered minerals are boiled down with phosphoric acid to syrupy consistency, a beautiful violet liquid, which becomes, when diluted with water, and then shaken with some crystals of iron-vitriol, entirely discolored.

(Compare FRANKLINITE in the following division. It attracts the magnetic needle.)

LITHIOPHORITE = $MnO, CuO, CoO, Li_2O, BaO, Al_2O_3, MnO_2, H_2O$. Colors the flame carmine-red (lithia). With salt of phosphorus gives reactions for copper and cobalt.

CREDNERITE (mangankupferoxide), $Cu_3\bar{M}_2O_9$. B. B. moistened with muriatic acid it imparts to the flame a fine blue color. The solution yields, with ammonia in excess, a brown precipitate and an azure-blue liquid, which is not the case with the following.

BRAUNITE (sesquioxide of manganese), $2MnO,MnO_2 + MnSiO_4$. Color, dark brownish-black. Streak blackish, inclining to brown. Hardness 6–6.5 (between orthoclase and quartz). B. B. in a matrass affords none, or only traces of water. H. 6. G. 4.7.

HAUSMANNITE (red oxide of manganese), $2MnO + MnO_2$. Color brownish-black. Streak reddish and chestnut-brown. Hardness 5–5.5, between apatite and orthoclase. B. B. in a bolt head affords no water.

MANGANITE (hydrated oxide of manganese), Mn_2O_3,H_2O. Steel-gray to iron-black. Streak, dark reddish-brown. Hardness 4, between calcite and fluorspar. B. B. in a bolt head affords much water.

PSILOMELANE (compact oxide of manganese), $(Mn, Ba, K_2)_5O_9 + Aq$ (compos. doubtful). Color, bluish to grayish-black and blackish-gray. Streak, brownish black to black. Hardness 5–6. B. B. in a bolt head it affords water. The solution of most varieties in muriatic acid yields with sulphuric acid a heavy precipitate of sulphate of barium. (At present only found amorphous, but more generally diffused than any of the ores of manganese.)

PYROLUSITE (polianite, peroxide of manganese), MnO_2. Color, iron-black, steel-gray. Streak, black. Hardness 2–2.5, between rock-salt and calcite. B. B. in a bolt head it yields none or only a trace of water.

(Compare *Alabandine* and *Hauerite.*)

Division 2.—*Are magnetic, or B. B. when heated on charcoal perseveringly in the R. Fl. become so.*

Lölingite.

Arsenopyrite.

In different varieties; imperfectly fusible, are distinguished from the next following by evolving an arsenical odor B. B. on charcoal.

Hæmatite (specular iron, red iron ore, Rotheisenerz), Fe_2O_3. Distinguished from the following by its cherry-red streak and its iron-black, steel-gray, or brownish-red color. Dissolves slowly in muriatic acid.

Franklinite, $(Zn,Mn,Fe)O,(Mn,Fe)_2O_3$, and

Magnetite (magnetic iron ore, Magneteisenerz), Fe_3O_4, are strongly magnetic; both are slowly dissolved in concentrated muriatic acid, by which the former evolves chlorine; the latter does not. Pulverized franklinite, boiled down with phosphoric acid, yields a beautiful violet color; magnetite does not. The color of both is iron-black. The streak of franklinite is reddish-brown, that of magnetite black. A similar deportment to franklinite is shown by

Jacobsite $(Mn,Mg)O,(Fe,Mn)_2O_3$. Color, deep black. Is magnetic, and occurs in distorted octohedrons. Its phosphoric acid solution turns violet upon addition of nitric acid only after heating.

Magnoferrite, or *magnesioferrite*, MgO,Fe_2O_3. Soluble with difficulty in hydrochloric acid. In the solution after the oxidation of the protoxide of iron with chlorate of potash and its precipitation with an excess of ammonia, phosphate of soda gives a precipitate of ammonio-phosphate of magnesia in the filtrate. H. 6–6.5. G. 4.5.

MENACCANITE (titanic iron, ilmenite, hystatite, Titaneisen, Kibdelophan, Iserin, etc.), $(Ti, Fe)_2O_3$. Influences the magnetic needle, but is easily distinguished from the preceding by the following process: Pulverize and boil the powder with concentrated muriatic acid, and filter; the filtered liquid boiled with tinfoil assumes gradually a fine blue or violet color turning a pink-red when diluted. Streak, black. Color, iron-black, inclining to steel-gray. H. 5–6. G. 4.5–5.

We may also boil the powder of menaccanite, at first with conc. sulphuric acid, then evaporate to dryness and add to the residue conc. hydrochloric acid and tinfoil. In this way the mineral is more easily dissolved. Sometimes the hydrochloric acid solution boiled with tinfoil passes through the filter with a brownish color, in which case it must again be boiled with additional conc. hydrochloric acid and tinfoil, in order to obtain a violet solution, turning to a rose-color when diluted.

(Compare rutile and arkansite, which through an admixture of menaccanite frequently exhibit magnetic properties. Muriatic acid attacks them but slightly.)

LIMONITE (brown hematite, Brauneisenerz), $Fe_2O_3,3H_2O$. The lustre in many varieties is submetallic; is distinguished from the preceding by its ochre-yellow streak. H. 5.5. G. 3.6–4.

SPHALERITE (Zincblende) (Zn, Fe)S. containing oftentimes iron, and having a submetallic lustre, is recognized by the fact that muriatic acid evolves sulphuretted hydrogen. H. 3.5–4. G. 3.9–4.2.

Compare the following division:—

Division 3.—*Not included, but in some respects related to, the preceding are:*

CHROMITE (COLUMBITE AND NIOBITE) FERROILMENITE CHROMITE (chromic iron, Chromeisenerz), FeO,Cr_2O_3, or $(Fe,Mg)O,(Al,Cr)_2O_3$. In many varieties strongly magnetic, in others only very feebly so. Hydrochloric acid has little effect on it. Evaporated with phosphoric acid an emerald-green solution is obtained; those varieties containing oxide of manganese yield a violet solution (manganese) which, agitated with crystals of green vitriol, disappears while the green color of oxide of chromium appears. B. B. alone it remains unchanged. Borax and phosphorus slowly and perfectly dissolve it, forming beads of a fine emerald green when cold. Color, iron-black, pitch-black. Streak, yellowish-brown. H. 5.5. G. 4.3.

Some varieties of Cassiterite, SnO_2, have a metallic lustre. B. B. on charcoal heated with cyanide of potassium, metallic tin is obtained.

MOLYBDENITE (sulphuret of molybdenum, Molybdänglanz), MoS_2 (H. 1–2. G. 6.2), and

GRAPHITE (carburet of iron and black lead), C, are both very soft and leave a gray trace on paper. H. 1.5. Color of the former is lead-gray inclining to red; of the latter, iron-black, steel-gray. B. B. molybdenite, confined with the forceps, colors the flame light green; with soda it gives hepar. Heated in a platinum spoon with nitre, it explodes with evolution of light and heat. The mineral boiled down with con. nitric acid, furnishes a white mass (molybdenum trioxide) which, when boiled with caustic potash, yields a partial solution that upon being acidulated with hydrochloric acid, and afterwards diluted, assumes, when stirred with a strip of tin, a fine blue color.

A splinter of graphite, held in forceps made of zinc, becomes covered quickly with copper when dipped into a solution of sulphate of copper.

PEROFSKITE, $CaTiO_3$, as also some RUTILE, TiO_2, with sub-metallic lustre. When the fine powder of these minerals is fused together with caustic potash, water added, and the solution evaporated after addition of an excess of HCl and a piece of tinfoil, the liquid becomes violet-colored, and, on dilution with water, rose-red. (Reaction of TiO_2.) Perofskite crystallizes in cubes.

(Compare rutile and brookite.)

IRIDOSIMINE, Ir, Os, Rh, Ru. Fused in a matrass with nitre evolves the peculiar odor of oxide of osmium. Not perceptibly attacked by Bx and S. Ph. or aqua regia. Color, tin-white. Streak, gray. H. 6–7. G. 19.3–21.1.

TANTALITE, $Fe(Mn)Ta_2O_6$, and

COLUMBITE, $FeCb_2(Ta_2)O_6$;

YTTROTANTALITE, $(Fe, Ca, Y)_2 (TaCb)_2O_7$.

The color of these minerals is iron-black. Yttrotantalite loses its color before the blowpipe, and becomes yellowish or white; that of the others remains unchanged. Acids affect them but little. If tantalite and columbite are powdered, fused with caustic potash in a silver crucible, dissolved in water, and filtered, a precipitate is formed with hydrochloric acid, which, boiled with dilute sulphuric acid, becomes white; on the addition of zinc the precipitate from the columbite becomes intensely blue in the hot solution, and retains this color on the addition of water for a considerable time. The precipitate from *tantalite* is lighter colored, and loses its color quicker with water.

(Compare polycrase and aeschynite.)

URANITE, U_3O_4. Color, usually velvet-black; lustre, greasy; partially soluble in nitric acid to a yellow liquid; the solution gives a sulphur-yellow precipitate with ammonia. Boiled with phosphoric acid gives an emerald-green solution. G. 6.4–7.

GROUP II.—MINERALS WITHOUT METALLIC LUSTRE.

Class I.—Easily Volatile or Combustible.

NATIVE SULPHUR, S. H. 1.5; G. 2. Completely volatile; burns with a blue flame and evolution of sulphur dioxide, SO_2. Color, sulphur-yellow, honey-yellow, and brown from impurities.

REALGAR, As_2S_2. Arsenic disulphide, orange-yellow. H. 1.5–2. G. 3.5.

ORPIMENT, As_2S_3. Arsenic trisulphide (auripigmentum), yellow sulphide. Both fuse easily and volatilize with emission of arsenical fumes. Soluble in potassa. HCl precipitates from this solution lemon-yellow flocks.

ARSENITE (arsenious acid, white arsenic), As_2O_3. B. B. on ch. with soda emits an arsenical odor, and in a bolt head gives a white crystalline sublimate. Color, white. H. 1.5. G. 3.8.

VALENTINITE (oxide of antimony, Weisspiessglanzerz, Germ.), Sb_2O_3 and

KERMESITE (pyrostibite, red antimony, Antimonblende, Germ.), $2Sb_2S_2+Sb_2O_3$. B. B. fuse and evaporate easily, coating the charcoal white. Are insoluble in water. *Valentinite* dissolves readily in muriatic acid without evolution of gas. Kermesite (pyrostibite) is partly soluble with the escape of sulphide of hydrogen (H_2S). The powder of the first, treated with potassa, does not change color; that of the second, immediately assumes an ochre-yellow. The former is white, the latter cherry-red.

SENARMONTITE (Sb_2O_3), has the same composition as *valentinite*, but crystallizes in the isometric system, whilst valentinite is trimetric.

SAL AMMONIAC (ammonium chloride, Salmiak, Germ.), NH_4Cl, and

MASCAGNITE (hydrous ammonium sulphate), $(NH_4)_2SO_4$

+Aq. B. B. volatilize with abundant fumes; the first without fusing; the second fusing and puffing up at the first application of heat. Both dissolve easily in water. The solution of sal ammoniac gives no precipitate with chloride of barium. Mascagnite yields a heavy precipitate of sulphate of barium. When treated with potassa liquor they both evolve an ammoniacal odor. Color, white.

CINNABAR (sulphuret of mercury, Zinnober, Germ.), HgS. Streak, red. When the mineral powder is ground together with iron powder, wrapped in copper foil, and heated in a closed tube, metallic mercury sublimates, and the residue yields with hydrochloric acid, hydrosulphuric acid (SH_2). H. 2–2.5. G. 9.

CALOMEL (*horn quicksilver*, Mercurous chloride), HgCl. B. B. in a bolt head with soda yield metallic mercury. For trial not too little of the substance must be taken. The mixture may be wrapped up in thin paper, and introduced into the middle of an open tube, and the flame applied to this spot until the glass begins to melt. The metal may be collected in globules on the sides of the tube by means of a feather. Calomel is white, but potassa renders it black, mercurous oxide (Hg_2O) being produced. The alkaline solution, acidulated with nitric acid, after being filtered off, yields with nitrate of silver a heavy precipitate of chloride of silver. H. 1.5. G. 6.5.

COTUNNITE* (Chlorblei, Germ.).—Chloride of lead, $PbCl_2$.

Color, yellowish-white. Streak, white. May be scratched by the nail. Soluble in about 22 parts of hot water. B. B. partly volatile. Fuses on charcoal readily, and deposits a white coating, the inner edge of which is tinged yellow from oxide of lead. With soda on coal gives lead globules. See mineral coals in the appendix to ores.

---

* Dana, Syst. of Min., 5th edit., p. 117; also, Brush's Determinat. Min., etc., p. 72.

Class II.—**Fuse easily between 1 and 5, and volatilize only partially or not at all.**

Part **A.**—B. B. FUSED WITH SODA ON CHARCOAL YIELD A METALLIC GLOBULE, OR, FUSED ALONE IN THE R. F., FORM A MASS* WHICH ACTS ON THE MAGNETIC NEEDLE.

Division 1.—*B. B. yield with soda or soda and borax together a silver globule. Those decomposable by nitric acid yield, when this solution is treated with hydrochloric acid, a white precipitate of chloride of silver, which B. B. is easily reduced on charcoal to metallic silver. (It is well to fuse the globule once more with borax, to obtain the silver entirely pure and ductile.)*

Proustite. Light red, silver ore.

Lichtes Rothgültigerz, Germ., Ag_3AsS_3 (or $3Ag_2S + As_2S_3$), and

Pyrargyrite (dark-red, silver ore. Dunkles Rothgültigerz, Ag_3SbS_3 (or $3Ag_2S+Sb_2S_3$)). May be distinguished from the following by their cherry-red streak. B. B. the first evolves the strong odor of arsenic; the second coats the coal with the fumes of antimony. Either mineral reduced to powder and heated with potassa assumes a black color, and is partly decomposed and dissolved. If this potash solution be neutralized with muriatic acid, proustite will form lemon-yellow flocks of sulphuret of arsenic, *pyrargyrite*, orange flocks of sulphuret of antimony. Color of the former is cochineal-red; of the latter dark-red to blackish lead-gray. A similar behavior is shown by proustite.

Xanthoconite (*Xanthokon*), $3AgS + As_2O_5) + 2(3AgS + As_2S_3)$ (Da).† Color, dull red to clove-brown. Crystals, orange-yellow on the edges by transmitted light. Streak, powder yellow. Brittle—qualities which readily distinguish it.

---

* All minerals with non-metallic lustre, which emit an arsenical odor before the blowpipe belong to this class, except *pharmacolite*.

† According to Brush, $Ag_9As_3S_{10}$. Determin. Min., etc., p. 72.

(Compare *miargyrite*, $AgSbS_2$ (or $Ag_2S+Sb_2S_2$), which sometimes resembles very much the *pyrargyrite*. The specific gravity of the former is 5.2, that of the latter 5.7.)

Cerargyrite (*Kerargyrit*, Horn Silver, Silberhornerz), AgCl.

Iodyrite (iodargyrite, Iodsilber, Germ.), AgI, and

Embolite, Ag (ClBr) are ductile, and may be hammered out. In closed tube fused with bisulphate of potassa, the following phenomena take place. The bead of AgI* swimming in the flux is dark, almost black, whilst hot, turning by the gradual cooling process to red. The bead of AgCl, when hot, has a pale hyacinth-red color; that of AgBr an intense garnet-red, both turning to yellow when cold. When these silver compounds are mixed with zinc filings in a cylindrical glass, and next treated with very dilute sulphuric acid, they assume after a while, a blackish color. If the solution is poured off, some starch added, and a few drops of potassic permanganate solution ($MnKO_4$) acidulated with conc. HCl, the liquor of iodyrite shows a blue or bluish-black color, that of embolite a yellow color, that of cerargyrite is not colored at all. When the above solution of embolite (without starch solution) is treated with solution of $MnKO_4$, acidulated with HCl, then mixed with ether, and diligently stirred, the layer of ether assumes a yellow color, whilst the liquor beneath is colorless. This department is very characteristic for bromine after we have convinced ourselves that no iodine is present, since that body yields similar reactions. Chlorine produces under these circumstances no coloring of the ether.

SELBITE (carbonate of silver), $AgCO_3$, dissolves easily in nitric acid, with effervescence. Color, ash-gray inclining to black. Streak has metallic lustre. According to Walchner it is only a mixture; and according to Sandberger, one of Selb's original specimens, examined under the lens, showed to

---

* *Iodyrite* by this fusion process gives off iodine vapors; and *embolite* bromine vapors.

contain earthy argentite, besides dolomite and silver, and all parts afforded a *sulphur* reaction.*

Division 2.—*B. B. with soda yield a lead globule. The compounds of this group are soluble in nitric acid; zinc precipitates metallic lead from the solution; sulphuric acid forms a heavy white precipitate of sulphate of lead.*

When boiled with caustic potash solution a liquid is obtained, which, either with chromate of potassium alone, or after treatment with some acetic acid, gives an orange or yellow precipitate of chromate of lead.

BINDHEIMITE (Bleiniere), $Pb_3Sb_2O_8 + 4Aq$, and

NADORITE, $PbSb_2O_4 + PbCl_2$.

B. B. on charcoal both yield metallic lead and coatings of lead and antimony. Bindheimite affords water in a closed tube. Nadorite fused in a salt of phosphorus bead, which has previously been saturated with oxide of copper, colors the flame blue (chloride of copper).

MIMETITE, MIMETISITE (lead arsenate), $3Pb_3As_2O_8 + PbCl_2$. B. B. on coal is reduced; evolves a strong arsenical odor. Confined with the forceps and fused in the external flame, some varieties crystallize like pyromorphite (phosphate of lead). Color, yellowish-green, brownish. Closely related to this mineral is

HEDYPHANE (arsenate and chloride of lead with phosphate of lime), $3(Pb,Ca)_3As_2O_8 + (Pb,Ca)Cl_2$. B. B. alone on coal gives arsenical odors and, containing phosphate of calcium, gives the reaction for phosphoric acid.

PYROMORPHITE, $3Pb_3P_2O_8 + PbCl_2$. B. B. is not reduced alone on coal; fuses to a bead which, after cooling, is distinctly crystalline. The nitric acid solution gives, when boiled with molybdate of ammonium, an ochre-yellow precipitate of phospho-molybdate of ammonium. Color, generally green, of different shades; also brown and white. H. 3.5–4. G. 6.5–7.

---

* Dana, Syst. of Min., fifth ed., p. 804.

Minium (Mennige), $Pb_3O_4 = PbO_2 + 2PbO$.

Crocoite (crocoisite, chromate of lead), $PbCrO_4$.

Phœnicochroite, **Phönicite** (melanochroite, sesquichromate of lead), $Pb_3CrO_6 = 2PbCrO_4 + PbO$.

Dechenite (araeoxene, PbZn) V_2O_6. Have a red color. B. B. Crocoisite, phœnicite, and dechenite, added in small quantities, impart to a borax bead an emerald-green color which, with dechenite, turns, in the oxidizing flame, gradually light olive-green, then yellow, and next disappears. They are soluble in boiling muriatic acid without effervescence, with separation of chloride of lead, and form an emerald-green liquid.* This liquid concentrated by the addition of alcohol, and poured off from the separating chloride of lead, assumes upon dilution with water a sky-blue color if dechenite is present, with the others it remains green. Crocoite yields with phosphoric acid at first a reddish-yellow solution which, when concentrated, turns emerald-green, and diluted with water loses it entirely. Dechenite treated thus produces, not a green, but a yellow solution. Minium gives with borax a yellow bead which becomes colorless on cooling. It does not change the color of muriatic acid. The streak powder of crocoite and dechenite is orange; of phœnicite, brick-red.

Linarite (cuprous sulphate of lead, Kupferbleispath), $\dot{\mathrm{P}}\mathrm{b}\dddot{\mathrm{S}} + \dot{\mathrm{C}}\mathrm{u}\dot{\bar{\mathrm{H}}}$ is characterized by its deep azure-blue color. Nitric acid, at the commencement of heating, discolors it, while sulphate of lead is precipitated.

Cerussite (carbonate of lead, Weissbleirz), $PbCO_3$.

Lanarkite (sulphato-carbonate of lead), $PbSO_4 + PbCO_3$.

Phosgenite (Hornblei, Kerasin), $PbCO_3 + PbCl_2$ are dissolved by nitric acid with effervescence. *Lanarkite* only incompletely. The solution of phosgenite gives, with nitrate of silver, a heavy precipitate of chloride of silver, that of lanarkite with nitrate of barium a precipitate of sulphate of barium, that of cerussite affords none with either reagent.

---

* Provided. that sufficient HCl was present and the boiling continued long enough.

Color of cerussite, white, of lanarkite, greenish-white to yellow-gray, of phosgenite, white. Similar to *lanarkite* is

LEADHILLITE, $PbSO_4 + 3PbCO_3$, crystallizes in the *orthorhombic system.* Of the same composition is

Susannite, $PbSO_4 + 3PbCO_3$, crystallizing in the *hexagonal system* (rhombohedrons). Lanarkite crystallizes in the monoclinic system.

ANGLESITE (sulphate of lead), $PbSO_4$, soluble in nitric acid with difficulty. B. B. with soda yields hepar and is reduced to metallic lead. H. 3. G. 6.1–6.3.

WULFENITE (molybdate of lead), $PbMoO_4$. Boiled with concentrated muriatic acid is dissolved with separation of chloride of lead, forming a green liquid, which diluted somewhat and stirred with tinfoil, assumes immediately a blue color. Boiled with concentrated phosphoric acid, a pale green solution is obtained, which, when diluted with four times its bulk of water, sometimes becomes turbid. If now this liquid is agitated with a very little iron powder, it turns blue, with more iron olive-green (at a common temperature).

After the mineral powder has been heated in a porcelain dish with concentrated sulphuric acid, the addition of alcohol, on cooling, colors the liquor, especially at the sides of the dish, a fine blue. Color, honey, wax, and orange-yellow. H. 3. G. 6.9.

STOLZITE (tungstate of lead, schuletine, Wolframsaures Bleioxyd), $PbWO_4$. Boiled with phosphoric acid, like the preceding solution, does not grow turbid when diluted and the liquid turns, with a little iron powder, a beautiful blue, but not before heat is applied. A greater addition of iron-powder does not alter the color. Sulphuric acid colors the powder lemon-yellow, while the acid remains colorless. Color, yellow, yellowish-brown. H. 3. G. 7.9.

VAUQUELINITE (chromate of lead and copper), $Pb_2CuCr_2O_9$.

Vanadinite, Vanadinbleierz, $3Pb_3V_2O_8 + PbCl_2$.

Eusynchite,* $Pb_1ZnV_2O_6$.

---

* A variety of Dechenite. See Brush Manual of Determinative Mineralogy, pp. 73 and 74.

B. B. they impart to borax glass an emerald-green color which remains so with vauquelinite even in the O. F. while the others turn yellow. They are soluble in nitric acid. The solution of vauquelinite is green, that of vanadinite and eusynchite, yellow or colorless. The solutions of *vauquelinite* and *eusynchite* yield with nitrate of silver no precipitate, that of *vanadinite* gives a precipitate or becomes turbid. All three produce with concentrated hydrochloric acid upon the addition of alcohol, an emerald-green solution which concentrated until the PbCl separates, turns, upon the addition of water, sky-blue, by vanadinite and eusynchite, while it remains green with vauquelinite. Color of the last is blackish to olive-green; that of vanadinite, brown or yellowish; that of eusynchite yellowish red to ochre-yellow. Vanadinite crystallizes in the hexagonal, and the chemically related

Descloizite, $Pb_2V_2O_7$, cryst in the orthorhombic system.

(Compare plumbo-resinite, Bleigummi, Germ.)

Closely related to *vauquelinite* are :—

Laxmannite.[*] $(PbCu)_6(P,Cr)_4O_{17}$ and

Phosphochromite.

Their nitric acid solution reacts with molybdate of ammonium, of phosphoric acid, and when gently heated, forms after a lapse of time a yellow precipitate.[†]

Division 3.—*Moistened with hydrochloric acid they communicate to the blowpipe flame a transient blue color; with nitric acid, form a sky-blue or a green solution, which becomes azure-blue by the addition of ammonia in excess.*

The compounds of oxide of copper belonging to this class are principally so much decomposed by boiling with potassa, that their acids combine with the potassa.

---

[*] Held by *Beresof* to be a phosphochromite. See Text-Book of Mineralogy, p. 364. E. S. Dana's.

[†] The yellow precipitate (often termed phospho-molybdate of ammonium) contains molybdic acid, ammonia, water, and about 3 per cent. of phosphoric acid. Is soluble in phosphoric, and other acids.

Section i.—*B. B. evolve a strong arsenical odor (and generally give alone on coal a white, brittle metallic globule of arsenical copper). Are of a green color.*

Chenevixite, $(\text{Ꞙe},Cu_3)_2\ As_2O_{11}+3Aq$.

Fuses to a black magnetic slag. The following yield no magnetic product:—

Bayldonite, $(CuPb)_4As_2O_9+2Aq$.

The nitric acid solution affords, with sulphuric acid, a white precipitate of sulphate of lead.

Olivenite (prismatic arsenate of copper), $Cu_5As_2O_9+Aq$. B. B. in the forceps affords on cooling a blackish, radiating crystalline mass, the surface of which is covered with prismatic crystals. It yields but little water (4 per cent.) in a bolt head. Color, olive-green, passing into leek or blackish-green. A similar mineral with 7 per cent. of water is:—

Abichite (clinoclasite) $Cu_6As_2O_{11}+3Aq$.

Tyrolite (Kupferschaum), $Cu_5As_2O_{10}+9Aq$.

Chalcophyllite (copper mica, Kupferglimmer) $Cu_8As_2O_{13}+7Aq$.

B. B. decrepitate violently, and in a bolt head afford much water. The second is soluble in ammonia without residue; the first with separation of carbonate of calcium. Both are perfectly cleavable in one direction. Tyrolite is apple-green and verdigris-green. Chalcophyllite emerald-green, grass-green.

Closely allied to these is:—

Conichalcite, (Konichalcit) $2(Cu,Ca)_4(As,P,V)_2O_9+3Aq$.

Reniform and massive. Fraction splintery brittle. Color, pistachio-green to emerald-green. Some vanadic acid replaces part of the phosphoric. The fused assay has an alkaline reaction.

LIROCONITE (Linsenerz), $(Cu_8Al)_2(As,P)_2O_{11}+12Aq$.

B. B. does not crepitate, and heated slightly, assumes a smalt-blue color. In ammonia it is soluble with separation of white flocks. Contains a large quantity of water, and loses by ignition 22 per cent. of its weight. Color, sky-blue, also green.

EUCHROITE, $Cu_4As_2O_9+7Aq$, and

ERINITE, $Cu_5As_2O_{10}+2Aq$, are distinguished principally by their loss of weight on ignition. The former loses 18½ per cent., the latter 5 per cent. of water. Color, emerald-green. Amorphous. A mineral similar to the preceding is:—

Cornwallite, $Cu_5As_2O_{10}+3Aq=Cu_3As_2O_8+2H_2Cu_2O_2+Aq$.

Amorphous, with about 13 per cent. of water. Color, green (emerald to verdigris green).

Section ii.—*B. B. evolve no arsenical odor, but generally give alone on coal a malleable globule of copper.*

ATACAMITE (chloride of copper), $CuCl_2+3H_2CuO_2$, without being moistened with muriatic acid communicates to the blowpipe flame a fine blue color, and thereby may be easily distinguished from all similar minerals. The nitric acid solution yields with nitrate of silver, white chloride of silver. Color, leek, blackish-olive, emerald-green. H. 3.5. G. 4.25

Closely allied are:—

Tallingite, $CuCl_2+4H_2CuO_2+4Aq$. Color blue to green.

Percylite, $(Pb,Cu)\ (Cl_2,O)+Aq$. Color sky-blue.

Both color the flame blue like the preceding.

Percylite dissolved in nitric acid yields with sulphuric acid a white precipitate of sulphate of lead.

Nantokite, $CuCl$. Color when fresh, white; colors the flame blue and yields no water in a closed tube.

(Compare *Atlasite*, $7Cu_2CO_4+CuCl_2+10Aq$.)

Chalcanthite (blue vitriol, sulphate of copper), $CuSO_4+5Aq$.

Brochantite Cu_4SO_7+3Aq. and *Covellite* (*Covellin*, *Kupferindig*) CuS,

B. B. with soda give hepar, which is not the case with the remaining minerals of this division. Blue vitriol dissolves easily in water. Color, sky-blue. The second and third are insoluble in water, but soluble in nitric acid. The solutions of the first two give, with nitrate of barium, a heavy precipitate of sulphate of barium. Covellite in the exterior flame burns and emits the odor of sulphurous acid. It is not reduced until all the sulphur is expelled by roasting. Color, indigo blue-blackish. Brochantite exhibits no such deportment. Color, emerald green.

Related *to brochantite* is :—

Langite, Cu_4SO_6+4Aq. Color, greenish-blue. *Brochantite* contains 12, langite 16 per cent. water.

Pisanite,* FeO, CuO, SO_3+7H_2O; or a copperas with three-fifths of the iron replaced by copper. In concretionary and stalactitic forms, color light-blue. Occurs with chalcopyrite at a copper mine in the interior of Turkey. Gives B. B. with fluxes reactions for copper, otherwise like copperas.

CUPRITE (red oxide of copper, *Rothkupfererz*) Cu_2O, and

BLACK COPPER ORE (Kupferschwaerze), CuO, are easily and quietly dissolved in acids. The concentrated solution of the former in muriatic acid gives, when diluted with water, a white precipitate (of protochloride of copper); with potassa an ochre-yellow deposit. The solution of the black oxide of copper, with water, does not give any; with potassa, a bluish precipitate. Color of the first is cochineal-red; of the second, brown or brownish-black. The last mineral generally slightly effervesces in acids owing to impurities.

Pure black oxide of copper constitutes :—

Tenosite, *melaconite*, CuO, of dark steel-gray color, in thin laminæ transparent, brown.

MALACHITE (green carbonate of copper), $Cu_2CO_4+H_2O$.

AZURITE (blue carbonate of copper), $Cu_3C_2O_7+H_2O$, and

MYSORINE (anhydrous carbonate of copper), $CuCO_3$, dissolve in nitric acid with effervescence, caused by the escape of carbonic acid. The first two in a matrass afford a large amount of water; the third only a little or no water. Color of the first is always green; the second blue, usually sky-blue; the third brownish-black.

Aurichalcite, $(Zn, Cu)_3\ CO_5+2Aq$.

Buratite (according to J. D. Dana identical with the former, System of Min., 5th ed., p. 712).

---

* Dana's System of Min., 5th ed., p. 646–47.

B. B. Give with soda on charcoal a zinc coating. Atlasite, $Cu_2CO_3+CuCl_2+10Aq$.

The nitric acid solution gives with nitrate of silver a precipitate of chloride of silver.

LIBETHENITE (phosphate of copper), $Cu_4P_2O_9+H_2O$, and

Lunnite (phosphochalcite, pseudomalachite), $Cu_6P_2O_{11}+3H_2O$.

Easily and quietly soluble in nitric acid. The solution yields with molybdate of ammonia a yellow precipitate (P_2O_5). Color of libethenite dark olive-green, when ignited loses 7 per cent. of water; color of lunnite dark green, loses 14 per cent. of water by ignition.

A similar deportment is shown by—

*Ehlite** (prasine), $Cu_3P_2O_8+2H_2CuO_2+Aq$. Ramm. Cleavage in one direction perfect. Color, dark olive-green.

Tagilite, $Cu_4P_2O_9+3Aq=Cu_3P_2O_8+H_2CuO_2+2Aq$. Color, emerald-green. Lose on ignition 9 to 10½ per cent. of water.

Torbernite (*Chalcolit*, Kupfer-Uranit, Germ.), $CuU_2P_2O_{12}+8Aq=2(UO_2)_3P_2O_8+Cu_3P_2O_8+24Aq$. The solution in nitric acid has a yellowish-green color, and forms, with ammonia in excess, a blue liquid, with a bluish-green precipitate; by this it can be distinguished from the preceding minerals, since the precipitates which they form with ammonia are almost entirely soluble in excess of ammonia. The solution gives, when warmed with molybdate of ammonium, a yellow precipitate. Color, emerald-green. In one direction perfectly cleavable.

Volborthite, $(CuCa)_4V_2O_9+H_2O$. Melts very easily, yielding with soda a copper globule. Its powder, ground with soda and heated to fusion in a platinum crucible, furnishes a mass which, extracted with boiling water, produces, upon addition of hydrochloric acid and proper evaporation, an emerald-green liquor, changing to a sky-blue when more water is added. Color of the mineral yellowish-green.

---

* Pseudomalachite, $Cu_6P_2O_{11}+3Aq$. Brush's Determ. Min., p. 75.

Division 4.—*B. B. impart to a borax bead a fine sapphire-blue color.* (*Cobalt.*)

Erythrite (cobalt bloom, Kobaltbluethe), $Co_3As_2O_8 + 8Aq$. B. B. in a matrass affords water and becomes smalt-blue. Dissolves in muriatic acid to a rose-red liquid. Color, carmine-peach, rose-red.

ANNABERGITE, NICKELBLUETHE (Nickelocker), $Ni_3As_2O_8 + 8Aq$ (always containing oxide of cobalt). B. B. in a matrass yields a large quantity of water. Its solution in muriatic or nitric acid is of a green color. Ammonia gives a greenish precipitate soluble in excess to a sapphire-blue liquid. Color, fine apple-green.

Heterogenite, $(CoO + 2Co_2O_3) + 6Aq.$) Soluble in HCl with evolution of chlorine, colors the flame green. Color, black, red, brown.

Division 5.—*Fused B. B. in the forceps or on coal in the reduction flame, yield a black mass which acts upon the magnetic needle (this includes none contained in the preceding divisions).*

In order to discover the magnetism of a mineral it is well to use large masses of such as fuse easily, and to expose them for some time to the reduction flame.

Section i.—*Evolve when fused upon coal strong arsenical odor.*

PITTICITE (*Pittizit*, iron sinter, Eisensinter). Composition uncertain; contains $As_2O_4\bar{\mathrm{F}}\mathrm{e}O_3SO_3H_2O$.

PHARMACOSIDERITE (*beudantite*, cube ore, Wuerfelerz), $\bar{\mathrm{F}}\mathrm{e}_4As_6O_{27} + 15Aq$, and

SCORODITE (Skorodit), $\bar{\mathrm{F}}\mathrm{e}As_2O_8 + 4Aq$. B. B. fuse easily to a magnetic globule. In potassa the powder immediately assumes a reddish-brown color. The last two are found crystallized, the former one in the isometric (or cubic), the latter in trimetric (or rhombic) system. Their color is green of different shades. Iron sinter is amorphous. Lustre, opalescent or vitreous. Color, brownish, blood-red, also white.

Arseniosiderite (arsenocrocite), $(\mathrm{Ca_3}\not{\mathrm{F}}\mathrm{e})\mathrm{As_2O_8} + \mathrm{H_6}\not{\mathrm{F}}\mathrm{eO_6}$. Fibrous, of silky lustre, and brownish-yellow color.

Morenosite (*pyromeline*, nickel vitriol), $\mathrm{NiSO_4} + 7\mathrm{Aq}$. Light blue-green; mostly soluble in water; with caustic ammonia in excess it yields a blue liquid. (Sometimes contains arsenic.)

Section ii.—*Soluble in HCl without perceptible residue, and without gelatinizing. (Evolve B. B. no arsenical odor when fused on Ch.)*

*Ludwigite.** Comp. $\mathrm{R_4}\not{\mathrm{F}}\mathrm{B_2O_{10}}$. Contains $\dot{\mathrm{M}}\mathrm{g}$, $\dot{\mathrm{F}}\mathrm{e}$, $\not{\mathrm{F}}\mathrm{e}$ (von Kob.)

*Sussexite.** General formula $\mathrm{R_2B_2O_5} + \mathrm{Aq} = (\mathrm{Mn}, \mathrm{Mg})_2\mathrm{B_2O_5} + \mathrm{H_2O}$. Both give the boric acid reaction with sulphuric acid and alcohol. B. B. sussexite imparts a violet color to the hot borax bead (oxide of manganese).

Rabdionite $(\mathrm{Cu}, \mathrm{Mn}, \mathrm{Co})(\not{\mathrm{F}}\mathrm{e}, \not{\mathrm{M}}\mathrm{n})\mathrm{O_4}$. B. B. gives much water in a closed tube (13 p. c.), and colors the borax bead blue. Soluble in strong HCl with evolution of chlorine. Soluble in phosphoric acid to a violet fluid. Color, black.

Pettkoite $(\mathrm{Fe_3}, \not{\mathrm{F}}\mathrm{e})\mathrm{S_3O_{12}}$. B. B. gives little or no water in the closed tube ($1\frac{1}{2}$ p. c.), is soluble in water. Chloride of barium gives a white precipitate of sulphate of barium. Color, black. Streak, dirty-green.

Melanterite (copperas, iron vitriol). $\mathrm{FeSO_4} + 7\ \mathrm{Aq}$, and

Botryogen (red iron vitriol), $(\mathrm{Fe}, \mathrm{Mg})\mathrm{Fe_2S_4O_{16}} + 12\mathrm{Aq}$. B. B. intumesce strongly, and in the reduction flame fuse to a magnetic slag. Copperas is entirely soluble in water. Botryogen leaves a yellow residue of peroxide of iron. The solution gives with chloride of barium a heavy precipitate of sulphate of barium. With ammonia it forms a greenish precipitate, which exposed to the air changes to a brownish-red.

---

* According to Brush (Determ. Min., p. 82), ludwigite is only a sub-species of sussexite. See, also, E. S. Dana's Textb., p. 358.

Color of botryogen, ochre-yellow to red. Streak, yellow. *Melanterite* is green.

A deportment similar to botryogen is exhibited by—

Coquimbite, $\text{Ꞙe}S_3O_{12} + 9Aq$.

Roemerite, $(Fe, Zn)\text{Ꞙe}S_4O_{16} + 12Aq$ (is yellowish-brown).

Jarosite, $K_2\text{Ꞙe}_3S_4O_{22} + 6Aq$.

Fibroferrite (stypticite), $\text{Ꞙe}S_2O_9 + 10Aq$.

All of these are yellow. Fibroferrite occurs in fibres of a silken lustre and pale yellow color. Their powders are immediately turned brownish-red by solution of potassa (Fe_2O_3). *Melanterite* at first greenish, then black.

Here belong (likewise furnishing a yellow powder)—

Copiapite, $\text{Ꞙe}_2S_5O_{21} + 18Aq$.

Raimondite, $\text{Ꞙe}_2S_3O_{15} + 7Aq$.

Pastreite or *jarosite* (Brush), $K_2\text{Ꞙe}_3S_4O_{22} + 6Aq$.

Carphosiderite, $\text{Ꞙe}_4S_5O_{27} + 13Aq$. Insoluble in water. Powders yellow.

Voltaite, $3\text{Ꞙe}S_3O_{12} + 20Aq$. Characterized by its black to dark-green color and octahedral crystallization. All these sulphates B. B. in the closed tube yield water.

SIDERITE (*spathic-iron*, *Eisenspath*), $FeCO_3$. With difficulty fusible, becomes by heating black and magnetic. Dissolves in warm HCl with effervescence. H. 4. G. 3.75. Compare Mesitine-spar (Mesitite).

The following minerals, inclusive of ***beraunite***, contain phosphoric acid, and their nitric acid solution yields with molybdate of ammonium, at a gentle heat, a yellow precipitate.

HUREAULITE (Huraulith, hydrous phosphate of iron and manganese), $(Mn, Fe, H_2)_3P_2O_8 + 4Aq$, and

TRIPLITE (phosphate of iron and manganese), $(Fe, Mn)_3 P_2O_8(Fe, Mn, Fl)$. B. B. fuse easily, and, when moistened with sulphuric acid, tinge the flame with a feeble bluish-green. They dissolve with borax in the exterior flame to an amethystine bead. Hureaulite in a matrass yields a considerable amount of water; the other only a trace. With phosphoric acid, boiled down, both yield a colorless liquid, which, upon addition of nitric acid, turns violet. Hureaulite is of a reddish-yellow color; is not cleavable. Triplite is brownish or black, cleavable at right angles in three right angular directions. A similar deportment to *triplite* is shown by *zwieselite*.* Both give the reaction for fluorine when fused in a close tube with bisulphate of potassa.

Sarcopside $4(\mathrm{Mn, Fe})_3\mathrm{P}_2\mathrm{O}_8 + \mathrm{H}_4\mathrm{FeO}_6$. Color, flesh-red to lavender-blue. Streak, straw-yellow. Compare the following:—

Triphylite. Triphyline, $(\mathrm{Fe, Mn, Li}_2)_3\mathrm{P}_2\mathrm{O}_8$.

B. B. gives a deportment similar to the preceding; the reaction of manganese with borax is less distinct, but the bead is colored more strongly with iron. When the solution in HCl with addition of nitric acid is evaporated to dryness, and alcohol added, then heated to the boiling point and lighted, purple-red stripes will be visible occasionally in the flame, especially towards the last. This behavior (caused by the presence of lithia) easily distinguishes it from similar phosphates of iron. Color, greenish-gray, bluish, etc. Cleavable in four directions.

Diadochite, $\mathrm{Fe}_2\mathrm{O}_3$, SO_3, $\mathrm{P}_2\mathrm{O}_5$, $\mathrm{H}_2\mathrm{O}$. Easily soluble in hydrochloric acid, the solution yields with chloride of barium a heavy white precipitate of sulphate of baruim. Amorphous. Color red to yellowish-brown. The powder is yellow.

Vivianite (blue iron earth), $\mathrm{Fe}_3\mathrm{P}_2\mathrm{O}_8 + \mathrm{Aq}$.

Dufrenite, kraurite (green iron ore), $\mathrm{Fe}_2\mathrm{P}_2\mathrm{O}_{11} + 3\mathrm{Aq}$.

Cacoxenite, kacoxene, $\mathrm{Fe}_2\mathrm{P}_2\mathrm{O}_8 + 12\mathrm{Aq}$, and *borickite* $(\mathrm{Fe, Ca}_3)_5\mathrm{PO}_4\mathrm{O}_{25} + 15\mathrm{Aq}$.

B. B. fuse easily, and when moistened with sulphuric acid they exhibit the same reaction as the preceding. They impart to borax bead only the color of oxide of iron (*i. e.* in the exterior flame it is red when hot, after cooling yellow); in the reduction flame it is bottle-green. The hydrochloric acid solution yields with chloride of barium no precipitate. In a

---

* Brush considers both identical.

matrass they yield a large proportion of water. Cocoxene loses by ignition 3.3, vivianite 28, borickite 19, and dufrenite 8½ per cent. of water. Color of vivianite is blue of different shades; that of anglarite gray inclining to blue; that of dufrenite dark leek-green; that of cacoxene ochre-yellow; and that of borickite reddish-brown. Another phosphate resembling these is beraunite.

Beraunite, $\bar{\mathrm{F}}\mathrm{eP_2O_8} + \mathrm{Aq}$, exhibits a hyacinth-red, or reddish-brown color.

Hematite, peroxide of iron, red iron ore, specular iron, is easily distinguished by the cherry-red color of its streak (generally fusible above 5). Compare limonite. H. 6–6.5. G.4.5.

Section iii. *With hydrochloric acid form a jelly, or is decomposed with separation of silica.**

Cronstedtite, $3(\mathrm{Fe, Mg})_2\mathrm{SiO_4} + \bar{\mathrm{F}}\mathrm{e_2SiO_8} + 6\mathrm{Aq}$. In a matrass affords water, and B. B. fuses with intumescence to a black bead. With muriatic acid it forms a perfect jelly. (*Sideroschisolite*† shows a similar deportment, and belongs probably to the same species.) Color, raven-black. Streak, dark leek-green. Hardness between 2 and 3.

A similar deportment is shown by *thuringite.* The analysis‡ yielded: SiO_2 23, Fe_2O_3 15, Al_2O_3 17, FeO 33, H_2O 12 = 100. The solution in aqua regia yields, with ammonia, a precipitate of Fe_2O_3 and Al_2O_3. If this mixture is boiled with caustic potash, Al_2O_3 is extracted, leaving Fe_2O_3 behind. From the potassa solution, rendered acid with HCl, ammonia throws down Al_2O_3. Found in Thüringen, and in the United States at the Hot Springs, Ark., and at Harper's Ferry.

---

* The residue may be recognized as pure silica when it is easily and perfectly soluble in potassa, or at least the greater portion. The solution yields by the addition of a sufficient quantity of dissolved sal ammoniac, a white flaky precipitate of *hydrous silica*. B. B. silica fuses readily with soda to a transparent glass (the soda should be added gradually).

† J. D. Dana's Syst. of Min., 5th ed., p. 504.

‡ F. von Kobell's Mineralogie, 5 Aufl. Leipzig, 1878, p. 225.

Chalcodite, $(\mathrm{Fe, Mg})_2 (\bar{\mathrm{Fe}}, \bar{\mathrm{Al}})\mathrm{Si_5O_{15}} + 3\mathrm{Aq}$, and *stilpnomelane*, of nearly the same composition, yield water in a bolt-head (9 per cent.), are decomposed by hydrochloric acid without gelatinizing. The color of chalcodite is green, inclining to bronze; that of stilpnomelane black. Their streak is greenish-gray. Related closely with chalcodite are:—

Voigtite, $\dddot{\bar{\mathrm{Al}}}$, $\dddot{\bar{\mathrm{Fe}}}$, $\dot{\mathrm{Mg}}$, $\ddot{\mathrm{Si}}$, Aq.

Ekmannite, $\dot{\mathrm{Fe}}$, $\dot{\mathrm{Mn}}$, $\dddot{\bar{\mathrm{Fe}}}$, $\dddot{\mathrm{Si}}$, Aq and

Euralite, $\dot{\mathrm{Fe}}$, $\dot{\mathrm{Mg}}$, $\dddot{\bar{\mathrm{Al}}}$, $\dddot{\bar{\mathrm{Fe}}}$, $\ddot{\mathrm{Si}}$, Aq.

Whilst chalcodite is radiated and sometimes foliated, voigtite is micaceous, and the last two are massive. In the matrass yield water, and are decomposed by HCl without gelatinizing.

Palagonite, $\dddot{\bar{\mathrm{Al}}}$, $\dddot{\bar{\mathrm{Fe}}}$, $\dot{\mathrm{Mg}}$, $\dot{\mathrm{Ca}}$, $\ddot{\mathrm{Si}}$, Aq. Is amorphous, and has a brownish-yellow streak. Yields much water (16 p. c.), fuses at 3 to a black, lustrous, magnetic glass. Sometimes gelatinizes, sometimes does not, with HCl. Compare jollyte.

Lievrite (Ilvaite), $\mathrm{H_2Ca_2Fe_4\bar{Fe}Si_4O_{18}}$.

Allanite (Orthite), $(\mathrm{Ce, La, Di, Fe, Ca})_3(\bar{\mathrm{Al}}\bar{\mathrm{Fe}})\mathrm{Si_3O_{12}}$. Are not cleavable, gelatinize with HCl. Give little or no water in the closed tube. Allanite swells much and fuses easily to a bulky brown or black glass. After separation of $\mathrm{SiO_2}$ from the HCl solution, ammonia gives a heavy precipitate, which dissolves in oxalic acid, leaving a white residue, which, ignited and treated with dilute HCl to separate carbonate of calcium and again ignited, gives a brick-red mass (oxide of cerium). Color, pitch-brown to greenish-black. Streak, greenish-gray. Hardness, 5.5–6 (orthaclase).

Lievrite (ilvaite). Intumesces slightly; decrepitates slightly and fuses easily to an iron black magnetic bead. Color brownish-black; streak, black. Hardness, between apatite and orthoclase.

Fayalite, $\mathrm{Fe_2SiO_4}$, and

Hortonolite, $(\mathrm{Fe,Mg})_2\mathrm{SiO_4}$. Crystalline and cleavable; gelatinize perfectly. Decomposed by phosphoric acid. The jelly of hortonolite turns immediately violet when treated with nitric acid.

The same deportment is exhibited by

Knebelite, $(Fe,Mn)_2SiO_4$, and

Röpperite, $(Fe,Mn,Zn,Mg)_2SiO_4$.

The latter gives, with soda on coal, a deposit of oxide of zinc.

Pyrosmalite, $((FeMn)Cl_2+7(Fe,Mn)SiO_3)+5Aq$, and

Astrophyllite, $(K,Na)_6(Fe,Mn)_{15}(\bar{\mathrm{F}}\mathrm{e},\bar{\mathrm{A}}\mathrm{l})_2(Si,Ti)_{16}O_{56}$, are decomposed by HCl, leaving a residue of silica without gelatinizing. B. B. they fuse easily at 2–2.5.

Pyrosmalite mixed with salt of phosphorus and oxide of copper tinges the flame bluish-green (chlorine). Astrophyllite does not.

Both distinctly cleavable in one direction; the latter often micaceous.

The hydrochloric acid solution of the latter when boiled with tin is colored violet, turning rose-red when diluted (titanic acid reaction).

Lepidomelane, $K_4Fe_2(\bar{\mathrm{A}}\mathrm{l},\bar{\mathrm{F}}\mathrm{e})_3Si_6O_{24}$. In small six-sided tables, or an aggregate of minute scales. Color, raven black. Streak, grayish-green. Decomposed easily by HCl, leaving a residue of silica in the form of scaly flakes.

Allochroite (iron-lime garnet, Eisenkalkgranat), $Ca_3\bar{\mathrm{F}}\mathrm{e}Si_3O_{12}$ in some varieties forms an imperfect jelly with conc. HCl. Not cleavable, easily fusible. Color, green, yellow to black.

Gillingite, $\ddot{\bar{\mathrm{F}}}\mathrm{e},\dot{\mathrm{F}}\mathrm{e},\dot{\mathrm{M}}\mathrm{g},\dot{\mathrm{C}}\mathrm{a},\dot{\mathrm{S}}\mathrm{i}$, Aq, and

Xylotile (Bergholz, Germ.), $\ddot{\bar{\mathrm{F}}}\mathrm{e},\dot{\mathrm{M}}\mathrm{g},\ddot{\mathrm{S}}\mathrm{i}$, Aq, are fusible with difficulty, and become magnetic only after long blowing. They are decomposed by muriatic acid without gelatinizing. The former is brownish-black; amorphous; the last is brown; fibrous, like wood. In a matrass both give water.*

---

* Many limonites (hydrated peroxide of iron, Thoneisenstein), $\ddot{\bar{\mathrm{F}}}\mathrm{e}_2\dot{\bar{\mathrm{H}}}_3$, fuse and become magnetic; they dissolve in concentrated muriatic acid with separation of clay. Streak, mostly ochre-yellow or brownish-red.

Section iv.—*Only slightly attacked by hydrochloric acid.*

CROCIDOLITE (Krokydolith, blue asbestos), $\dot{Fe}$, $\dot{Na}_2$, $\dot{Mg}$, $\dddot{Si}$, Aq.

ARFVEDSONITE (black hornblende), $\dot{Na}\dddot{Si}+\dot{Fe}_3\dddot{Si}_2$. $2(Na_2, Fe, Ca)SiO_3 + \bar{Fe}, Si_3O_9$.—B. B. fuse easily at from 1.7 to 2 with intumescence and frothing, to a black mass. In a matrass the second affords no water; is perfectly cleavable under 123° 55′. Color, black. Streak, grayish to green. Crocidolite in a matrass affords some water. Color, green to lavender-blue; has been noticed only in aggregated fibres.

(Compare *amphibole* and *tourmaline* (some varieties of which act feebly upon the magnet after fusion).)

GLAUCONITE. SELADONITE (green earth, Grünerde), $\dot{Fe}$, $\dot{Mg}$, $\dot{K}_2$, $\ddot{\bar{Al}}$, $\dddot{Si}$, Aq.—B. B. fuses at 3 quietly without intumescence. In a matrass yields some water. Color, olive to sea-green. Hardness 1.

ACMITE (Achmit), $(Na_6\,Fe_3\,\bar{Fe})\,Si_3\,O_9$, and

Babingtonite, $\ddot{\bar{Fe}}$,$\dot{Ca}$,$\dot{Fe}$,$\dot{Mn}$,$\dddot{Si}$, fuse quietly. Acmite at 2, babingtonite at 2.6 to a black glistening mass. Acmite is cleavable at an angle of about 93°. Babingtonite when fused with potassa and dissolved in muriatic acid gives with ammonia, or better with oxalate of ammonium, a heavy precipitate of lime; acmite gives none or only a very slight precipitate.

(Compare augite (black crystallized pyroxene).)

Almandite (Almandine garnet, Thoneisengranat), $\dot{Fe}_3\bar{Al}Si_3O_{12}$. B. B. fuses quietly at 3. Gelatinizes after fusion. Is not cleavable. Hardness, 7–7.5. Color, red, brown-red. Sp. gr. 3.7–4.

(Compare also allochroite (Eisenkalk-granat).)

Wolframite (Wolfram), $(Fe,Mn)WO_4$, and

Ferberite (of the same composition).*

Color, black. Streak, ochre-yellow. Lustre, submetallic. Boiled with conc. phosphoric acid give a blue liquid, which

---

* The ferberite of von Kobell is considered identical with wolframite. See Brush, Determ. Min., p. 78.

diluted with water becomes colorless. Upon addition of iron powder and shaking the solution turns fine blue again.

B. B. with soda and nitre on platinum foil give the bluish-green manganese reaction.

A similar deportment is shown by

Megabasite (Blumit), $(Mn,Fe)WO_4$. Color, brown. Streak, ochre-yellow.

Rhodonite (Mangankiesel), $MnSiO_3$. Color, rose-red, brownish-red. Lustre, vitreous.

B. B. some varieties become, after fusing, magnetic. Imparts a violet color to the borax bead.

Lepidolite (lithionite, Lithionglimmer), $(K,NaLi)_6\bar{A}l_4Si_{12}O_{39}$. After fusion frequently magnetic. Tinge the flame distinctly purple-red (lithia); eminently cleavable in one direction (micaceous).

(Compare Lepidomelane, $K_4Fe_2(\bar{A}l\bar{F}e)_3Si_6O_{24}$.)

Division 6.—*Not included in the foregoing divisions.*

Molybdite (Molybdänocker), MoO_3. B. B. on coal fuses, fumes, and is absorbed. By fusion with soda and elutriation of the coal we can obtain a steel-gray powder of reduced molybdenum. With salt of phosphorus in the reduction flame a dark glass is formed, which on cooling acquires a clear green. In muriatic acid it dissolves easily, the solution being colorless, but when stirred with tinfoil immediately assumes a blue color. Color, sulphur-yellow, inclining to orange.

Eulytite (Wismuthblende).

Silicate of bismuth, $Bi_4Si_3O_{12}$, and

Bismutite, $2Bi_8C_3O_{18} + 9H_2O$, B. B. fused with sulphur and iodide of potassium on charcoal give a fine red sublimate on the coal (bismuth).

Eulytite gelatinizes perfectly with HCl.

Bismutite dissolves with effervescence in it.

Pucherite, $BiVO_4$. B. B. reacts of bismuth like the preceding; gives with HCl a greenish-blue solution which, diluted with water, yields a yellow precipitate, whilst the filtrate has a sky-blue color. Color, reddish-brown. Streak, ochre-yellow.

(Compare *samarskite.*)

Also *allanite* in the preceding division, which after fusion is not always magnetic.

(Compare likewise *lepidomelane.*)

Part **B.**—B. B. FUSED WITH SODA ON COAL YIELD NO METALLIC GLOBULE, OR FUSED ALONE IN THE R. F. DO NOT ACT ON THE MAGNETIC NEEDLE.

Division 1.—*After fusion and continued ignition on coal in the forceps or the platinum spoon, give an alkaline reaction, turning moistened red litmus paper blue; and yellow turmeric paper, brown. The assay must be employed in splinters and not in powder form.**

Section i.—*In water easily and perfectly soluble.*

Nitrate of potassium (saltpetre), KNO_3.

Nitratine (nitrate of sodium, soda nitre), $NaNO_3$. B. B. heated gently on charcoal they deflagrate in a lively manner, which does not occur with those following. Fused on platinum wire, nitrate of potassium tinges the flame bluish, inclining to red. Nitrate of sodium colors it strongly yellow. In the solution of nitrate of potassium, chloride of platinum causes a yellow precipitate (potassa). In nitrate of sodium solution it occasions none.

Sodium carbonate, $Na_2CO_3 + 10Aq$.

Thermonatrite, $Na_2CO_3 + Aq$, and

Trona or *sesquicarbonate of sodium*, $Na_4C_3O_8 + 3Aq$.

B. B. in the closed glass tube give much water. Their solution in water is alkaline and effervesces on the addition of an

---

* Kenngott has shown that many silicates and other compounds react before, or only after fusion, *alkaline*, when they are placed in *powder* form upon moist turmeric paper, but not when in the shape of *splinters*. The above-mentioned minerals, however, exhibit an alkaline reaction even in *splinter* form.

acid. The crystals of the former soon deliquesce by exposure in the air. Sesquicarbonate of sodium does not.

Mirabilite (sulphate of sodium, Glauber's salt), $Na_2SO_4 + 10Aq$.

Thenardite (anhydrous sulphate of sodium), Na_2SO_4.

Aphthitalite (glaserite, sulphate of potassium), K_2SO_4.

*Epsomite** (sulphate of magnesium, Epsom salt), $MgSO_4 + 7Aq$.

Kalinite (sulphate of potassium and aluminium, potash alum), $K_2AlS_4O_{16} + 24Aq$. Their solution in water does not give an alkaline reaction or effervesce by the addition of an acid; chloride of barium causes a heavy precipitate of sulphate of barium which is insoluble in acids. In the solutions of alum and of *epsomite*, carbonate of potassium produces white precipitates. They are easily distinguished B. B., since the mass that remains after expulsion of the water and continued strong ignition, assumes, moistened with cobalt solution and heated again, in the former (alumina) a fine blue, in the latter a flesh-red color (magnesia). In the solutions of the other minerals alkalies cause no precipitates. A concentrated solution of glaserite yields a yellow precipitate with chloride of platinum, while the first two give none. In a matrass, mirabilite affords a large quantity of water, but thenardite gives none.

Tachhydrite, $CaMg_2Cl_6 + 12Aq = CaCl_2 + 2MgCl_2 + 12Aq$ (Rammelsb.). Gives in the closed tube much water. B. B. fuses at first on its surface when a non-fusible mass remains, which colors the flame finely red and reacts alkaline. In water easily and completely soluble. The solution reacts of lime and magnesia. Color, yellowish. Deliquescent.

---

* *Epsomite* contains 50 per cent. of water. Similar compounds are
Löweite, $2Na_2MgS_2O_8 + 5Aq$, and
Kieserite, $MgSO_4 + Aq$; both with 14 per cent. of Aq.
Blöedite, $Na_2MgS_2O_8 + 4Aq$, and
Simonyite, $Na_2MgS_2O_8 + 4Aq$; both with 21 per cent. of Aq.
Picromerite (kainite), $K_2MgS_2O_8 + 6Aq$.

The aqueous solution of the last yields with nitrate of silver a white precipitate of chloride of silver.

Carnallite, $KMgCl_3 + 6Aq = KCl + MgCl_2 + 6Aq$. B. B. fuses easily. After continued fusion on platinum foil, the remaining mass reacts alkaline. Soluble in water. Gives no reaction of lime, but of magnesia with phosphate of sodium; when free ammonia is present, a white, crystalline precipitate of ammonio-magnesium phosphate being formed. A solution of chloride of platinum indicates the presence of K_2O by furnishing a yellow, crystalline precipitate in moderately dilute solutions of the mineral.

HALITE (rocksalt, common salt, *chloride of sodium*), NaCl and *sylvite*, KCl. Are anhydrous, and easily recognized by their taste. The aqueous solution gives with chloride of barium and alkalies no precipitate; with nitrate of silver a curdy precipitate of chloride of silver. Chloride of platinum produces with the first, none; with the second, a yellow precipitate (K_2O). The solution shows no alkaline reaction.

BORAX (tinkal, *biborate of sodium*), $Na_2B_4O_7 + 10Aq$. The solution has an alkaline reaction, and does not effervesce with acids. After being treated with sulphuric acid and evaporated to dryness, if alcohol be added, it burns with a green flame (caused by boric acid). B. B. bubbles, swells up, and fuses to a clear bead.

Section ii.—*Insoluble in water, or dissolving with difficulty.*

ULEXITE* (*Borocalcite*, boronatrocalcite), $NaCaB_5O_9 + 5Aq$. Fuses at 1. Alone it tinges the flame yellow. Moistened with sulphuric acid imparts to it a beautiful green (boric acid). Yields much water in a matrass. Partially soluble in hot water. The solution is alkaline in its character. In muriatic acid easily and quietly soluble. The solution when evaporated leaves a residue which imparts to alcohol the property of burn-

---

* Von Kobell describes under the name of "borocalcite" a mineral, CaO, $2BO_3$ (*containing no sodium*), and a mineral "ulexite" of the above formula, both from southern Peru. According to J. D. Dana's Syst. of Mineralogy, 5th ed., p. 599, both minerals are alike, sodium being an essential constituent found in both. A. A. Hayes, who analyzed it, had *overlooked the sodium.*

ing with green color. The mineral is insoluble in sulphuric acid.* (Occurs in delicate, fibrous, felt-like masses.)

Gay-lussite (carbonate of calcium and sodium), $Na_2CO_3 + CaCO_3 + 5Aq$.

Witherite (carbonate of barium), $BaCO_3$, and

Staffelite, $Ca_3P_2O_8 + CaCO_3$. Are dissolved in dilute hydrochloric acid with effervescence. The acid solutions of gay-lussite and staffelite, largely diluted with water, give with sulphuric acid no precipitate; that of witherite an abundant deposit of sulphate of barium. In a matrass gay-lussite affords much water; *witherite* and *staffelite* none. The solution of staffelite in HCl gives with NH_3 a precipitate, the others do not. The HCl solution of staffelite yields with molybdate of ammonium at a gentle heat a yellow precipitate (phosphoric acid).

(Compare *strontianite*, which colors the flame purple (strontium).)

ANHYDRITE (anhydrous sulphate of calcium), $CaSO_4$.

GYPSUM (hydrated sulphate of calcium), $CaSO_4 + 2Aq$.

POLYHALITE (sulphate of potassium, calcium, and magnesium), $Ca_2MgK_2S_4O_{16} + 2Aq$.

BRONGNIARTINE (glauberite, sulphate of sodium and calcium), $Na_2CaS_2O_8$. Are quietly soluble in sufficient muriatic acid. The solution gives with chloride of barium a heavy precipitate of sulphate of barium, and with oxalate of ammonium, after being neutralized with caustic ammonia, it yields a precipitate of *oxalate of calcium*. In a matrass polyhalite yields some water; gypsum a large amount; the others only traces of water. *Polyhalite* and *brongniartine* are soluble in water with separation of sulphate of calcium. If a small quantity of these minerals is boiled with water, a solution is obtained, yielding a *slight precipitate* with oxalate of ammonium (lime), and after that is filtered off, phosphate of sodium, in the presence of free ammonia, throws down a heavy precipitate of *phosphate of ammonium-*

---

* Compare strassfurtite (boracite), $Mg_7B_{16}Cl_2O_{30}$. Soluble in sulphuric acid. Reacts alkaline after fusion, from an admixture of NaCl and $MgCl_2$.

magnesium in the filtrate of polyhallite, but none in that of *brongniartine* (glauberite). Their fusibility is 1.5.

In the solution of *polyhalite*, chloride of platinum gives a *yellow* precipitate (K_2O); in that of *brongniartine*, none.

Anhydrite and *gypsum* are only slightly soluble in water, and their fusibilities = 2.5–3. Hardness of *anhydrite* is 3.5, all the others are softer.

Closely related to brongniartine is—

Syngenite (kaluszite), $CaSO_4 + K_2SO_4 + Aq$, from Kalusz in Gallizien.

BARITE. *Heavy spar*, *sulphate of barium*, $BaSO_4$, and

Celestite (celestine, sulphate of strontium), $SrSO_4$. Are not, or but very little, attacked by HCl. When finely pulverized celestite is boiled with HCl enough is dissolved to form, upon the addition of chloride of barium, a slight precipitate of sulphate of barium. B. B. with soda yield hepar. Heated in the forceps, barite tinges the flame a pale yellowish-green; celestite a feeble purple-red. By moistening with a drop of HCl the particles which have been fused and long heated in the reduction flame, and then holding the mass in the blue portion of a candle flame (without blowing) it colors it purple-red, when the assay is celestite, but does not with *barite.*

FLUORITE (fluespath, Germ.), $CaFl_2$.

CRYOLITE (fluoride of sodium and aluminium, Kryolith), Na_6AlF_{12} (or $6NaF + AlF_6$).

PHARMACOLITE (arsenate of calcium), $\dot{C}a_2\overset{\cdot\cdot\cdot\cdot\cdot}{\bar{A}}s + 6\dot{\bar{H}}$. B. B. with soda do not give hepar. Do not effervesce with muriatic acid. Arsenate of calcium is easily distinguished by its alliaceous odor when fused on coal (the fragments used should be as large as possible). The other two heated in a glass tube with sulphuric acid give off much hydrofluoric acid gas, which strongly attacks the glass, the water which condenses at the upper end of the tube reacts for fluorine with Brazil-wood paper. Fusibility of liparite 3, of cryolite 1.* Phosphores-

---

* Fuses in the flame of a candle.

cence is obtained from the coarsely-powdered fluor-spar below a red heat. At a high temperature it ceases, but is partially restored by an electric discharge. Cleavage, octahedral.

Closely related with cryolite is—

Chiolite, Na_3AlF_9 (or $3NaF + AlF_6$), occurs in granular masses, while cryolite is found in large crystalline lumps, cleavable in three rectangular directions. Also related is—

Pachnolite (thomsenolite), $Na_2Ca_2AlF_{12} + 2Aq$. Heated in the closed tube yields water which has a strongly acid reaction. Similar compounds not containing water are—

Arksutite, $CaNa_2AlF_{10}$.

Chodneffite, Na_4AlF_{10}.

Others containing water are—

Thomsenolite.[*]

Gearksutite, $Ca_2AlF_{10} + 4Aq$ (19 p. c. water).

Cancrinite, $Na_2AlSi_2O_8$, effervesces with concentrated hydrochloric acid, and gelatinizes when heated with it. B. B. it turns white and turbid; fuses at 2.5 with intumescence, and foaming to a white, porous glass, which, when moistened and placed upon turmeric paper, reacts alkaline (brown). Related to nephelite (nepheline), $(NaK)_2AlSi_2O_8$.

Division 2.—*Soluble in hydrochloric acid; some also in water without perceptible residue; the solution does not form a gelatinous mass.*

(Compare from the preceding division those minerals which after fusion react only feebly alkaline, viz., *kieserite*, *kainite* (picromerite, Brush), *and epsomite.*)

---

[*] Prof. von Kobell in his tables, 11th edit., 1878, mentions "*pachnolite*" and "*thomsenolite*" under two heads as distinct minerals, while the chemical identity of *thomsenolite* and *pachnolite* was shown by the analyses of Knop and Wöhler to be merely varieties of one and the same species. Consult Textbook of Mineralogy, by E. J. Dana. New York, 1877, p. 243. Also, Brush's Manual of Determinative Mineralogy, 3d edit., 1878, p. 81, giving both names to the same mineral.

Durangite $\mathrm{(NaLi)_2(\dot{\bar{A}}l\bar{F}e\bar{M}n)As_4(O,F)_9}$. Fuses easily, with strong sulphuric acid it gives off hydrochloric acid, which corrodes glass. B. B. on charcoal evolves fumes of arsenic. Color, orange-red. Streak, yellowish.

Chondroarsenite, $\mathrm{Mn_6As_2O_{11} + 3Aq}$.

Trögerite, $\mathrm{U_3As_2O_{14} + 12Aq}$, and

Walpurgite (Walpurgin), $\mathrm{Bi_{10}U_3As_4O_{34} + 12Aq}$. All have a yellow color, and B. B. on charcoal develop arsenical fumes. Chondroarsenite colors a bead of salt of phosphorus amethystine (oxide of manganese); the others color it green. Walpurgite with $\mathrm{S + KI}$ fused together gives a red sublimate on charcoal (iodide of bismuth).

Adamite (Adamin, Germ.), $\mathrm{Zn_4As_2O_9 + Aq}$. B. B. easily fusible. On charcoal evolves arsenical fumes, giving at the same time a zinc coating. Color, honey-yellow.

Fauserite $\mathrm{(Mn, Mg)\,SO_4 + Aq}$. Soluble in water. Heated with $\mathrm{P_2O_5}$ and $\mathrm{HNO_3}$, forms a violet solution. B. B. colors the borax bead violet when hot (oxide of manganese). Contains 40 p. c. of water.

Tschermigite (ammonia-alum) $\mathrm{(\dot{N}H)_2\bar{A}lS_4O_{16}+24Aq}$.

Keramohalite (alunogen), $\mathrm{\bar{A}lS_3O_{12} + 18Aq}$, and

Goslarite (sulphate of zinc), $\mathrm{ZnSO_2+7H_2O}$. Fuse when first heated, puff up, and form an infusible mass, which, moistened with cobalt solution and again heated, assumes a fine blue color when it is tschermigite and alunogen, but a green color when it is sulphate of zinc. With soda they give hepar, and are soluble in water. Tschermigite evolves ammonia vapor when treated with caustic potash solution, alunogen does not.

Struvite, $\mathrm{NH_4MgPO_4 + 12Aq}$. Fuses easily. Gives much water in a matrass, but with soda no hepar; evolves when treated in powder form with caustic potash (KHO) or soda (NaHO)* the odor of ammonia, and forming white fumes when any volatile acid as HCl is brought in contact with it. This

---

* Caustic lime ($\mathrm{CaH_2O_2}$) may also be employed; in that case, however, it must be in the solid state, not in solution.

experiment is best performed by inserting a glass rod moistened with HCl into the mouth of a test-tube in which the decomposition of the ammonium salt is being effected, and immediately withdrawing it. The HCl employed should not be concentrated, but should be diluted with an equal volume of water. The presence of vapor of free ammonia may be recognized by turning red litmus paper blue.

Sassolite (boron trioxide, boric acid), $H_6B_2O_6$.

Boracite (borate of magnesium), $Mg_7B_{16}Cl_2O_{30}$, and

Stassfurthite, $2Mg_3B_8O_{15} + MgCl_2$.*

Hydroboracite (hydroborate of calcium and magnesium), $CaMgB_6\,O_{11} + 6Aq$.

Larderellite,† $NH_4O\dddot{B}_4 + 4H_2O$.

Sussexite $(Mn,Mg)_2B_2O_5 + H_2O$. Fuse easily with intumescence and color (except stassfurthite)† the flame green (boric acid). When the powdered minerals are heated with sulphuric acid, then alcohol added and set on fire, the flame is tinged intensely green (boric acid). Larderellite evolves, when treated in powder form with caustic potash or soda-solution, the odor and test of ammonia. Sussexite is easily distinguished from the others, that it yields a violet liquid when boiled with phosphoric acid and nitric acid (manganese).

B. B. Boracite gives none or only traces of water, whilst the others yield water abundantly. Sassolite is soluble in water and alcohol; the others are not. Hydroboracite contains 26 per cent. of water, while the similar mineral szaibelyite, $Mg_5B_4O_{11} + 3Aq$, contains only 7 per cent. of water. Very closely related to boracite is stassfurthite,‡ and similar to hydroboracite is

---

* Prof. v. Kobell mentions boracite and stassfurthite as two distinct minerals, although of an identical chemical composition; while Profs. Dana and Brush consider both under one head, "boracite."

† J. D. Dana's Syst. of Min., fifth edit., p. 600; also Am. Journ. Sci., ii. xvii. 130. A rare borate from the Tuscan lagoons. Analysis by E. Bechi.

‡ Constitutes only a *variety of boracite*, as already stated.

Lüneburgite, $Mg_3P_2B_2O_{11} + 8Aq$. It yields, however, in a nitric acid solution with molybdate of ammonium a yellow precipitate (P_2O_5), which is not the case with the others.

(Compare: *Tinkal*, $NaO,B_2O_3 + 10Aq$.)

Alabandite (alabandine) MnS, and

Hauerite, MnS_2. When boiled with phosphoric acid and nitric acid is added, violet solutions are produced. The roasted minerals give, with borax, a violet bead in O. F. (manganese). The powder of alabandite is leek-green, that of hauerite brownish-red.

(Compare: I. A. 5.)

Wagnerite, $Mg_3P_2O_8 + MgF_2$.

Apatite, $3Ca_3P_2O_8 + Ca(Cl,F)_2$, and

Kjerulfine, $2Mg_3P_2O_8 + CaF_2$.

B. B. Apatite fuses quietly at 5. Wagnerite and kjerulfine with bubbling at 3–3.5. Kjerulfine in the closed tube phosphoresces with a faint white light. Moistened with strong sulphuric acid all color the flame bluish-green. The nitric acid solutions give with molybdate of ammonium a yellow precipitate (phospho-molybdate of ammonium). Wagnerite is soluble in dilute sulphuric acid. Apatite is not. Kjerulfine is with separation of sulphate of calcium. The solution of the latter, in somewhat concentrated HCl, yields with sulphuric acid at once a heavy precipitate of gypsum. Wagnerite gives none, or furnishes one only after a lapse of time.

Brushite, $HCaPO_4 + 2Aq$. Reacts like apatite in the wet way, but gives much water in the closed tube (26 per cent.).

Likewise:

Isoclasite, $Ca_4P_2O_9 + 5Aq$, with 18 per cent. of water.

Amblygonite, $2AlP_2O_8 + 3(Li,Na)F$. Fuses easily at 2, coloring the flame purple-red (lithia). Soluble with difficulty in conc. HCl and H_2SO_4; with the latter evolves hydrofluoric acid, also when fused with bisulphate of potassium. The nitric acid solution gives a yellow precipitate with molybdate of ammonium (P_2O_5).

A closely related mineral is

Hebronite, with 4 per cent. of water give a pure lithia flame. Both are cleavable at an angle of 105°. Hardness, 6. Phosphoresce with a light-blue color.

Autunite (*uranite*, Kalk-Uranit, Germ.), $CaU_2P_2O_{12}+10Aq$, or $2(UO_2)_3P_2O_8+Ca_3P_2O_5+30$ Aq. B. B. fuses easily in the closed tube, and, with salt of phosphorus in O. F., a yellow glass, which in R. F. turns handsomely green. The solutions in HCl and HNO_3 have a yellow color, and yield with ammonia a yellow precipitate. Give like amblygonite the phosphoric acid reaction with molybdate of ammonium.

(Compare chalcolite (phosphate of uranium and copper).)

Division 3.—*Are entirely soluble in muriatic acid, forming a stiff jelly upon partial evaporation.*

Section i.—*B. B. in a matrass afford water.*

DATOLITE (Datolith, borosilicate of calcium), $H_2Ca_2B_2Si_2O_{10}$. In a matrass gives but little water (the others much water); fuses to a dense, clear, and mostly colorless bead, tinging the flame green. Gives the boric acid reaction likewise with sulphuric acid and alcohol, the latter burning with a green flame when set on fire. Prismatic cleavage perfect.

EDINGTONITE, $Ba\dot{\text{Ⱥ}}lSi_3O_{10}+3Aq$. The diluted hydrochloric acid solution produces, with sulphuric acid, a white precipitate of sulphate of barium. Sp. gr. 2.7.

NATROLITE (mesotype). B. B. fuses at 2, quietly without any perceptible intumescence. The HCl solution yields, after the alumina has been thrown down by caustic ammonia, no precipitate, or a very slight one, by carbonate of ammonium. Loss by ignition 9 p. c. (Compare analcime.)

Scolecite (Skolezit, Germ.), $Ca\dot{\text{Ⱥ}}lSi_3O_{10}+3Aq$, and *laumontite*, $Ca\dot{\text{Ⱥ}}lSi_4O_{12}+4Aq$. B. B. curl up in worm-like forms on fusion, especially scolecite, which, in the O. F., gives a voluminous, frothy, shining slag, that, in the R. F., fuses further into a vesicular slightly transparent glass. Laumontite fuses, emitting few air-bubbles, to a white translucent enamel.

H. of scolecite, 5.5; of laumontite, 3. Scolecite becomes electric on heating. Closely related to scolecite are:—

Mesolite $(\text{Ca},\text{Na}_2)\bar{\text{A}}\text{lSi}_3\text{O}_{10}+3\text{Aq}$, and *thomsonite* (*comptonite*), $2(\text{Ca},\text{Na}_2)\bar{\text{A}}\text{lSi}_2\text{O}_8+5\text{Aq}$, but neither of them is pyro-electrical.

PHILLIPSITE (lime harmotome) $(\text{Ca},\text{K}_2)\bar{\text{A}}\text{lSi}_2\text{O}_8+5\text{Aq}$. Fuses at 3, with slight intumescence; many varieties fall to powder like arragonite; occurs crystallized only in rectangular prisms, terminated with rhombic pyramids, and generally in twins, one individual being united to another by a common main axis at 90°.

Here belong also—

Gismondite $(\text{Ca},\text{K}_2)\bar{\text{A}}\text{lSi}_3\text{O}_{10}+4\,\text{Aq}$. Usually has the appearance of the square octahedron. Fuses at 3 with slight intumescence.

Ittnerite, $\dddot{\bar{\text{A}}}\text{l},\dot{\text{C}}\text{a},\dot{\text{N}}\text{a}_2,\dot{\text{H}}_2,\dddot{\text{S}},\dddot{\text{S}}\text{i}$. Fuses with intumescence. In the HCl solution, chloride of barium produces a slight precipitate (BaSO_4).

(Compare also the following division, *apophillite*, *okenite*, and *analcime*, which are decomposed by muriatic acid to a gelatinous mass, but not to a thick jelly.)

Section ii.—*B. B. in a matrass give none, or only traces of water.*

(Compare *datolite*, of the preceding division.)

TEPHROITE (mangan-chrysolite), Mn_2SiO_4.

HELVITE (*Helvin*), $3(\text{Be},\text{Mn},\text{Fe})_2\text{SiO}_4+(\text{Mn},\text{Fe})\text{S}$. Boiled with P_2O_5, with addition of HNO_3, both give a violet solution.

B. B. in the oxidizing flame impart to a borax bead an amethystine hue. *Helvite* evolves, with muriatic acid, sulphuretted hydrogen. *Tephroite* does not. Tephroite is cleavable at right angles (in one direction perfectly), the other not. Color of helvite is honey-yellow, wax-yellow; of tephroite, reddish-brown, grayish.

Closely related with helvite is—

Danalite, $3(\text{Be},\text{Mn},\text{Fe},\text{Zn})_2\text{SiO}_4+(\text{Fe},\text{Mn},\text{Zn})\text{S}$. This mineral, containing zinc, gives B. B. a slight coating of zinc.

With soda on charcoal and with borax the iron reaction. Heated with HCl evolves H_2S. Color, flesh-red, gray.

HAUYNITE (HAUYNE), $2(Na_2Ca)\bar{A}lSi_2O_8+(Na_2Ca)SO_4$. LAPIS-LAZULI, and LASURSTEIN (ultramarine) of similar composition, are of sky-blue and azure-blue color. Haüynite fuses with difficulty at 4.5; lapis-lazuli easily at 3; both to a white glass. B. B. both yield with soda upon coal hepar, with characteristic brownish-red spots.

Nosite (*Nosean*, *Nosin*), a soda haüynite, $2Na_2+\bar{A}lSiO_8+Na_2SO_4$, and

Scolopsite (*Skolopsite*), $\ddot{\bar{A}}l, \dot{C}a, \dot{N}a_2, \dddot{S}, Cl, \ddot{S}i, \bar{H}_2$. Color, grayish or brownish. Nosite melts at 4.5; skolopsite at 3, with foaming and spirting. The hydrochloric acid solutions of both yield, with chloride of barium, a white precipitate of sulphate of barium. Nosite occurs mostly in rhombic dodecahedrons; skolopsite massive with splintery fracture.

SODALITE (Sodalith), $3Na_2\bar{A}lSi_2O_8+2NaCl$, and

EUDIALYTE (*eucolite*), $6Na_2(Ca,Fe)_2(Si,Zr)_6O_{15} + NaCl$. B. B. heated with a flux of phosphorus salt and oxide of copper give the reaction of chlorine, by imparting to the flame a transient blue color. The solution in nitric acid gives with nitrate of silver a curdy precipitate of chloride of silver. The diluted HCl solution of *eudialyte* colors turmeric paper orange (reaction for zirconia). When the solution is boiled down sulphate of potassium to crystallization, and this mass boiled with water, the solution is rendered turbid from precipitated zirconia. Sodalite fuses B. B. to a clear, colorless bead. Eudialyte to an opaque pistachio-green glass. Spec. grav. of sodalite, 2.3; of eudialyte, 2.9.

Wollastonite (tabular spar), $CaSiO_2$. B. B. fuses to a colorless semi-transparent bead. After separation of the silica from its muriatic acid solution, it gives with ammonia none, or only a slight precipitate; with carbonate of ammonium an abundant precipitate of carbonate of calcium. (Compare pectolite (Pektolith), $HNaCa_2Si_3O_9$).

Nephelite (elaeolite, Davyne), $(Na,K)_2\bar{A}lSi_2O_8$.

Meionite (Mejonit), $Ca_6\cancel{A}l_4Si_9O_{36}$, and

Melilite (Humboldtilite), $(Na_2Ca,Mg)_{12}(\cancel{A}l,Fe)_2Si_9O_{36}$.

In the HCl solution of these minerals, after separation of the silica, ammonia gives a precipitate (Fe_2O_3 and Al_2O_3). Meionite fuses, with intumescence and evolution of light, to a vesicular glass, which cannot be perfectly rounded by fusion. The others fuse quietly without intumescence. The solution of nephelite gives, after separation of alumina by NH_3 and filtration with oxalate of ammonium, none or a slight precipitate. That of melilite a heavy precipitate (lime). The decomposed nephelite, when containing lime, reacts alkaline after fusion. Melilite does not. (Compare cancrinite.) Nephelite crystallizes hexagonal. Melolite in the tetragonal (dimetric) system. A variety of nephelite (elæolite) has a fatty lustre.

A similar deportment to melilite is shown by

*Barsowite** (variety anorthite), $Ca\cancel{A}lSi_2O_8$. B. B. fuses at 4, Melilite at 3; the latter with some intumescence, the former quietly.

(Compare *gehlenite*, $Ca_3(\cancel{A}l\cancel{F}e)Si_2O_{10}$. Fusible in very thin splinters; does not swell. Also

Tachylite, $\dot{Fe},\dot{Mg},\dot{Ca},\dot{Na}_2,\ddot{\cancel{A}l},\ddot{Si},\dot{H}_2$.)

Division 4.—*Dissolve in hydrochloric acid, the silicic acid separating without forming a perfect jelly.*

(Many must be finely pulverized before being treated with concentrated acid.)

Section i.—*B. B. in a matrass afford water.*

Klipsteinite, $\ddot{\cancel{M}n}_3\dot{Mn},\ddot{Si}_2\dot{H}_2$. Treated with HCl, evolves chlorine, and silica separates as a slimy powder. With conc. phosphoric acid it yields a violet solution. Gives 9 per cent. of water on ignition. B. B. with borax gives the amethystine color of manganese.

---

* Brush (Manual of Determinative Mineralogy, pp. 84 and 86) considers amorthite to be a variety of barsowite, both having an identical composition. (Compare also Dana's Syst. of Mineralogy, p. 340.)

Apophyllite, $4(H_2CaSi_2O_6+Aq)+KF$.

Pectolite (Pektolith), $HNaCa_2Si_3O_9$, and

Okenite, $H_2CaSi_2O_6+Aq$.

Easily decomposed by HCl, the silica separating in gelatinous lumps, without forming a stiff jelly. After the separation of the silica[*] the solution gives (with an excess of HCl) with ammonia no, or only a slight, precipitate. Pectolite fuses B. B. with slight intumescence to a white enamel, like glass. Yields but little water (4 per cent.). After fusion gelatinizes perfectly with HCl. The others yield much water. Apophyllite 16 per cent., okenite 17 per cent. After fusion are but slightly attacked by HCl. Apophyllite fuses at 1.5 to a vesicular white glass. Okenite at 2.5–3, with frothing to a porcelain-like mass.[†]

(Compare *xonaltite*, $4CaSiO_3+H_2O$.)

Analcite (Analcime), $Na_2AlSi_4O_{12}+2Aq$, like the preceding, is decomposed by HCl to a gelatinous mass, but after separation of the silicic acid, the solution gives, with ammonia, a copious precipitate of alumina. B. B. the first action of the flame renders it white and turbid, but when fusion takes place it becomes clear, like water, and gives, without intumescence, a shining glass. It is usually found crystallized in cubes and trapezohedrons. Not cleavable. 8 per cent. of water.

Pyrosclerite (Pyrosklerit), $Mg_{12}Al_2Si_9O_{36}+12Aq$.

Chonicrite (Chonikrit), $(Ca,Mg)_{10}Al_2Si_7O_{30}+6Aq$, and

Jollyte $(Fe,Mg)_6Al_4Si_9O_{36}+12Aq$, are readily distinguished from the preceding, and following, by their lower degree of hardness, which is equal to that of calc-spar (=3). B. B. chonicrite fuses at 3.5 to 4, with escape of bubbles; pyrosclerite at 4 without bubbles; pyrosclerite is perfectly cleavable in one direction; color, green; 11 per cent. of water. Chonicrite is not cleavable; white-yellow; 9 per cent. of water. Jolyte swells up, fuses with difficulty, is amorphous; color, brown; streak, light-green;

---

[*] In order to separate all the silica completely, the solution in HCl must be evaporated to dryness in a porcelain dish, again digested (moistened) with some HCl, then water added and filtered.

[†] Compare *sepiolite* (*meerschaum*, sea foam), $Mg_2Si_3O_8+2Aq$.

water, 13 per cent. The following have a similar composition to pyrosclerite:

Vermiculite $(Mg,Fe)_{12}\cancel{A}l_2Si_9O_{36}+12Aq$, and

Jefferisite, $Mg_4(\cancel{A}l\cancel{F}e)_2Si_5O_{20}+6Aq$, which B. B. swell up exceedingly. The first exfoliates in wormlike masses, the second swells up prodigiously.

Mosandrite, $\dot{C}e,\dot{L}a,\dot{D}i,\dot{C}a,\dot{N}a_2,\ddot{T}i,\dddot{S}i,\dot{H}_2$, and

Catapleiite (*Katapleït*), $(Na_2,Ca)(Si,Zr)_4O_9+2Aq$. Have a hardness of 4–4.5, and exhibit cleavage. The former fuses at first with frothing, and then quietly at 2.5–3 to a yellowish-brown glass. The second quietly at 3 to a white porcelain-like bead. The diluted HCl solution of catapleiite colors yellow turmeric paper orange, and furnishes a precipitate of zirconia ($\cancel{Z}r$) when boiled down with sulphate of potassium. The boiling down must be carried on nearly to dryness, and the mass again treated (dissolved) with water. Mosandrite shows no such deportment.* They contain 9 per cent. of water.

Brewstrite, $(Sr,Ba)\cancel{A}lSi_6O_{16}+5Aq$. B. B. fuses at 3 with frothing and swelling. May easily be distinguished from similar minerals by its solution in muriatic acid, giving with sulphuric acid a heavy precipitate of sulphate of barium which is insoluble in acids. Contains 13 per cent. of water.

Stilbite, $(Ca,Na_2)\cancel{A}lSi_6O_{16}+6Aq$.

Hipostilbite (desmine), $(Ca,Na_2)_2\cancel{A}l_2Si_9O_{26}+12Aq$.

Chabazite (chabasite), $(HK_2Ca)\cancel{A}lSi_5O_{15}+6Aq$.

Prehnite, $H_2Ca\cancel{A}lSi_3O_{12}$. B. B. swell up more or less, and fuse, curling up to an enamel-like mass.† Prehnite yields but little water (4.3 per cent.). The others give in a bolthead much water, losing by ignition 15 to 20 per cent. Chabasite

---

* The titanium in mosandrite is recognized by boiling of the muriatic acid solution with tin-foil; it may contain so little that the liquid thus obtained turns merely reddish.

† Von Kobell states that, although operating with perfectly normal crystals of stilbite and hypostilbite, he could never verify a difference in the point of fusion between the two minerals, while according to Fischer desmine fuses to a vesicular glass.

is distinguished by its rhombohedral crystallization and imperfect cleavage. Stilbite and hypostilbite are perfectly cleavable in one direction.

Stilbite crystallizes in the monoclinic (Dana), hypostilbite in the trimetric system. A similar, small hemispherical, reniform or cylindrical fibrous mineral is

Mordenite $(\mathrm{Ca,Na_2})\cancel{\mathrm{Al}}\mathrm{Si_9O_{22}} + 6\,\mathrm{Aq}$. The mineral yields 12 per cent. of water. B. B. fuses without intumescence.

Sepiolite (meerschaum, sea-foam) $= [\dot{\mathrm{M}}\mathrm{g}\ddot{\mathrm{S}}\mathrm{i}+\dot{\cancel{\mathrm{H}}}]$ (Dana), is distinguished from the above by being difficult to fuse, and by absorbing moisture with avidity.

Deweylite (gymnite), $\mathrm{Mg_4Si_3O_{10}} + 5\,\mathrm{Aq}$, melts with difficulty at 5; is amorphous, of a waxy lustre, and resembles somewhat gum-arabic. Absorbs no water. Contains 20 per cent. of water.

Sordavalite (Sordawalit), $\ddot{\mathrm{S}}\mathrm{i},\ddot{\cancel{\mathrm{A}}}\mathrm{l},\dot{\mathrm{F}}\mathrm{e},\dot{\mathrm{M}}\mathrm{g},\dot{\cancel{\mathrm{H}}}_2$. Amorphous, fuses at 2.5 quietly to a dense, black, shiny glass. With difficulty decomposed with hydrochloric acid. The solution yields, with caustic ammonia, a heavy greenish-gray precipitate. Color, grayish-black; streak, liver-brown. Contains 4 per cent. of water.

Section ii.—*B. B. in a matrass yield no water, or only a trace.*

(Compare pectolite, chronicrite, and prehnite of the preceding section.)

Some specimens of *Lapis-Lazuli* (Lasurstein) afford no complete jelly, but may be easily recognized by their sky-blue color. B. B. with soda on charcoal yield hepar in characteristic brownish-red spots.

Cryophyllite (Kryophyllit), $(\mathrm{K,Li})_{12}\mathrm{Fe_3}(\cancel{\mathrm{Al}},\cancel{\mathrm{Fe}})_4\mathrm{Si_{21}O_{63}}$. Micaceous; also, scaly, massive. Color, by transmitted light, dull emerald-green; transverse to the axis, brownish-red. Fuses easily in the candle flame, and B. B. with intumescence to a gray enamel, giving a red *lithia flame*.

Tachylite, $\dot{\mathrm{F}}\mathrm{e},\dot{\mathrm{M}}\mathrm{g},\dot{\mathrm{C}}\mathrm{a},\dot{\mathrm{N}}\mathrm{a}_2,\ddot{\cancel{\mathrm{A}}}\mathrm{l},\ddot{\mathrm{S}}\mathrm{i},\dot{\cancel{\mathrm{H}}}_2$. Amorphous. B. B. fuses at 2.5 easily and quietly to a black, shining glass. Muriatic acid decomposes the mineral with separation of gelatinous silica. The solution boiled down with tin-foil does not assume a violet color.

Schorlomite, $\mathrm{Ca_9\bar{F}e_2(Si,Ti)_{12}O_{39}}$, and *Tscheffkinite* (*Tscherokinite*), $\mathrm{\dot{C}e,\dot{F}e,\dot{C}a,\ddot{\bar{T}}i,\dddot{S}i}$. The first fuses quietly, the second with much effervescence, at 3–4, to a black glass or a gray mass. Schorlomite is decomposed by HCl with some difficulty, leaving the silica behind as a slimy powder. The HCl solution of both, when evaporated with addition of tin-foil, assumes a violet color, turning to a rose-red by dilution with water (titanic acid). Tscheffkinite is easily decomposed by conc. HCl, the silica separating in gelatinous lumps. Both are *black*, with a vitreous lustre on a fresh fracture. Streak-powder, gray.

A similar behavior to schorlomite is exhibited by ivaarite, both of which ought perhaps to be united.

Wernerite (scapolite*), $\mathrm{(Ca,Na_2,K_2)\ddot{\bar{A}}lSi_2O_8}$.

Porcellanite† (porcelain-spar), $\mathrm{\dddot{S}i,\ddot{\bar{A}}l,\dot{C}a,\dot{N}a_2}$, 1, fuse B. B. at 2.5 with intumescence and emission of light, forming a white blebby glass which is not easily rounded. They are distinctly cleavable in two right angular directions.

To *wernerite* belong, according to v. Kobell, *nuttalite*, *glaucolite*, *stroganowite*.

Wöhlerite, $\mathrm{\dot{C}a,\dot{N}a_2,\ddot{Z}r,\overset{\cdot\cdot}{\ddot{C}}b,\dddot{S}i}$, B. B. easily fusible at 3 to a light-green, much blistered glass. HCl dissolves it with separation of silicic acid in flakes. This solution boiled down with tin-foil assumes at last a fine blue color; after a slight dilution with water a blue filtrate is obtained, which turns yellow turmeric paper orange. Color, wine-yellow to honey-yellow.

Eukolite probably belongs here.

Labradorite, $\mathrm{(Ca,Na_2)\bar{A}lSi_3O_{10}}$, and

Anorthite, $\mathrm{Ca\bar{A}lSi_2O_8}$. B. B. fuse quietly at 3–4 to a tolerably dense, clear glass. Labradorite is cleavable unequally in two

---

* See Brush's Manual of Det. Min., 3d edit., p. 86; also E. S. Dana's Textbook of Min., p. 294.

† Ekebergite, scapolite, wernerite, porcellanite (v. Kob.), Syn. under wernerite. See Dana's Syst. of Min., 5th edit., p. 324.

directions at an angle of 86° 40′; on the perfect faces of cleavage slight striæ are visible; on the less perfect, none. Shows frequently a play of colors, from blue to green, also red and yellow. Anorthite is perfectly cleavable at 85° 48′.

Labradorite is not completely decomposed by HCl.

Grossularite, or lime-alumina-garnet. The general formula of garnet is $R_3AlSi_3O_{12}$, and grossularite is usually $Ca_3AlSi_3O_{12}$. Many varieties are in a great measure decomposed by concentrated *muriatic* acid. B. B. fuse quietly at 3, and are readily distinguished from the above by want of cleavage. Many varieties of sphene are also decomposed by concentrated acid with separation of silicic acid. The solution boiled with metallic tin assumes a violet color.

See danburite, which colors the blowpipe flame beautifully green. Compare tephroite, which imparts to a borax bead an amethystine color (manganese oxide).

Division 5.—*Are only slightly attacked by hydrochloric acid, and B. B. impart to borax glass the deep amethystine color of manganese.*

They yield, when boiled down with phosphoric acid to a syrupy consistency, a mass which, with piemontite, assumes directly a violet color; with the others, only after stirring with a glass rod previously dipped into *nitric acid.*

Carpholite (Karpholit), $H_4Mn\,(Al,Fe,Mn)\,Si_2O_{10}$ and *Ardennite.** Analysis, $SiO_2 = 29.60$, $AlO_3 = 23.50$, $MnO = 25.88$, $FeO_3 = 1.86$, $CaO = 1.68$, $MgO = 3.38$, $V_2O_5 = 9.20$, ign. $4.04 = 99.09$.

In the closed tube yield water, the first contains 11 p. c. the second 5 p. c. of water. Carpholite fuses at 2.5–3; ardennite, at 2. Carpholite is fibrous; color, straw-yellow. Ardennite, radiated. Locality, Ottrez, in the Ardennes, Belgium. Analyses by Lasaulx and Bettendorf. Color, brownish-yellow.

Spessartite (Spessartin), manganese garnet, $(Mn,Fe)_3AlSi_3O_{12}$.

---

* E. S. Dana's Textbook of Min., page 288.

B. B. fuses quietly at 3. Cleavage indistinct, sometimes dodecahedral. Color, brownish-red.

Piedmontite (Piemontit), manganese epidote, $H_2Ca_4(Mn,Fe,Al)_3Si_6O_{26}$. B. B. fuses with intumescence at 2–2.5. In one direction the cleavage is distinct; less so in another. Color, cherry-red, reddish black.

Rhodonite (Rother Mangankiesel), $MnSiO_3$, fuses quietly at 3; distinctly cleavable at 92° 55′. Color, rose-red, peach-blossom red.

*Richterite** (Manganamphibol), which resembles it, cleaves at 124°.

Division 6.—*Not included in the preceding divisions. The remaining minerals are all silicates, except scheelite, which are not attacked, or are imperfectly decomposed by hydrochloric acid.*

(Compare pyrophyllite, B. B. swelling up and becoming partially rounded.)

DANBURITE,† $CaB_2Si_2O_8$. B. B easily fuses at 3 to a bead which is clear while hot; opaque when cold. It tinges the flame green. Boiled with sulphuric acid to dryness the residue imparts to burning alcohol a green color.

Very closely related is

Howlite, $Ca_4B_5Si_2O_{23} + 5Aq$.

SCHEELITE (tungstate of calcium), $CaWO_4$. B. B. fuses with difficulty at 5. The powder dissolves in HCl, leaving a greenish-yellow or lemon-yellow residue of tungstic acid, soluble in caustic ammonia. If this residue, while yet moist,

---

* Brush and E. S. Dana call this mineral *pyroxene*, including many varieties, from the colorless *diopside* and *white malacolite* to black augite; light-colored varieties fuse to a white glass, while the dark ones give a black glass.

† I was the first who discovered the presence of boracic acid in danburite, at that time a very rare mineral, but, owing to impurities, gangue, etc., my analysis proved not entirely correct. To Prof. Brush chiefly, belongs the honor of setting matters right, and establishing the above formula.—H. E.

be rubbed with a knife blade on paper, it at once changes to a green or bluish-green color. If the solution is boiled down with phosphoric acid until volatilization begins, the cold mass becomes blue; dissolved in water, the color disappears, but reappears permanently upon the addition of iron powder.

Lepidolite (lithia mica, *Lithionglimmer*, Germ.), $(\mathrm{K,Li})_6$, $\bar{\mathrm{A}}\mathrm{l}_4\mathrm{Si}_{12}\mathrm{O}_{42}$, and

Cookeite, $\dot{\mathrm{K}}_2, \dot{\mathrm{L}}\mathrm{i}_2, \ddot{\bar{\mathrm{A}}}\mathrm{l}, \ddot{\mathrm{S}}\mathrm{i}, \dot{\mathrm{H}}_2$. Are micaceous. Cleavage in one direction very perfect. Give to the blowpipe flame the purple-red color of lithia. Lepidolite fuses at 2. Gives in the closed tube little or no water. B. B. cookeite exfoliates, vermicular, and gives much water.

*Thermophyllite** (serpentine), $\mathrm{Mg_3Si_2O_7} + 2\mathrm{Aq}$.

Euphyllite $(\ddot{\bar{\mathrm{A}}}\mathrm{l}, \dot{\mathrm{K}}_2, \dot{\mathrm{N}}\mathrm{a}_2. \ddot{\mathrm{S}}\mathrm{i}, \dot{\mathrm{H}}_2)$, and

Margarite, emerylite, $\mathrm{H_2Ca}\bar{\mathrm{A}}\mathrm{l_2Si_2Q_{12}}$. Are, like the preceding, micaceous.

Thermophyllite. B. B. swells up and gives much water in the closed tube (11 p. c.). The others fuse without swelling at 4–4.5, and give little water. Their laminæ are not elastic. Euphyllite is easily decomposed by sulphuric acid. Margarite with difficulty. Compare

Muscovite, $\mathrm{K_2}\bar{\mathrm{A}}\mathrm{lSi_2O_8}$, and

Biotite, $\mathrm{K_2(Fe,Mg)_7}\bar{\mathrm{A}}\mathrm{l_2Si_7O_{28}}$.

Gümbelite, $\ddot{\bar{\mathrm{A}}}\mathrm{l}, \dot{\mathrm{K}}_2, \ddot{\mathrm{S}}\mathrm{i}, \dot{\mathrm{H}}_2$. Occurs in thin, short, fibrous layers. B. B. swells up to a fan-like mass, fuses in thin fibres, and yields water in the closed tube (7 p. c.). Color, green-white. Not attacked by HCl and $\mathrm{H_2SO_4}$.

Petalite $(\mathrm{Li_6}\bar{\mathrm{A}}\mathrm{l})\mathrm{Si_6O_{15}}$, and

Spodumene (*Triphane*) $(\mathrm{Li_6}\bar{\mathrm{A}}\mathrm{l})\mathrm{Si_3O_9}$. Do not exhibit the ready and perfect cleavage of the preceding, and their hardness is 6.5; give to the blowpipe flame the purple-red color of lithia, especially so when the assay held in the forceps is fused together with some bisulphate of potassium. This reaction is rendered more perceptible by taking in the forceps a piece of the mineral

---

* Identical with serpentine, see Brush's Determ. Min., p. 87.

and fusing on it bisulphate of potassium, which is repeated several times; during the blowing the bead is gently moved through the flame. It then shows occasionally purple-red streaks. Petalite fuses quietly to a white enamel.

Spodumene intumesces, throwing out fine branches, which fuse to a clear transparent glass. Specific gravity of petalite $= 2.45$, that of spodumene $= 3.2$. To petalite belongs the variety called

Castor (Kastor), which distinctly colors the blowpipe flame red.

Leucophanite (Leucophan), $4NaF + 3(Ca,Be)_4Si_3O_{10}$, fuses quietly at below 3 to a transparent colorless glass; with salt of phosphorus in the open tube gives the fluorine reaction. Phosphoresces when heated, or when struck with a hammer, emitting a reddish-violet light. Cleavage in one direction excellent. H. $= 3.5$–4.

Wilsonite,* $\ddot{\bar{\mathrm{A}}}\mathrm{l},\dot{\mathrm{K}}_2,\dot{\mathrm{M}}\mathrm{g},\ddot{\mathrm{S}}\mathrm{i},\dot{\mathrm{H}}_2$. Fusible at 2 with intumescence to a whitish glass; yields in a matrass some water. Hardens 3. Distinctly cleavable at right angles.

Nohlite, $\dddot{\bar{\mathrm{N}}}\mathrm{b},\ddot{\bar{\mathrm{U}}}\mathrm{r},\dot{\mathrm{Y}},\dot{\mathrm{H}}_2$. Amorphous; color, blackish-brown; lustre, vitreous. B. B. fuses with difficulty, and yields in the closed tube $4\frac{1}{2}$ per cent. of water. In its chemical deportment it is near samarskite.

Compare sordawalite, Div. 4, a.

DIALLAGE† (pyroxene). Malacolite or white augite,

---

* According to Brush, it is only altered scapolite. See Determinative Min., page 88.

† Professors Dana and Brush consider this mineral a thin, foliated lime-magnesia-pyroxene, *i. e.*, a variety of pyroxene or augite, the general formula of which is $RSiO_3$, where R may be Ca,Mg,Fe,Mn, and sometimes also Zn,K_2Na_2. Usually two or more of these bases are present. The first three are most common; but calcium is the only one that is present always and in large percentage. Besides the substitution of the above bases for one another, these same bases are at times replaced by $\bar{\mathrm{A}}\mathrm{l},\bar{\mathrm{F}}\mathrm{e},\bar{\mathrm{M}}\mathrm{n}$, though sparingly, and the silicon occasionally by aluminum. Consult James D. Dana's Manual of Mineralogy and Lithology, 3d edition, page 245. New York, 1881.

$\mathrm{CaMgSi_2O_6}$. Fusibility, 3.5; is distinguished by its pearly, submetallic lustre, and distinct cleavage in one direction.

Harmotome (Baryt-harmotome), $\mathrm{Ba\bar{A}lSi_5O_{14}} + 5\,\mathrm{Aq}$. Distinguished from the preceding and following by yielding a considerable amount of water in a matrass; and the partial solution in muriatic acid is rendered turbid or gives a precipitate with sulphuric acid of sulphate of barium. It occurs like lime-harmotome in twin crystals.

Axinite, $\mathrm{(Ca,Fe,K_2)_7(\bar{A}l,\bar{F}e,\bar{B})_3Si_8O_{32}}$, and

Tourmaline, $\mathrm{\bar{A}l,\ddot{\bar{B}},\dot{F}e,\dot{M}n,\dot{M}g,\dot{K}_2,\dot{N}a_2,\dot{L}i_2,\ddot{S}i,\ddot{T}i}$, with a mixture of fluor-spar and bisulphate of potassium, impart to the blowpipe flame a transient green color.* Axinite fuses readily and with strong intumescence to a shining dark-green glass. When finely pulverized and fused, axinite gelatinizes in muriatic acid. Different species of tourmaline show different deportments; some fuse easily and with intumescence, some curl up to a white greenish-gray, rarely black glass; others fuse with difficulty (and a few lithia tourmalines are infusible). Most tourmalines become strongly electric when heated; axinite does not.

Diopside† (Pyroxene, Dana), $\mathrm{Ca,Mg,Si_2O_6}$, and

---

* By taking the mixture on a hot platinum wire and covering the surface of the flux with the mineral in fine powder form, and heating it, without blowing, in the blue point of a good flame, the color is perceptible at the first moment of fusion. When axinite and tourmaline are reduced to fine powder and fused, then treated with sulphuric acid and evaporated to the consistence of syrup, then alcohol added to it, the latter will, when lighted, burn with a green flame. If about 1 gram. each of finely-powdered axinite or tourmaline are ground together with 3 grams. of bisulphate of potassium, and the mixture fused in a small platinum dish at a red heat, and next a small quantity of alcohol is added, this latter, when lighted, will burn with a distinct green flame, especially towards the end. The platinum dish can be cleaned again with boiling dilute HCl.

† Diopside is, according to Dana, a pyroxene of the same composition as the previously described lime-magnesia-pyroxene or malacolite, occurs in greenish-white or grayish-green crystals. See Dana's Manual of Min., 3d edition, 1881, page 246.

*Augite.** An analysis from Montreal by Hunt gave SiO_2 49.40, AlO_3 6.70, FeO_3 7.83, MgO 13.66, CaO 21.88, Na_2O 0.74, H_2O 0.50 = 100.11. Their hardness is 6; fuse at 3.5–4, some quietly, some with slight effervescence. Diopside forming a white, augite a black glass. Both are distinctly cleavable at 93 and 87°. Diopside is colorless, or light green and gray; augite, black or dark-green.

Tremolite (grammatite), $(Ca,Mg)SiO_3$, and

Amphibole (Strahlstein, hornblende), $RSiO_3$, as for pyroxene. Hardness, 5.5. B. B. they swell up, and at 3–4 fuse with effervescence; tremolite to a white or slightly colored; amphibole to a black or grayish glass. Both are distinctly cleavable at 124½° and 55½°. Color of the first is white, inclining

---

* Hedenbergite is, according to von Kobell, an iron-lime augite, containing but little magnesia. Polylite, hudsonite, and jeffersonite come in here. By the mutual action of acids or negative oxides, three classes of salts are produced, viz., *normal*, *acid*, and *basic*. *Normal* salts are those in which the acid and base saturate each other, in which, therefore, all the hydroxyles, whether of acid or base, are eliminated (in the form of Aq.), and the acid radical remains united to metal by means of oxygen, *e. g.*, potassium nitrate and potassium and zinc sulphates (see above). *Acid* salts are those which retain a part of the acid hydroxyle, *e. g.*, hydrogen potassium sulphate. *Basic* salts are those in which a part of the hydroxyl of the base, or of the oxygen of the positive oxide, remains in the combination, *e. g.*, basic zinc sulphate (see above). The sulphur acids may be regarded as compounds of negative radicals with hydrosulphuryl (SH); *e. g.*, sulphocarbonic acid $CS(SH)_2$, and hydrosulphuric acid (hydrogen sulphide) H(SH). Sulphur bases are K(SH), $Ca(SH)_2$, etc. Sulphur salts result from the reaction of sulphur acids upon sulphur bases. Most sulphur salts, however, are produced by the action of negative anhydrosulphides on sulphur bases, or on positive anhydrosulphides, *e. g.*,

$$\underset{\substack{\text{Arsenic,}\\ \text{sulphide,}}}{As_2S_5} + \underset{\substack{\text{potassium,}\\ \text{hydrosulphide,}}}{6(KSH)} = \underset{\substack{\text{potassium,}\\ \text{sulphursenate,}}}{2[AsS(SK)_3]} + \underset{\substack{\text{hydrogen.}\\ \text{sulphide.}}}{3H_2S.}$$

(Manual of Qualitative Chemical Analysis; Fresenius's New System. New York, Wiley & Sons, publishers, 1883.)

to green, gray, etc.; of the second, green inclining to black. To these belong *asbestos* $(Ca,Mg,Fe)SiO_3$, and

Amianthus,* a name applied to the finer and more silky kinds of asbestos.

Richterite† is a tremolite containing manganese. Boiled down with concentrated phosphoric acid yields upon addition of some HNO_3 a beautiful violet mass. Chemically related with tremolite is also

Nephrite. Compact, fine-grained tremolite, having a tinge of green or blue, and breaking with a splintery fracture. H.=6. Feels greasy to the touch.

Titanite (sphene) $CaTiSiO_5$. B. B. fuses with slight intumescence to a blackish glass. Partially decomposed by conc. hydrochloric acid. The solution, when boiled with tin, becomes violet (titanic acid), the violet color turning into a rose-red upon dilution with water. We obtain the HCl solution more readily when the mineral powder is boiled previously with H_2SO_4, and the latter completely evaporated, and the residue treated with conc. HCl. System of crystallization, clinorhombic. (Monoclinic. Dana.)

Guarinite is of the same composition, but crystallizes in the rhombic system. (Orthorombic. D.)

YTTROTITANITE (*keilhauite*), $\dot{\mathrm{Ca}},\dot{\mathrm{Y}},\dddot{\bar{\mathrm{F}}\mathrm{e}},\dddot{\bar{\mathrm{A}}\mathrm{l}},\ddot{\mathrm{Si}},\ddot{\mathrm{Ti}}$. Fuses imperfectly at its edges, with lively frothing, to a blackish mass. Muriatic acid attacks it but little. If the mineral is fused with caustic potash and the mass treated with muriatic acid, so as to separate the silicic acid, the remaining solution, when boiled with tinfoil, gives the same reactions as sphene.

---

* Mountain leather, mountain cork, and mountain wood are similar varieties.

† Richertite, tremolite, and nephrite are varieties of Dana's pyroxene, one of the most common minerals. It occurs in almost all basic eruptive rocks, like dolerite, as an essential constituent, and is frequently met with in rocks of other kinds. Common also in granular limestone. In basalt the crystals are generally small and black, or greenish-black.

ORTHOCLASE (common feldspar, potash-feldspar), $K_2\overline{Al}Si_6O_{16}$, and

ALBITE (soda-feldspar), $Na_2\overline{Al}Si_6O_{16}$. Hardness, 6. They fuse quietly; the former at 5, the latter at 4. Are not attacked by acids. Cleavage of orthoclase is distinct in two directions at right angles (90°). Albite in two directions at an angle of 93½°.

Closely related to Albite stands

OLIGOCLASE. Soda-lime feldspar $(Ca,Na_2,K_2)\overline{Al}Si_5O_{14}$. Fuses at 3.5. Shows striations on one cleavage surface, like

Labradorite (Labrador feldspar), $(Ca,Na_2)\overline{Al}Si_3O_{10}$. The latter is, however, mostly decomposed by HCl, which is not the case with oligoclase. The lime in oligoclase is easily traced, thus: The finely powdered mineral is mixed with *fluoride of ammonium* and the mixture fused in a platinum dish. The residue is boiled with HCl, and the ensuing solution neutralized to excess with ammonia and filtered. In the filtrate oxalate of ammonium produces a white precipitate of *oxalate of calcium*.

Similar to *orthoclase* is

Hyalophane, $(Ba,K_2)\overline{Al}Si_4O_{12}$. This mineral, when fused with soda, hydrochloric acid added, and the silica separated from the HCl solution, gives with H_2SO_4 a precipitate of white sulphate of barium.

ZOISITE, $H_2Ca_4(\overline{Al}\overline{Fe})_3Si_6O_{26}$, and

PISTACITE (epidote) of the same composition. H. = 6.5. B. B. fuse at 3–3.5, with swelling and intumescence to a slaggy mass which with zoisite is white or yellowish, with pistacite, black or dark brown. After fusion, they gelatinize with HCl. The color of zoisite is gray, yellowish-gray, grayish-white; that of *pistacite*, green (pistachio-green). Zoisite cleaves finely and very distinctly in one direction; *pistacite*, pretty distinctly in two directions at 115°.

Grossularite (*Grossular*, lime-alumina-garnet), $Ca_3\overline{Al}Si_3O_{12}$.

Vesuvianite (*Vesuvian*. idocrase), $Ca_8(\overline{Al},\overline{Fe})_2Si_7O_{28}$.

Pyrope (Magnesia-alumina-garnet), $(Mg,Ca,Fe,Mn)_3\overline{Al}$

Si_3O_{12}. Hardness, 6.5–7.5. The first and second fuse at 3; the first quietly, the second with intumescence; both gelatinizing with HCl after fusion. The third melts quietly at 3, 5–4. Vesuvian is cleavable in the planes of a quadrangular prism. Grossular and pyrope are not cleavable. Grossular is strongly attacked by concentrated muriatic acid; its color is green, yellowish-brown, hyacinth-red, and also white. Pyrope is not attacked by acids, and occurs only of a blood-red color. B. B. with borax yields a chrome-green glass.

MONZONITE, $\dddot{\overline{\mathrm{Al}}},\dot{\mathrm{Fe}},\dot{\mathrm{Ca}},\dot{\mathrm{Na}}_2,\dddot{\mathrm{Si}}$, resembles grossolurite, but does not gelatinize after fusion, and is not decomposed either by HCl or H_2SO_4.

EDELFORSITE* (AEDELFORSITE) (or red zeolite of Adelfors), $\dot{\mathrm{Ca}}\dddot{\mathrm{Si}} + \dddot{\overline{\mathrm{Al}}}\dddot{\mathrm{Si}}_3$ (v. Kob.)

SPHENOCLASE† (Sphenoklas, v. Kob.), $\dot{\mathrm{Ca}},\dot{\mathrm{Mg}},\dot{\mathrm{Fe}},\dddot{\overline{\mathrm{Al}}}\dddot{\mathrm{Si}}$, have nearly the hardness of 6; are not much attacked by acids. The first fuses at 4, with frothing, and, when heated, phosphoresces strongly with a greenish light. The second fuses at 3 quietly; phosphoresces feebly with a yellow light.

Compare the following division, C., emerald (beryl), euclase, cordierite (iolite), also biotite (uniaxial mica), and muscovite (biaxial mica).

Obsidian, or volcanic glass,
Pitchstone, Pechstein,
Pearlstone, Perlstein,
Pumice, Bimsstein.
$\dddot{\overline{\mathrm{Al}}},\dddot{\overline{\mathrm{Fe}}},\dot{\mathrm{Ca}},\dot{\mathrm{K}}_2,\dot{\mathrm{Na}}_2,\dddot{\mathrm{Si}}$.

These fuse with swelling at 3.5 to 4, to a blebby white glass or a porcelain-like mass. They are amorphous. Obsidian is characterized by its glassy lustre, conchoidal and sharp-edged fracture. Pitchstone by its greasy lustre. Pearlstone by its mother-of-pearl lustre, and pumice by its porous, scoria-like form. They are volcanic products. Many pitchstones afford water in the closed tube.

---

* Dana (Man. of Min., p. 245) considers this impure *Wollastonite* ($CaSiO_3$).

† Dana's Syst. of Min., p. 280.

Class III.—**Infusible, or fusibility above 5.**

Division 1.—*Some assume a fine blue color when, after previous ignition B. B., they are moistened with cobalt solution and again heated.* (alumina.)

(Some minerals should be first calcined and pulverized.)

The hardest anhydrous minerals belonging to this class show this color most distinctly after they are finely pulverized and then moistened with cobalt solution and ignited; the color appears as the mass cools, and is distinctly seen only by daylight.

Section i.—*B. B. yield much water in a matrass.*

RALSTONITE, $\dddot{\bar{\mathrm{A}}}\mathrm{l},\dot{\mathrm{M}}\mathrm{g},\dot{\mathrm{N}}\mathrm{a}_2,\mathrm{F},\dot{\bar{\mathrm{H}}}_2$, fused in a closed tube with bisulphate of potassium, gives the fluorine reaction. The water yielded in the closed tube reacts for fluorine.

ALUNITE (*alum-stone*), $\mathrm{K}_2\bar{\mathrm{A}}\mathrm{l}_3\mathrm{S}_4\mathrm{O}_{22} + 6\ \mathrm{Aq}$.

ALUMINITE (*sulphate of aluminium*), $\bar{\mathrm{A}}\mathrm{lSO}_6 + 9\mathrm{Aq}$. With soda on coal give hepar, which is not the case with the others. Aluminite is easily soluble in muriatic acid; alunite is not perceptibly attacked, but when it has been ignited, water extracts alum, which may be obtained in octohedral crystals by the slow evaporation of the aqueous solution. The alunite loses 13 per cent. of water by ignition, the aluminite 47 per cent. A similar mineral, felsobanyte, $\bar{\mathrm{A}}\mathrm{l}_2\mathrm{SO}_6 + 10\ \mathrm{Aq}$, loses 37 per cent. of water. A similar behavior to aluminite is shown by

PISSOPHANITE (*pissophane*, garnsdorffite), $\dddot{\bar{\mathrm{A}}}\mathrm{l},\dddot{\bar{\mathrm{F}}}\mathrm{e},\dddot{\mathrm{S}},\mathrm{H}_2$. It occurs at Garnsdorf, near Saalfeld, and at Reichenbach, Saxony, on alum slate. B. B. it becomes black, and colors the flame slightly greenish. The aluminite is white or opaque. Pissophane is pistachio-asparagus, or olive-green, and transparent.

Compare potash-alum, ammonia-alum, and *Keramohalite* (alunogen), which are soluble in water, which is not the case with the preceding minerals.

PLUMBOGUMMITE (*plumbo-resinite*, Bleigummi), $\dot{\mathrm{P}}\mathrm{b}\ddot{\bar{\mathrm{A}}}\mathrm{l}\overset{\cdot\cdot\cdot\cdot\cdot}{\mathrm{P}}_2\dot{\mathrm{H}}_2$, decrepitates and affords water in a matrass, carefully heated. B. B. it swells up, and at a strong heat softens without liquefying. With soda on coal yields metallic lead. Is soluble in nitric acid. The solution yields with molybdate of ammonium, at a gentle heat, a yellow precipitate (P_2O_5).

CALAMINE (*electric-calamine*, Kieselgalmei), Zn_2SiO_4, forms with muriatic acid a perfect jelly. B. B. on coal with soda it yields, after long blowing, a yellowish-white coating, which, treated with cobalt solution and heated, becomes green in specks. After the separation of silica, the muriatic acid solution is precipitated white by ammonia, and the oxide of zinc thus formed redissolved by an excess of ammonia.

WAVELLITE (subphosphate of aluminium), $\bar{\mathrm{A}}\mathrm{l}_3P_4O_{19} + 12\mathrm{Aq}$.

Evansite, $\bar{\mathrm{A}}\mathrm{l}_3P_2O_{14} + 18\mathrm{Aq}$.

Peganite, $\bar{\mathrm{A}}\mathrm{l}_2P_2O_{11} + 6\mathrm{Aq}$.

Fischerite, $\bar{\mathrm{A}}\mathrm{l}_2P_2O_{11} + 8\mathrm{Aq}$.

Berlinite, $2\bar{\mathrm{A}}\mathrm{l}P_2O_8 + \mathrm{Aq}$.

Richmondite, $\overset{\cdot\cdot\cdot\cdot\cdot}{\mathrm{P}},\ddot{\bar{\mathrm{A}}}\mathrm{l},\dot{\mathrm{H}}_2$, and

Zepharovichite, $\bar{\mathrm{A}}\mathrm{l}P_2O_8 + 6\mathrm{Aq}$. Are principally soluble in caustic potassa. When this solution is mixed with HNO_3 in excess, some molybdate of ammonium added, and heat applied, a yellow precipitate is obtained (P_2O_5).

Berlinite loses by ignition only 4 per cent. of water; peganite 24 per cent.; wavellite and

Zepharovichite 27 per cent.; fischerite 29 per cent.

Richmondite 35 per cent.; evansite 40 per cent.

Similar compounds are:—

Trolleite, $\bar{\mathrm{A}}\mathrm{l}_4P_6O_{27} + 3\mathrm{Aq}$., with 6 per cent. of water.

Spaerite, $\bar{\mathrm{A}}\mathrm{l}_5P_4O_{25} + 16\mathrm{Aq}$.

Redondite, $\ddot{\bar{\mathrm{A}}}\mathrm{l},\ddot{\bar{\mathrm{F}}}\mathrm{e},\overset{\cdot\cdot\cdot\cdot\cdot}{\mathrm{P}}_2\dot{\mathrm{H}}_2$.

The last two contain 23 per cent. of water each.

Tavistockite, $Ca_3\bar{\mathrm{A}}\mathrm{l}P_2O_{11} + 3\mathrm{Aq}$.

Amphithalite, $\ddot{\bar{\mathrm{A}}}\mathrm{l},\dot{\mathrm{C}}\mathrm{a},\overset{\cdot\cdot\cdot\cdot\cdot}{\mathrm{P}}_2,\dot{\mathrm{H}}_2$.

The last two contain 12 per cent. of water each.

Coeruleolactite, $\bar{\mathrm{A}}\mathrm{l}_3P_4O_{19} + 10\mathrm{Aq}$, with 21 per cent. of water.

Gibbsite (Hydrargillite), $H_6\text{Ⱥl}O_6$.

Diaspore, $H_2\text{Ⱥl}O_4$.

Xanthophyllite (Seybertite), $\text{Ⱥl},\text{F̶e},\dot{M}g,\dot{C}a,\ddot{S}i,\text{Ħ}_2$.

Pholerite (Nacrite),* $\text{Ⱥl}_2Si_3O_{12} + 4Aq$.

Gibbsite is tolerably easily dissolved by caustic potash, loses by ignition 34½ per cent. of water. The others are not soluble in caustic potash. They cleave distinctly in one direction. *Xanthophyllite* is wax-yellow, loses by ignition only 4½ per cent. of water. *Diaspore* and *pholerite* nearly 15 per cent. of water. Distinguished by their hardness, as nearly 6 for diaspore to only 1 for pholerite. This latter (v. Kobell's nacrite) occurs in scales with a pearly lustre.

Allophane, $\text{Ⱥl}SiO_5 + 5Aq$.

Halloysite, $\text{Ⱥl}Si_2O_7+4Aq$.

Samoite, $\text{Ⱥl}_2Si_2O_{10} + 10Aq$. and

Collyrite (Kollyrit),† $\text{Ⱥl}_2SiO_6 + 9Aq$, are decomposed by HCl with separation of gelatinous silica. H. of allophane 3; it gelatinizes perfectly and colors the blowpipe-flame usually green from an accidental admixture of copper, and loses by ignition 42 per cent. of water; is amorphous. H. of samoite is 4, has a lamellar structure, and loses 30 per cent. of water. The remainder have a hardness of 1–2. Halloysite contains 16, collyrite 33½ per cent. of water.

Cimolite, $\text{Ⱥl}_2Si_9O_{24} + 6Aq$., and

Kaolinite (*kaolin*, porcelain earth), $\text{Ⱥl}SiO_5 + 2Aq$. (v. Kob.) are with difficulty affected by HCl. Usually amorphous.

Porcelain earth feels smooth, not greasy, but rather pulverulent; is decomposed by H_2SO_4.

Cimolite is tough, and gives by scraping, shavings. Is im-

---

* Brush considers nacrite identical with kaolinite, $\text{Ⱥl}Si_2O_7+2Aq$, whilst *pholerite* is looked upon as a separate species with the above formula. See Brush's Determ. Min., p. 89.

† Von Kobell's "Kollyrit," analyzed by *Klaproth*, has the same formula with 10Aq. He states in a note that he refers to a species found in the "*Stephani mine*," at *Chemnitz*, which gelatinizes with acids, while other kinds, like that from Weissenfels, do not gelatinize.

perfectly decomposed by sulphuric acid. These minerals lose by ignition 12 to 16 per cent. of water. Many aluminous earths, argillites, or clays, which are not sufficiently known, but form with water a doughy mass, and develop the odor of clay, might be appended here; also *lithomarge* (*Steinmark*), with 14 per cent. of water; also *schrötterite* (*opal allophane*), with 35 per cent. of water; miloschite and bolus, with 24 to 26 per cent. of water. These form with water no dough; the latter two, on the contrary, fall to pieces with crackling.

(Compare from the following division, lazulite, svanbergite, pyrophillite, agalmatolite, disterite, wörthite, myeline, which in a matrass likewise yield water, but only a small quantity. Compare also ripidolite.)

Section ii.—*B. B. in the closed tube yield little, or no water.*

Alumian, $\not{\mathrm{A}}\mathrm{lS_2O_7}$. B. B. yields with soda on charcoal hepar.

Lazulite, $\mathrm{(Mg,Fe)}\not{\mathrm{A}}\mathrm{lP_2O_9+H_2O}$. B. B. tinges the flame with a feeble greenish color,* swells up, and crumbles to small pieces, thereby losing its blue color, and becoming white. By acids it is not directly attacked, and its blue color undergoes no change. Caustic potash produces a partial solution, which, treated with HNO_3 in excess, yields, when boiled with molybdate of ammonium, a yellow precipitate (P_2O_5).

Svanbergite, $\ddot{\not{\mathrm{A}}}\mathrm{l},\dot{\mathrm{C}}\mathrm{a},\dot{\mathrm{N}}\mathrm{a_2},\overset{\cdot\cdot\cdot\cdot\cdot}{\mathrm{P}}_2,\dddot{\mathrm{S}},\dot{\mathrm{H}}_2$. B. B. with soda on coal gives a sulphur reaction. The partial nitric acid solution gives a reaction for phosphoric acid with molybdate of ammonium. Color, yellow or yellowish-brown.

WILLEMITE (Hebetine, anhydrous silicate of zinc), Zn_2SiO_4. B. B. assumes with cobalt a blue, and in places a green color. Gelatinizes in muriatic acid. The solution yields with ammonia, after separation of silicon, a precipitate (ZnO) soluble in an excess. From the ammoniacal solution sulphide of ammonium throws down white sulphide of zinc.

MYELINE (Talksteinmark), $\not{\mathrm{A}}\mathrm{lSiO_5}$.

AGALMATOLITE (figure stone), $\not{\mathrm{A}}\mathrm{l},\dot{\mathrm{K}}_2,\dddot{\mathrm{S}},\dot{\mathrm{H}}_2$.

---

* Rendered distinct if previously moistened with sulphuric acid.

PYROPHYLLITE, $\not{\mathrm{A}}\mathrm{l},\mathrm{Si}_3\mathrm{O}_9 + \mathrm{H}_2\mathrm{O}$, have a low degree of hardness, 1–3. Pyrophyllite in one direction is perfectly cleavable. B. B. it spreads out into fan-like shapes, and increases to twenty times its former bulk. It is infusible, but partially crumbles to pieces and glows with a white light. Loses by ignition 5 per cent. of water. The others are not cleavable, and B. B. unalterable. Myelin is somewhat decomposed by acids. Related to *pyrophyllite* is—

Westanite, $\ddot{\not{\mathrm{A}}}\mathrm{l},\ddot{\mathrm{S}}\mathrm{i},\dot{\mathrm{H}}_2$, which has a brick-red color.

Muscovite (bi-axial mica, potash mica), $\mathrm{H}_2\not{\mathrm{A}}\mathrm{lSi}_2\mathrm{O}_8$, in one direction is perfectly cleavable; the thin laminæ are flexible and elastic. B. B. does not expand perceptibly, and with difficulty fuses in very thin scales. With cobalt solution it acquires partially a pure blue color; is not attacked by acids. Hardness, 2.5.

*Disterrite** (brandisite) (variety of clintonite, see Dana), $(\mathrm{Mg}_6,\mathrm{Ca}_6,\not{\mathrm{A}}\mathrm{l}_2,\not{\mathrm{F}}\mathrm{e}_2)\mathrm{SiO}_{20}$. Orthorhombic. Cleavable in one direction. Fresh laminæ B. B. turn grayish-white and turbid, and thence moistened with cobalt solution and reheated, assume a blue color. Hardness, 4–5. Concentrated sulphuric acid decomposes it.

ANDALUSITE (chiastolite), $\not{\mathrm{A}}\mathrm{lSiO}_5$, and

DISTHENE (cyanite, kyanite), $\not{\mathrm{A}}\mathrm{lSiO}_5$, are only slightly attacked by acids. B. B. phosphorus salt decomposes them, and separates a siliceous skeleton. Andalusite cleaves tolerably well in two directions at an angle of 91½°; its hardness 7.5. The crystals called chiastolite have undergone decomposition, and have usually a hardness of 5.5. They are generally in twins consisting of four individual prismatic crystals, so grown together with their principal axes parallel, that a cavity remains between them which contains generally clay slate. Disthene is distinctly cleavable in two directions at 106°, especially distinct in one direction. Hardness, 6, and some-

---

* Brush considers it identical with *seybertite* (Determ. Min., p. 90.)

times less. The spec. grav. of andalusite is 3.2; that of *disthene* 3.6. Closely approaching to disthenite is

Sillimanite (*wörthite*, *monrolite*, tribolite),* $AlSiO_5$. Its spec. grav., however, is less, namely, 3.

TOPAZ (fluosilicate of aluminium), $AlSi(O,F_2)_5$.

Rubellite† (lithia tourmaline), $(Li,Na,K)_6Al_6B_2Si_9O_{45}$, are not attacked by acids. B. B. not perfectly dissolved by phosphorous salt, the bead becoming opalescent on cooling. Topaz retains its transparency, and does not swell when ignited. Heated in larger pieces the yellow varieties turn white, assuming upon cooling a rose-red hue. Rubellite becomes white, puffs sometimes to a slaggy mass. Topaz is in one direction distinctly cleavable. Hardness, 8. Rubellite is not cleavable. Hardness, 6.5. The last-named mineral becomes electric when heated, which happens only with a few varieties of topaz. The spec. grav. of topaz is 3.5; that of *rubellite*, 3.

CORUNDUM (sapphire, emery, crystallized alumina), AlO_3.

CHRYSOBERYL, Be,AlO_4. These minerals are not attacked by ordinary acids, but when they are heated with phosphoric acid until volatilization commences the fine powder of corundum is completely dissolved, less so that of chrysoberyl. The solutions yield with caustic potash a precipitate which is redissolved by an excess (alumina). B. B. in fine powder form they are slowly but perfectly dissolved by salt of phosphorus, and the bead is not opalescent when cold. Hardness of sapphire, 9; its specific gravity, 4. Hardness of chrysoberyl, 8.5; its specific gravity, 3.7.

(Compare *spinel.*)

Many varieties of spinel and leucite, when pulverized, moistened with cobalt solution and ignited, become blue. Some kinds of cassiterite, or tin stone, in powder form assume, when moistened with cobalt solution upon ignition, a bluish or

---

* Dana (Man. of Min. and Lithol., New York, 1881, p. 285) calls the mineral "tribolite," syn. with *sillimanite* and *bucholzite.*

† Rubellite is a variety of tourmaline. See Brush, Determ. Min., etc., p. 90.

greenish tint, but readily yield with cyanide of potassium on coal globules of tin.

The blue color, which quartz in a fine powder form acquires with cobalt solution, differs from that of the preceding minerals by inclining to red, and by the blue being less intense.

Division 2.—*Moistened with cobalt solution, and ignited, assume a green color (zinc).*

It is sufficient to heat the moistened bead to a red heat.

The compounds of oxide of zinc belonging to this division give to the coal a coating which is yellow while hot, but becomes paler on cooling, and when moistened with *cobalt solution* and again ignited assumes a *green* color.

SMITHSONITE (Zinkspath, carbonate of zinc), $ZnCO_3$.

Hydrozincite (Zincblüthe), $Zn_3CO_5 + 2Aq$, dissolve in HCl with effervescence by the escape of carbonic acid; the solution yields with caustic ammonia a precipitate soluble in excess. In a matrass smithsonite affords little or no water; hydrozincite, a large quantity.

WILLEMITE (hebetine, anhydrous silicate of zinc), $\dot{Z}n_2\ddot{S}i$.

CALAMINE,(hydrous silicate of zinc, Kieselgalmei), $\dot{Z}n_2\ddot{S}i+\dot{H}_2$, with muriatic acid form a perfect jelly. In a matrass the latter yields water, the former none. B. B. silicates of zinc, when treated with cobalt solution, become green in places, with a large share of blue.

(Compare zinc vitriol and zincblende; also kassiterite.)

Division 3.—*After ignition, give an alkaline reaction, and color moistened turmeric paper brown, or red litmus paper blue.*

BRUCITE* (hydrate of magnesia), H_2MgO_2.

HYDROMAGNOCALCITE, $(\dot{C}a,\dot{M}g)\ddot{C} + \frac{1}{3}\dot{H}_2$.

---

* A manganese brucite is *pyrochroite*, $H_2(MnMg)O_2$, showing a similar deportment to *brucite*, yielding, however, when boiled with conc. phosphoric acid, and addition of some nitric acid, a violet color (manganese).

Hydromagnesite (hydrocarbonate of magnesium), $2CaCO_3 + H_2MgO_2$, in a matrass affords much water, which is not the case with the remaining ones. Brucite dissolves easily and quietly in muriatic acid; the other two minerals with effervescence. The concentrated muriatic acid solution of brucite and hydromagnesite yields no precipitate with sulphuric acid; that of hydromagnocalcite a heavy one (gypsum).

A similar behavior as the last is exhibited by—

Predazzite, $2CaCO_3 + H_2MgO_2$, and

Pencatite, $CaCO_3 + H_2MgO_2$.

Related to hydromagnesite is nemalite, H_2MgO_2. (Probably a mixture of hydromagnesite and brucite, v. Kob.)

Calcite (carbonate of calcium), $CaCO_3$, and

Arragonite (needle spar), $\dot{Ca}\ddot{C}$, effervesce strongly when moistened with muriatic acid, and are soluble even in large lumps without the aid of heat. The concentrated solution gives, without sulphuric acid, a precipitate of sulphate of calcium, but none when largely diluted. B. B. arragonite crumbles to powder; calcite decrepitates, but does not crumble like arragonite. Specific gravity of calcite, 2.6–2.8; that of arragonite, 2.9–3.

(Compare Strontianite.)

Dolomite (magnesian limestone), $(Ca,Mg)CO_3$.

Magnesite (carbonate of magnesium), $MgCO_3$, moistened with muriatic acid do not effervesce, unless reduced to a powder, and then only slightly; but by application of heat they effervesce strongly and dissolve. The concentrated solution of dolomite gives with sulphuric acid a precipitate of sulphate of calcium; that of magnesite, none. Magnesite is entirely or chiefly dissolved in sulphuric acid; the other only partially.*

(Compare the next following minerals.)

Strontianite (carbonate of strontium), $SrCO_3$, and

---

* Brown spar (mesetine spar) shows a behavior similar to dolomite, but it becomes by ignition black and feebly magnetic. Compare also siderite (ironspar) and diallogite (manganese spar), many varieties of which upon ignition exhibit an alkaline reaction.

Baryto-calcite (carbonate of barium and calcium), $(Ba, Ca)CO_3$, are readily distinguished from the preceding, since in small lumps they do not, or only transiently, effervesce with conc. HCl, but are soluble with effervescence in very dilute muriatic acid; the solution, even when largely diluted, gives with sulphuric acid a precipitate, with baryto-calcite at once, with strontianite only after a while. B. B. strontianite spreads out into cauliflower-like ramifications, which emit a brilliant white light, and tinge the flame with a purple-red. Baryto-calcite tinges the flame with a feeble greenish-yellow, while the mineral acquires a green color.

(Compare yttrocerite; likewise talc and muscovite, some varieties of which after ignition react alkaline.)

Division 4.—*In hydrochloric acid, or, if this has no effect, in nitric acid, entirely or chiefly dissolved, without forming a jelly or leaving any considerable residue of silicic acid.*

Lithiophorite, $\ddot{Mn},\dot{Cu},\dot{Co}\dot{Li}_2,\dot{Ba},\dddot{\bar{Al}},\ddot{Mn},\dot{\bar{H}}_2$, color, bluish-black; lustre, dull. B. B. colors the flame carmine-red (lithia). With salt of phosphorus gives reactions for copper and cobalt.

Ludwigite,* Comp. $R_4\bar{Fe}B_2O_{10}$. R., iron protoxide and magnesia, combined with iron sesquioxide, and boron trioxide. Color, black. Fusible with difficulty. Gives with sulphuric acid and alcohol the green reaction of boric acid.

Cervantite, $SbO_2 = Sb_2O_3 + Sb_2O_5$. B. B. on coal infusible, but with soda on coal easily reduced to metallic antimony, yielding also the antimony coating. Affords little or no water in the closed tube.

Siderite (carbonate of iron, spathic iron), $FeCO_3$ (Mn, CaMg);

Mesitite, *Mesitine* (mesitine spar, breunnerite, braunspath), $Mg_2FeC_3O_9$;

Diallogite (*rhodochrosite*, carbonate of manganese), $MnCO_3$; and

---

* Brush considers it only a variety of sussexite.—Man. of Determ. Min., page 82. Consult E. S. Dana's Textbook of Min., 1880, page 358.

Zaratite (*emerald nickel*, Nickelsmaragd), $Ni_3CO_5 + 6Aq$, are soluble in muriatic acid (by the aid of heat) with effervescence caused by the escape of carbonic acid; the remainder do not effervesce. Siderite, mesitite, and emerald nickel B. B. form a black or gray mass which is attracted by the magnet. Emerald nickel is recognizable by its green color, and the fact that its muriatic acid solution turns pale blue by an excess of ammonia. Siderite in most varieties decrepitates very strongly; to borax glass it imparts a bottle-green color. Mesitite dissolved in nitric acid, and the oxide of iron precipitated with ammonia, yields with oxalate of ammonium no precipitate, but if ammonia be added, and then phosphate of soda, a heavy precipitate (of phosphate of magnesium and ammonium) falls. The solution of siderite gives with the last-named reagents only a slight precipitate or none. Diallogite B. B. becomes gray or black, and sometimes magnetic; to borax glass in the oxidizing flame it imparts an amethystine-red.

Hydrotalcite (völknerite), $\ddot{\bar{A}}l,\dot{M}g,\dot{H}_2,\ddot{C}$. Yields in a matrass much water. B. B. in the R. F. does not become magnetic. The powder effervesces with muriatic acid, and is thence dissolved. Neutralizing the acid solution with bicarbonate of sodium and filtering off the precipitate, the filtrate gives with oxalate of ammonium none, but with phosphate of sodium and ammonium a heavy white precipitate.

Parisite, $3(Ce,La,Di)CO_3 + (Ca,Ce)Fl$. Slowly soluble in HCl; the not too acid solution gives with oxalic acid a white precipitate, which on ignition becomes brick-red (oxide of cerium).

GOETHITE (pyrrhosiderite, Eisenrutil), $H_2\bar{F}eO_4$.

LIMONITE (brown hematite, brown ochre), $H_6\bar{F}e_2O_9$,* heated

---

* The yellow clay iron stone, Bohnerz, bog iron ore, Eisenniere (reniform iron ore), are mixtures of limonite, clay, sand, phosphate of calcium and of iron, etc. They are generally fusible, sometimes easily so, and are dissolved by muriatic acid with separation of clay, etc. *Anthosiderite*, $\bar{F}eO_3 35.7, SiO_2 60.3, H_4O 4.0 = 100$.

before B. B. in the reduction flame become black and magnetic; in a matrass afford water; they dissolve slowly and without effervescence in concentrated muriatic acid; the solution with ammonia gives a reddish-brown precipitate. *Goethite* occurs crystallized, and in one direction is distinctly cleavable; color is hyacinth-red, also brown, and blackish-brown; by ignition it loses 10 per cent. Limonite occurs sometimes in fibrous, but generally in dense masses, of a brown color; upon ignition it loses 14½ per cent. The streak of each is ochre-yellow.

Turgite (*hydro-hematite*), $H_2Fe_2O_7$, has a brownish-red streak, and loses in the closed tube 5–7 per cent. of water. B. B. heated in R. F. becomes black and magnetic; soluble with difficulty in HCl. Compare—

Hematite (specular iron, red hematite), Fe_2O_3, which in many varieties is without metallic lustre. Can easily be distinguished by the cherry-red color of its streak, and by its yielding no water, or only traces of it in the closed tube.

SPHALERITE* (zincblende, black jack, sulphuret of zinc), ZnS.

MARMATITE* (sulphuret of zinc and iron), (Zn,Fe)S, and

GREENOCKITE (sulphuret of cadmium), CdS, boiled with muriatic acid give off sulphuretted hydrogen (and if previously mixed with iron powder, even at ordinary temperature). B. B. with soda they form hepar. On coal, greenockite deposits a brownish-red ring of oxide of cadmium; the others leave a yellowish coat of oxide of zinc. Concentrated nitric acid dis-

---

From Antonio Pereia, Brazil, where it is intimately associated with magnetic iron, appears to be a mixture of limonite with quartz, for the silica separated by the decomposition with HCl behaves with caustic potash like quartz powder.

* Von Kobell. Brush makes no distinction between the two minerals, but considers *marmatite* a ferriferous variety of *sphalerite*, and gives to the latter the formula (Zn,Fe)S. A part of the Zn being often replaced also by cadmium; also containing in minute quantities *thallium*, indium, and gallium.

solves all three with separation of sulphur; in this solution ammonia causes a precipitate, which is principally redissolved in excess when the mineral is sphalerite or greenockite, while marmatite leaves a perceptible amount of oxide of iron as a residue. The ammoniacal solution yields with sulphide of ammonium either a white precipitate of sulphide of zinc, or a yellow one of sulphide of cadmium.

WAD (bog manganese, earthy manganese), $H_2Mn_2O_5$.

ZINCITE (red zinc ore, manganesian oxide of zinc, Rothzinkerz), ZnO (with MnO). B. B. with borax give the reaction of manganese. The first has a brown, the second a red color.

(Compare psilomelane (is of a gray color). Also pyrochroite and the next mineral.)

ASBOLITE* (earthy cobalt), $\dot{\mathrm{M}}\mathrm{n},\dot{\mathrm{C}}\mathrm{o},\dot{\mathrm{C}}\mathrm{u},\dot{\mathrm{H}}_2$. B. B. with borax forms a fine sapphire-blue glass (Co). With soda on platinum foil yields a green color (Mn). On charcoal generally emits a slight arsenical odor. (Some varieties of asbolite fuse.)

Uraninite (Uranpecherz, pitchblende), U_3O_8, and

Zippeite (Uranocker), $U_3S_2O_{15} + 12Aq$. B. B. give with salt of phosphorus in O. F. a yellow bead, which in R. F. becomes deep green (uranium). In nitric acid they are soluble, forming a yellow liquid, from which ammonia throws down a sulphur-yellow precipitate. The nitric solution of zippeite gives a heavy precipitate with nitrate of barium.

The color of uraninite is pitch-black, that of zippeite† yellow. The spec. grav. of uraninite is 6.5, that of zippeite 3.

Turquois‡ (*callaite*, Kalait, Germ.), $\bar{\mathrm{A}}\mathrm{l}_2P_2O_{11} + 5Aq$, containing Cu, colors the blowpipe flame green; when moistened, muriatic acid tinges it with a transient blue color. In potassa it is chiefly soluble, leaving only a cupreous residue. The nitric solution gives a yellow precipitate with molybdate

---

* A variety of *wad*.

† Many impure varieties of uranochre are fusible.

‡ *Turquois* receives a good polish, and is highly esteemed in Persia, where it is mainly found, as a gem.

of ammonium (phosphoric acid). In the closed tube much water (19 per cent.). Color, sky-blue to green. Spec. grav. 2–2.8.

APATITE (phosphate of calcium), $3CaP_2O_8 + CaCl,F)_2$. Fusibility, 5. B. B. moistened with sulphuric acid it colors the flame feebly green. The nitric acid solution gives with molybdate of ammonium a yellow precipitate of phosphoric acid. The nearly neutral solution gives with oxalate of ammonium a white precipitate of oxalate of calcium. B. B. in a matrass yields no water. Spec. grav. 3.2.

MONAZITE (*mengite*, *emerite*), $5(Ca,La,Di)_3P_2O_8,Th_2P_2O_9$. Infusible. The mineral powder in the loop of a platinum wire, moistened with sulphuric acid, tinges the flame green. Soluble in muriatic acid with difficulty. The powdered mineral fused with caustic potash, and the mass treated with water and filtered, and the filtrate, acidulated with nitric acid, produces, with molybdate of ammonium, a yellow precipitate (P_2O_5). The residue not dissolved by water is dissolved in a little HCl, and oxalic acid added, when a heavy precipitate is thrown down, which, ignited in a platinum spoon, turns brick-red (oxide of cerium). At present found only in small, tabular crystals of a reddish-brown or yellow color. Spec. grav. 4.9–5.2.

CHILDRENITE, $(Fe,Mn)_8Al_2P_6O_{29} + 15Aq$. B. B. frits (bakes) only on the surface, affects after ignition in the reducing flame the magnetic needle. Moistened with sulphuric acid it colors the flame greenish. Soluble with difficulty in muriatic acid. The partial solution yields with molybdate of ammonium a yellow precipitate (P_2O_5).

POLYCRASE (*polymignite*), $\dot{Y},\ddot{\bar{U}},\dot{F}e,\ddot{T}i,\overset{\cdot\,\cdot}{\overset{\cdot\cdot\cdot}{C}}b_2$,*$\dot{H}_2$. B. B. decrepitates when heated suddenly, but is infusible and unchangeable. If the powder is melted with caustic potassa, and the mass boiled with muriatic acid and then filtered, the liquid assumes, if boiled down in contact with tinfoil, a blue color

---

* Or $\overset{\cdot\,\cdot}{\overset{\cdot\cdot\cdot}{\bar{N}}}b_2$ (niobic acid of Continental chemists). $\overset{\cdot\,\cdot}{\overset{\cdot\cdot\cdot}{C}}b_2$ (columbic acid according to Dana).

(the liquid must be considerably concentrated however), which upon the addition of very little water becomes more clear, and yields a blue filtrate ; or, the mineral may be fused with bisulphate of potassium, the mass dissolved in dilute HCl, and boiled with tin, when the same blue solution is obtained. The dilute acid solution colors turmeric paper orange-yellow (zirconia). Color, black. Spec. grav. 4.7–5. H. 5.5–6.5.

Fluocerite (fluoride of cerium), Ce_3Fl_4, and

Bastnäsite (hamartite), $CeF,2(\dot{Ce},\dot{La})\ddot{C}$, evolve with bisulphate of potassa or strong sulphuric acid hydrofluoric acid gas, corroding glass (a watch glass or glass tube may be exposed to the fumes).* *Bastnäsite* gives off at the same time carbon dioxide (CO_2). Their color is yellow. Spec. grav. of fluocerite 4.7, that of bastnäsite 4.93.

A similar deportment is shown by—

Yttrocerite, $(Cu,Ce,Y)F_2$. Like fluorecite ; but has an imperfect cleavage in two directions in the planes of a quadratic prism. Color, violet-blue, inclining to white and gray or grayish-red. Lustre, weak, vitreous.

Division 5.— *With muriatic acid form a jelly, or are decomposed with separation of silicic acid, without gelatinizing ; do not exhibit the characters of the preceding numbers.*

Section i.—*In a matrass afford water.*

Dioptase (emerald copper), H_2CuSiO_4.

Chrysocolla (copper-green, Kieselmalachit), $CuSiO_3 + 2Aq$.

Cyanochalcite, $\dot{Cu},\overset{\cdot\cdot\cdot\cdot\cdot}{\bar{P}}_2,\ddot{Si},\dot{\bar{H}}_2$, and

Asperolite† (chrysocalla), $CuSiO_3 + 3Aq$. B. B. fused with soda on charcoal effervesce and yield a glass which in-

---

* Must not be inhaled, being corroding and poisonous.

† Hermann has given this name to an amorphous mineral from Tagilsk, Russia, so named on account of its great brittleness. Dana considers it a variety of chrysocolla. See System of Min., pp. 402, 403, and 404.

closes a ductile copper globule. Dioptase gives with acids a perfect jelly. Chrysocolla, cyanochalcite, and asperolite are decomposed without gelatinization. When the powdered minerals are boiled with caustic potash, a deep blue solution is obtained, and the powder turns a brownish color. By continued boiling, the blue color of the lye diminishes again, and the powder turns brownish-black. From the filtered solution, sal ammoniac, when added in sufficient quantity, throws down hydrous silica. Dioptase loses by ignition 11 per cent. of water. Cyanochalcite 16 per cent. Chrysocolla 20 per cent. Asperolite 27 per cent. of water. Cyanochalcite as an azure-blue color; the others are either green or bluish-green.

Uranotil, $\mathrm{Ca_2U_6Si_5O_{30}} + 15\mathrm{Aq}$. Color, lemon-yellow, turning black by ignition. The HCl solution yields after separation of the silica, with ammonia, a sulphur-yellow precipitate ($\dddot{\bar{\mathrm{U}}}$). Loses by ignition 12.7 per cent. of water. Crystallizes in needles.

Xonaltite, $4\mathrm{CaSiO_3} + \mathrm{H_2O}$. Infusible according to Rammelsberg. The HCl solution gives, after separation of the silica, with ammonia no precipitate, but oxalate of ammonium throws down oxalate of calcium. Yields 3.7 per cent. of water. Massive; color, white.

Thorite, $\mathrm{ThSiO_4} + \mathrm{H_2O}$, and

Cerite, $\mathrm{(Ce,La,Di)_2SiO_4} + \mathrm{H_2O}$, gelatinize with hydrochloric acid.* B. B. with soda on charcoal give no copper globule. The solution of cerite yields (when not too acid) with oxalic acid a white precipitate, which, upon being heated in a platinum spoon, turns brick-red (cerium oxide). The color of thorite is black; streak, dark brown. Color of cerite, reddish-gray; streak, white. Their spec. gravities are from 4.7–5.

Chloropal (*nontronite*), ($\bar{\mathrm{F}}\mathrm{eSi_3O_9} + 5\mathrm{Aq}$.

Wolchonskoite, $\dddot{\bar{\mathrm{C}}}\mathrm{r}, \dddot{\bar{\mathrm{A}}}\mathrm{l}, \dddot{\bar{\mathrm{F}}}\mathrm{e}, \dot{\mathrm{M}}\mathrm{g}, \dddot{\mathrm{S}}\mathrm{i}, \dot{\mathrm{H}}_4$.

---

* The jelly of cerite produced with dilute HCl is somewhat soft, that obtained with conc. HCl forms a gelatinous mass.

Röttisite (genthite), $H_4(Ni,Mg)_4Si_3O_{12}$, are amorphous and of a green color. Wolchonskoite of a dark leech-green, the others yellowish-green. B. B. wolchonskoite gives to the borax bead in both O. F. and R. F. an emerald-green color which, on cooling, does not fade (chromium). Chloropal gives a green glass which fades on cooling. If the powdered mineral is treated with caustic potash, it turns without boiling, blackish, if the species is chloropal; if röttisite, the color is, only after boiling and with a strongly concentrated solution, changed to brown. Wolchonskoite undergoes very little change. The HCl solution of röttisite assumes with ammonia a blue color.

Röttisite closely resembles

Genthite (v. Kob.)*

Thraulite (hisingerite, gillingite), $\overset{\dots}{\overline{\mathrm{F}}}\mathrm{e}.\dot{\mathrm{F}}\mathrm{e},\dot{\mathrm{M}}\mathrm{g},\dot{\mathrm{C}}\mathrm{a},\dddot{\mathrm{S}}\mathrm{i}$,Aq.

Xylotyle (mountain wood, Bergholz), $\overset{\dots}{\overline{\mathrm{F}}}\mathrm{e},\dot{\mathrm{M}}\mathrm{g},\dddot{\mathrm{S}}\mathrm{i}$,Aq. B. B. after fusion or long heating in the reduction flame become magnetic; are readily decomposed in muriatic acid without forming a perfect jelly. The solution of the second, after separation of the oxide of iron by ammonia, gives a heavy precipitate with ammonia and phosphate of sodium; that of the first gives none. Thraulite is friable and brittle; its color brownish-black. Mountain wood has been found only in tough, fibrous, wood-like masses, exhibiting a wood-brown color.

SEPIOLITE (meerschaum), $Mg_2Si_3O_8 + 2Aq$, is very light; specific gravity, 1.5. B. B. burns white and shrinks. Muriatic acid decomposes it easily into a gelatinous mass. Absorbs water greedily. Contains 10 per cent. of water.

BASTITE (Schillerspath).

CHRYSOTILE (an asbestiform variety of serpentine allied to picrolite, Dana), show submetallic, opalescent, pearly lustre, the first upon one cleavage plane, the second upon its composing fibres. Roasted B. B. bastite turns brown; chrysotyle white. Both are decomposed by concentrated muriatic acid

---

* Brush calls both minerals "genthite."

with gelatinization, still easier by sulphuric acid without gelatinization. Loss by ignition, 12 per cent.

METAXITE[*] resembles chrysotile, but is of feeble, silky lustre both in its massive and fibrous variety.

Cerolite (kerolite), $H_2Mg_2Si_2O_7 + H_2O$. Hardness, 2–3. Assumes, when moistened with cobalt solution, and heated B. B., a pale flesh color. When heated loses 30 per cent. of water.

SERPENTINE (hydrated silicate of magnesium), $Mg_3Si_2O_7 + 2Aq$. Concentrated muriatic acid dissolves it without gelatinization. Usually massive and dense. Hardness, 3–4. Loss by ignition 12 to 13 per cent. The following hydrous magnesium silicates show a similar deportment, but exhibit, however, a crystalline structure and cleavage.

PYCROPHYLL,[†] hardness, 2.5. Loss by ignition $10\frac{1}{2}$ per cent.

PICROSMINE,[‡] hardness, 2.7. Loss by ignition 9 per cent.

MARMOLITE,[§] hardness, 2.5 to 3. Loss by ignition 15.7 per cent.

Kämmererite[‖] (penninite), $Mg_5AlSi_3O_{14} + 4Aq$, hardness, 1.5 to 2. Loss by ignition 13 per cent. Color, crimson-red; the others are of a greenish or greenish-gray color. Kämmererite is chemically identical with Kotschubeit (ripidiolite, Brush), $Mg_5AlSi_3O_{14} + 4Aq$, but are distinguished optically, the former being mon-axial, the latter bin-axial.

(Compare also *chlorite* and *ripidolite*, which are decomposed by muriatic acid, though with difficulty, 6. Compare *gymnite*.)

---

[*] Dana (Manual of Min. and Lithol., pp. 307–9) considers bastite, chrysotile, and metaxite as different varieties of serpentine, $H_2Mg_3Si_2O_8 + 1Aq$. Consult likewise Dana's Textbook of Min., p. 328, and Brush's Determinative Min., p. 94, "serpentine."

[†] *Pycrophyll* and

[‡] *Picrosmine* are varieties of pyroxene (Brush, Determ. Min., p. 88).

[§] *Marmolite* is a thin, foliated, and pearly variety of serpentine (Brush, Ibid., p. 94).

[‖] According to Kenngott, kämmererite is only a variety of *ripidiolite* colored red by chromic acid.

Antigorite* (a foliated variety of serpentine).

Monradite (pyroxene), $(Mg,Fe)SiO_3 + H_2O$.

Neolite, $\dot{Mg},\dddot{\bar{A}l},\ddot{Si},\dot{H}_2$.

Clintonite† (*seybertite*), $(\dot{Mg}_6,\dot{Ca}_6,\dddot{\bar{A}l}_2,\dddot{\bar{F}e})_2\ddot{Si}$. Likewise decomposed by concentrated muriatic acid with formation of jelly. Loss by ignition amounts only from 4 to 6 per cent. Antigorite is found in foliated masses, cleavable perfectly in one direction. Hardness, 2.5. Monradite, crystalline, foliated. Hardness, 6. Clintonite distinctly cleavable in one direction. Hardness, 4.4 to 5. Neolite very soft. Hardness, 1. Is greasy like soap to the touch.

Section ii.—*In a matrass give no water, or only a trace.*

(Compare the last-named minerals of the preceding division.)

Gadolinite, $(Y,Ce,Be,Fe)_3SiO_5$, and

Gehlenite,‡ $Ca_3(\bar{A}l\bar{F}e)Si_2O_{10}$. Gelatinize perfectly with muriatic acid. B. B. gadolinite swells up, and many varieties exhibit a momentary glow. At a long-continued heating assume a dirty green color, some varieties becoming rounded on their sharp edges; is not cleavable. Color, black, blackish-green. Specific gravity, 4 to 4.3. Gehlenite does not swell up. In thin scales becomes rounded on the edges without showing any peculiar phenomena. Color, grayish-white. Specific gravity, 3.

Chrysolite (olivine), $(Mg,Fe)_2SiO_4$, and

Chrondrodite, $Mg_8Si_3O_{14}$ (contains F). Gelatinize perfectly with muriatic acid. With sulphuric acid the second evolves a large proportion of hydrofluoric acid gas; the former gives none. B. B. chrysolite is but little alterable. Color, olive-green. Hardness, 7. H. of chondrodite, 6.5. Color,

---

* A variety of serpentine, $Mg_3Si_2O_7 + 2Aq.$, with a small amount of $\dot{F}e$, according to Brush's Determin. Min., p. 94.

† Analysis by G. Brush obtained SiO_2, 20.24; $\bar{A}lO_3$, 39.13; $\bar{F}eO_3$, 3.27; MgO, 20.84; CaO, 13.69; H_2O, 1.04; $Na_2O(K_2O)$, 1.43; ZrO_2, 0.75 = 100.39 from Amity, N. Y. Dana's Textbook, p. 336.

‡ The mineral found at Monzoni, called massive gehlenite, fuses much more easily, and forms a separate species.

yellow, brownish, greenish. Hyalosiderite is an olivine containing iron. The solution in aqua regia yields, after separation of the silica, with ammonia a brownish-red precipitate of hydrated sesquioxide of iron.

Monticellite (*batrachite*), $(Ca,Mg)_2SiO_4$. The solution gives after the precipitation by ammonia of some iron, with oxalate of ammonium a white precipitate (lime).

(Compare *röpperite.*)

BOLTONITE (forsterite), Mg_2SiO_4, in one direction perfectly cleavable; hardness, 5; specific gravity, 3; color, yellow. Conc. HCl decomposes it, and the silica separates as a slimy powder.

LEUCITE (amphigene), $K_2\text{Al},Si_4O_{12}$. Decomposed by HCl without gelatinizing; the silicic acid being separated as fine powder. Many varieties give with cobalt solution a fine blue. Not cleavable. It occurs crystallized almost always in trapezohedrons. Hardness, 5.5; specific gravity, 2.5; color, grayish or yellowish-white.

Division 6.—*The species yet remaining, which could not be arranged under the foregoing divisions, may be separated into two groups distinguished by their hardness.*

Section i.—*Hardness under* 7 (*quartz*).

BIOTITE, HEXAGONAL MICA (uniaxial mica, Einaxiger Glimmer), $K_2(Fe,Mg)_7\text{Al}_2Si_7O_{28}$.

MUSCOVITE, OBLIQUE MICA (biaxial mica, common mica, Zweiaxiger Glimmer, Germ.), $K_2\text{Al}Si_2O_8$.

TALC (soapstone, steatite, Speckstein), $H_2Mg_3Si_4O_{12}$. B. B. in a matrass yield none, or little water. Talc and soapstone (massive talc) do not lose more than 5 per cent. All, except the last, distinctly cleavable in one direction; hardness, 1–2.5. Talc has a greasy feel, the others have not. Biotite is decomposed by concentrated sulphuric acid, the others are not. Biotite is optically uniaxial, sometimes biaxial, but the angle of divergence does not exceed 5° and seldom 1°. Turned in the *stauroscope*, the black cross is not changed, while with the others it is changed with various colors. The optical angle of muscovite is 44°–48°; of magarite, the same; and of phlogopite, 3°–20°, seldom less than 5°. The laminæ of muscovite are elastic, flexible; those of talc are flexible but not elastic. Steatite (Speckstein) is a dense talc, feels also greasy to the touch.

(Compare pyrophyilite.)

A similar behavior to biotite is shown by

Margarodite, $K_2\bar{\mathrm{A}}\mathrm{l}Si_2O_8(+ Aq)$, and

Phlogopite, $K_2Mg_6\bar{\mathrm{A}}\mathrm{l}Si_5O_{20}$, which are decomposed by concentrated sulphuric acid. They are optically biaxial, and alter the cross in the stauroscope of Kobell with different colors.

Chlorite, $\dot{\mathrm{M}}\mathrm{g},\dot{\mathrm{F}}\mathrm{e},\dddot{\bar{\mathrm{A}}}\mathrm{l},\ddot{\mathrm{S}}\mathrm{i},\dot{\mathrm{H}}_2$.

DELESSITE, $\dot{\mathrm{M}}\mathrm{g},\dot{\mathrm{F}}\mathrm{e},\dddot{\bar{\mathrm{A}}}\mathrm{l},\dddot{\bar{\mathrm{F}}}\mathrm{e},\ddot{\mathrm{S}}\mathrm{i},\dot{\mathrm{H}}_2$.

RIPODOLITE (Klinochlor) $Mg_5\dddot{\bar{\mathrm{A}}}\mathrm{l}Si_3O_{14} + 4Aq$. B. B. in a matrass affords a considerable amount of water. Loss by ignition, 12 per cent; cleavage distinct in one direction; laminæ not elastic. Chlorite usually forms micaceous, granular masses. Delessite is fibrous; their hardness 1 to 2.5. By boiling with muriatic acid (or still more easily with sulphuric acid) they are decomposed. Ripidolite B. B. burns white, and fuses at 5.5 to a grayish-yellow enamel. Chlorite turns black, and moves a delicate magnetic needle. B. B. ripidolite gives when fused together with the proper amount of borax a green bead (oxide of chromium). Chlorite gives the reaction for iron.

Closely related to ripidolite is

Leuchtenbergite of a yellow color, is optically uniaxial, while

Ripidolite, especially the variety clinochlor, is binaxial.

Here belongs

Pennitite (Pennin), $Mg_5\bar{\mathrm{A}}\mathrm{l}Si_3O_{14} + 4Aq$. Color, green, like chlorite; is uniaxial, and crystallizes in rhombohedrons of 65½°.

Related with the preceding minerals are

Chloritoid (Sismondin, masonite), $(Fe,Mg)(\bar{\mathrm{A}}\mathrm{l},\bar{\mathrm{F}}\mathrm{e})SiO_6+H_2O$, is not essentially attacked by muriatic acid, but is decomposed by concentrated sulphuric acid. It is easily distinguished by its hardness, 5–6, and its loss by ignition amounting to only 7½ per cent.

Cerolite (Kerolith). (Compare Division 5, *a.*) Amorphous, yellowish-white; hardness, 2–3; loses 30 per cent. by heating. HCl decomposes it mostly.

Bauxite (beauxite) $(\overline{\mathrm{Al}}\overline{\mathrm{Fe}})O_3 + 2\,\mathrm{Aq}$. Amorphous, grayish-white, reddish-brown. In the closed tube loses 20 per cent. of water. Hydrochloric acid affects it but little, while concentrated phosphoric acid dissolves it almost entirely. Soluble, also, in sulphuric acid.

(Compare argyllite.)

WOLCHONSKOITE, $\ddot{\overline{\mathrm{Cr}}}, \ddot{\overline{\mathrm{Al}}}, \overline{\mathrm{Fe}}.\dot{\mathrm{Mg}}, \ddot{\mathrm{Si}}, \dot{\mathrm{H}}_4$. Amorphous, dark green. Boiled down with phosphoric acid it furnishes an emerald-green solution, not altered by dilution with water, while gelatinous silicic acid separates. Chromite, sometimes of a metal-like fatty lustre, gives also the above chromium reaction, but the mineral is black, and the streak yellowish-brown.

(Compare I. B. 3.)

WARWICKITE, $2MgTiO_3 + Mg_4B_6O_{13}$. Its powder is decomposed by concentrated sulphuric acid. The solution when evaporated to dryness imparts to burning alcohol a green color. When this mass is boiled with hydrochloric acid and tin-foil, the liquid, when duly concentrated, assumes a violet color, which upon the addition of water turns into a rose-red.

BRONZITE (broncite, hypersthene), $(Mg,Fe)SiO_3$.

ANTHOPHYLLITE, $\dot{\mathrm{Fe}}\ddot{\mathrm{Si}} + \dot{\mathrm{Mg}}_3\ddot{\mathrm{Si}}_2$. The former is perfectly cleavable in one direction, and shows a pearly, metallic lustre; the second is distinctly cleavable in two directions at 124½°, and presents a similar but inferior lustre. Their hardness, 5–5.5. Hypersthene, while closely approaching to bronzite, cleaves distinctly at 86½°.

Tungstite (tungstic acid, Wolframsaeure), WO_3. Color, yellow. Gives, when boiled with phosphoric acid, a bluish solution, which, when stirred while warm with iron powder and a little water, assumes at once a dark-blue color. Soluble in alkalies. B. B. gives with salt of phosphorus in O. F, a colorless bead, which in R. F., or better with tin on charcoal, turns blue on cooling. Occurs in soft earthy masses.

Scheelite (tungstate of calcium), $CaWO_4$. Fuses at 5. When boiled in nitric acid there remains a lemon-yellow residue of tunstic acid, which is soluble in alkalies. Boiled down with phosphoric acid yields a blue mass, which diluted with much water forms a colorless solution, which, when agitated with iron powder, assumes a fine blue color. H. 4.5–6. Spec. grav. 6.

Cassiterite (tinstone, peroxide of tin), SnO_2 B. B. fused on coal with cyanide of potassium the splinters are reduced to metallic tin (alone, only with much difficulty); is considerably heavier than similar minerals. Specific gravity, 6.8–7. Hardness, 6.5.

Octahedrite (anatase) also *rutile* (titanic acid), TiO_2. When the fine powder has been fused with potassa and then dissolved in muriatic acid, the solution boiled with metallic tin assumes a violet color, which, upon addition of water, turns red without further change. The fine powder may, before treating it with HCl, also be first fused with bisulphate of potassium, or dissolved with hot conc. sulphuric acid. Anatase is perfectly cleavable in the planes of a quadratic pyramid at 136° 22′. Rutile in the planes of a quadratic or equiangular octagonal prism. Hardness of anatase 5.5. Color, indigo-blue, brown, rarely red. Hardness of rutile, 6.5. Color, generally red, brownish-red, blackish. Both possess a strong metallic adamantine lustre. A similar deportment is shown by

Brookite,[*] also TiO_2. Crystallization rhombic, primary form, a right rhombic prism. Hardness, 5.5–6. Color, yellowish to reddish-brown.

(Compare perofskite, which is sometimes hyacinth-red, and crystallizes in cubic crystals. Compare sphene.)

Æschynite, $(Ce,La,Di,Fe,Y)_3Cb_2(Ti,Th)_3O_{14}$, and

---

[*] The opaque, iron-black crystals with submetallic lustre, from Arkansas, have been named by Sheppard arkansite.

Euxenite $(Y,Fe,U)_3Ti_2Cb_2O_{12},H_2O$. When the powder is fused with caustic potash in a silver crucible, and the mass lixiviated with water, the filtered solution neutralized with muriatic acid yields a precipitate, which, boiled with an excess of concentrated muriatic acid and tin-foil, furnishes, upon the addition of water, a blue solution, which turns olive-green in the air, and then fades. If the residue from the lye is boiled with muriatic acid and tin-foil, a rose-red solution is obtained, upon dilution with water, which turns turmeric paper orange if the mineral is æschynite. B. B. æschynite swells up and becomes yellow or brownish. Color of the mineral, black; streak, light brown. Euxenite is not altered B. B. Its color is brownish-black; the streak, reddish-brown. Both possess a fatty, metal-like lustre.

A very similar chemical compound is

Pyrochlore (from Miask), $\overset{\cdot\cdot\cdot}{\ddot{\mathrm{C}}}\mathrm{b}_2;\ddot{\mathrm{T}}\mathrm{i},\mathrm{Th}\dot{\mathrm{C}}\mathrm{e},\dot{\mathrm{C}}\mathrm{a},\dot{\mathrm{F}}\mathrm{e},\dot{\mathrm{N}}\mathrm{a}_2,\mathrm{F}$. Found in octahedrons. Color, brown-red. Streak, light yellow.

OPAL, $SiO_2 + Aq$, in a matrass affords water. B. B. with soda effervesces and forms a transparent glass; infusible by itself. Hardness, 6–6.5; amorphous. Boiled in potassa liquor it is mostly, or entirely, dissolved. The solution treated with a sufficient quantity of sal ammoniac throws down hydrous silicic acid. Colorless, milk-white, yellow, brown, red.

Xenotime (phosphate of yttrium), $(Y,Ce)_3P_2O_8$. B. B. moistened with sulphuric acid it colors the flame feebly green; in phosphorus salt it dissolves with difficulty, forming a colorless glass. Hardness, 5.

(Compare childrenite, also orthoclase, and hyalophane.)

Section ii.—*Hardness*, 7, *and above* 7.

(Compare of the preceding division cassiterite, rutile, and opal, the hardness of which approaches 7 closely.)

QUARTZ (amethyst, chalcedony, jasper, flintstone, rock crystal), SiO_2. B. B. on coal, with soda, effervesce and fuse easily to a transparent glass (too much soda must not be added). Alone they remain infusible and unchanged in the strongest heat of the blowpipe. The powdered mineral fused with caustic potash yields, with water, a more or less complete solution, which, when mixed with a sufficient quantity of chloride of ammonium, gives a heavy white precipitate of hydrous silica. Hardness of quartz, 7. Struck with a steel gives sparks. Its usual crystalline form is a hexagonal prism, sometimes terminated at both ends by six-sided pyramids. Spec. grav. 2.5–2.8. Crystals often as pellucid as glass, and colorless; sometimes topaz-yellow, red, green, blue, and brown colors to black. In some varieties the colors are in bands or stripes (agate).

Here belongs

Tridymite, a hexagonal form of silica with a spec. grav. 2.2–2.3.

Cordierite (iolite), $\mathrm{(Mg,Fe)_2\cancel{Al}_2Si_5O_{18}}$.

Staurotite (staurolite), $\mathrm{H_2(Mg,Fe)_3\cancel{Al}_6Si_6O_{34}}$. Hardness, 7. B. B. do not form a transparent glass with soda. The former is fusible at 5–5.5. Color, blue and grayish-blue. Spec. grav., 2.6. The latter is infusible. Color, brown, reddish-brown. Spec. grav., 3.6.

Beryl (emerald, aquamarine, Smaragd), $\mathrm{Be_3\cancel{Al}Si_6O_{18}}$.

Euclase, $\mathrm{H_2Be_2\cancel{Al}Si_2O_{10}}$.

Phenacite (Phenakit), $\dot{\cancel{\mathrm{Be}}}_3\ddot{\mathrm{Si}}$.

Zirconite (Zirkon), $\mathrm{ZrSiO_4}$. Their hardness, 7.5. B. B. beryl and euclase, at a strong heat, become milk-white and rounded on the thin edges. Beryl crystallizes in hexagonal prisms; cleavage basal and pretty distinct. Euclase crystallizes in clino-rhombic prisms; is perfectly cleavable in two directions at right angles. Phenacite and zirconite B. B. are unchangeable, except that the last loses its color. If powdered zircon is fused with caustic potassa, and the mass boiled with muriatic acid, the diluted acid colors turmeric paper orange (zirconia). If the HCl solution is evaporated to crystallization and the mass boiled with a saturated solution of sulphate of potassium, a white precipitate falls (zirconia); both occur only crystallized. Phenacite in hexagonal pyramids, prisms, or rhombohedrons; its specific gravity, 2.7 to 3. Zirconite in quadratic pyramids and prisms. Specific gravity, 4.4–4.6.

TOPAZ* (topaz, fluosilicate of aluminium, physalite), ($\ddot{\text{Ⱥ}}\text{l},\ddot{\text{S}}\text{i}$, Fl). Hardness, 8; crystallizes in rhombic prisms; basal cleavage distinct. The yellow variety† by exposure to a gentle heat changes from yellow to pink or pale crimson, only seen after cooling. If boracic acid is fused and heated on platinum wire until the flame ceases to be tinged with green, the bead, upon the addition of finely pulverized topaz, again imparts, after continued blowing, a green color to the flame (fluo-boron gas). Gives with salt of phosphorus in the open tube the fluorine reaction.

UWAROWITE (*Ouvarovite*, lime-chrome garnet), $\text{Ca}_3\text{Ꞓr}\text{Si}_3\text{O}_{12}$. Color, emerald-green. B. B. infusible; changes upon heating to a blackish-green, but resuming, upon cooling, its former color; with borax it fuses to an emerald-green glass. Hardness, 7.5–8. Spec. grav., 3.5.

Spinel (aluminate of magnesium), $(\text{Mg},\text{Fe})(\text{Ⱥl},\text{Ꞙe})\text{O}_4$.

Pleonaste (*ceylonite*, ceylanite, iron-magnesia spinel).

GAHNITE (zinc spinel), $(\text{Zn},\text{Mg})(\text{Ⱥl},\text{Ꞙe})\text{O}_4$.

CHLOROSPINEL (magnesia-iron spinel). Their hardness 7.5–8; they occur nearly always crystallized in octahedrons. The mineral powder heated together with phosphoric acid in a platinum crucible until volatilization commences, produces, when cold, upon the addition of water, an almost complete solution. This solution, treated with an excess of caustic potash, yields a copious white precipitate when the mineral is spinel. Chlorospinel gives a yellowish, pleonast a greenish precipitate. The liquid filtered off from these deposits gives, with sulphide of ammonium, no precipitate. *Gahnite* gives, in the phosphoric acid solution with caustic potash, a slight precipitate, and the liquid portion, when filtered off, yields with sulphide of ammonium a greenish-black deposit, which later

---

* According to St. Claire-Deville, and Fauqué, topaz, and some other silicates containing fluorine, when highly heated lose the fluorine as fluoride of silicon. Topaz thus loses 23 per cent. of this fluoride (Dana).

† Brazilian topaz.

B. B. on charcoal gives a heavy coating of zinc oxide. *Spinel* and *pleonast* in powder form are B. B. rather easily soluble in a bead of salt of phosphorus. The glass does not become opalescent on cooling. Gahnite B. B. treated with borax and phosphorus salt is nearly insoluble. Spinel has a red or bluish color; pleonast is black; gahnite dark-green; chlorospinel olive-green and translucent. Very similar to gahnite are—

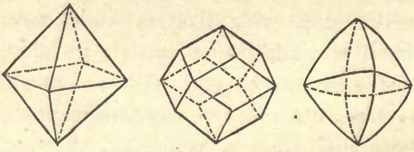
*Dysulite** and

*Kreittonite.** The latter acts before ignition upon a delicate magnetic needle. The spec. grav. of gahnite, dysluite, and kreittonite, 4.3–4.6; that of other spinels, 3.6.

CARBON GROUP.

Diamond (Diamant, Germ.), C. Crystallizes in the tesseral (isometric, D.) system. In octahedrons, dodecahedrons, and more complex forms (Fig. 121). Faces often curved. Cleavage, octahedral and perfect. Color, white or colorless, also yellowish, red, orange, green, blue, brown, and black. Lustre, adamantine. Transparent; translucent when dark-colored. H. 10. G. 3.5–3.6. When rubbed exhibits positive or vitreous electricity. Diamond consists of pure carbon; it is infusible, and not attacked by any acids. At a high temperature, and in contact with air (oxygen), it is consumed, producing carbonic acid gas, CO_2 (carbon dioxide). Diamonds are dis-

Fig. 121.



---

* Brush considers both these as varieties of gahnite.

tinguished by their superior hardness and brilliant reflection of light. Some specimens exposed to the sun for a short time give out light when carried to a dark place. Diamond strongly refracts and disperses light (sparkles). No other gems, unless they are polished, become positive (+) electric when rubbed. It may also be easily distinguished by the use of a small writing or scratching diamond, which fails to mark the faces of a real diamond when drawn lightly across them. The coarse diamonds, unfit for jewelry, are called "*bort*," and the kind in black pebbles or masses, from Brazil, "*carbonado*." The latter occur sometimes in pieces 1000 carats* in weight; they have a spec. grav., 3 to 3.42. Another kind is much like anthracite. Spec. grav. 1.66, although as hard as diamond crystals.

Göppert states that he found algæ-like plants inclosed in diamonds.

They occur principally in alluvial soil and in rocks of secondary formation in the East Indies, Golconda, and in Brazil. They are also found in the sands of the rivers which have their sources in the Uralian Mountains in Russia. In South Africa, where they were first discovered in 1867, they occur in the gravel in the Vaal River. In the United States the diamond has been met with in North Carolina, Georgia, Virginia, Calfornia, Oregon, and Idaho. The prevalent opinion is that diamond, like coal and petroleum, is of vegetable or animal origin.

Diamonds are valued according to their color, transparency, and size. The rose diamond is more valuable than the pure white, owing to the great beauty of its color and its rarity. The green diamond is also much esteemed. The blue is prized

---

* A carat is a conventional weight, and is divided into 4 grains, which are a little lighter than 4 grains Troy; 74$\frac{1}{16}$ carat grains are equal to 72 Troy grains. The term carat is derived from the name of a bean in Africa, which in a dried state has long been used in that country for weighing gold. These beans were early carried to India, and were employed there for weighing diamonds.

only for its rarity, as the color is seldom pure. The brown, gray, and yellow varieties are of much less value than the pure white or limpid diamond. The black diamond is exceedingly rare, but without beauty.

1 carat (4 grains) of small diamonds, employed for polishing the larger ones, for cutting glass, etc., costs from $5 to $6.

A polished diamond (brilliant) weighing 1 carat is valued at from $40 to $50. The prices of diamonds increase to such an extent with their size that a brilliant weighing 5 carats may cost as much as $750 to $1000. The largest diamond at present in Europe is in the possession of the Queen of Portugal; it weighs 215 carats, and is valued at upwards of $750,000.

Mock diamonds. "Bristol stones," "Irish diamonds," "Cape May diamonds," and "California diamonds" are skillfully cut quartz crystals. They are easily detected by the file and their lightness.

CHAPTER X.

CHARACTERISTIC BEHAVIOR OF THE MOST IMPORTANT ORES BEFORE THE BLOWPIPE AND WITH SOLVENTS.*

An ore is a mineral compound in which some metal, usually a valuable metal, forms a prominent constituent. Although a native metal is in this sense not an ore, still, where a native metal or other valuable compound mineral is distributed intimately through the gangue, the mineral and gangue together constitute, in the language of the miner, the ore of the metal it produces.

The more common ores are compounds of the metals with metalloids, such as sulphur, arsenic, oxygen, chlorine, bromine, iodine, phosphorus, silicon, etc.

---

* On this subject the author has made free use of Elderhorst-Nason's Manual on Blowpipe Analysis and Dana's Manual of Mineralogy and Lithology, 3d edit. New York, 1881.

Ores of Antimony.

NATIVE ANTIMONY.—Rhombohedral. Color and streak, tin-white. Lustre, metallic. Brittle.

Composition: Antimony, containing sometimes silver, iron, or arsenic.

B. B. on charcoal fuses easily, and gives a white coating in both O. F. and R. F. If the blowing be intermitted, the globule continues to glow, giving off white fumes, until it is finally covered with antimonious oxide, tinging the R. F. bluish-green.

Stibnite, gray antimony, antimony sulphide.—Color and streak, lead-gray. Lustre, metallic. Brittle. H. 2. G. 4.5. Trimetric.

Composition: $Sb_2S_3 = S.\ 28.2,\ Sb.\ 71.8.$ Fuses in the flame of a candle.

B. B. on coal it is absorbed, giving off white fumes and a sulphurous odor. When pulverized and treated with caustic potassa, is rapidly colored ochre-yellow, and mostly dissolved. The solution, when mixed with an acid, yields an orange-colored precipitate. When pure entirely soluble in hot HCl, with evolution of H_2S.

Berthierite, (iron sulphantimonite). Composition: $FeSb_2S_4 = S.\ 29.12,\ Sb.\ 56.61,\ Fe.\ 10.09,\ Mn.\ 4.9.$

Color, dark steel-gray. Lustre, metallic, less bright than gray antimony. H. 2–3. G. 4.2. Trimetric. On charcoal coats the coal with white oxide of antimony, and after long heating yields a magnetic globule (iron). Gives with fluxes the iron reaction. Easily dissolved by hydrochloric acid with evolution of sulphide of hydrogen.

Kermesite (red antimony). In tufts of cherry-red capillary crystals. Lustre, adamantine. H. 1.5, G. 4.5. Monoclinic. Streak, brownish-red.

Composition: $Sb_2O_3 + 2Sb_2S_3 = Sb.\ 75.3,\ O.\ 4.9,\ S.\ 19.8.$ Is an antimony oxide and sulphide.

B. B. on charcoal behaves like gray antimony. It dissolves mostly in HCl with evolution of sulphide of hydrogen. The powdered mineral, when heated with potash solution, turns yellow and dissolves.

Minerals containing antimony: allemontite, valentinite, senarmontite, cervantite, livingstonite, etc.

Ores of Arsenic.

NATIVE ARSENIC.—Rhombohedral. Color and streak, tin-white, but usually dark-grayish from tarnish. Brittle. H. 3.5. G. 5.6. Hexagonal.

Composition: As, with traces of Sb, Ag, Fe, Co, and Ni.

B. B. volatilizes readily before fusing, with the odor of garlic; also burns with a pale bluish flame when heated just below redness.

Orpiment, yellow arsenic sulphide. In foliated masses.

Color and streak, fine yellow. Lustre, brilliant pearly. H. 1.5. G. 3.4. Trimetric.

Composition: $As_2S_3 = S. 39.0, As. 61.0$.

B. B. it wholly evaporates with an alliaceous odor, and on charcoal burns with a blue flame. Soluble in aqua regia and caustic potassa.

Realgar, red arsenic sulphide. Color, bright red to orange. Lustre, resinous. H. 1.5. M. 3.5. Monoclinic.

Composition: $AsS = S. 29.9, As. 70.1$. Fuses readily and volatilizes like the former.

B. B. on coal with soda in R. F. gives off arsenical fumes, burns with a yellowish-white flame. Aqua regia dissolves it with difficulty, sulphur being precipitated. Boiled with caustic potassa it is decomposed, leaving a brown powder (As_6S) undissolved.

Arsenolite, white arsenic. Color, white. Lustre, silky. H. 1.5. G. 3.7. Isometric.

Composition: $As_2O_3 = As. 75.8, O. 24.2 = 100$. Heated in a tube gives a crystalline sublimate octahedrons.

B. B. on coal with soda gives a strong garlic odor. Slightly soluble in water, more so in water acidulated with HCl.

Minerals containing arsenic: arsenopyrite, scorodite, polybasite, enargite, domeykite, whitneyite, algodonite, smaltite, cobaltite, niccolite, pharmacosiderite, arseniosiderite, etc.

Ores of Bismuth.

NATIVE BISMUTH.—Bi. Color, reddish-white; streak, white; subject to tarnish; brittle when cold, but somewhat malleable when heated. H. 2.5. G. 9.7. Hexagonal.

Composition: Pure bismuth, with traces of arsenic, sulphur, or tellurium.

B. B. on charcoal vaporizes, and leaves a yellow coating on the coal. Fused with sulphur and iodide of potassium, coats the coal with a red sublimate of iodide of bismuth. Readily dissolved by nitric acid; the solution is precipitated white by water.

Tetradymite (*telluric bismuth*).—Massive or granular. Lustre, splendent metallic. H. 2.–2.5. G. 9.7. Hexagonal. Color, steel-gray; soils paper.

Composition: Consists of Bi and Te, with sometimes S and Se. General formula mostly $Bi_2(Te,S)_3 = $ Te. 48.1, Bi. 51.9 (when free of S).

The sulphurous variety contains some 5 per cent. of S, replacing Te.

In the open tube yields a white sublimate of tellurous acid, which B. B. fuses to colorless drops. On coal fuses, gives white fumes, and entirely volatilizes; tinges the R. F. bluish-green; coats the coal at first white (tellurous oxide), and finally orange-yellow (bismuth oxide). Fused together with sulphur and iodide of potassium, coats the coal red, like native Bi.

Bismutite (*Wismuthspath*, Germ.).—Color, white, or light green; streak, greenish-gray to colorless. Lustre, vitreous. Brittle. H. 4. G. 6.9. In acicular crystallizations (pseudomorphous), also incrusting or amorphous; pulverulent.

Composition: $\dddot{\mathrm{B}}\mathrm{i},\ddot{\mathrm{C}},\bar{\mathrm{H}}_2 = $ Carbon dioxide 6.38, bismuth oxide 89.75, water 3.87 = 100.

B. B. fuses readily, and on coal is reduced to Bi, and coats the coal with yellow bismuth oxide. Fused with sulphur and iodide of potassium, behaves like bismuth. Dissolves in HCl with effervescence. The solution has a yellow color.

Bismuthinite (*bismuth glance*).—Color and streak, lead-gray, inclining to tin-white. H. 2. G. 6.4. In acicular crystals, also massive.

Composition: $Bi_2S_3 = S.\ 18.75,\ Bi.\ 81.25$.

In the open tube yields sulphurous fumes, and a white sublimate which B. B. fuses into drops, brown, while hot, and opaque-yellow on cooling. On charcoal gives sulphurous fumes, then fuses with spirting, and coats the coal yellow. When fused with sulphur and iodide of potassium it behaves like Bi. Dissolves in nitric acid, and water produces white precipitate.

Bismite (*bismuth ochre*).—Composition: Bi_2O_3, containing sometimes traces of Fe_2O_3, CuO and As_2O_5. Occurs massive, earthy. G. 4.36.

B. B. it behaves like pure oxide of bismuth. Soluble in HNO_3. Addition of H_2O causes a white precipitate.

Minerals containing bismuth: maldonite, josite, aikinite, chiviatite, emplectite, wittichenite, englytite, bismutoferrite, etc.

Ores of Chromium.

CHROMITE (CHROMIC IRON).—Color, iron-black; streak, dark-brown. Lustre, submetallic. H. 5.5. G. 4.3. Isometric. In octahedral crystals or massive. In small fragments attracted by the magnet. Possesses a less metallic lustre than other black iron ores.

Composition: General formula, $R\text{Ɍ}O_4$ or $Fe\text{Ȼ}rO_4$. Analysis gives $FeO.\ 32,\ Cr_2O_3.\ 68 = 100$. Only slightly attacked by HCl. B. B. infusible alone. Imparts a beautiful green color to the beads of borax and salt of phosphorus when cold. The powdered mineral, when fused with caustic potassa, forms potassium chromate.

The compounds of chromium, used extensively as pigments, are obtained mostly from this ore, for which reason it has been described here.

Daubréelite is a chromium sulphide found in some meteorites.

Minerals containing chromium: crocoite, melanochroite, vanquelinite, walchonskoite, etc.

Ores of Cobalt.

Smaltite (*smaltine*, *Speis-cobalt*, *Germ.*).—Color, tin-white. Streak, grayish-black. Brittle. H. 5.5. G. 6.4. Isometric. Occurs in octahedrons, cubes, dodecahedrons, and massive.

Composition: $(CoNi)As_2$, the ore being either a cobalt arsenide or cobalt-nickel arsenide, and graduating into nickel arsenide, called *chloanthite.* The cobalt in the ore may constitute 23.5 per cent., or it may be wholly absent in the chloanthite.

In the closed tube gives a sublimate of metallic arsenic; in the open tube a white sublimate of arsenous oxide, and sometimes traces of sulphurous acid. B. B. on charcoal affords a garlic odor, fuses to a magnetic globule, which, with fluxes, gives the indications of Fe, Co, and Ni. Gives with HNO_3 a pink solution, As_2O_3 being deposited.

Diff.: Has the white color of mispickel, but this latter yields S and As, and in a closed tube affords arsenic sulphide, orpiment, and realgar.

Cobaltite (*glance cobalt*, *Kobaltglanz*, *Germ.*).—Crystals like those of pyrite, but silver-white in color with a tinge of red, or inclined to steel-gray. Streak, gray-black. Brittle. H. 5.5. G. 6–6.3. Isometric.

Composition: $CoS_2 + CoAs_2 = CoAsS$ = As. 4.52; S. 19.3; Co. 35.5 = 100. Contains often much iron and a little copper.

Unaltered in the closed tube, but in the open tube yields sulphurous fumes and a white sublimate of arsenous oxide. B. B. on coal yields copious arsenical and sulphur fumes, and fuses to a black metallic globule, which is magnetic; with borax a cobalt-blue globule.

Linnaeite (*cobalt pyrites, cobalt sulphide*).—Color, pale steel-gray, tarnishing copper red. Streak, blackish-gray. H. 5.5. G. 4.8–5. Isometric.

Composition: $(Co,Ni)_3S_4$ = S. 42.0; Co. 58.0, but having the Co partly replaced by Ni or Cu.

B. B. on coal yields sulphurous odor and a magnetic globule, often also arsenical fumes.

Erythrite (*cobalt bloom, hydrous cobalt arsenate*).—Color, crimson or peach-red, having a cleavage like mica. Lustre of laminæ, pearly; earthy varieties without lustre. H. 1.5–2. G. 2.9. Monoclinic. Valuable for the manufacture of smalt.

Composition: $Co_3O_8As_2 + 8Aq$ = arsenic acid, 38.4; oxide of cobalt, 37.6; water, 24.0.

B. B. on coal gives arsenical fumes and fuses; yields a blue glass with borax (cobalt).

Acids dissolve it readily to a rose-colored liquid. The solution in concentrated HCl appears blue while hot.

Asbolite (*black cobalt oxide, earthy cobalt*) is a variety of "*wad*" (see Manganese Ores), containing cobalt oxide, which sometimes amounts to 32 per cent.

Composition: MnO_2,CoO,CuO,H_2O.

Color, black. Lustre, dull. H. 2–2.5. G. 3.1–3.3.

B. B. gives a blue bead with salt of phosphorus in O. F. (cobalt), and when heated in R. F. on coal with tin some specimens yield a red, opaque, copper bead. With soda on platinum gives a manganese reaction. Soluble in HCl with evolution of Cl; the solution is usually blue, turning rose-red on addition of water.

Minerals containing cobalt: carrollite, glaucodot, chathamite, skutterudite, alloclasite, bieberite, roselite, etc.

Ores of Copper.

NATIVE COPPER.—Color, copper-red, contains often a little silver disseminated throughout it. Ductile and malleable. H. 2.5–3. G. 8.84. Isometric.

B. B. it fuses readily, and on cooling is covered with black oxide. Dissolves in nitric acid, and produces a deep azure-blue solution on the addition of ammonia.

Obs.: Native copper accompanies the ores of copper, and usually occurs in the vicinity of dykes of igneous rocks.

Chalcopyrite (*copper pyrites*).—Color, brass-yellow, often tarnished deep yellow and also iridescent. Streak, non-metallic, greenish-black, and but little shining. H. 3.5–4. G. 4.15–4.3. Tetragonal.

Composition: $(CuFe)S_2 =$ S, 34.9; Cu, 34.6; iron, 30.5 = 100.

B. B. fuses to a globule which is magnetic (Fe). Gives sulphur fumes on coal. With soda on coal affords a globule of metallic iron with copper. With fluxes the pulverized mineral after roasting gives the reaction of copper and iron. Moistened with HCl it colors the flame blue, even previous to fusion. Dissolves easily in aqua regia, less so in nitric acid.

Bornite (*variegated copper pyrites, erubescite*).—Color, between copper-red and pinchbeck-brown. Tarnishes rapidly on exposure. Streak, pale grayish-black, and but slightly shining. Brittle. H. 3. G. 5. Isometric.

Composition: $(Cu_2Fe)S_3 =$ S, 28.6; Cu, 55.58; Fe, 16.36, but varies much.

B. B. on coal fuses to a brittle globule, attractable by the magnet. Dissolves in nitric acid with separation of sulphur.

Chalcocite (*copper glance*).—Third vitreous copper ore. Color and streak, blackish lead-gray; often tarnished blue or green; streak sometimes shining. H. 2.5–3. G. 5.5. Orthorhombic.

Composition: $Cu_2S =$ S, 20.2; copper, 79.8 = 100.

B. B. on coal gives off fumes of sulphur, fuses easily in the exterior flame, and after the sulphur is driven off, a globule of copper remains. Dissolves in nitric acid, leaving a residue of sulphur.

Tetrahedrite (*gray copper, Fahlerz*).—Color, between steel-gray and iron-black; streak, nearly like the color, sometimes inclined to brown and cherry-red. Rather brittle. Occurs in tetrahedral forms. H. 3–4.5. G. 4.5–5. Isometric (hemihedral).

Composition: $Cu_8S_7Sb_2 (= 4Cu_2S + Sb_2S_3)$. Contains frequently iron and zinc, and sometimes quicksilver.

B. B. the roasted mineral gives with soda on charcoal, after long heating, a globule of copper. Heated in closed tube, fuses and finally yields a dark-red sublimate of tersulphide of antimony, with antimonious acid, and if an excess of soda be added, a sublimate of mercury. The nitric acid solution gives no precipitate with hydrochloric acid, but usually the reaction of iron and zinc.

Domeykite (*arsenical copper*).—Color, tin-white to steel-gray, with a yellow or iridescent tarnish. Lustre, metallic. H. 3–3.5 G. 7–75. Reniform, massive, or disseminated.

Composition: $Cu_3As = As, 28.3; Cu, 71.7 = 100$.

In an open tube fuses and gives a white crystalline sublimate of arsenious oxide. B. B. on charcoal, arsenical fumes and a malleable metallic globule, which on treatment with soda gives a globule of pure copper. Not soluble in hydrochloric, but soluble in nitric acid.

Atacamite (*copper oxychloride*).—Color, various shades of bright-green, sometimes blackish-green; streak, apple-green; translucent. Lustre, adamantine, vitreous. H. 3–3.5. G. 3.7. Trimetric.

Composition: $CuCl_2 + 3H_2CuO_2 = Cl, 16.64; Cu, 59.45; O, 11.25$; water, 12.66 = 100.

In the closed tube gives off much water of an acid reaction, and forms a gray sublimate. B. B. on coal fuses, coloring the O. F. azure-blue, with a green edge, and giving two coatings, one brownish and the other grayish-white; continued blowing yields a globule of metallic copper; the coatings touched with the R. F. volatilize, coloring the flame azure-blue. In acids easily soluble.

Cuprite (*red copper ore*, *Rothkupfererz*, Germ.).—Color, deep red, of various shades; streak, brownish-red. Lustre, adamantine or submetallic. Subtransparent; brittle. H. 3.5–4.

G. 5.8. Isometric. In regular octahedrons, and modified forms of the same; also massive and earthy.

Composition: $Cu_2O = O, 11.2$; copper, $88.8 = 100$.

B. B. on coal yields a globule of copper. In the forceps fuses and colors the flame emerald-green; if previously moistened with HCl the flame is momentarily azure-blue. With the fluxes gives reactions for oxide of copper. Soluble in conc. HCl.

Malachite (*green copper carbonate*).—Color, light green; streak, paler. Usually nearly opaque; crystals, translucent. H. 3.5–4. G. 3.7–4. Monoclinic.

Composition: $Cu_2O_4C + H_2O = CO_2, 19.9$; $CuO, 71.9$; water, $8.2 = 100$. Dissolves with effervescence in nitric acid (distinction from other green ores), also in ammonia.

B. B. Decrepitates and blackens, colors the flame green, and becomes partly a black scoria. With borax it fuses to a deep-green globule, and ultimately affords a bead of copper.

Azurite (*blue malachite*).—Color, deep blue. Streak, bluish, transparent to nearly opaque. Lustre, vitreous. H. 3.5–4. G. 3.5–3.8. Monoclinic.

Composition: $Cu_3O_7C_2 + H_2O = CO_2$, 25.6; CuO, 69.2; $H_2O, 5.2 = 100$.

B. B. and in acids like the preceding.

Chalcanthite (*copper vitriol*, *blue vitriol*).—Color, deep sky-blue. Streak, colorless. Lustre, vitreous. Soluble in water. Taste, nauseous and metallic. H. 2–2.5. G. 2.21. Triclinic.

Composition: $CuSO_4 + 5HO = SO_3, 32.1$; $CuO, 31.8$; $H_2O, 36.1 = 100$.

B. B. on coal, colors the outer flame green, fuses, and affords a globule of copper, crusted with a coat of sulphide. After calcination, gives, with fluxes, the reactions of copper. A piece of polished iron introduced into the solution becomes coated with copper.

Olivenite (*hydrous copper arsenate*).—Color, usually olive-green. Streak, the same. Brittle. H. 3. G. 4.1–4.4. Trimetric.

Composition: $Cu_4O_9As_2 = As_2O_5$, 40.66; CuO, 56.15; water, 3.19 = 100. Fuses easily, coloring the flame bluish-green. B. B. fuses with deflagration, giving off arsenical fumes, and affords a little globule, which, with soda, yield metallic copper. Dissolves in nitric acid, also in ammonia.

Tyrolite (*copper froth*).—Color, verdigris-green or pale apple-green.

Composition: $Cu_5As_2O_{10} + 11Aq$, 45.2 per cent. of copper. A hydrated arsenate of copper, containing also calcium carbonate (as an impurity?) H. 1–2. G. 3. Triclinic.

B. B. on coal, heated with soda and borax until the copper oxide is completely reduced, and the slag dissolved in HCl, a solution is obtained which shows the presence of lime. Dissolves in nitric acid with effervescence; also in ammonia, with a blue color.

Chrysocolla (*hydrous copper silicate*).—Usually as incrustations. Also in thin seams and stains. Color, bright green, resembling malachite. H. 2–4. G. 2–2.4. Usually as an incrustation.

Composition: $CuO_3Si + 2Aq. = SiO_2$, 34.2; CuO, 45.3; H_2O, 20.5 = 100.

B. B. it blackens in the R. F., and yields water without melting. With soda on coal yields a globule of copper. Heated in a glass tube, yields water and blackens. In the forceps, infusible, coloring the O. F. intensely green. Borax and salts of phosphorus dissolve in it with the usual reactions of copper. It is decomposed by acids, silica remaining behind (distinction from malachite, which is completely soluble with effervescence in nitric acid).

General remarks. The most valuable sources of copper for the arts are: *native copper*, *chalcopyrite*, or "*yellow copper ore*," *chalcocite*, or "*copper glance*," *bornite*, or "*variegated copper ore*," *malachite*, or "*green carbonate of copper*," *chrysocolla*, or "*silicate*," *cuprite*, or "*red oxide of copper*," and occasionally, *melaconite*, or "*black copper*."

Minerals containing copper: Dioptase, algodonite, whitneyite, enargite, tenorite (melaconite).

Ores of Gold, Platinum, Iridium, and Palladium.

NATIVE GOLD.—Color and streak, various shades of gold-yellow, becoming pale from alloy with silver; occasionally almost silver-white from the silver present. Easily distinguished by its malleability, its cutting like lead, its high specific gravity, and its resistance to acid. H. 2.5–3. G. 12–20, varying according to the metals alloyed with the gold. Fuses at 2016° F. (1102° C.). Isometric.

Composition: Native gold usually contains silver in various proportions. The finest native gold from Russia yielded gold 98.96, silver, 0.16, copper, 0.35, iron, 0 05. G. 19.099.

The following proportions of gold and silver have been observed in other varieties:—

Gold.		Silver.
3	to	2
3½	"	2
5	"	2
4	"	1 (most common).
6	"	1 (also frequent).

Average of California native gold is 88 per cent. gold, and the range mostly between 87 and 89; the range of the Canadian, mostly between 87 and 89; the range of the Australian, between 90 and 96 per cent. The Chilian gold affords 84 to 96 per cent. of gold, and 15–3 per cent. of silver. The more argentiferous gold has been called *electrum*.

Gold resists the action of heated concentrated nitric acid, and is soluble only in *aqua regia*.

Copper is occasionally found in alloy with gold, and sometimes also iron, bismuth, palladium, and rhodium. A rhodium gold from Mexico, gave the spec. gravity 15.5–16.8, and contained 34–43 per cent. of rhodium. A bismuth gold has been called *maldonite*.

Calaverite is a bronze-yellow gold telluride, $AuTe_4 = Te\ 55.5, Au\ 44.5 = 100$, with a little silver, occurring massive at the

Stanislaus mine, California, and the Red Cloud mine, Colorado, and also the Keystone and Mountain Lion mines, in the Magnolia district.

Krennerite is another gold telluride.

Sylvanite, or *graphic tellurium.* A telluride of gold and silver $(Ag,Au)Te_3 =$ (if $Ag : Au = 1 : 1$) Te, 55.8; Au, 28.5; Ag, $15.7 = 100$. Color and streak, steel-gray to silver-white, and sometimes nearly brass-yellow. H. 1.5–2. G. 7.99–8.33. Monoclinic. Called *graphic* because of a resemblance in the arrangement of the crystals to written characters. Found in California and Colorado.* In an open glass tube yields a white sublimate, which, when played upon by the flame, fuses to transparent drops. On coal fuses to a dark-gray globule, depositing at the same time a white coating, which in the R. F. disappears, tinging the flame bluish-green. Soluble in aqua regia, leaving a residue of chloride of silver. The solution gives a white precipitate with water.

Nagyagite, or foliated tellurium, is a telluride of lead containing 9 to 13 per cent. of gold. (See Lead Ores.)

Petzite is a telluride of silver containing gold; a specimen from Golden Rule Mine, Colorado, contained, according to Genth, 25.60 per cent. (See Silver Ores.)

NATIVE PLATINUM (Pt).—Color and streak, pale or dark steel-gray. Lustre, metallic, shining like silver. Ductile and malleable. H. 4–4.5. G. 16–19. Isometric. Often slightly magnetic, and some masses will take up iron filings. Usually in flattened or angular grains or irregular masses.

Composition: Platinum is generally combined with more or less of the rare metals—iridium, rhodium, palladium, and osmium—besides copper and iron, which give it a darker color than belongs to the pure metal. A Russian specimen afforded Pt, 78.9; Ir, 5.0; Os and Ir, 1.9; Rh, 0.9; Pd, 0.3; Cu, 0.7; Fe, $11.0 = 98.75$.

---

* Consult James D. Dana's Manual of Mineralogy and Lithology, 3d ed. New York, 1881, p. 109.

It is one of the most infusible substances known. It is wholly unaltered before the blowpipe or by fluxes. Soluble only in heated aqua regia. The solution gives a yellow granular precipitate with chloride of potassium. Platinum fuses readily before the oxy-hydrogen blowpipe.

Platin-iridium.—Grains of iridium have been found in Russia, consisting of 76.8 iridium, and 19.64 platinum, with some palladium and copper. A specimen from Brazil contained 27.8 iridium, 55.5 Pt, and 6.9 Rh.

Osmium (*iridium*, *iridosmine*).—A compound of Ir and Os from the platinum mines of Russia, South America, the East Indies, and California. The crystals are pale steel-gray hexagonal prisms, usually found in flat grains. H. 6.7. G. 19.5–21. Hexagonal. Slightly malleable.

Composition variable. One variety, called *newjanskite*, contains Ir, 46.8; Os, 49.3; Rh, 3.2; Fe, 0.7. Another, *sisserskite*, Ir, 25.1; Os, 74.9. The grains are distinguished from those of platinum by their superior hardness. Iridosmine is common in the gold of Northern California, and injures its quality for jewelry.

B. B. infusible. When heated with nitre in a glass tube the characteristic osmium odor is produced. The fused mass is soluble in water; the solution gives, on addition of nitric acid, a green precipitate. Not visibly affected by any acid.

Palladium.—Color, steel-gray, inclining to silver-white. Ductile and malleable. H. 4.5–5. G. 11.3–12.2. Isometric.

Consists of Pd with some Pt and Ir.

Fuses with sulphur, but not alone. In hardness it is equal to fine steel.

Selenpalladite or *allopalladium* is native palladium in hexagonal tables from the Hartz Mountains.

Torpezite is gold containing about 10 per cent. of palladium.

Ores of Iron.

Iron occurs native, and alloyed with variable quantities of nickel in meteoric iron. Its ores are very widely disseminated.

The iron carbonate is one of the most abundant and valuable ores. The spec. grav. of the ordinary workable ores seldom exceeds 5. They are of difficult fusibility before the blowpipe, and nearly all minerals containing iron are attracted by the magnet, either before or after heating.

NATIVE IRON.—Color and streak, iron-gray. Fracture, hackly. Malleable and ductile. H. 4.5. G. 7.3–7.8. Acts strongly on the magnet. It occurs usually massive, disseminated in igneous rocks in grains, or is found in very large masses weighing over a ton (meteoric).

METEORIC IRON.—It contains from 1 to 20 per cent. of nickel, with traces of Co, Cu, Mn, Sn, Cr, P, S, Cl, C.

Color, iron-gray. Lustre, metallic. It possesses often a very broad crystalline structure, long lines and triangular figures being developed by putting nitric acid on a polished surface. Nodules of troilite (FeS) and schreibersite (FeP) are common constituents of iron meteorites. Meteoric iron may be worked like ordinary malleable iron. The nickel diminishes the tendency to rust.

To detect the presence of the other heavy metals, the assay-piece must be dissolved in aqua regia, the liquid mixed with an excess of ammonia, filtered, and the ammoniacal filtrate precipitated with sulphide of ammonium $(NH_4)_2S$. The precipitate consists of sulphides of nickel, cobalt, manganese, and copper, which may be collected on a filter, and treated with borax on coal in the reduction flame until all volatile substances are expelled, the remaining mass powdered in an agate mortar, the powder well calcined, and the calcined mass treated with borax on coal in the O. F. If Co is the only coloring metal present, the bead will exhibit a pure blue color, a small quantity of iron will make the glass appear green while hot, but blue when cold. Cu and Ni, when present to some extent, will interfere with the blue cobalt color. The bead in this case exposed to the R. F. until it appears transparent, and flows quietly. The oxides of copper and nickel are by this means reduced, and the pure color of cobalt or that of cobalt mixed with iron becomes distinct.

Limonite (*brown hematite*).—Color, dark brown and black to ochre-yellow ; streak, yellowish-brown to dull yellow. Lustre, sometimes submetallic, often dull and earthy. H. 5–5.5. G. 3.6–4. Usually massive and often in mammillary or stalactitic forms.

The following are the principal varieties :—

Brown hematite.—The botryoidal, stalactitic, and associated compact forms.

Brown ochre, yellow ochre.—Earthy ochreous varieties of a brown or yellow color.

Brown and yellow clay ironstone.—Impure ore, hard and compact, of a brown or yellow color.

Bog iron ore.—A loose, earthy ore of a brownish-black color, occuring in low grounds.

Composition : $\text{Ꞙe}_2\text{O}_9\text{H}_6(=2\text{ꞘeO}_3+2\text{H}_2\text{O})=\text{Fe}_2\text{O}_3$, 85.6, H_2O 14.4 $=100$; or it is a *hydrous iron sesquioxide*, containing, when pure, about two-thirds its weight of pure iron.

B. B. blackens and becomes magnetic ; with borax in the outer flame, a yellow glass. In a matrass yields water, and red sesquioxide remains ; the clayey varieties treated with salt of phosphorus gives a cloud of undissolved SiO_2 ; treated with soda and nitre on platinum-foil, the manganese reaction is almost always obtained.

Bog ores usually obtain much P, from organic sources.

Göthite (*pyrosiderite*, *Lepidokrokit*), is another iron hydrate, often in prismatic crystals, as well as fibrous and massive, of the formula $\text{ꞘeO}_4\text{H}_2(=\text{ꞘeO}_3+\text{H}_2\text{O})$, and G. 4.0–4.4. Orthorhombic.

Turgite has the formula, $\text{Ꞙe}_2\text{O}_7\text{H}_2=2\text{ꞘeO}_3+\text{H}_2\text{O}$. H. 5–6. G. 3.5–4. Xanthosiderite and limnite are other related hydrates.

Hematite (*specular iron*, *iron sesquioxide*).—Color, dark, steel-gray or iron-black, and often when crystallized having a highly splendent lustre (from Elba, St. Gothard, etc.) ; streak, powder cherry-red to brown. H. 5.5–6.5 (of crystals). G.

4.5–5.3. Hexagonal varieties: Crystallizes in complex modifications of a rhombohedron; also, massive, granular, or micaceous.

Specular iron.—Having a perfectly metallic lustre.

Micaceous iron.—Structure foliated.

Red hematite.—Submetallic, or non-metallic, and of a brownish-red color.

Red ochre.—Soft and earthy, and often containing clay.

Red chalk.—More firm and compact than red ochre, and of a fine texture.

Jaspery clay-iron.—A hard, impure, silicious clayey ore, having a brownish-red, jaspery look and compactness.

Clay ironstone.—The same as the last; the color and appearance less like jasper. But this is one variety only of what is called clay iron, "clay ironstone," a name including also a related variety of *siderite* and *limonite.*

Lenticular argillaceous ore.—A red ore, consisting of small, flattened grains.

Martite is a hematite in octahedrons, derived, it is supposed, from the oxidation of magnetite.

Composition: $\bar{\mathrm{F}}\mathrm{eO_3} = \mathrm{O}, 30; \mathrm{Fe}, 70 = 100.$

B. B. Infusible alone. Heated in the inner flame it becomes strongly magnetic, and gives the usual indications of iron with the fluxes. It dissolves in HCl. Contains sometimes chromium and titanium.

Diff. The red streak and the magnetism produced in the R. F. distinguish hematite (blood-stone) from all other ores.

Magnetite (*magnetic iron ore*).—Color, iron-black; streak, black. Brittle. H. 5.5–6.5. G. 5.0–5.1. Isometric. Strongly attracted by the magnet, and sometimes showing polarity. Often in octahedrons and dodecahedrons, also granularly massive.

Composition: $\mathrm{Fe}\bar{\mathrm{F}}\mathrm{eO_4} = \mathrm{FeO} + \bar{\mathrm{F}}\mathrm{eO_3} = \mathrm{O}, 27.6; \mathrm{Fe}, 72.4 = 100.$

B. B. infusible, and gives the usual reactions of iron with the fluxes, *e. g.*, with borax in the outer flame, a yellow glass.

Diff. The black streak and strong magnetism distinguish it from other species. It constitutes what are called loadstones, or native magnets.

Pyrite (*iron pyrites, iron bisulphide*).—Color, bronze-yellow; streak, brownish-black. Lustre of crystals often splendent metallic. Brittle. H. 6–6.5. G. 4–8.5, being hard enough to strike fire with steel. G. 4.8–5.1. Isometric. Usually in cubes, the striæ of one face at right angles with those of the adjoining faces.

Composition: $FeS_2 = S, 53.3; Fe, 46.7 + 100$. Pyrite often contains a minute quantity of gold.

B. B. on charcoal gives off sulphur, and ultimately affords a globule attractable by the magnet.

Heated in a closed tube, it usually evolves SH_2, and yields a sublimate of S; the residue is attracted by the magnet. But slightly affected by HCl; HNO_3 dissolves it, leaving a residue of S.

Marcasite (*white iron pyrites*).—Color, usually light bronze-yellow, sometimes inclined to green or gray. H. 6–6.5. G. 4.6–4.85. Trimetric. Occurs frequently in radiated masses. Very liable to decomposition.

Composition, FeS_2.

B. B. like the preceding.

Pyrrhotite (*magnetic pyrites, iron sulphide*).—Color, between bronze-yellow and copper-red; streak, dark grayish-black. Brittle. H. 3.5–4.5. G. 4.4–4.65. Hexagonal. slightly attracted by the magnet.

Composition: $Fe_7S_8 = S, 39.5; Fe, 60.5$. Contains sometimes from 3 to 5 per cent. of nickel.

B. B. on charcoal in the O. F. converted into red oxide of iron. In the R. F. it fuses and glows, and yields a black globule which is magnetic, and has a yellow color on a surface of fracture.

Heated in a matrass, it remains unchanged; in the open tube, evolves SO_2, but yields no sublimate.

Soluble in HCl, exceping the S, with evolution of H_2S.

Diff. From common iron pyrites, which it resembles, it is distinguished by its inferior hardness and its magnetic quality; and from chalcopyrite or copper pyrites, by its paleness of color.

Arsenopyrite (*mispickel*).—Color, silver-white. Streak, dark grayish-black. Lustre, shining. Brittle. H. 5.5–6. G. 6.3. Trimetric. Occurs in rhombic prisms and also massive.

Composition: $FeAsS = As, 46.0; S, 19.6; Fe, 34.4 = 100$.

Danaite, a cobaltic variety found in New Hampshire, consists of As, 41.4; S, 17.8; Fe, 32.9; Co, 6.5.

B. B. affords fumes of As and a globule of iron sulphide, which is attracted by the magnet.

Heated in a matrass, yields first a red sublimate of arsenic sulphide, and afterwards a black crystalline one of metallic As. Gives fire with a steel and emits a garlic odor.

Soluble in HNO_3 and aqua regia, leaving a residue of S, and As_2O_5, which dissolve by continued digestion.

Diff. Resembles arsenical cobalt, but is much *harder* and yields a magnetic globule, and does not afford the cobalt reaction with fluxes.

Scorodite.—Color, pale leek-green or liver-brown. Streak, uncolored. Lustre, vitreous. H. 3.5–4. G. 3.1–3.3. Trimetric. Crystallizes in rhombic prisms.

Composition: $FeAs_2O_8 + 4Aq$. A hydrous arsenate of iron, containing As_2O_5, 49.8; Fe_2O_3, 34.6; H_2O, 15.6 = 100.

B. B. fuses easily, coloring the flame blue, P_2O_5. On charcoal gives arsenical fumes, and with soda a black magnetic scoria. With the fluxes reacts for iron.

In a matrass, yields pure water and turns yellow.

Not affected by HNO_3; forms a brown solution with HCl.

Iron sinter is an amorphous form of the same mineral.

Menaccanite (*titaniferous iron*, *ilmenite*, *titanic iron*, *washingtonite*).—Color, iron-black. Streak, submetallic. Lustre, metallic or submetallic. H. 5.6. G. 4.5–5. Hexagonal. Acts slightly on the magnetic needle.

Composition: $(Ti,Fe)_2O_3$, or TiO_3 and Fe_2O_3 in variable proportions. It is a hematite, in which a part of the iron is replaced by Ti.

B. B. alone infusible. With borax and salt of phosphorus in O. F., gives the reactions of pure oxide of iron; but the salt of phosphorus bead, when treated with the R. F., assumes a brownish-red color, the intensity of which depends upon the amount of TiO_3 present; this glass, when treated with tin on charcoal, turns violet.

Diff. It resembles specular iron, but gives no red powder.

It is of no value in the arts, and forms a deleterious constituent of many iron ores.

Siderite (*spathic iron*, *iron carbonate*).—Color, light-grayish to brown; often dark brownish-red; crystallizes in rhombohedrons with distinct cleavage. Usually massive. H. 3–4.5. G. 3.7–3.9. Hexagonal. Streak, uncolored.

Composition: $FeO_3C = CO_2$, 37.9; FeO, 62.1 = 100. Contains frequently some manganese oxide or magnesia, and lime replacing part of the iron protoxide.

B. B. it blackens and becomes magnetic; but alone it is infusible. With borax and salt of phosphorus it gives the pure iron reactions, and with soda and a little nitre sometimes the green manganese reaction. It dissolves in heated HCl with effervescence.

Diff. This mineral, called spathic iron, because it has the aspect of a spar, cleaves like calcite and dolomite, but it has a much higher spec. gravity. Heated in a close glass tube, it gives off CO_2 and becomes magnetic, which distinguishes it from other iron ores.

Melanterite (*copperas*, *green vitriol*).—Color, greenish to white. Lustre, vitreous. Taste, astringent and metallic. Becomes yellowish (oxidizes) when exposed to the air. H. 2. G. 1.83. Monoclinic.

Composition: $FeO_4S + 7Aq = SO_3$, 28.8; FeO, 25.9, H_2O 45.2 = 100.

B. B. becomes magnetic, yields glass with borax.

In a matrass gives off SO_2 and H_2O, which shows acid reaction. Strongly heated, only Fe_2O_3 remains. Soluble in water.

Vivianite (*hydrous iron phosphate*).—Color, deep blue to green. Streak, bluish. Lustre, pearly. H. 1.5–2. G. 2.66. Monoclinic. Crystallized, or in reniform and globular masses.

Composition: $Fe_3O_8P_2 + 8Aq = P_2O_5$, 28.3; FeO, 43.0; H_2O, 28.7 = 100.

B. B. fuses easily to a magnetic globule, coloring the outer flame greenish-blue (P_2O_5). In the forceps the coloring becomes very perceptible. In a matrass, swells and gives pure water. Easily soluble in HCl and HNO_3. A solution of HKO blackens it.

Franklinite.—Color, iron-black. Streak, dark reddish-brown. Brittle. H. 5.5–6.5. G. 4.85–5.1. Isometric. Usually attracted by the magnet. In octahedral and dodecahedral crystals. Also coarse, granular, massive.

Composition: General formula like that of *magnetite*, $\text{R}\,\text{Ɍ}\,\text{O}_4$, but having zinc and manganese replacing part of the iron, as indicated in the formula $(\text{Fe,Zn,Mn})\,(\text{Ꞙe,M̶n})O_4$. A common variety corresponds to Fe_2O_3, 67.6; FeO, 5.8; ZnO, 6.9; MnO, 9.7 = 100.

B. B. with soda on charcoal, a zinc coating is obtained. A soda bead in the outer flame is colored green by manganese. The addition of a little saltpetre and soda to the powdered mineral, and heating the mixture on platinum foil over a Bunsen burner, facilitates the production of a green mass. Soluble in HCl, with evolution of a little chlorine.

Diff. Resembles magnetic iron, but is of a more decided black color, and the streak is a reddish-brown. Found abundantly in New Jersey.

Ores of Lead.

NATIVE LEAD.—A rare mineral, occurring in thin laminæ or globules. G. 11.35.

Galenite (*galena*, *lead sulphide*).—Color and streak, lead-gray. Lustre, shining metallic. Fragile. H. 2.5. G. 7.25–7.7. Isometric. Cleavage, cubic, and easily obtained.

Composition: $PbS = S, 13.4; Pb, 86.6 = 100$. Often contains some silver sulphide, and at times zinc sulphide.

B. B. on charcoal, it decrepitates, unless heated with caution, and fuses, giving off sulphur, coats the coal yellow, and finally yields a globule of lead. It dissolves with difficulty in boiling HCl with evolution of H_2S. Concentrated HNO_3 dissolves it with evolution of red nitrous acid vapor.

Diff. Galena resembles some silver and copper ores in color, but its cubical cleavage, or granular structure when massive, will distinguish it. Its reactions B. B. show it to be a lead ore, and a sulphide.

The lead of commerce is obtained from this ore. It is also employed in glazing common stoneware.

Bournonite (*Rädelerz*, Germ., *wheel ore*).—Color and streak, steel-gray. Lustre, metallic. Brittle. H. 2.5–3. G. 5.7–5.9. Trimetric. Occurs crystallized and massive, granular, compact.

Composition: Variable, $CuPbSbS_3$. Rammelsb. (or $3RS + Sb_2S_3$, with $3RS. = 2PbS + Cu_2S) = S, 19.6; Sb, 25.0; Pb, 42.4; Cu, 13.0 = 100$.

In the closed tube decrepitates, and gives a dark-red sublimate. In the open tube, gives sulphurous acid, and a white sublimate of antimonous oxide. B. B. on charcoal fuses easily, and at first coats the coal white, from antimonious oxide; continued blowing gives a yellow coating of lead oxide; the residue, treated with soda in R. F., gives a globule of copper.

Decomposed by nitric acid, affording a blue solution, and leaving a residue of sulphur, and a white powder, containing antimony and lead.

The following antimonial and arsenical sulphides of lead behave B. B. in a similar manner.

These ores include: *sartorite*, *zinkenite*, *plagionite*, *jamesonite*, *dufrenoysite*, *boulangerite*, *kobellite*, *meneghinite*, *geocronite;* also, *brogniardite*, and *freieslebenite*, in which silver is present, and *stylotypite* and *aikenite*, in which copper is present.

Those minerals in which a part of the SbS_3 is substituted by AsS_3, afford on charcoal arsenical vapors, and in the open tube a crystalline sublimate.

Cerussite (*white lead ore, lead carbonate*).—Color, white, yellow, or gray. Lustre, adamantine. H. 3–3.5. G. 6.46–6.48. Trimetric. Occurs in modified right rhombic prisms; also massive, rarely fibrous.

Composition; $PbO_3C = CO_2$, 16.5; PbO, 83.5 = 100.

B. B. decrepitates, fuses, and, by careful blowing, affords on charcoal a globule of lead. Treated with fluxes, dissolves with effervescence, and gives the reactions of pure lead oxide. Dissolves readily with effervescence in dilute HNO_3; with HCl leaves a white residue of lead chloride; dissolves in a solution of KHO. Associated usually with galena.

Anglesite (*lead sulphate*).—Color, white, or slightly gray or green. Lustre, adamantine. H. 2.75–3. G. 6.1–6.4. Trimetric. Occurs in rhombic prisms, and other forms; often in laminar masses.

Composition: $PbSO_4$, affording about 73 per cent. of oxide of lead.

B. B. fuses in the flame of a candle, and on coal yields lead with soda. The soda is absorbed by the coal, and shows on silver-foil, or a coin, a *strong sulphur reaction.* With great difficulty dissolved by acids. The powdered mineral is soluble in caustic potassa solution.

Minium (*oxide of lead*, *Mennige*, Germ.).—Pulverulent. Color, bright red tinged with yellow. G. 4.6.

Composition: $Pb_3O_4PbO_2 + 2PbO$. Usually associated with galena.

B. B. affords globules of lead in R. F. With HCl evolves chlorine, and is converted into lead chloride.

Massicot (*plumbic ochre*, *Bleiglätte*, Germ.) —Color, yellow. Composed of lead protoxide, PbO; but generally impure.

B. B. behaves like oxide of lead.

Plumbogummite (*Bleigummi*). — Contains Al_2O_3,Pb,H_2O,P_2O_5, in globular forms, having a lustre like gum arabic, and a yellowish or reddish-brown color. H. 4–4.5. G. 6.3–6.4.

Crocoite (*crocoisite*, *lead chromate*, *Rothbleierz*, Germ.).—Color, bright red; streak, orange-yellow. H. 2.5–3. G. 5.9–61. Monoclinic. Occurs in oblique rhombic prisms and massive.

Composition: $PbO_4Cr = CrO_3$, 31.1; PbO, 68.9 = 100.

B. B. fuses at 1.5, and on coal is reduced to metallic lead with deflagration, leaving a residue of chromic oxide, and giving a lead coating. With salt of phosphorus gives an emerald-green bead in both flames. Heated in a matrass, decrepitates, blackens, but recovers its original color on cooling. Fused with potassium bisulphate in the platinum spoon, forms a dark violet mass, which on solidifying becomes reddish, and when cold, greenish-white, thus differing from vanadanite, which on similar treatment gives a yellow mass. (Plattner.)

VAUQUELINITE.—A lead and *copper chromate*, of a very dark green or pearly-black color, occurring usually in minute, irregularly aggregated crystals; also, reniform and massive. H. 2.5–3. G. 5.5–5.8. Monoclinic.

Composition: $Pb_2CuCr_2O_9$. The formula requires: CrO_3, 27.6; PbO, 61.5; CuO, 10.9 = 100.

B. B. on coal slightly intumesces, and fuses to a gray submetallic globule, yielding at the same time small globules of metal. With borax or salt of phosphorus affords a green transparent glass in the outer flame, which in the inner, after cooling, is red to black, according to the amount of mineral in the assay; the red color is more distinct with tin. Partly soluble in HNO_3 to a dark green liquid; the residue is yellow.

Stolzite or *lead tungstate.*—In square octahedrons or prisms. Color, green, gray, brown, or red. Lustre, resinous. H. 2.5–3. G. 7.9–8.1.

Composition: $PbWO_4 = WO_3$, 51; PbO, 49 = 100.

Wulfenite (lead molybdate, Gelbbleierz, Germ.) In dull yellow octahedral crystals, and also massive. Lustre, resinous or adamantine. H. 2.75–3. G. 6.03–7.01. Dimetric; brittle.

Composition: $PbMO_4 = MO_3$, 38.5; PbO, 61.5 = 100. Some varieties contain chromium.

B. B. decrepitates and fuses below 2; with borax in O. F. gives a colorless glass, in R. F. it becomes opaque, black, or dirty green, with black flakes. With salt of phosphorus in O. F. gives a yellowish-green glass, which in R. F. becomes dark green. With soda on charcoal yields metallic lead. Decomposed on evaporation with HCl, with the formation of PbCl and MoO_3; on moistening the residue with water, and adding metallic zinc, it gives an intense blue color, which does not fade on dilution of the liquid.

Lanarkite, $PbSO_4 + PbO$. The formula requires $PbSO_4$, 57.6; PbO, 42.4 = 100. H. 2–2.5. G. 6.3.—Color, pale yellow. Monoclinic.

Leadhillite, $PbSO_4 + 3PbCO_3 = PbSO_4$, 27.45; $PbCO_3$, 72.55 = 100. Recent analyses show the presence of some water. H. 2.5. G. 6.26–6.44. Orthorhombic. Lustre, pearly. Color, white, passing into yellow, green, or gray. Streak, uncolored.

B. B. intumesces, fuses at 1.5. and turns yellow, but white on cooling. Easily reduced on charcoal. With soda affords the reaction for sulphuric acid. Dissolves in HNO_3 with effervescence, leaving a white residue of lead sulphate.

Phosgenite, or corneous lead. $PbCO_3 + PbCl_2$ 73.8, Pb. H. 2.75–4. G. 6–6.31. Dimetric. Occurring in whitish adamantine crystals. Streak, white.

B. B. fuses readily, emits acid vapors, becomes reduced to metallic lead, and gives a white coating of $PbCl_2$, and a yellow one of PbO_2. With salt of phosphorus and copper oxide gives the chlorine reaction.

Soluble in HNO_3 with effervescence.

Pyromorphite (*lead phosphate*). — Color, bright green to brown; sometimes fine orange-yellow, owing to an intermixture with chromate of lead. Streak, white, or nearly so. Lustre, resinous. Nearly transparent. Brittle. H. 3.5–4. G. 6.5–7.1. Hexagonal. In hexagonal prisms, also in globular masses.

Composition: Analogous to apatite, $Pb_3O_8P_2 + \frac{1}{3}PbCl_2 = PO_5$, 15.71; PbO, 82.27; Cl, 2.62 = 100.60. Some varieties contain As, replacing part of the P, and others, calcium replacing the lead.

B. B. in the forceps fuses easily at 1.5, coloring the flame bluish-green; on charcoal fuses without reduction to a globule, which on cooling assumes a crystalline polyhedral form, while the coal is coated white from the chloride, and nearer to the assay, yellow from lead oxide. With soda on coal yields metallic lead; some varieties contain As and give, on charcoal, in the R. F. the odor of garlic. With salt of phosphorus, previously saturated with CuO, gives an azure-blue color to the flame when treated in O. F. (chlorine). In a closed tube gives a white sublimate of $PbCl_2$.

Soluble in HNO_3 and a solution of KHO.

Minerals containing lead: clausthalite, mendipite, caledonite, mimetite, vanadinite, melanochroite, stolzite, etc.

Ores of Manganese.

Pyrolusite (*black oxide of manganese*, *manganese dioxide*).—Color, iron-black. Streak, black, non-metallic. H. 2–2.5. G. 4.8. Trimetric. In small modified rectangular prisms, or in globular masses.

Composition: $MnO_2 = Mn, 63.2; O, 36.8 = 100$.

B. B. with borax affords a deep amethystine color while hot, which becomes red-brown on cooling. In a matrass yields little or no water; when heated to redness, oxygen is evolved.

Differs from psilomelane by its inferior hardness, and from iron ores by the violet glass with borax; gives frequently indications of iron.

Soluble in HCl with evolution of Cl.

Hausmannite, $Mn_3O_4 = 2MnO, MnO_2$, when pure, contains 72.1 per cent. of manganese. Color, brownish-black. Streak, chestnut-brown. H. 5–5.5. G. 4.7. Dimetric.

B. B. and to HCl behaves like the preceding ore.

Braunite, $2(2MnO,MnO_2) + MnO_2,SiO_2$. An oxide of manganese, containing 69 per cent. of Mn when pure. Color and streak, dark brownish-black. Lustre, submetallic. Occurs in square octahedrons and massive. H. 6–6.5. G. 4.8. Dimetric.

B. B. like pyrolusite dissolves in HCl, giving off chlorine, leaving sometimes a residue of SiO_2.

Manganite. A hydrous oxide of manganese. Occurs massive and in rhombic prisms. Color, steel-black to iron-black H. 4–4.5. G. 4.3–4.4. Trimetric. Columnar, often stalactitic. Lustre, submetallic. Color, steel-gray. Streak, reddish-brown, opaque. Fracture, uneven.

In the closed tube yields water; otherwise similar to braunite.

Psilomelane.—Color, black or greenish-black. Streak, reddish or brownish-black, shining. H. 5–6. G. 4–4.4. Massive and botryoidal.

Composition: Doubtful. Essentially MnO_2, with some BaO or K_2O and H_2O. H. 5.6. G. 3.7–4.3. Massive. Color, iron-black to steel-gray.

B. B. like pyrolusite, except that it affords water.

Wad (*bog manganese*).—Color and streak, black or brownish-black. Lustre, dull, earthy. H. 1–6. G. 3–4. Soils the fingers. Massive, reniform, or earthy.

Composition: Consists of manganese dioxide, in varying proportions, from 30 to 70 per cent. mechanically mixed with more or less of iron sesquioxide, 10 to 25 per cent. of water, and often several per cent. of oxide of cobalt or copper.

In a matrass yields water abundantly, and affords a violet glass with borax. There are several varieties.

Lampadite, or cupreous manganese, constitutes a wad, containing 4 to 18 per cent. of copper oxide.

B. B., when treated with soda and borax on charcoal, affords a globule of metallic copper.

Rhodochrosite (*manganese carbonate* dialogite, Mangaspath).—Color, rose-red. Streak, white. H. 3.5–4.5. G. 3.4–3.7. Hexagonal. Like calcite in having three easy cleavages, and in lustre.

Composition: $MnO_3C = CO_2$, 38.6; MnO, 61.4 = 100. Part of the Mn often replaced by Ca,Mg, or Fe.

B. B. changes color to gray, brown, black, and decrepitates strongly, but is infusible. With salt of phosphorus and borax in O. F. gives an amethystine colored bead; in R. F. becomes colorless. With soda and saltpetre on platinum foil yields a green manganate.

Heated with HCl dissolves with effervescence.

Rhodonite.—Usually massive. Color, light brownish-red, flesh-red, sometimes greenish or yellowish when impure; or black on the surface from exposure. Streak, uncolored. H. 5.5–6.5. G. 3.4–3.7. Triclinic. Usually massive.

Composition: Var. $MnSiO_3 = SiO_2$, 45.9; MnO, 54.1 = 100. When heated becomes dark-brown, and gives to borax a deep violet while hot, and reddish-brown when cold.

Resembles red feldspar, but differs in specific gravity, blackening on exposure, and coloring the borax bead.

Franklinite $(\mathrm{Fe,ZnMn})\,(\overline{\mathrm{Fe}}\overline{\mathrm{Mn}})\,O_4$. (See Ores of Iron.) This, and other iron ores containing manganese, are used for making "*spiegeleisen.*"

Minerals containing manganese: wolframite, alabandite, hauerite, chalcophanite, lithiopholite, triphillite, triplite, dickinsonite, reddingite, fairfieldite, triploidite, etc.

Ores of Mercury.

NATIVE MERCURY. Hg. Occurs in fluid globules scattered through the gangue. Color, tin-white. G. 13.56. Becomes solid and crystallizes at —39° F. (—39.40 C.).

Heated in a matrass, it volatilizes, condensing in the neck of the matrass in minute globules. Dissolves readily in HNO_3. Hg is used for the extraction of gold and silver ores.

Native amalgam is a compound of silver and mercury. H. 3–3.5. G. 13.5–14. Isometric. The compounds AgHg = Ag, 35.1; Hg, 64.9, or Ag_2Hg_3 = Ag, 26.5; Hg, 73.5, are included. Another from Chili having the formula $Ag_{12}Hg$, and containing 86.6 per cent. of silver, has been called arguerite; and still another $Ag_{18}Hg$, kongsbergite.

All the ores of mercury are completely volatile, excepting when Ag and Cu are present. In a matrass boils, gives a sublimate of metallic Hg, and leaves a spongy residue of Ag, which, on charcoal, fuses readily to a globule. Dissolves readily in nitric acid.

Cerargyrite (*calomel*, *hornsilver*), occurs usually in distinct crystals or crystalline coats of a pearl-gray color, and resinous adamantine lustre. H. 1–1.5. G. 5.5. Dimetric.

Composition: HgCl.

In a matrass yields a white sublimate of HgCl. In a closed tube, with bisulphate of potassium, gives off vapors of HCl, fuses to a pale hyacinth-red globule, becomes yellow when cold. Not affected by HNO_3. Dissolved by aqua regia. With a solution of KHO, becomes black.

Cinnabar (*mercury sulphide*).—Color, bright red to brownish-red, and brownish-black. Streak, scarlet-red. Occurs in small tabular or six-sided crystals. Also massive. Lustre, unmetallic; of crystals, adamantine. H. 2–2.5. G. 8.5–9. Hexagonal.

Composition: HgS_2=S, 13.8; Hg, 86.2. It contains often impurities. Carbon and clay are found in the *liver ore*, or hepatic cinnabar, which has a brownish color and streak. The pure variety volatilizes entirely before the blowpipe, which fact distinguishes it from *red oxide of iron* or *chromate of lead;* from *realgar* it differs by giving off no alliaceous fumes (As). Mixed with soda and heated in a matrass, affords globules of Hg. In an open tube it is partially decomposed into metallic Hg and SO_2.

HNO_3 and HCl have no visible effect on it. Aqua regia dissolves it, part of the sulphur being precipitated. Insoluble in KHO.

Metacinnabarite has the same composition as cinnabar, but differs in crystallization; it is from Redington Mine, Lake County, California.

Guadalcazarite, of Mexico, is HgS, in which a little of the sulphur is replaced by selenium.

Mercury iodide.—A reddish-brown ore from Mexico.

Tiemannite.—A dark steel-gray mercury selenide, from the Hartz and California.

Coloradoite.—A grayish-black mercury telluride, with G. 8.627, from Colorado. (Genth.)

Magnolite.—A mercurous tellurate, HgO_4Te, from Colorado.

Ores of Nickel.

Niccolite, Copper Nickel, Arsenical Nickel.—Color, pale, copper-red; streak, pale brownish-red. Lustre, metallic. Brittle. H. 5–5.5. G. 7.3–7.7. Hexagonal; usually massive.

Composition: $NiAs = Ni, 44; As, 56 = 100$. Sometimes a part of the arsenic is replaced by Sb.

B. B. gives off arsenical fumes, and fuses to a pale globule, which darkens on exposure. In an open tube yields a copious sublimate of As_2O_3, and the assay piece assumes a yellowish-green color, and crumbles to pieces. Dissolves almost entirely in HNO_3; the solution has a green color; on cooling As_2O_3 separates. Dissolves readily in aqua regia.

Breithauptite or antimonial nickel.—Composition: $NiSb = Sb, 67.8; Ni, 32.2 = 100$. It has a pale copper-red color, inclining to violet. H. 5.5–6. G. 7.54. Crystals hexagonal.

B. B. after long heating on charcoal it yields a magnetic globule. Fuses with difficulty. In an open tube it gives no sulphur reaction. HCl acts but little on it, but aqua regia dissolves it completely.

Gersdorffite.—Nickel glance; a nickel arseno-sulphide; $NiS_2 + NiAs_2 = NiAsS = As, 45.5; S, 19.4; Ni, 35.1$, but varying much in composition. Color, sulphur-white to steel-gray. H. 5.5. G. 5.6–6.9. Isometric. In a matrass decrepitates violently, yelding a yellowish-brown As_2S_3. In an open tube evolves As_2O_5 and SO_2. Partly dissolved by HNO_3, while S and As_2O_3 are precipitated. Aqua regia dissolves it to an apple-green solution, which an excess of NH_3 turns sapphire-blue.

Ullmannite (nickel stibine, nickeliferous gray antimony).—Composition: NiSbS. An antimonial nickel sulphide, containing 25 to 28 per cent. of nickel.

Color, steel-gray, inclining to silver-white. In cubical crystals also massive. H. 5–5.5. G. 6.45. Isometric.

B. B. on charcoal in R. F. fuses to a globule, and yields a white coat of SbO_3, sometimes emits the odor of As. The melting globule treated with borax frequently gives the reaction of Fe and Co, besides those of Ni. Concentrated HNO_3 acts violently on it, S and Sb_2O_3 being precipitated. Aqua regia dissolves it, excepting some S, to a green liquid.

Grünanite (*bismuth-nickel*).—A sulphide containing 31 to 38.5 per cent. of S, 10 to 14 per cent. of Bi, and 22 to 40.7 per cent. of Ni. Contains also Cu and Fe.

Color, light steel-gray to silver-white. Often tarnished yellowish. H. 4.5. G. 5.13.

Millerite (*capillary pyrites*, nickel sulphide).—Color, brass-yellow. Lustre, metallic. Streak, bright. Occurs usually in capillary- or needle-like crystallizations, sometimes like wool. Brittle. H. 3–3.5. G. 4.6–5.65. Hexagonal.

Composition: $NiS = S, 35.6; Ni, 64.4 = 100$.

B. B. on charcoal fuses to a globule, and, after roasting, gives, with borax and salt of phosphorus, a violet bead in O. F. which in R. F. becomes gray from reduced metallic nickel.

In the open tube affords fumes of SO_2. It is but little affected by concentrated HNO_3, but aqua regia dissolves it entirely.

Zaratite (*emerald nickel*).—Color, bright green. Lustre, vitreous. Usually forms incrustations. H. 3–3.25. G. 2.5–2.7.

Composition: $Ni_3CO_5 + 6Aq$. It is a hydrous nickel carbonate.

B. B. infusible alone. Dissolves with effervescence in borax and salt of phosphorus, exhibiting the characteristic nickel reactions. In a matrass loses at 212° F. a large amount of water and blackens. Dissolves readily in heated dilute HNO_3 with effervescence (CO_2).

Annabergite (nickel ochre, nickel arsenate).—Composition: $Ni_3As_2O_8 + 8Aq = As_2O_5, 38.6; NiO, 37.2; H_2O, 24.2 = 100$. Soft, earthy.

Color, apple-green.

B. B. on charcoal in R. F. fuses with emission of arsenical vapor to a blackish-gray globule. When treated with borax the globule gives the reactions of nickel, sometimes also those of iron and cobalt. Soluble in acids.

Morenosite.—A nickel vitriol, $NiO_4S + 7Aq$, having an apple-green to greenish-white color.

Lindackerite, hydrous nickel copper arsenate.

Remingtonite.—A hydrous nickel carbonate, rose-colored, from Maryland.

Genthite (*nickel silicates*), $H_4(Ni,Mg)_4Si_3O_{12}$, is a hydrous magnesium and nickel silicate, of a pale apple-green color, yielding in one analysis 80 per cent. of nickel oxide. H. 3.4. G. 2.4. Amorphous.

Röttisite is similar.

Primelite is an impure apple-green silicate, affording in one case 15.6 per cent. of NiO.

Alipite is similar; so, also, garnierite (and nauméite) from New Caledonia, and worked there for nickel.

Ores of Silver.

Silver occurs native and alloyed with gold, or sometimes with platinum; also combined with arsenic, sulphur, tellurium, antimony, bismuth, chlorine, bromine, iodine; but never as an oxide, carbonate, sulphate, or phosphate.

NATIVE SILVER.—Color and streak, silver-white and shining. Often black externally from tarnish; ductile and malleable. H. 2.5–3. G. 10–11. Isometric. Occurs usually in filiform and arborescent shapes, sometimes in laminæ and massive.

Composition: Native silver is usually an alloy of silver and copper, the latter amounting often to 10 per cent. Also alloyed with gold, as stated under that metal.

B. B. on charcoal fuses easily to a globule of a silver-white color. Dissolves in HNO_3, from which it is precipitated as chloride by HCl; the precipitate is soluble in NH_3. A bright plate of copper, immersed in the nitric-acid solution, becomes coated with silver. Native amalgam is a compound of mercury and silver. (See Mercury Ores.)

Argentite (silver glance, sulphide of silver).—Color and streak, blackish, lead-gray. Streak, shining. Very sectile. H. 2–2.5. G. 7.19–7.4. Isometric. In dodecahedrons. Also reticulated and massive. Cuts like lead (distinction from minerals of the same color).

Composition: When pure, $Ag_2S = S, 12.9; Ag, 87.1$.

B. B. on charcoal in O. F. intumesces, evolves SO_2, and finally yields a globule of metallic Ag. Soluble in dilute HNO_3, leaving a residue of sulphur. The solution, when treated with HCl affords a heavy white precipitate of AgCl, which is redissolved by an excess of ammonia.

Acanthite.—Ag_2S. Trimetric. Differs only in crystalline form from the preceding.

Daleminzite is another silver sulphide from near Freiberg.

Stromeyerite.—A steel-gray sulphide of silver and copper. $Ag_2S + Cu_2S = S, 15.7; Ag, 53.1; Cu, 31.2 = 100$. G. 6.26.

B. B. it fuses, and gives in the open tube SO_2, but a silver globule is not obtained, except by cupellation with *lead.*

Sternbergite.—$AgFe_2S_3$. A sulphide of silver and iron, containing 33 per cent. of silver.

Color, pinchbeck-brown. Streak, black. The ore is foliated, and leaves a tracing on paper like graphite.

B. B. partially reduced to Ag. Partly soluble in HNO_3. The solution yields with HCl a heavy precipitate of AgCl.

Naumannite.—A selenide of silver and lead in iron-black cubes and massive. G. 8. Contains 73 per cent. of silver.

B. B. fuses easily in O. F; quietly in R. F., with intumescence. With borax yields a pure silver globule.

Cerargyrite (hornsilver, silver chloride).—Color, gray, passing into green and blue. Looks somewhat like horn or wax, and cuts like it. H. 1–1.5. G. 5.5. Isometric. Lustre, resinous. Streak, shining. Extensively worked in the mines of South America and Mexico.

Composition: $AgCl = Cl, 24.7; Ag, 75.3 = 100$. Fuses in the flame of a candle, and emits acrid fumes.

B. B. on charcoal affords readily a silver globule. The surface of a plate of iron rubbed with it is silvered. Mixed with oxide of copper, and heated on charcoal in R. F., chloride of copper is formed, which colors the flame azure blue. Insoluble in H_2O and HNO_3, but soluble in NH_3. Partially decomposed by a boiling solution of caustic potash.

Embolite.—A chloro-bromide of silver, resembling the horn-silver.

Color, asparagus- to olive-green. Lustre, adamantine. H. 1–1.5. G. 5.3–5.8. Isometric. Malleable and sectile.

Composition: $Ag(Cl,Br) = AgCl, 51; AgBr, 49$.

B. B. fused with oxide of copper on charcoal in R. F. colors the O. F. greenish, then blue. With soda on charcoal reduced to metallic silver. Heated in a closed tube with bisulphate of potassium gives off bromine vapors, fuses to an intense garnet-red globule, becoming yellow when cold.

Bromyrite (bromic silver).—Color, yellowish-green or green. Lustre, splendent. H. 2–3. G. 5.8–6. Isometric.

Composition: $AgBr = Br, 42.6; Ag, 57.4 = 100$.

B. B. behaves like the preceding.

Iodyrite.—Silver iodide. $AgI = I, 54.0; Ag, 46.0 = 100$. Color, bright yellow. Lustre, adamantine. H. 1.5. G. 5.7. Hexagonal.

B. B. on charcoal fuses readily, colors the flame purple-red, and affords a globule of silver. In a closed tube, with bisulphate of potassium, gives off iodine vapors, fuses to a very dark, almost black, globule.

Tocornalite.—A silver and mercury iodide from Chili. Amorphous.

Color, pale yellow.

Hessite.—A telluride of silver, $Ag_2Te = Te, 37.2; Ag, 62.8 = 100$.

Color, between lead-gray and steel-gray. Sectile. G. 8.3–8.6. Malleable.

B. B. in the open tube a faint sublimate of tellurious acid; on charcoal with soda a silver globule. In HNO_3 dissolves entirely.

Petzite is a hessite with the silver replaced in part by gold, $(Ag,Au)_2Te$. G. 8.7–9.4. Between steel-gray to iron-black. Streak, same. One variety yielded Genth: Te, 32.68; Ag, 41.86; Au, 25.60 = 100.14. Occurs in Colorado, Utah, etc., with hessite.

Tapaltite is a telluride of bismuth and silver.

Sylvanite (graphite tellurium).—A telluride of gold and silver. (See Gold Ores.)

Eucairite, $(Cu,Ag)_2Se$.—A selenide of silver and copper, containing 42–45 per cent. of Ag.

Color, silver-white to lead-gray. Easily cut with the knife.

Solution in HNO_3 yields with HCl a heavy precipitate of AgCl.

Dyscrasite (*antimonial silver*) consists simply of Ag and $Sb = Ag_4Sb = Ag, 78; Sb, 22 = 100$. Color, nearly tin-white. G. 9.4–9.8. Trimetric.

B. B. affords fumes of Sb, leaving finally a globule of Ag. Dissolves in HNO_3, leaving a residue of Sb_2O_3.

Pyrargyrite (*ruby silver, dark-red silver ore*).—Color, black to dark cochineal-red. Streak, cochineal-red. Lustre, splendent, metallic, adamantine. H. 2–2.5. G. 5.7–5.9. Hexagonal.

Composition: $Ag_3S_3Sb(= 3Ag_2S + Sb_2S_3) = S, 17.7; Sb, 22.5; Ag, 59.8 = 100$. Crystallizes in hexagonal prisms.

B. B. fuses very easily; on charcoal a white deposit of SbO_3 is deposited, and, mixed with soda in R. F., a globule of Ag is obtained. In an open tube gives antimony fumes, and SO_2, reddening blue litmus paper. In a matrass fuses easily, yielding by continued heating a sublimate of SbS_3.

Proustite (light-red silver ore).—Resembles the preceding ore. It contains arsenic in place of much or all of the antimony. H. 2–2.5. G. 5.4–5.56. Hexagonal.

Composition: $Ag_3S_3As = S\ 19.4,\ As\ 15.1,\ Ag\ 65.5 = 100$.

B. B. gives off garlic odors.

Stephanite (brittle silver ore, black silver).—Color and streak, iron-black. H. 2–2.5. G. 6.27. Trimetric. Crystallized and massive.

Composition: $Ag_5S_4Sb (= 5Ag_2S + Sb_2S_3) = S\ 16.2,\ Sb\ 15.3,\ Ag\ 68.5$.

B. B. it gives an odor of SO_2, and also fumes of antimony, and yields a dark, metallic globule, from which silver may be obtained by the addition of soda. Soluble in dilute nitric acid, and the solution indicates the presence of silver by silvering a plate of copper.

Polybasite.—Composition: Ag_9Sb_6 (or $9Ag_2S + Sb_2S_3$), 75.5 Ag. Is near stephanite in color, spec. grav., and composition. It crystallizes usually in tabular, hexagonal prisms. H. 2–3. G. 6.214. Trimetric. In the open tube fuses, gives sulphurous and antimonial fumes.

B. B. fuses with spirting to a globule, gives off S (sometimes As), and coats the coal with SbO_3. Long-continued blowing yields a metallic globule, which, with salt of phosphorus, reacts for copper, and, cupelled with lead, gives pure silver. Decomposed by HNO_3.

Miargyrite.—Composition: $AgSbS_2$. Is an antimonial silver sulphide, containing but 36.5 per cent. of silver, and having a *dark, cherry-red streak*, while its color is iron-black. H. 2.5. G. 5.2. Monoclinic.

B. B. on charcoal gives off fumes of Sb, and an odor of SO_2; and in the O. F. a globule is left, which finally yields a button of pure silver. A mixture of borax and soda facilitates the formation of a malleable silver-bead.

Brongniardite.—Composition: $Ag_2PbSb_2S_5$ (or $PbS + Ag_2S + Sb_2S_3$). Contains about 25 per cent. of silver.

Color, black-gray. H. 3. G. 5.9. Isometric. Occurs in octahedrons and massive.

B. B. gives S reaction. The nitric acid solution yields with H_2SO_4 a precipitate of sulphate of lead.

Polyargyrite.—Composition: $12Ag_2S + Sb_2S_3$. Isometric. Cleavage, cubic. Malleable. Resembles polybasite in composition and behavior. Wolfach, Baden.

Freieslebenite (*Schilfglaserz*, Germ.).—Composition: $(Pb, Ag)_5Sb_2S_{11}$ = S, 18.8; Sb, 26.9; Pb, 30.5; Ag, 23.8 = 100.

Color and streak, steel-gray. Lustre, metallic. H. 2–2.5. G. 6–6.4. Monoclinic, yields easily to the knife, and is rather brittle. In an open tube gives sulphurous and antimonial fumes, the latter condensing as a white sublimate.

B. B. on charcoal fuses easily, giving a coating of white antimonious oxide on the outer edge, and near the assay, a yellow one from oxide of lead. Continued blowing leaves a globule of silver.

Pyrostilpnite, (*Feuerblende*, Germ.).—In delicate crystals. Color, hyacinth-red. Contains 62.3 per cent. of silver; also sulphur and antimony.

Ores of Tin.

CASSITERITE, TIN ORE, TIN OXIDE.—Color, brown, or black; streak, pale gray to brownish. Lustre, adamantine (of crystals). H. 6.7. G. 6.4–7.1. Dimetric. In square prisms and octahedrons; often twinned; also massive, in grains and rolled pebbles (Stream tin).

Composition: SnO_2 = O, 21.33; Sn, 78.67 = 100; often contains a little iron and sometimes tantalum.

B. B. alone infusible. On charcoal, with soda, affords a globule of tin. Insoluble in acids. Fused with HKO yields a mass which is mostly soluble in water.

Stannite (*tin pyrites*).—(Cu,Sn,Fe,Zn)S. A sulphide containing 26 per cent. of tin. Color, steel-gray. Lustre, metallic. Occurs usually massive. H. 4. G. 4.3–4.5. Probably dimetric and hemihedral. In an open glass tube yields SO_2 and SnO_2, which collect close to the assay-piece, and which cannot be volatilized by heat.

B. B. on charcoal, in R. F. fuses to a black scoriaceous globule; in O. F. gives off SO_2, and becomes covered with SnO_2. When well calcined by the alternate application of the O. F. and R. F., gives with borax the indications of Fe and Cu. Soluble in nitric acid to a blue solution, while a mixture of S and SnO remains undissolved.

Ores of Zinc.

ZINCITE, RED ZINC ORE, RED ZINC OXIDE.—Color, deep or bright red; streak, orange-yellow. Lustre, brilliant. H. 4–4.5. G. 5.4–5.7. Hexagonal. Of distinctly foliated structure.

Composition: ZnO = O, 19.7; Zn, 80.3 = 100.

B. B. infusible alone, but yields a yellow transparent glass with borax; sometimes the manganese reaction in O. F. with borax. On charcoal, a coating of ZnO.

Dissolves in HNO_3 without effervescence. Occurs with Franklinite at Mine Hill and Sterling Hill, Sussex County, N. J.

Sphalerite (*blende, zinc sulphide*).—Color, waxy-yellow to black; streak, white to reddish-brown. Lustre, resinous. Brittle. H. 3.5–4. G. 3.9–4.2. Isometric. Crystallizes in dodocahedrons.

Composition: ZnS = S, 33; Zn, 67 = 100. Contains frequently a portion of FeS when dark colored; often also 1 to 2 per cent. of CdS (especially the red variety). This ore is the blackjack of miners.

B. B. alone infusible. On charcoal in R. F. a feeble dark coat of CdO is usually obtained, which is followed by a coat of pure ZnO. With soda on coal it is easily reduced, and the characteristic zinc flame frequently observed. Fe is detected by calcining the mineral in O. F. and treating the residue with borax.

Strongly heated in an open tube SO_2 is evolved, and the color of the calcined assay is white, yellowish, or brownish, according to the amount of FeS.

The pulverized mineral dissolves in HNO_3, emitting H_2S.

Smithsonite (*carbonate of zinc*). — Color, impure white, green or brown. Streak, uncolored. Lustre, vitreous or pearly. H. 5. G. 4.3–4.45. Brittle. Hexagonal. Often reniform and stalactitic.

Composition: $ZnO_3C = CO_2$, 35.2; ZnO, 64.8 (four-fifths of which is pure zinc) = 100. Often contains Cd.

B. B. infusible alone, but CO_2 and ZnO are finally vaporized. Negatively electric by friction.

Mixed with soda and exposed to the R. F. it is decomposed and white ZnO deposited on the coal. The coating is at first dark-yellow, or reddish, when Cd is present. It dissolves readily in acids with effervescence; also in a solution of KHO.

Calamine (*hydrous zinc silicate*, *Galmei*).—Color, whitish or white, bluish, greenish, or brownish. Streak, uncolored. Lustre, vitreous or subnacreous. Brittle. H. 4.5–5. G. 3.16–3.9. Orthorhombic. Pyro-electric. The smallest fragment heated attracts light substances. In its physical characters it resembles the preceding ore.

Composition: $Zn_2O_4Si + Aq = SiO_2$, 25.0; ZnO, 67.5; H_2O, 7.5 = 100.

B. B. alone almost infusible. Forms a *clear glass with borax*. In heated H_2SO_4 it dissolves, and the solution gelatinizes on cooling. Partly dissolved by solution of HKO.

Willemite (*zinc silicate*, *troostite*).—Color, whitish, greenish-yellow, apple-green, flesh-red, yellowish-brown. Streak, uncolored. Brittle. H. 5.5. G. 3.89–4.18. Hexagonal.

Composition: $ZnO_3Si = SiO_2$, 27.1; ZnO, 72.9 = 100.

B. B. fuses with difficulty to an enamel; on charcoal with soda yields a coating which is yellow while hot, and white on cooling, and which, moistened with cobalt solution and treated in O. F., is colored bright green. Gelatinizes with HCl.

The zincite, willemite, and franklinite (the latter described under iron ores), of Frankline, N. J., are together worked as a zinc ore, and both zinc and zinc oxide are produced.

APPENDIX.

Carbonaceous Compounds.

Graphite (*plumbago*, *C.*) consists essentially of pure carbon; most specimens contain iron, the quantities of which vary from a mere trace up to 5 per cent. Hexagonal. In flat six-sided prisms or tables. Lustre, metallic. Color, iron-black to dark steel-gray. Thin laminæ, flexible. H. 1–2. G. 2.25–2.27. Soils paper, and feels greasy. The finest and most valuable mineral is used for lead pencils. At a high temperature it burns in the air without flame or smoke, leaving usually some red oxide of iron behind.

B. B. infusible, both alone and with reagents; not acted upon by acids; fused with nitre in a platinum spoon, deflagrates, converting the reagent into potassium carbonate, which effervesces with acids.

Anthracite.—Anthracite (called also glance coal, and stone coal) has a high lustre, and is often iridescent; fracture conchoidal. H. 2.25. G. 1.3–1.8.

Composition: It usually contains 80 to 83 per cent. of carbon, with 4 to 7 of volatile matter; the rest consisting of earthy impurities, which consist of SiO_2, Al_2O_3, and Fe_2O_3. Burns with a feeble blue flame. In a matrass, gives usually a little water, but no empyreumatic oil. Does not color a boiling solution of caustic potash.

Bituminous Coal.—C,H,O, in variable proportions. Bituminous coal varies much in the amount of oil, coal-tar, or gas it yields when heated; and there is a gradual passage in its varieties through semi-anthracite to anthracite. It is of a black color, with the powder black, but it is softer than anthracite. G. 1.2–1.5. The volatile bituminous matter contains from 76 to 90 per cent. of carbon. The earthy impurities consist principally of SiO_2, Al_2O_3, and CaO.

The following tabulation, from Wagner's *Technology*, exhibits at a glance the successive stages and nature of this conversion :—

	Carbon.	Hydrogen.	Oxygen.
Wood	52.65	5.25	42.10
Peat.	60.44	5.96	33.60
Lignite	66.96	5.27	27.76
Earthy brown coal . .	74.20	5.89	19.90
Coal (secondary) . .	76.18	5.64	18.07
Coal (older) . . .	90.50	5.05	4.40
Anthracite . . .	92.85	3.96	3.19

In a matrass some varieties of bituminous coal soften and cake (coking coal), while others are entirely infusible; all varieties are decomposed, evolve combustible gases and empyreumatic oils, and leave a porous residue of more or less metallic lustre (coke), which behaves like anthracite. On platinum foil burns with a luminous flame and emission of smoke, leaving an earthy residue. Boiled with a solution of caustic potash or with ether imparts to these solvents no color, or only a pale yellow.

Brown Coal.—Composition nearly the same as that of bituminous coal, but the organic constituents contain only from 60 to 75 per cent. of carbon. In physical properties bears sometimes a close resemblance to the preceding. Some varieties show distinctly the texture of wood (lignite).

In a matrass infusible, but some varieties soften; evolves combustible gases, empyreumatic oils, water of acid reaction, and a peculiar, disagreeable odor, leaving a residue which consists of carbon and a considerable amount of ash. On platinum foil burns with a smoky flame and emission of a peculiar odor. Boiled with a solution of caustic potash colors the liquid brown.

Asphaltum.—C,H,O in variable proportions, with about

75 per cent. of carbon. G. 1–1.8. Of black or brownish-black color and bituminous odor, is amorphous and pitch-like. Fuses at about 100° C., and burns with a bright flame and emission of a thick smoke, leaving little ash, which consists essentially of $\mathrm{SiO_2}$, $\mathrm{\bar{A}lO_3}$, and $\mathrm{\bar{F}eO_3}$.

In a matrass gives empyreumatic oil, some ammoniacal water, combustible gases, and leaves a carbonaceous residue. Treated with boiling ether colors the solvent wine-red to brownish-red (distinction from bituminous coal); when treated with a boiling solution of caustic potash it does not color the liquid, or at the most imparts to it a pale-yellow color (distinction from brown coal).

Albertite.—Coal-like in hardness. Color, jet-black, but slightly soluble in camphene, and only imperfectly fusing when heated, but having the lustre of asphaltum, and softens a little in boiling water. H. 1–2. G. 1.097.

Fills fissures in the subcarboniferous rocks near Hillsborough, Nova Scotia, and supposed to have been derived from the hydrocarbon of the adjoining rock, and to have been oxidized at the time it was formed, and filled the fissures (J. D. Dana).

Grahamite.—From West Virginia. Forms a related material. H. 2. G. 1.145.

Color, pitchy-black. Soluble mostly in camphene, but melts only imperfectly. An analysis afforded carbon, 70.45; hydrogen, 7.82; oxygen (with traces of nitrogen), 13.46; ash, 2.26 = 100.

Amber (*Bernstein*, Germ.).—Composition, C,H,O. Forms irregular masses.

Color, yellow, sometimes brownish or whitish. Lustre, resinous. Transparent to translucent. H. 2–2.5. G. 1.18. Electric by friction. It consists mainly (85 to 90 per cent.) of a resin, insoluble in all solvents, called *succinite*, and two other resins soluble in alcohol and ether—an ethereal oil and succinic acid ($2\frac{1}{2}$ to 6 per cent.). Amber fuses with difficulty in the matrass, yielding water, empyreumatic oil, gases, succinic acid, and a residue of amber-resin. It burns with a yellow flame, emitting an agreeable odor, leaving behind a black, shining, carbonaceous substance.

Elaterite (*mineral caoutchouc*, *elastic bitumen*) contains C and H. Found in soft flexible masses, hence its name. Color, brownish-black; sub-translucent. G. 0.9–1.25.

Composition: C, 85.5; H, 13.3–98.8. Burns in the flame of a candle with a yellow flame and bituminous odor.

Retinite or *retinasphalt.*—It is found in brown coal, and constitutes a fossil resin, which has a yellow color, is fusible and inflammable, and largely soluble in alcohol.

Hatchettine, similar to the last named, is met with in mineral coal-beds at Merthr Tydail, and near Loch Fyne in Scotland.

Ozocerite is like wax or spermaceti in consistence. G. 0.85–90. Color, white, yellowish-brown. Soluble in ether. It feels greasy, and fuses at 132° to 145° Fah. It has been obtained by destructive distillation from mineral coal, peat, petroleum, etc.

Petroleum.*

Mineral oils of density from 0.60–0.85. Soluble in benzine or camphene. Consists of many liquids of the *naphtha* and *ethylene* series. The composition of the naphtha, or marsh-gas series, is expressed by the general formula C_n+H_{2n+2}, of which methane, or *marsh-gas*, CH_4 is the first or lowest member; and that of the *ethylene* (olefiant gas) series by the formula $C_nH_{2n} =$ C, 85.71; H, 14.29 = 100. It occurs in rocks of all ages from the lower silurian to the most recent ones, and has been formed through the decomposition of animal or vegetable substances, or both.

Petroleum is obtained chiefly at the present time from more or less deeply-seated, subterranenean chambers, or cavities, among the rock-strata, only reached by boring. Being under

---

* See *Coal Oil and Petroleum.* Their Origin, History, Geology, and Chemistry, by Henri Erni. Philadelphia, 1865, published by Henry Carey Baird.

pressure of the gas, associated with it, and, in many cases, that of water also, it rises to the surface in boring, and sometimes makes a "spouting" well. The mineral oil of the rocks has been formed through the decomposition of animal or vegetable substances. From the nature of the rocks, which most abound in the species of hydrocarbons that yield oil, it is evident that the rock material was in the state of a fine mud; that through this mud much vegetable or animal matter was distributed, almost in the condition of an emulsion; that the stratum of this mud becoming afterwards overlaid by other strata, the decomposition of vegetable or animal matter went forward without the presence of atmospheric air, or with very little of it. Under such circumstances either vegetable material or animal oils might be converted, as chemists have shown, into mineral oil. Dry wood consisting approximately (excluding the ash and nitrogen) of 6 atoms of carbon to 9 of hydrogen, and 4 of oxygen. If now all the oxygen of the wood combines with a part of the carbon to form carbonic acid, and this $2CO_2$, thus made, is removed, there will be left C_4H_9; twice this, C_8H_{18}, is the formula of a compound of the marsh gas, or naphtha series. Again, animal oils, by decomposition under similar circumstances, produce like results. Removing from oleic acid its oxygen, O_2, and 1 of carbon, together equivalent to 1 of carbonic acid, there is left $C_{17}H_{34}$, which is an oil of the ethylene series. (J. D. Dana.)

Mendelejeff (Baird's Annual of 1878, p. 146) has proposed a new hypothesis of the origin of petroleum. Starting with the nebular hypothesis, the author regards the interior of the earth as metallic, doubtless composed largely of iron, and carbides of iron. Through rents made by earthquakes, water gained access to these bodies at a high temperature and under great pressure; and by their mutual chemical action metallic oxides and saturated hydro-carbons resulted. These latter, carried by watery vapor, have spread themselves through the overlying rocks. He gives various geological and chemical facts which go to sustain his hypothesis.

The petroleum, as obtained by boring, originally contains several gaseous carbo-hydrogens, viz., methane, CH_4; propane, C_3H_8; and butane (quartane): as fluids are present, pentane, C_5H_{12}; hexane, C_6H_{14}; heptane, C_7H_{16}; octane, C_8H_{18}; nonane, C_9H_{20}; and further, tridecane, $C_{13}H_{28}$; quatuordecane, $C_{14}H_{30}$; quindecane, $C_{15}H_{32}$. The higher members of the methane series, the paraffines* proper, containing 20 or more atoms of C, have the consistency of butter, or are more or less crystalline solids. In many kinds of petroleum they exist in a state of solution, and may be separated by distilling off the more volatile portions. Solid paraffine is a colorless, crystalline, fatty substance, probably consisting of a mixture of several of the higher members of the series, $C_n + H_{2n+2}$.

Alfred Allen has furnished the following table serving for the distinction of *petroleum benzine* or naptha from the coal-tar naptha or "benzol":—

PETROLEUM BENZINE.	COAL-TAR NAPHTA, OR BENZOLE.
1. Consists of heptane (C_7H_{16}) to the amount of about 50 per cent. and its homologues.	1. Consists of benzole (C_6H_6), and its homologues.
2. Heptane contains 84 per cent. C.	2. Benzole contains 92.3 per cent. C.
3. Begins to boil at 140°–170° Fah.	3. Begins to boil at 176° Fah.
4. Specific gravity about 0.69–0.72.	4. Specific gravity about 0.88.
5. Has the odor of petroleum.	5. Has the odor of coal-tar.
6. Dissolves iodine, forming a rasberry-red solution.	6. Dissolves iodine, forming a purple-red solution (similar to the aqueous solution of potassium permanganate).

* From *parum affinis*, indicating their chemical indifference. The name paraffine has long been applied to the solid compounds of the series, on account of this character; and many of the liquid compounds of the same series are known commercially as *paraffine* oils. It is convenient, therefore, to employ the term paraffine as a *generic* name for the whole series.

PETROLEUM BENZINE.	COAL-TAR NAPHTHA, OR BENZOLE.
7. Dissolves (even after some time) only very little pitch of pit coal, the solution being scarcely colored.	7. Dissolves coal-tar pitch freely, forming a dark-brown liquid.
8. Does not mix with carbolic acid, even when previously fused.	8. Mixes in all proportions with pure carbolic acid.
9. Soluble at a common temperature in a mixture of 2 volumes of absolute (100 per cent.) alcohol or in 4 to 5 volumes of methylic (wood spirit), spec. grav. 0.828.	9. With anhydrous alcohol miscible in all proportions. Forms with an equal volume of methylic alcohol (sp. grav. 0.828) a homogeneous liquid.
10. When heated with 4 vols. of nitric acid (spec. grav. 1.45) the acid assumes a brown color, while the oil swims on the top of it.	10. Readily miscible with 4 volumes of nitric acid (sp. grav. 1.45) with evolution of heat and formation of a dark-brown color. A portion of the nitro-benzol thus produced may, when cold, separate as a distinct layer.

Experiment 10 serves to separate petroleum-benzine from light coal-tar oils. The mixture of the oils is treated in a narrow bolt-head, with attached condenser, with nitric acid (spec. grav. 1.45). After the reaction has almost ceased, the liquid is poured into a narrow, graduated tube. The bulk of the upper layer read off gives approximately the quantity of petroleum benzine. The nitro-benzol produced from the coal-tar naphtha remains dissolved in the nitric acid. If a great deal of benzol is present, whereby the nitric acid is incapable to dissolve at all, an independent layer of a deep brown color collects beneath the petroleum benzine.

Detection of Small Quantities of Nitrogen in Organic Compounds.

The detection is based upon the reaction of metallic potassium, which, when heated with any nitrogenous organic compound, forms cyanide of potassium.

A piece of K is placed at the bottom of a narrow test-tube, and covered with the substance to be examined; the mixture is then heated to redness till the excess of K is volatilized, the residue dissolved in water; the solution precipitated by ferroso-ferric salt, *e. g.*, a solution of copperas (oxidized by standing in the air), and mixed with excess of HCl, which, if cyanide of potassium has been formed, leaves a residue of Prussian blue. Substances not containing nitrogen likewise give this reaction if they contain nitre or nitrous acid. Hydrate or carbonate of potassium, instead of potassium, does not give so delicate an indication of nitrogen.*

---

* Lassaigne, J. Chim. méd., 19, 201; also, Jour. pr. Chem., 20, p. 143; also, Gmelin's Handbook of Chem., vol. vii. 147, 153.

INDEX.

CATALOGUE
OF
Practical and Scientific Books
PUBLISHED BY
HENRY CAREY BAIRD & CO.
INDUSTRIAL PUBLISHERS, BOOKSELLERS AND IMPORTERS.
810 Walnut Street, Philadelphia.

☞ Any of the Books comprised in this Catalogue will be sent by mail, free of postage, to any address in the world, at the publication prices.

☞ A Descriptive Catalogue, 84 pages, 8vo., will be sent free and free of postage, to any one in any part of the world, who will furnish his address.

☞ Where not otherwise stated, all of the Books in this Catalogue are bound in muslin.

AMATEUR MECHANICS' WORKSHOP:
A treatise containing plain and concise directions for the manipulation of Wood and Metals, including Casting, Forging, Brazing, Soldering and Carpentry. By the author of the "Lathe and Its Uses." Seventh edition. Illustrated. 8vo. $3.00

ANDRES.—A Practical Treatise on the Fabrication of Volatile and Fat Varnishes, Lacquers, Siccatives and Sealing Waxes.
From the German of ERWIN ANDRES, Manufacturer of Varnishes and Lacquers. With additions on the Manufacture and Application of Varnishes, Stains for Wood, Horn, Ivory, Bone and Leather. From the German of DR. EMIL WINCKLER and LOUIS E. ANDES. The whole translated and edited by WILLIAM T. BRANNT. With 11 illustrations. 12mo. $2.50

ARLOT.—A Complete Guide for Coach Painters:
Translated from the French of M. ARLOT, Coach Painter, for eleven years Foreman of Painting to M. Eherler, Coach Maker, Paris. By A. A. FESQUET, Chemist and Engineer. To which is added an Appendix, containing Information respecting the Materials and the Practice of Coach and Car Painting and Varnishing in the United States and Great Britain. 12mo. $1.25

ARMENGAUD, AMOROUX, AND JOHNSON.—The Practical Draughtsman's Book of Industrial Design, and Machinist's and Engineer's Drawing Companion:

Forming a Complete Course of Mechanical Engineering and Architectural Drawing. From the French of M. Armengaud the elder, Prof. of Design in the Conservatoire of Arts and Industry, Paris, and MM. Armengaud the younger, and Amoroux, Civil Engineers. Rewritten and arranged with additional matter and plates, selections from and examples of the most useful and generally employed mechanism of the day. By WILLIAM JOHNSON, Assoc. Inst. C. E. Illustrated by fifty folio steel plates, and fifty wood-cuts. A new edition, 4to., half morocco $10.00

ARMSTRONG.—The Construction and Management of Steam Boilers:

By R. ARMSTRONG, C. E. With an Appendix by ROBERT MALLET, C. E., F. R. S. Seventh Edition. Illustrated. 1 vol. 12mo. 75

ARROWSMITH.—Paper-Hanger's Companion:

A Treatise in which the Practical Operations of the Trade are Systematically laid down: with Copious Directions Preparatory to Papering; Preventives against the Effect of Damp on Walls; the various Cements and Pastes Adapted to the Several Purposes of the Trade; Observations and Directions for the Panelling and Ornamenting of Rooms, etc. By JAMES ARROWSMITH. 12mo., cloth $1.25

ASHTON.—The Theory and Practice of the Art of Designing Fancy Cotton and Woollen Cloths from Sample:

Giving full instructions for reducing drafts, as well as the methods of spooling and making out harness for cross drafts and finding any required reed; with calculations and tables of yarn. By FREDERIC T. ASHTON, Designer, West Pittsfield, Mass. With fifty-two illustrations. One vol. folio $6.00

ASKINSON.—Perfumes and their Preparation:

A Comprehensive Treatise on Perfumery, containing Complete Directions for Making Handkerchief Perfumes, Smelling-Salts, Sachets, Fumigating Pastils; Preparations for the Care of the Skin, the Mouth, the Hair; Cosmetics, Hair Dyes, and other Toilet Articles. By G.W. ASKINSON. Translated from the German by ISIDOR FURST. Revised by CHARLES RICE. 32 Illustrations. 8vo. $3.00

BAIRD.—Miscellaneous Papers on Economic Questions. By Henry Carey Baird. (*In preparation.*)

BAIRD.—The American Cotton Spinner, and Manager's and Carder's Guide:

A Practical Treatise on Cotton Spinning; giving the Dimensions and Speed of Machinery, Draught and Twist Calculations, etc.; with notices of recent Improvements: together with Rules and Examples for making changes in the sizes and numbers of Roving and Yarn. Compiled from the papers of the late ROBERT H. BAIRD. 12mo. $1.50

BAIRD.—Standard Wages Computing Tables:
An Improvement in all former Methods of Computation, so arranged that wages for days, hours, or fractions of hours, at a specified rate per day or hour, may be ascertained at a glance. By T. SPANGLER BAIRD. Oblong folio $5.00

BAKER.—Long-Span Railway Bridges:
Comprising Investigations of the Comparative Theoretical and Practical Advantages of the various Adopted or Proposed Type Systems of Construction; with numerous Formulæ and Tables. By B. BAKER. 12mo. $1.50

BAKER.—The Mathematical Theory of the Steam-Engine:
With Rules at length, and Examples worked out for the use of Practical Men. By T. BAKER, C. E., with numerous Diagrams. Sixth Edition, Revised by Prof. J. R. YOUNG. 12mo. . 75

BARLOW.—The History and Principles of Weaving, by Hand and by Power:
Reprinted, with Considerable Additions, from "Engineering," with a chapter on Lace-making Machinery, reprinted from the Journal of the "Society of Arts." By ALFRED BARLOW. With several hundred illustrations. 8vo., 443 pages $10.00

BARR.—A Practical Treatise on the Combustion of Coal:
Including descriptions of various mechanical devices for the Economic Generation of Heat by the Combustion of Fuel, whether solid, liquid or gaseous. 8vo. $2.50

BARR.—A Practical Treatise on High Pressure Steam Boilers:
Including Results of Recent Experimental Tests of Boiler Materials, together with a Description of Approved Safety Apparatus, Steam Pumps, Injectors and Economizers in actual use. By WM. M. BARR. 204 Illustrations. 8vo. $3.00

BAUERMAN.—A Treatise on the Metallurgy of Iron:
Containing Outlines of the History of Iron Manufacture, Methods of Assay, and Analysis of Iron Ores, Processes of Manufacture of Iron and Steel, etc., etc. By H. BAUERMAN, F. G. S., Associate of the Royal School of Mines. Fifth Edition, Revised and Enlarged. Illustrated with numerous Wood Engravings from Drawings by J. B. JORDAN. 12mo. $2.00

BAYLES.—House Drainage and Water Service:
In Cities, Villages and Rural Neighborhoods. With Incidental Consideration of Certain Causes Affecting the Healthfulness of Dwellings. By JAMES C. BAYLES, Editor of "The Iron Age" and "The Metal Worker." With numerous illustrations. 8vo. cloth, $3.00

BEANS.—A Treatise on Railway Curves and Location of Railroads:
By E. W. BEANS, C. E. Illustrated. 12mo. Tucks . $1.50

BECKETT.—A Rudimentary Treatise on Clocks, and Watches and Bells:
By Sir EDMUND BECKETT, Bart., LL. D., Q. C. F. R. A. S. With numerous illustrations. Seventh Edition, Revised and Enlarged. 12mo. $2.25

BELL.—Carpentry Made Easy:
Or, The Science and Art of Framing on a New and Improved System. With Specific Instructions for Building Balloon Frames, Barn Frames, Mill Frames, Warehouses, Church Spires, etc. Comprising also a System of Bridge Building, with Bills, Estimates of Cost, and valuable Tables. Illustrated by forty-four plates, comprising nearly 200 figures. By WILLIAM E. BELL, Architect and Practical Builder. 8vo. $5.00

BEMROSE.—Fret-Cutting and Perforated Carving:
With fifty-three practical illustrations. By W. BEMROSE, JR. 1 vol. quarto $3.00

BEMROSE.—Manual of Buhl-work and Marquetry:
With Practical Instructions for Learners, and ninety colored designs. By W. BEMROSE, JR. 1 vol. quarto $3.00

BEMROSE.—Manual of Wood Carving:
With Practical Illustrations for Learners of the Art, and Original and Selected Designs. By WILLIAM BEMROSE, JR. With an Introduction by LLEWELLYN JEWITT, F. S. A., etc. With 128 illustrations, 4to. $3.00

BILLINGS.—Tobacco:
Its History, Variety, Culture, Manufacture, Commerce, and Various Modes of Use. By E. R. BILLINGS. Illustrated by nearly 200 engravings. 8vo. $3.00

BIRD.—The American Practical Dyers' Companion:
Comprising a Description of the Principal Dye-Stuffs and Chemicals used in Dyeing, their Natures and Uses; Mordants, and How Made; with the best American, English, French and German processes for Bleaching and Dyeing Silk, Wool, Cotton, Linen, Flannel, Felt, Dress Goods, Mixed and Hosiery Yarns, Feathers, Grass, Felt, Fur, Wool, and Straw Hats, Jute Yarn, Vegetable Ivory, Mats, Skins, Furs, Leather, etc., etc. By Wood, Aniline, and other Processes, together with Remarks on Finishing Agents, and Instructions in the Finishing of Fabrics, Substitutes for Indigo, Water-Proofing of Materials, Tests and Purification of Water, Manufacture of Aniline and other New Dye Wares, Harmonizing Colors, etc., etc.; embracing in all over 800 Receipts for Colors and Shades, *accompanied by 170 Dyed Samples of Raw Materials and Fabrics.* By F. J. BIRD, Practical Dyer, Author of "The Dyers' Hand-Book." 8vo. $10.00

BLINN.—A Practical Workshop Companion for Tin, Sheet-Iron, and Copper-plate Workers:
Containing Rules for describing various kinds of Patterns used by Tin, Sheet-Iron and Copper-plate Workers; Practical Geometry; Mensuration of Surfaces and Solids; Tables of the Weights of Metals, Lead-pipe, etc.; Tables of Areas and Circumferences of Circles; Japan, Varnishes, Lackers, Cements, Compositions, etc., etc. By LEROY J. BLINN, Master Mechanic. With over One Hundred Illustrations. 12mo. $2.50

BOOTH.—Marble Worker's Manual:
Containing Practical Information respecting Marbles in general, their Cutting, Working and Polishing; Veneering of Marble; Mosaics; Composition and Use of Artificial Marble, Stuccos, Cements, Receipts, Secrets, etc., etc. Translated from the French by M. L. BOOTH. With an Appendix concerning American Marbles. 12mo., cloth $1.50

BOOTH and MORFIT.—The Encyclopædia of Chemistry, Practical and Theoretical:
Embracing its application to the Arts, Metallurgy, Mineralogy, Geology, Medicine and Pharmacy. By JAMES C. BOOTH, Melter and Refiner in the United States Mint, Professor of Applied Chemistry in the Franklin Institute, etc., assisted by CAMPBELL MORFIT, author of "Chemical Manipulations," etc. Seventh Edition. Complete in one volume, royal 8vo., 978 pages, with numerous wood-cuts and other illustrations $5.00

BRAMWELL.—The Wool Carder's Vade-Mecum:
A Complete Manual of the Art of Carding Textile Fabrics. By W. C. BRAMWELL. Third Edition, revised and enlarged. Illustrated. Pp. 400. 12mo. $2.50

BRANNT.—A Practical Treatise on Animal and Vegetable Fats and Oils:
Comprising both Fixed and Volatile Oils, their Physical and Chemical Properties and Uses, the Manner of Extracting and Refining them, and Practical Rules for Testing them; as well as the Manufacture of Artificial Butter, Lubricants, including Mineral Lubricating Oils, etc., and on Ozokerite. Edited chiefly from the German of DRS. KARL SCHAEDLER, G. W. ASKINSON, and RICHARD BRUNNER, with Additions and Lists of American Patents relating to the Extraction, Rendering, Refining, Decomposing, and Bleaching of Fats and Oils. By WILLIAM T. BRANNT. Illustrated by 244 engravings. 739 pages. 8vo. $7.50

BRANNT.—A Practical Treatise on the Manufacture of Soap and Candles:
Based upon the most Recent Experiences in the Practice and Science; comprising the Chemistry, Raw Materials, Machinery, and Utensils and Various Processes of Manufacture, including a great variety of formulas. Edited chiefly from the German of Dr. C. Deite, A. Engelhardt, Dr. C. Schaedler and others; with additions and lists of American Patents relating to these subjects. By WM. T. BRANNT. Illustrated by 163 engravings. 677 pages. 8vo. . . $7.50

BRANNT.—A Practical Treatise on the Raw Materials and the Distillation and Rectification of Alcohol, and the Preparation of Alcoholic Liquors, Liqueurs, Cordials, Bitters, etc.:
Edited chiefly from the German of Dr. K. Stammer, Dr. F. Elsner, and E. Schubert. By WM. T. BRANNT. Illustrated by thirty-one engravings. 12mo. $2.50

BRANNT—WAHL.—The Techno-Chemical Receipt Book:
Containing several thousand Receipts covering the latest, most important, and most useful discoveries in Chemical Technology, and their Practical Application in the Arts and the Industries. Edited chiefly from the German of Drs. Winckler, Elsner, Heintze, Mierzinski, Jacobsen, Koller, and Heinzerling, with additions by WM. T. BRANNT and WM. H. WAHL, PH. D. Illustrated by 78 engravings. 12mo. 495 pages $2.00

ROWN.—Five Hundred and Seven Mechanical Movements:
Embracing all those which are most important in Dynamics, Hydraulics, Hydrostatics, Pneumatics, Steam-Engines, Mill and other Gearing, Presses, Horology and Miscellaneous Machinery; and including many movements never before published, and several of which have only recently come into use. By HENRY T. BROWN 12mo. $1.00

BUCKMASTER.—The Elements of Mechanical Physics:
By J. C. BUCKMASTER. Illustrated with numerous engravings. 12mo. $1.50

BULLOCK.—The American Cottage Builder:
A Series of Designs, Plans and Specifications, from $200 to $20,000, for Homes for the People; together with Warming, Ventilation, Drainage, Painting and Landscape Gardening. By JOHN BULLOCK, Architect and Editor of "The Rudiments of Architecture and Building," etc., etc. Illustrated by 75 engravings. 8vo. $3.50

BULLOCK.—The Rudiments of Architecture and Building:
For the use of Architects, Builders, Draughtsmen, Machinists, Engineers and Mechanics. Edited by JOHN BULLOCK, author of "The American Cottage Builder." Illustrated by 250 Engravings. 8vo. $3.50

BURGH.—Practical Rules for the Proportions of Modern Engines and Boilers for Land and Marine Purposes.
By N. P. BURGH, Engineer. 12mo. $1.50

BYLES.—Sophisms of Free Trade and Popular Political Economy Examined.
By a BARRISTER (SIR JOHN BARNARD BYLES, Judge of Common Pleas). From the Ninth English Edition, as published by the Manchester Reciprocity Association. 12mo. $1

BOWMAN.—The Structure of the Wool Fibre in its Relation to the Use of Wool for Technical Purposes:
Being the substance, with additions, of Five Lectures, delivered at the request of the Council, to the members of the Bradford Technical College, and the Society of Dyers and Colorists. By F. H. BOWMAN, D. Sc., F. R. S. E., F. L. S. Illustrated by 32 engravings. 8vo. $6.50

BYRNE.—Hand-Book for the Artisan, Mechanic, and Engineer:
Comprising the Grinding and Sharpening of Cutting Tools, Abrasive Processes, Lapidary Work, Gem and Glass Engraving, Varnishing and Lackering, Apparatus, Materials and Processes for Grinding and

Polishing, etc. By OLIVER BYRNE. Illustrated by 185 wood engravings. 8vo. $5.00

BYRNE.—Pocket-Book for Railroad and Civil Engineers:
Containing New, Exact and Concise Methods for Laying out Railroad Curves, Switches, Frog Angles and Crossings; the Staking out of work; Levelling; the Calculation of Cuttings; Embankments; Earthwork, etc. By OLIVER BYRNE. 18mo., full bound, pocket-book form $1.75

BYRNE.—The Practical Metal-Worker's Assistant:
Comprising Metallurgic Chemistry; the Arts of Working all Metals and Alloys; Forging of Iron and Steel; Hardening and Tempering; Melting and Mixing; Casting and Founding; Works in Sheet Metal; the Processes Dependent on the Ductility of the Metals; Soldering; and the most Improved Processes and Tools employed by Metal-Workers. With the Application of the Art of Electro-Metallurgy to Manufacturing Processes; collected from Original Sources, and from the works of Holtzapffel, Bergeron, Leupold, Plumier, Napier, Scoffern, Clay, Fairbairn and others. By OLIVER BYRNE. A new, revised and improved edition, to which is added an Appendix, containing The Manufacture of Russian Sheet-Iron. By JOHN PERCY, M. D., F. R. S. The Manufacture of Malleable Iron Castings, and Improvements in Bessemer Steel. By A. A. FESQUET, Chemist and Engineer. With over Six Hundred Engravings, Illustrating every Branch of the Subject. 8vo. $5.00

BYRNE.—The Practical Model Calculator:
For the Engineer, Mechanic, Manufacturer of Engine Work, Naval Architect, Miner and Millwright. By OLIVER BYRNE. 8vo., nearly 600 pages $4.50

CABINET MAKER'S ALBUM OF FURNITURE:
Comprising a Collection of Designs for various Styles of Furniture. Illustrated by Forty-eight Large and Beautifully Engraved Plates. Oblong, 8vo. $3.50

CALLINGHAM.—Sign Writing and Glass Embossing:
A Complete Practical Illustrated Manual of the Art. By JAMES CALLINGHAM. 12mo. $1.50

CAMPIN.—A Practical Treatise on Mechanical Engineering:
Comprising Metallurgy, Moulding, Casting, Forging, Tools, Workshop Machinery, Mechanical Manipulation, Manufacture of Steam-Engines, etc. With an Appendix on the Analysis of Iron and Iron Ores. By FRANCIS CAMPIN, C. E. To which are added, Observations on the Construction of Steam Boilers, and Remarks upon Furnaces used for Smoke Prevention; with a Chapter on Explosions. By R. ARMSTRONG, C. E., and JOHN BOURNE. Rules for Calculating the Change Wheels for Screws on a Turning Lathe, and for a Wheel-cutting Machine. By J. LA NICCA. Management of Steel, Including Forging, Hardening, Tempering, Annealing, Shrinking and Expansion; and the Case-hardening of Iron. By G. EDE. 8vo. Illustrated with twenty-nine plates and 100 wood engravings $5.00

CAREY.—A Memoir of Henry C. Carey.
By DR. WM. ELDER. With a portrait. 8vo., cloth . . 75

CAREY.—The Works of Henry C. Carey:

Harmony of Interests: Agricultural, Manufacturing and Commercial. 8vo. $1.50

Manual of Social Science. Condensed from Carey's "Principles of Social Science." By KATE MCKEAN. 1 vol. 12mo. . $2.25

Miscellaneous Works. With a Portrait. 2 vols. 8vo. $10.00

Past, Present and Future. 8vo. $2.50

Principles of Social Science. 3 volumes, 8vo. . . $10.00

The Slave-Trade, Domestic and Foreign; Why it Exists, and How it may be Extinguished (1853). 8vo. . . . $2.00

The Unity of Law: As Exhibited in the Relations of Physical, Social, Mental and Moral Science (1872). 8vo. . . . $3.50

CLARK.—Tramways, their Construction and Working:
Embracing a Comprehensive History of the System. With an exhaustive analysis of the various modes of traction, including horse-power, steam, heated water and compressed air; a description of the varieties of Rolling stock, and ample details of cost and working expenses. By D. KINNEAR CLARK. Illustrated by over 200 wood engravings, and thirteen folding plates. 2 vols. 8vo. . $12.50

COLBURN.—The Locomotive Engine:
Including a Description of its Structure, Rules for Estimating its Capabilities, and Practical Observations on its Construction and Management. By ZERAH COLBURN. Illustrated. 12mo. . $1.00

COLLENS.—The Eden of Labor; or, the Christian Utopia.
By T. WHARTON COLLENS, author of "Humanics," "The History of Charity," etc. 12mo. Paper cover, $1.00; Cloth . $1.25

COOLEY.—A Complete Practical Treatise on Perfumery:
Being a Hand-book of Perfumes, Cosmetics and other Toilet Articles. With a Comprehensive Collection of Formulæ. By ARNOLD J. COOLEY. 12mo. $1.50

COOPER.—A Treatise on the use of Belting for the Transmission of Power.
With numerous illustrations of approved and actual methods of arranging Main Driving and Quarter Twist Belts, and of Belt Fastenings. Examples and Rules in great number for exhibiting and calculating the size and driving power of Belts. Plain, Particular and Practical Directions for the Treatment, Care and Management of Belts. Descriptions of many varieties of Beltings, together with chapters on the Transmission of Power by Ropes; by Iron and Wood Frictional Gearing; on the Strength of Belting Leather; and on the Experimental Investigations of Morin, Briggs, and others. By JOHN H. COOPER, M. E. 8vo. $3.50

CRAIK.—The Practical American Millwright and Miller.
By DAVID CRAIK, Millwright. Illustrated by numerous wood engravings and two folding plates. 8vo. $5.00

CREW.—A Practical Treatise on Petroleum:

Comprising its Origin, Geology, Geographical Distribution, History, Chemistry, Mining, Technology, Uses and Transportation. Together with a Description of Gas Wells, the Application of Gas as Fuel, etc. By BENJAMIN J. CREW. With an Appendix on the Product and Exhaustion of the Oil Regions, and the Geology of Natural Gas in Pennsylvania and New York. By CHARLES A. ASHBURNER, M. S., Geologist in Charge Pennsylvania Survey, Philadelphia Illustrated by 70 engravings. 8vo. 508 pages $5.00

CROSS.—The Cotton Yarn Spinner:

Showing how the Preparation should be arranged for Different Counts of Yarns by a System more uniform than has hitherto been practiced; by having a Standard Schedule from which we make all our Changes. By RICHARD CROSS. 122 pp. 12mo. . 75

CRISTIANI.—A Technical Treatise on Soap and Candles:

With a Glance at the Industry of Fats and Oils. By R. S. CRISTIANI, Chemist. Author of "Perfumery and Kindred Arts." Illustrated by 176 engravings. 581 pages, 8vo. . . . $12.50

CRISTIANI.—Perfumery and Kindred Arts:

A Comprehensive Treatise on Perfumery, containing a History of Perfumes from the remotest ages to the present time. A complete detailed description of the various Materials and Apparatus used in the Perfumer's Art, with thorough Practical Instruction and careful Formulæ, and advice for the fabrication of all known preparations of the day, including Essences, Tinctures, Extracts, Spirits, Waters, Vinegars, Pomades, Powders, Paints, Oils, Emulsions, Cosmetics, Infusions, Pastilles, Tooth Powders and Washes, Cachous, Hair Dyes, Sachets, Essential Oils, Flavoring Extracts, etc.; and full details for making and manipulating Fancy Toilet Soaps, Shaving Creams, etc., by new and improved methods. With an Appendix giving hints and advice for making and fermenting Domestic Wines, Cordials, Liquors, Candies, Jellies, Syrups, Colors, etc., and for Perfuming and Flavoring Segars, Snuff and Tobacco, and Miscellaneous Receipts for various useful Analogous Articles. By R. S. CRISTIANI, Consulting Chemist and Perfumer, Philadelphia. 8vo. . . $10.00

DAVIDSON.—A Practical Manual of House Painting, Graining, Marbling, and Sign-Writing:

Containing full information on the processes of House Painting in Oil and Distemper, the Formation of Letters and Practice of Sign-Writing, the Principles of Decorative Art, a Course of Elementary Drawing for House Painters, Writers, etc., and a Collection of Useful Receipts. With nine colored illustrations of Woods and Marbles, and numerous wood engravings. By ELLIS A. DAVIDSON. 12mo. $3.00

DAVIES.—A Treatise on Earthy and Other Minerals and Mining:

By D. C. DAVIES, F. G. S., Mining Engineer, etc. Illustrated by 76 Engravings. 12mo. $5.00

DAVIES.—A Treatise on Metalliferous Minerals and Mining:
By D. C. DAVIES, F. G. S., Mining Engineer, Examiner of Mines, Quarries and Collieries. Illustrated by 148 engravings of Geological Formations, Mining Operations and Machinery, drawn from the practice of all parts of the world. 2d Edition, 12mo., 450 pages $5.00

DAVIES.—A Treatise on Slate and Slate Quarrying:
Scientific, Practical and Commercial. By D. C. DAVIES, F. G. S., Mining Engineer, etc. With numerous illustrations and folding plates. 12mo. $2.00

DAVIS.—A Treatise on Steam-Boiler Incrustation and Methods for Preventing Corrosion and the Formation of Scale:
By CHARLES T. DAVIS. Illustrated by 65 engravings. 8vo. $1.50

DAVIS.—The Manufacture of Paper:
Being a Description of the various Processes for the Fabrication, Coloring and Finishing of every kind of Paper, Including the Different Raw Materials and the Methods for Determining their Values, the Tools, Machines and Practical Details connected with an intelligent and a profitable prosecution of the art, with special reference to the best American Practice. To which are added a History of Paper, complete Lists of Paper-Making Materials, List of American Machines, Tools and Processes used in treating the Raw Materials, and in Making, Coloring and Finishing Paper. By CHARLES T. DAVIS. Illustrated by 156 engravings. 608 pages, 8vo. $6.00

DAVIS.—The Manufacture of Leather:
Being a description of all of the Processes for the Tanning, Tawing, Currying, Finishing and Dyeing of every kind of Leather; including the various Raw Materials and the Methods for Determining their Values; the Tools, Machines, and all Details of Importance connected with an Intelligent and Profitable Prosecution of the Art, with Special Reference to the Best American Practice. To which are added Complete Lists of all American Patents for Materials, Processes, Tools, and Machines for Tanning, Currying, etc. By CHARLES THOMAS DAVIS. Illustrated by 302 engravings and 12 Samples of Dyed Leathers. One vol., 8vo., 824 pages . . . $10.00

DAWIDOWSKY—BRANNT.—A Practical Treatise on the Raw Materials and Fabrication of Glue, Gelatine, Gelatine Veneers and Foils, Isinglass, Cements, Pastes, Mucilages, etc.:
Based upon Actual Experience. By F. DAWIDOWSKY, Technical Chemist. Translated from the German, with extensive additions, including a description of the most Recent American Processes, by WILLIAM T. BRANNT, Graduate of the Royal Agricultural College of Eldena, Prussia. 35 Engravings. 12mo. . . . $2.50

DE GRAFF.—The Geometrical Stair-Builders' Guide:
Being a Plain Practical System of Hand-Railing, embracing all its necessary Details, and Geometrically Illustrated by twenty-two Steel Engravings; together with the use of the most approved principles of Practical Geometry. By SIMON DE GRAFF, Architect. 4to. $2.50

DE KONINCK—DIETZ.—A Practical Manual of Chemical Analysis and Assaying:

As applied to the Manufacture of Iron from its Ores, and to Cast Iron, Wrought Iron, and Steel, as found in Commerce. By L. L. DE KONINCK, Dr. Sc., and E. DIETZ, Engineer. Edited with Notes, by ROBERT MALLET, F. R. S., F. S. G., M. I. C. E., etc. American Edition, Edited with Notes and an Appendix on Iron Ores, by A. A. FESQUET, Chemist and Engineer. 12mo. . . . $2.50

DUNCAN.—Practical Surveyor's Guide:

Containing the necessary information to make any person of common capacity, a finished land surveyor without the aid of a teacher By ANDREW DUNCAN. Illustrated. 12mo. . . . $1 25

DUPLAIS.—A Treatise on the Manufacture and Distillation of Alcoholic Liquors:

Comprising Accurate and Complete Details in Regard to Alcohol from Wine, Molasses, Beets, Grain, Rice, Potatoes, Sorghum, Asphodel, Fruits, etc.; with the Distillation and Rectification of Brandy, Whiskey, Rum, Gin, Swiss Absinthe, etc., the Preparation of Aromatic Waters, Volatile Oils or Essences, Sugars, Syrups, Aromatic Tinctures, Liqueurs, Cordial Wines, Effervescing Wines, etc., the Ageing of Brandy and the improvement of Spirits, with Copious Directions and Tables for Testing and Reducing Spirituous Liquors, etc., etc. Translated and Edited from the French of MM. DUPLAIS, Ainé et Jeune. By M. MCKENNIE, M. D. To which are added the United States Internal Revenue Regulations for the Assessment and Collection of Taxes on Distilled Spirits. Illustrated by fourteen folding plates and several wood engravings. 743 pp. 8vo. $10 00

DUSSAUCE.—Practical Treatise on the Fabrication of Matches, Gun Cotton, and Fulminating Powder.

By Professor H. DUSSAUCE. 12mo. $3 00

DYER AND COLOR-MAKER'S COMPANION:

Containing upwards of two hundred Receipts for making Colors, on the most approved principles, for all the various styles and fabrics now in existence; with the Scouring Process, and plain Directions for Preparing, Washing-off, and Finishing the Goods. 12mo. $1 25

EDWARDS.—A Catechism of the Marine Steam-Engine,

For the use of Engineers, Firemen, and Mechanics. A Practical Work for Practical Men. By EMORY EDWARDS, Mechanical Engineer. Illustrated by sixty-three Engravings, including examples of the most modern Engines. Third edition, thoroughly revised, with much additional matter. 12mo. 414 pages . . . $2 00

EDWARDS.—Modern American Locomotive Engines,

Their Design, Construction and Management. By EMORY EDWARDS. Illustrated 12mo. $2.00

EDWARDS.—The American Steam Engineer:

Theoretical and Practical, with examples of the latest and most approved American practice in the design and construction of Steam Engines and Boilers. For the use of engineers, machinists, boiler-makers, and engineering students. By EMORY EDWARDS. Fully illustrated, 419 pages. 12mo. $2.50

EDWARDS.—Modern American Marine Engines, Boilers, and Screw Propellers,

Their Design and Construction. Showing the Present Practice of the most Eminent Engineers and Marine Engine Builders in the United States. Illustrated by 30 large and elaborate plates. 4to. $5.00

EDWARDS.—The Practical Steam Engineer's Guide

In the Design, Construction, and Management of American Stationary, Portable, and Steam Fire-Engines, Steam Pumps, Boilers, Injectors, Governors, Indicators, Pistons and Rings, Safety Valves and Steam Gauges. For the use of Engineers, Firemen, and Steam Users. By EMORY EDWARDS. Illustrated by 119 engravings. 420 pages. 12mo. $2 50

EISSLER.—The Metallurgy of Gold:

A Practical Treatise on the Metallurgical Treatment of Gold-Bearing Ores, including the Processes of Concentration and Chlorination, and the Assaying, Melting, and Refining of Gold. By M. EISSLER. With 132 Illustrations. 12mo. $3.50

EISSLER.—The Metallurgy of Silver:

A Practical Treatise on the Amalgamation, Roasting, and Lixiviation of Silver Ores, including the Assaying, Melting, and Refining of Silver Bullion. By M. EISSLER. 124 Illustrations. 336 pp. 12mo. $4.25

ELDER.—Conversations on the Principal Subjects of Political Economy.

By DR. WILLIAM ELDER. 8vo. $2.50

ELDER.—Questions of the Day,

Economic and Social. By DR. WILLIAM ELDER. 8vo. . $3.00

ERNI.—Mineralogy Simplified.

Easy Methods of Determining and Classifying Minerals, including Ores, by means of the Blowpipe, and by Humid Chemical Analysis, based on Professor von Kobell's Tables for the Determination of Minerals, with an Introduction to Modern Chemistry. By HENRY ERNI, A.M., M.D., Professor of Chemistry. Second Edition, rewritten, enlarged and improved. 12mo. $3.00

FAIRBAIRN.—The Principles of Mechanism and Machinery of Transmission:

Comprising the Principles of Mechanism, Wheels, and Pulleys, Strength and Proportions of Shafts, Coupling of Shafts, and Engaging and Disengaging Gear. By SIR WILLIAM FAIRBAIRN, Bart C. E. Beautifully illustrated by over 150 wood-cuts. In one volume. 12mo $2.50

FLEMING.—Narrow Gauge Railways in America.

A Sketch of their Rise, Progress, and Success. Valuable Statistics as to Grades, Curves, Weight of Rail, Locomotives, Cars, etc. By HOWARD FLEMING. Illustrated, 8vo. $1 00

FORSYTH.—Book of Designs for Headstones, Mural, and other Monuments:

Containing 78 Designs. By JAMES FORSYTH. With an Introduction by CHARLES BOUTELL, M. A. 4 to., cloth . . . $5 00

FRANKEL—HUTTER.—A Practical Treatise on the Manufacture of Starch, Glucose, Starch-Sugar, and Dextrine:
Based on the German of LADISLAUS VON WAGNER, Professor in the Royal Technical High School, Buda-Pest, Hungary, and other authorities. By JULIUS FRANKEL, Graduate of the Polytechnic School of Hanover. Edited by ROBERT HUTTER, Chemist, Practical Manufacturer of Starch-Sugar. Illustrated by 58 engravings, covering every branch of the subject, including examples of the most Recent and Best American Machinery. 8vo., 344 pp. . $3.50

GARDNER.—The Painter's Encyclopædia:
Containing Definitions of all Important Words in the Art of Plain and Artistic Painting, with Details of Practice in Coach, Carriage, Railway Car, House, Sign, and Ornamental Painting, including Graining, Marbling, Staining, Varnishing, Polishing, Lettering, Stenciling, Gilding, Bronzing, etc. By FRANKLIN B. GARDNER. 158 Illustrations. 12mo. 427 pp. $2.00

GARDNER.—Everybody's Paint Book:
A Complete Guide to the Art of Outdoor and Indoor Painting, Designed for the Special Use of those who wish to do their own work, and consisting of Practical Lessons in Plain Painting, Varnishing, Polishing, Staining, Paper Hanging, Kalsomining, etc., as well as Directions for Renovating Furniture, and Hints on Artistic Work for Home Decoration. 38 Illustrations. 12mo., 183 pp. . $1.00

GEE.—The Goldsmith's Handbook:
Containing full instructions for the Alloying and Working of Gold, including the Art of Alloying, Melting, Reducing, Coloring, Collecting, and Refining; the Processes of Manipulation, Recovery of Waste; Chemical and Physical Properties of Gold; with a New System of Mixing its Alloys; Solders, Enamels, and other Useful Rules and Recipes. By GEORGE E. GEE. 12mo. . . $1.75

GEE.—The Silversmith's Handbook:
Containing full instructions for the Alloying and Working of Silver, including the different modes of Refining and Melting the Metal; its Solders; the Preparation of Imitation Alloys; Methods of Manipulation; Prevention of Waste; Instructions for Improving and Finishing the Surface of the Work; together with other Useful Information and Memoranda. By GEORGE E. GEE. Illustrated. 12mo. $1.75

GOTHIC ALBUM FOR CABINET-MAKERS:
Designs for Gothic Furniture. Twenty-three plates. Oblong $2.00

GRANT.—A Handbook on the Teeth of Gears:
Their Curves, Properties, and Practical Construction. By GEORGE B. GRANT. Illustrated. Third Edition, enlarged. 8vo. $1.50

GREENWOOD.—Steel and Iron:
Comprising the Practice and Theory of the Several Methods Pursued in their Manufacture, and of their Treatment in the Rolling-Mills, the Forge, and the Foundry. By WILLIAM HENRY GREENWOOD, F. C. S. With 97 Diagrams, 536 pages. 12mo. $2.00

GREGORY.—Mathematics for Practical Men:

Adapted to the Pursuits of Surveyors, Architects, Mechanics, and Civil Engineers. By OLINTHUS GREGORY. 8vo., plates $3.00

GRIMSHAW.—Saws:

The History, Development, Action, Classification, and Comparison of Saws of all kinds. *With Copious Appendices.* Giving the details of Manufacture, Filing, Setting, Gumming, etc. Care and Use of Saws; Tables of Gauges; Capacities of Saw-Mills; List of Saw-Patents, and other valuable information. By ROBERT GRIMSHAW. Second and greatly enlarged edition, *with Supplement*, and 354 Illustrations. Quarto $5.00

GRISWOLD.—Railroad Engineer's Pocket Companion for the Field:

Comprising Rules for Calculating Deflection Distances and Angles, Tangential Distances and Angles, and all Necessary Tables for Engineers; also the Art of Levelling from Preliminary Survey to the Construction of Railroads, intended Expressly for the Young Engineer, together with Numerous Valuable Rules and Examples. By W. GRISWOLD. 12mo., tucks $1.75

GRUNER.—Studies of Blast Furnace Phenomena:

By M. L. GRUNER, President of the General Council of Mines of France, and lately Professor of Metallurgy at the Ecole des Mines. Translated, with the author's sanction, with an Appendix, by L. D. B. GORDON, F. R. S. E., F. G. S. 8vo. $2.50

Hand-Book of Useful Tables for the Lumberman, Farmer and Mechanic:

Containing Accurate Tables of Logs Reduced to Inch Board Measure, Plank, Scantling and Timber Measure; Wages and Rent, by Week or Month; Capacity of Granaries, Bins and Cisterns; Land Measure, Interest Tables, with Directions for Finding the Interest on any sum at 4, 5, 6, 7 and 8 per cent., and many other Useful Tables. 32 mo., boards. 186 pages 25

HASERICK.—The Secrets of the Art of Dyeing Wool, Cotton, and Linen,

Including Bleaching and Coloring Wool and Cotton Hosiery and Random Yarns. A Treatise based on Economy and Practice. By E. C. HASERICK. *Illustrated by* 323 *Dyed Patterns of the Yarns or Fabrics.* 8vo. $7.50

HATS AND FELTING:

A Practical Treatise on their Manufacture. By a Practical Hatter. Illustrated by Drawings of Machinery, etc. 8vo. . . . $1.25

HOFFER.—A Practical Treatise on Caoutchouc and Gutta Percha,

Comprising the Properties of the Raw Materials, and the manner of Mixing and Working them; with the Fabrication of Vulcanized and Hard Rubbers, Caoutchouc and Gutta Percha Compositions, Water-proof Substances, Elastic Tissues, the Utilization of Waste, etc., etc. From the German of RAIMUND HOFFER. By W. T. BRANNT. Illustrated 12mo. $2.50

HOFMANN.—A Practical Treatise on the Manufacture of Paper in all its Branches:

By CARL HOFMANN, Late Superintendent of Paper-Mills in Germany and the United States; recently Manager of the "Public Ledger" Paper-Mills, near Elkton, Maryland. Illustrated by 110 wood engravings, and five large Folding Plates. 4to., cloth; about 400 pages $35.00

HUGHES.—American Miller and Millwright's Assistant:

By WILLIAM CARTER HUGHES. 12mo. $1.50

HULME.—Worked Examination Questions in Plane Geometrical Drawing:

For the Use of Candidates for the Royal Military Academy, Woolwich; the Royal Military College, Sandhurst; the Indian Civil Engineering College, Cooper's Hill; Indian Public Works and Telegraph Departments; Royal Marine Light Infantry; the Oxford and Cambridge Local Examinations, etc. By F. EDWARD HULME, F. L. S., F. S. A., Art-Master Marlborough College. Illustrated by 300 examples. Small quarto $2.50

JERVIS.—Railroad Property:

A Treatise on the Construction and Management of Railways; designed to afford useful knowledge, in the popular style, to the holders of this class of property; as well as Railway Managers, Officers, and Agents. By JOHN B. JERVIS, late Civil Engineer of the Hudson River Railroad, Croton Aqueduct, etc. 12mo., cloth $2.00

KEENE.—A Hand-Book of Practical Gauging:

For the Use of Beginners, to which is added a Chapter on Distillation, describing the process in operation at the Custom-House for ascertaining the Strength of Wines. By JAMES B. KEENE, of H. M. Customs. 8vo. $1.25

KELLEY.—Speeches, Addresses, and Letters on Industrial and Financial Questions:

By HON. WILLIAM D. KELLEY, M. C. 544 pages, 8vo. . $3.00

KELLOGG.—A New Monetary System:

The only means of Securing the respective Rights of Labor and Property, and of Protecting the Public from Financial Revulsions. By EDWARD KELLOGG. Revised from his work on "Labor and other Capital." With numerous additions from his manuscript. Edited by MARY KELLOGG PUTNAM. Fifth edition. To which is added a Biographical Sketch of the Author. One volume, 12mo.

Paper cover $1.00
Bound in cloth 1.50

EMLO.—Watch-Repairer's Hand-Book:

Being a Complete Guide to the Young Beginner, in Taking Apart, Putting Together, and Thoroughly Cleaning the English Lever and other Foreign Watches, and all American Watches. By F. KEMLO, Practical Watchmaker. With Illustrations. 12mo. . $1.25

KENTISH.—A Treatise on a Box of Instruments,

And the Slide Rule; with the Theory of Trigonometry and Logarithms, including Practical Geometry, Surveying, Measuring of Timber, Cask and Malt Gauging, Heights, and Distances. By THOMAS KENTISH. In one volume. 12mo. $1.25

KERL.—The Assayer's Manual:

An Abridged Treatise on the Docimastic Examination of Ores, and Furnace and other Artificial Products. By BRUNO KERL, Professor in the Royal School of Mines. Translated from the German by WILLIAM T. BRANNT. Second American edition, edited with Extensive Additions by F. LYNWOOD GARRISON, Member of the American Institute of Mining Engineers, etc. Illustrated by 87 engravings. 8vo. $3.00

KICK.—Flour Manufacture.

A Treatise on Milling Science and Practice. By FREDERICK KICK, Imperial Regierungsrath, Professor of Mechanical Technology in the Imperial German Polytechnic Institute, Prague. Translated from the second enlarged and revised edition with supplement by H. H. P. POWLES, Assoc. Memb. Institution of Civil Engineers. Illustrated with 28 Plates, and 167 Wood-cuts. 367 pages. 8vo. . $10.00

KINGZETT.—The History, Products, and Processes of the Alkali Trade:

Including the most Recent Improvements. By CHARLES THOMAS KINGZETT, Consulting Chemist. With 23 illustrations. 8vo. $2.50

KIRK.—The Founding of Metals:

A Practical Treatise on the Melting of Iron, with a Description of the Founding of Alloys; also, of all the Metals and Mineral Substances used in the Art of Founding. Collected from original sources. By EDWARD KIRK, Practical Foundryman and Chemist. Illustrated. Third edition. 8vo. $2.50

LANDRIN.—A Treatise on Steel:

Comprising its Theory, Metallurgy, Properties, Practical Working, and Use. By M. H. C. LANDRIN, JR., Civil Engineer. Translated from the French, with Notes, by A. A. FESQUET, Chemist and Engineer. With an Appendix on the Bessemer and the Martin Processes for Manufacturing Steel, from the Report of Abram S. Hewitt United States Commissioner to the Universal Exposition, Paris, 1867. 12mo. $3.00

LANGBEIN.—A Complete Treatise on the Electro-Deposition of Metals:

Translated from the German, with Additions, by WM. T. BRANNT. 125 illustrations. 8vo. $4.00

LARDNER.—The Steam-Engine:

For the Use of Beginners. Illustrated. 12mo. 75

LARKIN.—The Practical Brass and Iron Founder's Guide:
A Concise Treatise on Brass Founding, Moulding, the Metals and their Alloys, etc.; to which are added Recent Improvements in the Manufacture of Iron, Steel by the Bessemer Process, etc., etc. By JAMES LARKIN, late Conductor of the Brass Foundry Department in Reany, Neafie & Co.'s Penn Works, Philadelphia. Fifth edition, revised, with extensive additions. 12mo. $2.25

LEROUX.—A Practical Treatise on the Manufacture of Worsteds and Carded Yarns:
Comprising Practical Mechanics, with Rules and Calculations applied to Spinning; Sorting, Cleaning, and Scouring Wools; the English and French Methods of Combing, Drawing, and Spinning Worsteds, and Manufacturing Carded Yarns. Translated from the French of CHARLES LEROUX, Mechanical Engineer and Superintendent of a Spinning-Mill, by HORATIO PAINE, M. D., and A. A. FESQUET, Chemist and Engineer. Illustrated by twelve large Plates. To which is added an Appendix, containing Extracts from the Reports of the International Jury, and of the Artisans selected by the Committee appointed by the Council of the Society of Arts, London, on Woolen and Worsted Machinery and Fabrics, as exhibited in the Paris Universal Exposition, 1867. 8vo. $5.00

LEFFEL.—The Construction of Mill-Dams:
Comprising also the Building of Race and Reservoir Embankments and Head-Gates, the Measurement of Streams, Gauging of Water Supply, etc. By JAMES LEFFEL & Co. Illustrated by 58 engravings. 8vo. $2.50

LESLIE.—Complete Cookery:
Directions for Cookery in its Various Branches. By MISS LESLIE. Sixtieth thousand. Thoroughly revised, with the addition of New Receipts. 12mo. $1.50

LE VAN.—The Steam Engine and the Indicator:
Their Origin and Progressive Development; including the Most Recent Examples of Steam and Gas Motors, together with the Indicator, its Principles, its Utility, and its Application. By WILLIAM BARNET LE VAN. Illustrated by 205 Engravings, chiefly of Indicator-Cards. 469 pp. 8vo. $4.00

LIEBER.—Assayer's Guide:
Or, Practical Directions to Assayers, Miners, and Smelters, for the Tests and Assays, by Heat and by Wet Processes, for the Ores of all the principal Metals, of Gold and Silver Coins and Alloys, and of Coal, etc. By OSCAR M. LIEBER. 12mo. $1.25

Lockwood's Dictionary of Terms:
Used in the Practice of Mechanical Engineering, embracing those Current in the Drawing Office, Pattern Shop, Foundry, Fitting, Turning, Smith's and Boiler Shops, etc., etc., comprising upwards of Six Thousand Definitions. Edited by a Foreman Pattern Maker, author of "Pattern Making." 417 pp. 12mo. . . . $3.00

LUKIN.—Amongst Machines:
Embracing Descriptions of the various Mechanical Appliances used in the Manufacture of Wood, Metal, and other Substances. 12mo. $1.75

LUKIN.—The Boy Engineers:
What They Did, and How They Did It. With 30 plates. 18mo. $1.75

LUKIN.—The Young Mechanic:
Practical Carpentry. Containing Directions for the Use of all kinds of Tools, and for Construction of Steam-Engines and Mechanical Models, including the Art of Turning in Wood and Metal. By JOHN LUKIN, Author of "The Lathe and Its Uses," etc. Illustrated. 12mo. $1.75

MAIN and BROWN.—Questions on Subjects Connected with the Marine Steam-Engine:
And Examination Papers; with Hints for their Solution. By THOMAS J. MAIN, Professor of Mathematics, Royal Naval College, and THOMAS BROWN, Chief Engineer, R. N. 12mo., cloth . $1.50

MAIN and BROWN.—The Indicator and Dynamometer:
With their Practical Applications to the Steam-Engine. By THOMAS J. MAIN, M. A. F. R., Ass't S. Professor Royal Naval College, Portsmouth, and THOMAS BROWN, Assoc. Inst. C. E., Chief Engineer R. N., attached to the R. N. College. Illustrated. 8vo. . $1.50

MAIN and BROWN.—The Marine Steam-Engine.
By THOMAS J. MAIN, F. R. Ass't S. Mathematical Professor at the Royal Naval College, Portsmouth, and THOMAS BROWN, Assoc. Inst. C. E., Chief Engineer R. N. Attached to the Royal Naval College. With numerous illustrations. 8vo. . . $5.00

MAKINS.—A Manual of Metallurgy:
By GEORGE HOGARTH MAKINS. 100 engravings. Second edition rewritten and much enlarged. 12mo., 592 pages . . $3.00

MARTIN.—Screw-Cutting Tables, for the Use of Mechanical Engineers:
Showing the Proper Arrangement of Wheels for Cutting the Threads of Screws of any Required Pitch; with a Table for Making the Universal Gas-Pipe Thread and Taps. By W. A. MARTIN, Engineer. 8vo. 50

MICHELL.—Mine Drainage:
Being a Complete and Practical Treatise on Direct-Acting Underground Steam Pumping Machinery. With a Description of a large number of the best known Engines, their General Utility and the Special Sphere of their Action, the Mode of their Application, and their Merits compared with other Pumping Machinery. By STEPHEN MICHELL. Illustrated by 137 engravings. 8vo., 277 pages . $6.00

MOLESWORTH.—Pocket-Book of Useful Formulæ and Memoranda for Civil and Mechanical Engineers.
By GUILFORD L. MOLESWORTH, Member of the Institution of Civil Engineers, Chief Resident Engineer of the Ceylon Railway. Full-bound in Pocket-book form $1.00

MOORE.—The Universal Assistant and the Complete Mechanic:

Containing over one million Industrial Facts, Calculations, Receipts, Processes, Trades Secrets, Rules, Business Forms, Legal Items, Etc., in every occupation, from the Household to the Manufactory. By R. MOORE. Illustrated by 500 Engravings. 12mo. . $2.50

MORRIS.—Easy Rules for the Measurement of Earthworks:

By means of the Prismoidal Formula. Illustrated with Numerous Wood-Cuts, Problems, and Examples, and concluded by an Extensive Table for finding the Solidity in cubic yards from Mean Areas. The whole being adapted for convenient use by Engineers, Surveyors, Contractors, and others needing Correct Measurements of Earthwork. By ELWOOD MORRIS, C. E. 8vo. $1.50

MORTON.—The System of Calculating Diameter, Circumference, Area, and Squaring the Circle:

Together with Interest and Miscellaneous Tables, and other information. By JAMES MORTON. Second Edition, enlarged, with the Metric System. 12mo. $1.00

NAPIER.—Manual of Electro-Metallurgy:

Including the Application of the Art to Manufacturing Processes. By JAMES NAPIER. Fourth American, from the Fourth London edition, revised and enlarged. Illustrated by engravings. 8vo.

NAPIER.—A System of Chemistry Applied to Dyeing.

By JAMES NAPIER, F. C. S. A New and Thoroughly Revised Edition. Completely brought up to the present state of the Science, including the Chemistry of Coal Tar Colors, by A. A. FESQUET, Chemist and Engineer. With an Appendix on Dyeing and Calico Printing, as shown at the Universal Exposition, Paris, 1867. Illustrated. 8vo. 422 pages $3.50

NEVILLE.—Hydraulic Tables, Coefficients, and Formulæ, for finding the Discharge of Water from Orifices, Notches, Weirs, Pipes, and Rivers:

Third Edition, with Additions, consisting of New Formulæ for the Discharge from Tidal and Flood Sluices and Siphons; general information on Rainfall, Catchment-Basins, Drainage, Sewerage, Water Supply for Towns and Mill Power. By JOHN NEVILLE, C. E. M. R. I. A.; Fellow of the Royal Geological Society of Ireland. Thick 12mo. $5.50

NEWBERY.—Gleanings from Ornamental Art of every style:

Drawn from Examples in the British, South Kensington, Indian, Crystal Palace, and other Museums, the Exhibitions of 1851 and 1862, and the best English and Foreign works. In a series of 100 exquisitely drawn Plates, containing many hundred examples. By ROBERT NEWBERY. 4to. $12.50

NICHOLLS.—The Theoretical and Practical Boiler-Maker and Engineer's Reference Book:

Containing a variety of Useful Information for Employers of Labor. Foremen and Working Boiler-Makers, Iron, Copper, and Tinsmiths

Draughtsmen, Engineers, the General Steam-using Public, and for the Use of Science Schools and Classes. By SAMUEL NICHOLLS. Illustrated by sixteen plates, 12mo. $2.50

NICHOLSON.—A Manual of the Art of Bookbinding:

Containing full instructions in the different Branches of Forwarding, Gilding, and Finishing. Also, the Art of Marbling Book-edges and Paper. By JAMES B. NICHOLSON. Illustrated. 12mo., cloth $2.25

NICOLLS.—The Railway Builder:

A Hand-Book for Estimating the Probable Cost of American Railway Construction and Equipment. By WILLIAM J. NICOLLS, Civil Engineer. Illustrated, full bound, pocket-book form . $2.00

NORMANDY.—The Commercial Handbook of Chemical Analysis:

Or Practical Instructions for the Determination of the Intrinsic or Commercial Value of Substances used in Manufactures, in Trades, and in the Arts. By A. NORMANDY. New Edition, Enlarged, and to a great extent rewritten. By HENRY M. NOAD, Ph.D., F.R.S., thick 12mo. $5.00

NORRIS.—A Handbook for Locomotive Engineers and Machinists:

Comprising the Proportions and Calculations for Constructing Locomotives; Manner of Setting Valves; Tables of Squares, Cubes, Areas, etc., etc. By SEPTIMUS NORRIS, M. E. New edition. Illustrated, 12mo. $1.50

NYSTROM.—A New Treatise on Elements of Mechanics:

Establishing Strict Precision in the Meaning of Dynamical Terms: accompanied with an Appendix on Duodenal Arithmetic and Metrology. By JOHN W. NYSTROM, C. E. Illustrated. 8vo. $2.00

NYSTROM.—On Technological Education and the Construction of Ships and Screw Propellers:

For Naval and Marine Engineers. By JOHN W. NYSTROM, late Acting Chief Engineer, U. S. N. Second edition, revised, with additional matter. Illustrated by seven engravings. 12mo. . $1.50

O'NEILL.—A Dictionary of Dyeing and Calico Printing:

Containing a brief account of all the Substances and Processes in use in the Art of Dyeing and Printing Textile Fabrics; with Practical Receipts and Scientific Information. By CHARLES O'NEILL, Analytical Chemist. To which is added an Essay on Coal Tar Colors and their application to Dyeing and Calico Printing. By A. A. FESQUET, Chemist and Engineer. With an appendix on Dyeing and Calico Printing, as shown at the Universal Exposition, Paris, 1867. 8vo., 491 pages $3.50

ORTON.—Underground Treasures:

How and Where to Find Them. A Key for the Ready Determination of all the Useful Minerals within the United States. By JAMES ORTON, A.M., Late Professor of Natural History in Vassar College, N. Y.; Cor. Mem. of the Academy of Natural Sciences, Philadelphia, and of the Lyceum of Natural History, New York; author of the "Andes and the Amazon," etc. A New Edition, with Additions. Illustrated $1.50

OSBORN.—The Prospector's Field Book and Guide:
In the Search for and the Easy Determination of Ores and Other Useful Minerals. By Prof. H. S. OSBORN, LL. D., Author of "The Metallurgy of Iron and Steel;" "A Practical Manual of Minerals, Mines, and Mining." Illustrated by 44 Engravings. 12mo. $1.50

OSBORN.—A Practical Manual of Minerals, Mines and Mining:
Comprising the Physical Properties, Geologic Positions, Local Occurrence and Associations of the Useful Minerals; their Methods of Chemical Analysis and Assay: together with Various Systems of Excavating and Timbering, Brick and Masonry Work, during Driving, Lining, Bracing and other Operations, etc. By Prof. H. S. OSBORN, LL. D., Author of the "Metallurgy of Iron and Steel." Illustrated by 171 engravings from original drawings. 8vo. $4.50

OVERMAN.—The Manufacture of Steel:
Containing the Practice and Principles of Working and Making Steel. A Handbook for Blacksmiths and Workers in Steel and Iron, Wagon Makers, Die Sinkers, Cutlers, and Manufacturers of Files and Hardware, of Steel and Iron, and for Men of Science and Art. By FREDERICK OVERMAN, Mining Engineer, Author of the "Manufacture of Iron," etc. A new, enlarged, and revised Edition. By A. A. FESQUET, Chemist and Engineer. 12mo. . . $1.50

OVERMAN.—The Moulder's and Founder's Pocket Guide:
A Treatise on Moulding and Founding in Green-sand, Dry-sand, Loam, and Cement; the Moulding of Machine Frames, Mill-gear, Hollow-ware, Ornaments, Trinkets, Bells, and Statues; Description of Moulds for Iron, Bronze, Brass, and other Metals; Plaster of Paris, Sulphur, Wax, etc.; the Construction of Melting Furnaces, the Melting and Founding of Metals; the Composition of Alloys and their Nature, etc., etc. By FREDERICK OVERMAN, M. E. A new Edition, to which is added a Supplement on Statuary and Ornamental Moulding, Ordnance, Malleable Iron Castings, etc. By A. A. FESQUET, Chemist and Engineer. Illustrated by 44 engravings. 12mo. . $2.00

PAINTER, GILDER, AND VARNISHER'S COMPANION:
Containing Rules and Regulations in everything relating to the Arts of Painting, Gilding, Varnishing, Glass-Staining, Graining, Marbling, Sign-Writing, Gilding on Glass, and Coach Painting and Varnishing; Tests for the Detection of Adulterations in Oils, Colors, etc.; and a Statement of the Diseases to which Painters are peculiarly liable, with the Simplest and Best Remedies. Sixteenth Edition. Revised, with an Appendix. Containing Colors and Coloring—Theoretical and Practical. Comprising descriptions of a great variety of Additional Pigments, their Qualities and Uses, to which are added, Dryers, and Modes and Operations of Painting, etc. Together with Chevreul's Principles of Harmony and Contrast of Colors. 12mo. Cloth $1.50

PALLETT.—The Miller's, Millwright's, and Engineer's Guide.
By HENRY PALLETT. Illustrated. 12mo. . . . $2.00

PERCY.—The Manufacture of Russian Sheet-Iron.

By JOHN PERCY, M. D., F. R. S., Lecturer on Metallurgy at the Royal School of Mines, and to The Advance Class of Artillery Officers at the Royal Artillery Institution, Woolwich; Author of "Metallurgy." With Illustrations. 8vo., paper . . 50 cts.

PERKINS.—Gas and Ventilation:

Practical Treatise on Gas and Ventilation. With Special Relation to Illuminating, Heating, and Cooking by Gas. Including Scientific Helps to Engineer-students and others. With Illustrated Diagrams. By E. E. PERKINS. 12mo., cloth $1.25

PERKINS AND STOWE.—A New Guide to the Sheet-iron and Boiler Plate Roller:

Containing a Series of Tables showing the Weight of Slabs and Piles to Produce Boiler Plates, and of the Weight of Piles and the Sizes of Bars to produce Sheet-iron; the Thickness of the Bar Gauge in decimals; the Weight per foot, and the Thickness on the Bar or Wire Gauge of the fractional parts of an inch; the Weight per sheet, and the Thickness on the Wire Gauge of Sheet-iron of various dimensions to weigh 112 lbs. per bundle; and the conversion of Short Weight into Long Weight, and Long Weight into Short. Estimated and collected by G. H. PERKINS and J. G. STOWE. $2.50

POWELL—CHANCE—HARRIS.—The Principles of Glass Making.

By HARRY J. POWELL, B. A. Together with Treatises on Crown and Sheet Glass; by HENRY CHANCE, M. A. And Plate Glass, by H. G. HARRIS, Asso. M. Inst. C. E. Illustrated 18mo. . $1.50

PROCTOR.—A Pocket-Book of Useful Tables and Formulæ for Marine Engineers:

By FRANK PROCTOR. Second Edition, Revised and Enlarged. Full-bound pocket-book form $1.50

REGNAULT.—Elements of Chemistry:

By M. V. REGNAULT. Translated from the French by T. FORREST BETTON, M. D., and edited, with Notes, by JAMES C. BOOTH, Melter and Refiner U. S. Mint, and WILLIAM L. FABER, Metallurgist and Mining Engineer. Illustrated by nearly 700 wood-engravings. Comprising nearly 1,500 pages. In two volumes, 8vo., cloth . $7.50

RICHARDS.—Aluminium:

Its History, Occurrence, Properties, Metallurgy and Applications, including its Alloys. By JOSEPH W. RICHARDS, A. C., Chemist and Practical Metallurgist, Member of the Deutsche Chemische Gesellschaft. Illustrated $5.00

RIFFAULT, VERGNAUD, and TOUSSAINT.—A Practical Treatise on the Manufacture of Colors for Painting:

Comprising the Origin, Definition, and Classification of Colors; the Treatment of the Raw Materials; the best Formulæ and the Newest Processes for the Preparation of every description of Pigment, and the Necessary Apparatus and Directions for its Use; Dryers; the Testing. Application, and Qualities of Paints, etc., etc. By MM. RIFFAULT, VERGNAUD, and TOUSSAINT. Revised and Edited by M.

F. MALEPEYRE. Translated from the French, by A. A. FESQUET, Chemist and Engineer. Illustrated by Eighty engravings. In one vol., 8vo., 659 pages $7.50

ROPER.—A Catechism of High-Pressure, or Non-Condensing Steam-Engines:

Including the Modelling, Constructing, and Management of Steam-Engines and Steam Boilers. With valuable illustrations. By STEPHEN ROPER, Engineer. Sixteenth edition, revised and enlarged. 18mo., tucks, gilt edge $2.00

ROPER.—Engineer's Handy-Book:

Containing a full Explanation of the Steam-Engine Indicator, and its Use and Advantages to Engineers and Steam Users. With Formulæ for Estimating the Power of all Classes of Steam-Engines; also, Facts, Figures, Questions, and Tables for Engineers who wish to qualify themselves for the United States Navy, the Revenue Service, the Mercantile Marine, or to take charge of the Better Class of Stationary Steam-Engines. Sixth edition. 16mo., 690 pages, tucks, gilt edge $3.50

ROPER.—Hand-Book of Land and Marine Engines:

Including the Modelling, Construction, Running, and Management of Land and Marine Engines and Boilers. With illustrations. By STEPHEN ROPER, Engineer. Sixth edition. 12mo., tucks, gilt edge. $3.50

ROPER.—Hand-Book of the Locomotive:

Including the Construction of Engines and Boilers, and the Construction, Management, and Running of Locomotives. By STEPHEN ROPER. Eleventh edition. 18mo., tucks, gilt edge . $2.50

ROPER.—Hand-Book of Modern Steam Fire-Engines.

With illustrations. By STEPHEN ROPER, Engineer. Fourth edition, 12mo., tucks, gilt edge $3.50

ROPER.—Questions and Answers for Engineers.

This little book contains all the Questions that Engineers will be asked when undergoing an Examination for the purpose of procuring Licenses, and they are so plain that any Engineer or Fireman of ordinary intelligence may commit them to memory in a short time. By STEPHEN ROPER, Engineer. Third edition . . . $3.00

ROPER.—Use and Abuse of the Steam Boiler.

By STEPHEN ROPER, Engineer. Eighth edition, with illustrations. 18mo., tucks, gilt edge $2.00

ROSE.—The Complete Practical Machinist:

Embracing Lathe Work, Vise Work, Drills and Drilling, Taps and Dies, Hardening and Tempering, the Making and Use of Tools, Tool Grinding, Marking out Work, etc. By JOSHUA ROSE. Illustrated by 356 engravings. Thirteenth edition, thoroughly revised and in great part rewritten. In one vol., 12mo., 439 pages $2.50

ROSE.—Mechanical Drawing Self-Taught:

Comprising Instructions in the Selection and Preparation of Drawing Instruments, Elementary Instruction in Practical Mechanical Drawing, together with Examples in Simple Geometry and Elementary Mechanism, including Screw Threads, Gear Wheels, Mechanical Motions, Engines and Boilers. By JOSHUA ROSE, M. E. Illustrated by 330 engravings. 8vo., 313 pages $4.00

ROSE.—The Slide-Valve Practically Explained:
Embracing simple and complete Practical Demonstrations of the operation of each element in a Slide-valve Movement, and illustrating the effects of Variations in their Proportions by examples carefully selected from the most recent and successful practice. By JOSHUA ROSE, M. E. Illustrated by 35 engravings . $1.00

ROSS.—The Blowpipe in Chemistry, Mineralogy and Geology:
Containing all Known Methods of Anhydrous Analysis, many Working Examples, and Instructions for Making Apparatus. By LIEUT.-COLONEL W. A. ROSS, R. A., F. G. S. With 120 Illustrations. 12mo. $2.00

SHAW.—Civil Architecture:
Being a Complete Theoretical and Practical System of Building, containing the Fundamental Principles of the Art. By EDWARD SHAW, Architect. To which is added a Treatise on Gothic Architecture, etc. By THOMAS W. SILLOWAY and GEORGE M. HARDING, Architects. The whole illustrated by 102 quarto plates finely engraved on copper. Eleventh edition. 4to. $10.00

SHUNK.—A Practical Treatise on Railway Curves and Location, for Young Engineers.
By W. F. SHUNK, C. E. 12mo. Full bound pocket-book form $2.00

SLATER.—The Manual of Colors and Dye Wares.
By J. W. SLATER. 12mo. $3.75

SLOAN.—American Houses:
A variety of Original Designs for Rural Buildings. Illustrated by 26 colored engravings, with descriptive references. By SAMUEL SLOAN, Architect. 8vo. $1.50

SLOAN.—Homestead Architecture:
Containing Forty Designs for Villas, Cottages, and Farm-houses, with Essays on Style, Construction, Landscape Gardening, Furniture, etc., etc. Illustrated by upwards of 200 engravings. By SAMUEL SLOAN, Architect. 8vo. $3.50

SLOANE.—Home Experiments in Science.
By T. O'CONOR SLOANE, E. M., A. M., Ph. D. Illustrated by 91 engravings. 12mo. $1.50

SMEATON.—Builder's Pocket-Companion:
Containing the Elements of Building, Surveying, and Architecture; with Practical Rules and Instructions connected with the subject. By A. C. SMEATON, Civil Engineer, etc. 12mo. . . $1.50

SMITH.—A Manual of Political Economy.
By E. PESHINE SMITH. A New Edition, to which is added a full Index. 12mo. $1 25

SMITH.—Parks and Pleasure-Grounds:
Or Practical Notes on Country Residences, Villas, Public Parks, and Gardens. By CHARLES H. J. SMITH, Landscape Gardener and Garden Architect, etc., etc. 12mo. $2.00

SMITH.—The Dyer's Instructor:
Comprising Practical Instructions in the Art of Dyeing Silk, Cotton, Wool, and Worsted, and Woolen Goods; containing nearly 800 Receipts. To which is added a Treatise on the Art of Padding; and the Printing of Silk Warps, Skeins, and Handkerchiefs, and the various Mordants and Colors for the different styles of such work. By DAVID SMITH, Pattern Dyer. 12mo. $2.00

SMYTH.—A Rudimentary Treatise on Coal and Coal-Mining.
By WARRINGTON W. SMYTH, M. A., F. R. G., President R. G. S. of Cornwall. Fifth edition, revised and corrected. With numerous illustrations. 12mo. $1.75

SNIVELY.—Tables for Systematic Qualitative Chemical Analysis.
By JOHN H. SNIVELY, Phr. D. 8vo. $1.00

SNIVELY.—The Elements of Systematic Qualitative Chemical Analysis:
A Hand-book for Beginners. By JOHN H. SNIVELY, Phr. D. 16mo. $2.00

STEWART.—The American System:
Speeches on the Tariff Question, and on Internal Improvements, principally delivered in the House of Representatives of the United States. By ANDREW STEWART, late M. C. from Pennsylvania. With a Portrait, and a Biographical Sketch. 8vo. . . $3.00

STOKES.—The Cabinet-Maker and Upholsterer's Companion:
Comprising the Art of Drawing, as applicable to Cabinet Work; Veneering, Inlaying, and Buhl-Work; the Art of Dyeing and Staining Wood, Ivory, Bone, Tortoise-Shell, etc. Directions for Lackering, Japanning, and Varnishing; to make French Polish, Glues, Cements, and Compositions; with numerous Receipts, useful to workmen generally. By STOKES. Illustrated. A New Edition, with an Appendix upon French Polishing, Staining, Imitating, Varnishing, etc., etc. 12mo $1.25

STRENGTH AND OTHER PROPERTIES OF METALS:
Reports of Experiments on the Strength and other Properties of Metals for Cannon. With a Description of the Machines for Testing Metals, and of the Classification of Cannon in service. By Officers of the Ordnance Department, U. S. Army. By authority of the Secretary of War. Illustrated by 25 large steel plates. Quarto . $10.00

SULLIVAN.—Protection to Native Industry.
By Sir EDWARD SULLIVAN, Baronet, author of "Ten Chapters on Social Reforms." 8vo. $1.50

SULZ.—A Treatise on Beverages:
Or the Complete Practical Bottler. Full instructions for Laboratory Work, with Original Practical Recipes for all kinds of Carbonated Drinks, Mineral Waters, Flavorings, Extracts, Syrups, etc. By CHAS. HERMAN SULZ, Technical Chemist and Practical Bottler Illustrated by 428 Engravings. 818 pp. 8vo. . . $10.00

SYME.—Outlines of an Industrial Science.

By DAVID SYME. 12mo. $2.00

TABLES SHOWING THE WEIGHT OF ROUND, SQUARE, AND FLAT BAR IRON, STEEL, ETC.,

By Measurement. Cloth 63

TAYLOR.—Statistics of Coal:

Including Mineral Bituminous Substances employed in Arts and Manufactures; with their Geographical, Geological, and Commercial Distribution and Amount of Production and Consumption on the American Continent. With Incidental Statistics of the Iron Manufacture. By R. C. TAYLOR. Second edition, revised by S. S. HALDEMAN. Illustrated by five Maps and many wood engravings. 8vo., cloth $10.00

TEMPLETON.—The Practical Examinator on Steam and the Steam-Engine:

With Instructive References relative thereto, arranged for the Use of Engineers, Students, and others. By WILLIAM TEMPLETON, Engineer. 12mo. $1.25

THAUSING.—The Theory and Practice of the Preparation of Malt and the Fabrication of Beer:

With especial reference to the Vienna Process of Brewing. Elaborated from personal experience by JULIUS E. THAUSING, Professor at the School for Brewers, and at the Agricultural Institute, Mödling, near Vienna. Translated from the German by WILLIAM T. BRANNT, Thoroughly and elaborately edited, with much American matter, and according to the latest and most Scientific Practice, by A. SCHWARZ and DR. A. H. BAUER. Illustrated by 140 Engravings. 8vo., 815 pages $10.00

THOMAS.—The Modern Practice of Photography:

By R. W. THOMAS, F. C. S. 8vo. 75

THOMPSON.—Political Economy. With Especial Reference to the Industrial History of Nations:

By ROBERT E. THOMPSON, M. A., Professor of Social Science in the University of Pennsylvania. 12mo. $1.50

THOMSON.—Freight Charges Calculator:

By ANDREW THOMSON, Freight Agent. 24mo. . . . $1.25

URNER'S (THE) COMPANION:

Containing Instructions in Concentric, Elliptic, and Eccentric Turning; also various Plates of Chucks, Tools, and Instruments; and Directions for using the Eccentric Cutter, Drill, Vertical Cutter, and Circular Rest; with Patterns and Instructions for working them 12mo. $1.25

TURNING: Specimens of Fancy Turning Executed on the Hand or Foot-Lathe:

With Geometric, Oval, and Eccentric Chucks, and Elliptical Cutting Frame. By an Amateur. Illustrated by 30 exquisite Photographs. 4to. $3.00

URBIN—BRULL.—A Practical Guide for Puddling Iron and Steel.

By ED. URBIN, Engineer of Arts and Manufactures. A Prize Essay, read before the Association of Engineers, Graduate of the School of Mines, of Liege, Belgium, at the Meeting of 1865–6. To which is added A COMPARISON OF THE RESISTING PROPERTIES OF IRON AND STEEL. By A. BRULL. Translated from the French by A. A. FESQUET, Chemist and Engineer. 8vo. $1.00

VAILE.—Galvanized-Iron Cornice-Worker's Manual:
Containing Instructions in Laying out the Different Mitres, and Making Patterns for all kinds of Plain and Circular Work. Also, Tables of Weights, Areas and Circumferences of Circles, and other Matter calculated to Benefit the Trade. By CHARLES A. VAILE. Illustrated by twenty-one plates. 4to. $5.00

VILLE.—On Artificial Manures:
Their Chemical Selection and Scientific Application to Agriculture. A series of Lectures given at the Experimental Farm at Vincennes, during 1867 and 1874–75. By M. GEORGES VILLE. Translated and Edited by WILLIAM CROOKES, F. R. S. Illustrated by thirty-one engravings. 8vo., 450 pages $6.00

VILLE.—The School of Chemical Manures:
Or, Elementary Principles in the Use of Fertilizing Agents. From the French of M. GEO. VILLE, by A. A. FESQUET, Chemist and Engineer. With Illustrations. 12mo. $1.25

VOGDES.—The Architect's and Builder's Pocket-Companion and Price-Book:
Consisting of a Short but Comprehensive Epitome of Decimals, Duodecimals, Geometry and Mensuration; with Tables of United States Measures, Sizes, Weights, Strengths, etc., of Iron, Wood, Stone, Brick, Cement and Concretes, Quantities of Materials in given Sizes and Dimensions of Wood, Brick and Stone; and full and complete Bills of Prices for Carpenter's Work and Painting; also, Rules for Computing and Valuing Brick and Brick Work, Stone Work, Painting, Plastering, with a Vocabulary of Technical Terms, etc. By FRANK W. VOGDES, Architect, Indianapolis, Ind. Enlarged, revised, and corrected. In one volume, 368 pages, full-bound, pocket-book form, gilt edges $2.00
Cloth 1.50

WAHL.—Galvanoplastic Manipulations:
A Practical Guide for the Gold and Silver Electroplater and the Galvanoplastic Operator. Comprising the Electro-Deposition of all Metals by means of the Battery and the Dynamo-Electric Machine, as well as the most approved Processes of Deposition by Simple Immersion, with Descriptions of Apparatus, Chemical Products employed in the Art, etc. Based largely on the "Manipulations Hydroplastiques" of ALFRED ROSELEUR. By WILLIAM H. WAHL, Ph. D. (Heid), Secretary of the Franklin Institute. Illustrated by 189 engravings. 8vo., 656 pages . . . .

WALTON.—Coal-Mining Described and Illustrated:
By THOMAS H. WALTON, Mining Engineer. Illustrated by 24 large and elaborate Plates, after Actual Workings and Apparatus. $5.00

WARE.—The Sugar Beet.

Including a History of the Beet Sugar Industry in Europe, Varieties of the Sugar Beet, Examination, Soils, Tillage, Seeds and Sowing, Yield and Cost of Cultivation, Harvesting, Transportation, Conservation, Feeding Qualities of the Beet and of the Pulp, etc. By LEWIS S. WARE, C. E., M. E. Illustrated by ninety engravings. 8vo. $4.00

WARN.—The Sheet-Metal Worker's Instructor:

For Zinc, Sheet-Iron, Copper, and Tin-Plate Workers, etc. Containing a selection of Geometrical Problems; also, Practical and Simple Rules for Describing the various Patterns required in the different branches of the above Trades. By REUBEN H. WARN, Practical Tin-Plate Worker. To which is added an Appendix, containing Instructions for Boiler-Making, Mensuration of Surfaces and Solids, Rules for Calculating the Weights of different Figures of Iron and Steel, Tables of the Weights of Iron, Steel, etc. Illustrated by thirty-two Plates and thirty-seven Wood Engravings. 8vo. . $3.00

WARNER.—New Theorems, Tables, and Diagrams, for the Computation of Earth-work:

Designed for the use of Engineers in Preliminary and Final Estimates, of Students in Engineering, and of Contractors and other non-professional Computers. In two parts, with an Appendix. Part I. A Practical Treatise; Part II. A Theoretical Treatise, and the Appendix. Containing Notes to the Rules and Examples of Part I.; Explanations of the Construction of Scales, Tables, and Diagrams, and a Treatise upon Equivalent Square Bases and Equivalent Level Heights. The whole illustrated by numerous original engravings, comprising explanatory cuts for Definitions and Problems, Stereometric Scales and Diagrams, and a series of Lithographic Drawings from Models: Showing all the Combinations of Solid Forms which occur in Railroad Excavations and Embankments. By JOHN WARNER, A. M., Mining and Mechanical Engineer. Illustrated by 14 Plates. A new, revised and improved edition. 8vo. $4.00

WATSON.—A Manual of the Hand-Lathe:

Comprising Concise Directions for Working Metals of all kinds, Ivory, Bone and Precious Woods; Dyeing, Coloring, and French Polishing; Inlaying by Veneers, and various methods practised to produce Elaborate work with Dispatch, and at Small Expense. By EGBERT P. WATSON, Author of "The Modern Practice of American Machinists and Engineers." Illustrated by 78 engravings. $1.50

WATSON.—The Modern Practice of American Machinists and Engineers:

Including the Construction, Application, and Use of Drills, Lathe Tools, Cutters for Boring Cylinders, and Hollow-work generally, with the most Economical Speed for the same; the Results verified by Actual Practice at the Lathe, the Vise, and on the Floor. Together with Workshop Management, Economy of Manufacture, the Steam-Engine, Boilers, Gears, Belting, etc., etc. By EGBERT P. WATSON. Illustrated by eighty-six engravings. 12mo. . . . $2.50

WATSON.—The Theory and Practice of the Art of Weaving by Hand and Power:

With Calculations and Tables for the Use of those connected with the Trade. By JOHN WATSON, Manufacturer and Practical Machine-Maker. Illustrated by large Drawings of the best Power Looms. 8vo. $7.50

WATT.—The Art of Soap Making:

A Practical Hand-book of the Manufacture of Hard and Soft Soaps, Toilet Soaps, etc., including many New Processes, and a Chapter on the Recovery of Glycerine from Waste Leys. By ALEXANDER WATT. Ill. 12mo. $3.00

WEATHERLY.—Treatise on the Art of Boiling Sugar, Crystallizing, Lozenge-making, Comfits, Gum Goods,

And other processes for Confectionery, etc., in which are explained, in an easy and familiar manner, the various Methods of Manufacturing every Description of Raw and Refined Sugar Goods, as sold by Confectioners and others. 12mo. $1.50

WIGHTWICK.—Hints to Young Architects:

Comprising Advice to those who, while yet at school, are destined to the Profession; to such as, having passed their pupilage, are about to travel; and to those who, having completed their education, are about to practise. Together with a Model Specification involving a great variety of instructive and suggestive matter. By GEORGE WIGHTWICK, Architect. A new edition, revised and considerably enlarged; comprising Treatises on the Principles of Construction and Design. By G. HUSKISSON GUILLAUME, Architect. Numerous Illustrations. One vol. 12mo. $2.00

WILL.—Tables of Qualitative Chemical Analysis.

With an Introductory Chapter on the Course of Analysis. By Professor HEINRICH WILL, of Giessen, Germany. Third American, from the eleventh German edition. Edited by CHARLES F. HIMES, Ph. D., Professor of Natural Science, Dickinson College, Carlisle, Pa. 8vo. $1.50

WILLIAMS.—On Heat and Steam:

Embracing New Views of Vaporization, Condensation, and Explosion. By CHARLES WYE WILLIAMS, A. I. C. E. Illustrated 8vo. $3.50

WILSON.—A Treatise on Steam Boilers:

Their Strength, Construction, and Economical Working. By ROBERT WILSON. Illustrated 12mo. $2.00

WILSON.—First Principles of Political Economy:

With Reference to Statesmanship and the Progress of Civilization. By Professor W. D. WILSON, of the Cornell University. A new and revised edition. 12mo. $1.50

WOHLER.—A Hand-Book of Mineral Analysis:

By F. WÖHLER, Professor of Chemistry in the University of Göttingen. Edited by HENRY B. NASON, Professor of Chemistry in the Renssalaer Polytechnic Institute, Troy, New York. Illustrated. 12mo. $3.00

WORSSAM.—On Mechanical Saws:

From the Transactions of the Society of Engineers, 1869. By S. W. WORSSAM, JR. Illustrated by eighteen large plates. 8vo. $2.50

RECENT ADDITIONS.

ANDERSON.—The Prospector's Hand-Book:

A Guide for the Prospector and Traveler in Search of Metal Bearing or other Valuable Minerals. By J. W. ANDERSON. 52 Illustrations. 12mo. $1.50

BEAUMONT.—Woollen and Worsted Cloth Manufacture:

Being a Practical Treatise for the use of all persons employed in the manipulation of Textile Fabrics. By ROBERT BEAUMONT, M. S. A. With over 200 illustrations, including Sketches of Machinery, Designs, Cloths, etc. 391 pp. 12mo. $2.50

BRANNT.—The Metallic Alloys:

A Practical Guide for the Manufacture of all kinds of Alloys, Amalgams and Solders used by Metal Workers, especially by Bell Founders, Bronze Workers, Tinsmiths, Gold and Silver Workers, Dentists, etc., etc., as well as their Chemical and Physical Properties. Edited chiefly from the German of A. Krupp and Andreas Wildberger, with additions by WM. T. BRANNT. Illustrated. 12mo. $3.00

BRANNT.—A Practical Treatise on the Manufacture of Vinegar and Acetates, Cider, and Fruit-Wines:

Preservation of Fruits and Vegetables by Canning and Evaporation; Preparation of Fruit-Butters, Jellies, Marmalades, Catchups, Pickles, Mustards, etc. Edited from various sources. By WILLIAM T. BRANNT. Illustrated by 79 Engravings. 479 pp. 8vo. $5.00

BRANNT.—The Metal Worker's Handy-Book of Receipts and Processes:

Being a Collection of Chemical Formulas and Practical Manipulations for the working of all Metals; including the Decoration and Beautifying of Articles Manufactured therefrom, as well as their Preservation. Edited from various sources. By WILLIAM T. BRANNT. Illustrated. 12mo. $2.50

DAVIS.—A Practical Treatise on the Manufacture of Bricks, Tiles, Terra-Cotta, etc.:

Including Hand-Made, Dry Clay, Tempered Clay, Soft-Mud, and Stiff-Clay Bricks, also Front, Hand-Pressed, Steam-Pressed, Re-pressed, Ornamentally Shaped and Enamelled Bricks, Drain Tiles, Straight and Curved Sewer and Water-Pipes, Fire-Clays, Fire-Bricks, Glass Pots, Terra-Cotta, Roofing Tiles, Flooring Tiles, Art Tiles, etc. By CHARLES THOMAS DAVIS. Second Edition. 217 Engravings. 501 pp. 8vo. . . . . $5.00.

EDWARDS.—American Marine Engineer, Theoretical and Practical:

With Examples of the latest and most approved American Practice. By EMORY EDWARDS. 85 illustrations. 12mo. . . . $2.50

EDWARDS.—600 Examination Questions and Answers:

For Engineers and Firemen (Land and Marine) who desire to obtain a United States Government or State License. Pocket-book form, gilt edge $1.50

POSSELT.—Technology of Textile Design:

Being a Practical Treatise on the Construction and Application of Weaves for all Textile Fabrics, with minute reference to the latest Inventions for Weaving. Containing also an Appendix, showing the Analysis and giving the Calculations necessary for the Manufacture of the various Textile Fabrics. By E. A. POSSELT, Head Master Textile Department, Pennsylvania Museum and School of Industrial Art, Philadelphia, with over 1000 illustrations. 292 pages. 4to. $5.00

POSSELT.—The Jacquard Machine Analysed and Explained:

With an Appendix on the Preparation of Jacquard Cards, and Practical Hints to Learners of Jacquard Designing. By E. A. POSSELT. With 230 illustrations and numerous diagrams. 127 pp. 4to. $3.00

RICH.—Artistic Horse-Shoeing:

A Practical and Scientific Treatise, giving Improved Methods of Shoeing, with Special Directions for Shaping Shoes to Cure Different Diseases of the Foot, and for the Correction of Faulty Action in Trotters. By GEORGE E. RICH. 62 Illustrations. 153 pages. 12mo. $1.00

RICHARDSON.—Practical Blacksmithing:

A Collection of Articles Contributed at Different Times by Skilled Workmen to the columns of "The Blacksmith and Wheelwright," and Covering nearly the Whole Range of Blacksmithing, from the Simplest Job of Work to some of the Most Complex Forgings. Compiled and Edited by M. T. RICHARDSON.

Vol. I. 210 Illustrations. 224 pp. 12mo. $1.00
Vol. II. 230 Illustrations. 262 pages. 12mo. . . $1.00

RICHARDSON.—The Practical Horseshoer:
Being a Collection of Articles on Horseshoeing in all its Branches which have appeared from time to time in the columns of "The Blacksmith and Wheelwright," etc. Compiled and edited by M. T. RICHARDSON. 174 illustrations. $1.00

ROPER.—Instructions and Suggestions for Engineers and Firemen:
By STEPHEN ROPER, Engineer. 18mo. Morocco . $2.00

ROPER.—The Steam Boiler: Its Care and Management:
By STEPHEN ROPER, Engineer. 12mo., tuck, gilt edges. $2.00

ROPER.—The Young Engineer's Own Book:
Containing an Explanation of the Principle and Theories on which the Steam Engine as a Prime Mover is Based. By STEPHEN ROPER, Engineer. 160 illustrations, 363 pages. 18mo., tuck . $3.00

ROSE.—Modern Steam-Engines:
An Elementary Treatise upon the Steam-Engine, written in Plain language; for Use in the Workshop as well as in the Drawing Office. Giving Full Explanations of the Construction of Modern Steam-Engines: Including Diagrams showing their Actual operation. Together with Complete but Simple Explanations of the operations of Various Kinds of Valves, Valve Motions, and Link Motions, etc., thereby Enabling the Ordinary Engineer to clearly Understand the Principles Involved in their Construction and Use, and to Plot out their Movements upon the Drawing Board. By JOSHUA ROSE. M. E. Illustrated by 422 engravings. 4to., 320 pages . . $6.00

ROSE.—Steam Boilers:
A Practical Treatise on Boiler Construction and Examination, for the Use of Practical Boiler Makers, Boiler Users, and Inspectors; and embracing in plain figures all the calculations necessary in Designing or Classifying Steam Boilers. By JOSHUA ROSE, M. E. Illustrated by 73 engravings. 250 pages. 8vo. $2.50

SCHRIBER.—The Complete Carriage and Wagon Painter:
A Concise Compendium of the Art of Painting Carriages, Wagons, and Sleighs, embracing Full Directions in all the Various Branches, including Lettering, Scrolling, Ornamenting, Striping, Varnishing, and Coloring, with numerous Recipes for Mixing Colors. 73 Illustrations. 177 pp. 12mo. $1.00

VAN CLEVE.—The English and American Mechanic:
Comprising a Collection of Over Three Thousand Receipts, Rules, and Tables, designed for the Use of every Mechanic and Manufacturer. By B. FRANK VAN CLEVE. Illustrated. 500 pp. 12mo. $2.00

WAHNSCHAFFE.—A Guide to the Scientific Examination of Soils:
Comprising Select Methods of Mechanical and Chemical Analysis and Physical Investigation. Translated from the German of Dr. F. WAHNSCHAFFE. With additions by WILLIAM T. BRANNT. Illustrated by 25 engravings. 12mo. 177 pages . . . $1.50