

for Dosage Calculations Veterinary Nurses and Technicians

Terry Lake

Forewords by Joy Howell and Margi Sirois



Dosage Calculations
for **Veterinary Nurses**
and Technicians

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Dosage Calculations *for* Veterinary Nurses and Technicians



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Contents

	Forewords vii
	Preface ix
1.	Calculations Involving Fractions 1
2.	Decimals and Percentages 9
3.	Scientific Notation 17
4.	Ratio and Proportion 23
5.	Dimensional Analysis 27
6.	Clinical Applications of Basic Principles 31
7.	Measurement Systems 37
8.	Oral Medication 45
9.	Parenteral Medication 49
10.	Clinical Problems Using Dosage Calculations 57
11.	Solutions 59
12.	Clinical Problems Using Solutions 67
13.	Intravenous Fluids 71
14.	Constant Rate Infusions 77
15.	Dilutions 83
16.	Clinical Problems Using Dilutions 95
17.	Anaesthesia and Nutrition Applications 99
18.	Statistics and Quality Control 103
	Index 115



Forewords

With the ever increasing demands being placed on the technical skills and responsibility of the veterinary nursing profession, it is now being acknowledged that the veterinary nurse has an important supporting role to play in enabling owners' compliance in companion animal medication. To be able to carry out this role, it is important that the veterinary nurse can ensure that the correct dosage regime is followed. In particular, owners may lack a thorough understanding of the metric system and require support in interpreting dosage instructions.

As well as explaining how to calculate medication dosages, this text illustrates practical applications of mathematics in disciplines such as percentage weight loss, intravenous fluid therapy and laboratory recording, anaesthesia and nutrition, and will be an invaluable addition to any practice library.

This textbook will also be an extremely useful teaching aid for veterinary nurses and technicians, as mathematics is often one of the most daunting aspects of the syllabus. With the very practical question and answer sections included in each chapter, it is expected to become an invaluable addition to every trainer's and student's reading list.

Newbury 2003

Joy Howell

Nearly every aspect of the veterinary nurse's or technician's responsibilities involves some element of mathematics. Mathematics is a tool used every day in the veterinary clinic and the types of mathematical problems encountered are as diverse as the duties that a veterinary nurse or technician performs. Veterinary personnel must have the skills needed to manipulate numbers in different systems and units of measure, to calculate drug dosages, and to develop pricing structures for marketing purposes. In spite of this, mathematics books for veterinary nursing/technology students and practitioners have been greatly lacking. This book is designed to provide simple, logical descriptions of these sometimes-complex calculations that veterinary nurses and technicians must perform. Theoretical concepts are described in simple, straightforward language. Detailed directions and explanations of common mathematical tasks are included and ample examples complement the text. A step-by-step approach makes the content easy to use and understand. Clinical relevance is especially stressed, making the book an excellent tool for practical application. The book is organised to provide basic skills early on and then progresses to more advanced calculations.

This One



OAYR-EG8-ZTZE

This text presents effective methods to learn the mathematical skills of veterinary technology. It is my hope that this long-awaited book will become the standard in the teaching of veterinary nurses and technicians.

Pennsylvania 2003

Margi Sirois

Preface

The veterinary profession is relatively small and yet incredibly diverse. Even the titles we use are diverse: veterinary nurses, veterinary technicians, animal health technologists and animal health technicians. In my part of the world, the term *animal health technologist* is used whereas for most of North America, the title *veterinary technician* is most common. In the UK, Australia and New Zealand, *veterinary nurse* is the preferred designation. From this point on, I will use the terms veterinary technician and veterinary nurse interchangeably.

Veterinary technicians work with companion animals, food animals, research animals, wild animals and, often, with no animals at all! The mathematical tasks encountered are also very diverse, from calculating an amount of medication to give to a cat, to devising a quality control chart for a piece of diagnostic machinery. These tasks are often the responsibility of the veterinary technician – a good thing, in my view, as many of my colleagues (myself included until I started teaching the course) are not the strongest mathematicians on the planet. It is a heavy responsibility when you think about it. The patient's life can be at stake when calculating medication; an error in one decimal place could be fatal.

When I was first asked to teach mathematics, I immediately searched for a comprehensive textbook that would lay it all out for me with lots of relevant examples to make the work interesting. No such luck! While there are many good books for human nurses and laboratory technicians, I could not find any that were specific to the veterinary profession and that included the wide range of problems we have to deal with. After patching notes together for a few years, I was encouraged to write a book that would meet this demand. I hope you feel this effort is successful in helping you learn the tools required to make maths a little easier, and maybe even fun!

This book relies heavily on *dimensional analysis*, a method of converting units from one form to another using conversion factors as 'bridges'. You may have encountered this method in chemistry courses. It removes the necessity of memorising formulae and takes advantage of simplifying equations so that calculators are often unnecessary. I have become such a proponent of the method that my students had a shirt made up that says, 'Never fear, super dimensional analysis man is here!' Not everyone takes to this technique, however, so other methods such as ratio and proportion are also outlined.

Although students in veterinary nursing courses have been taught basic arithmetic and the metric system prior to enrolling in the programme, it is often the case that a review is needed to recall these studies. We have come to rely so heavily on calculators that skills such as long division and working with scientific notation are quickly lost.

It is important to understand how these calculations are performed so that we can work in the absence of calculators, or at least recognise that we may have punched the wrong button.

Of all the courses in a programme of veterinary nursing or technology, the maths component is not likely to be your favourite, but I hope this text helps you through and gives you confidence in your future career.

Kamloops 2003

Terry Lake

Calculations Involving Fractions

Learning Objectives

- What is a fraction?
- Types of fractions
- How to convert and reduce fractions
- Finding the lowest common denominator
- How to add, subtract, multiply and divide fractions

What is a fraction?

When something is divided into equal parts, each part represents a *fraction* of the whole. The number of equal parts in the whole represents the *denominator* (lower figure in the fraction) and the number of parts being considered represents the *numerator* (upper figure). If a pie is cut into 8 equal pieces and 3 are eaten, we can say $\frac{3}{8}$ of the pie has been eaten.

A fraction allows us to consider a number of parts in relation to the whole. This may be a number smaller than the whole, as in the example above, in which case this is a *proper fraction*. We can also consider a fraction that is greater than the whole – an *improper fraction*. If I had 2 pies, each divided into 8 equal pieces, and 13 pieces were eaten, $\frac{13}{8}$ of a pie have been consumed. An improper fraction can also be expressed as a *mixed number* – a whole number and a proper fraction. In our example, $1\frac{5}{8}$ of a pie has been eaten.

Converting fractions

Converting mixed numbers to improper fractions makes it easier for us to work with fractions. This conversion involves two steps:

- Multiply the denominator by the whole number
- Add the numerator.

The denominator stays the same.

$$1\frac{5}{8} \text{ becomes: } 8 \times 1 = 8 \longrightarrow 8 + 5 = 13 \longrightarrow \frac{13}{8}$$



Let's do it again...

Convert the following mixed numbers to improper fractions.

1 $2\frac{3}{7}$ 2 $6\frac{3}{4}$ 3 $21\frac{8}{9}$ 4 $8\frac{2}{3}$ 5 $3\frac{5}{8}$

Answers

1 $\frac{17}{7}$ 2 $\frac{27}{4}$ 3 $\frac{197}{9}$ 4 $\frac{26}{3}$ 5 $\frac{29}{8}$

Of course we can convert improper fractions into mixed numbers by doing the reverse:

- Divide the numerator by the denominator
- The amount 'left over' becomes the new numerator.

$\frac{23}{6}$ becomes: $23 \div 6 = 3$, with 5 left over $\longrightarrow 3\frac{5}{6}$



Let's do it again...

Convert the following improper fractions to mixed numbers.

1 $\frac{13}{7}$ 2 $\frac{25}{9}$ 3 $\frac{47}{6}$ 4 $\frac{17}{8}$ 5 $\frac{19}{10}$

Answers

1 $1\frac{6}{7}$ 2 $2\frac{7}{9}$ 3 $7\frac{5}{6}$ 4 $2\frac{1}{8}$ 5 $1\frac{9}{10}$

Reducing fractions

Reducing a fraction to the lowest terms is also known as *simplifying* a fraction. This means converting a fraction to produce the smallest numbers possible in the numerator and denominator. This is accomplished by dividing the numerator and denominator by the largest common number possible.

$\frac{10}{12}$ becomes: $\frac{10 \div 2}{12 \div 2} = \frac{5}{6}$



This operation demonstrates an important concept: if you multiply or divide the numerator *and* the denominator by the same number, you do not change the value of the fraction, only its appearance. This is because you are simply multiplying or dividing the fraction by 1. In this example, we have divided both the numerator and denominator by 2, or if we consider the fraction, we have divided the fraction by $\frac{2}{2}$, which is of course 1.



Let's do it again...

Reduce the following fractions to their lowest terms.

1 $\frac{6}{8}$ 2 $\frac{4}{12}$ 3 $\frac{125}{500}$ 4 $\frac{64}{22}$ 5 $\frac{21}{56}$

Answers

1 $\frac{3}{4}$ 2 $\frac{1}{3}$ 3 $\frac{1}{4}$ 4 $\frac{32}{11}$ 5 $\frac{3}{8}$

Finding the common denominator

There are times when we need to make different fractions look similar so that we can work with them. This is called finding the *common denominator*. This is most easily done by multiplying all the denominators in a set of fractions.

For $\frac{3}{8}$ and $\frac{5}{6}$, the common denominator is 48 ($8 \times 6 = 48$)

8 goes into 48 6 times so we multiply 3 by 6 to give us 18 $\longrightarrow \frac{18}{48} \left(\frac{3}{8} \right)$

6 goes into 48 8 times so we multiply 5 by 8 to give us 40 $\longrightarrow \frac{40}{48} \left(\frac{5}{6} \right)$

The *lowest common denominator (LCD)* is the smallest number that is a multiple of all the denominators in a set of fractions. In our example above, 24 is the LCD, so that $\frac{3}{8}$ can be expressed as $\frac{9}{24}$ and $\frac{5}{6}$ can be expressed as $\frac{20}{24}$.

Finding the LCD is not always easy so we must have a method to help us. Consider the set of fractions: $\frac{1}{2}$, $\frac{2}{3}$, $\frac{5}{6}$, and $\frac{4}{9}$. The LCD is not obvious, so use this technique:

- 1 Place all the denominators in a line from lowest to highest: 2 3 6 9.
- 2 Divide the numbers by the *smallest* number that will go into at least two of them.
- 3 Bring down all the numbers that cannot be divided.
- 4 Continue until all denominators are reduced to one:

$$\begin{array}{r}
 2 \quad 3 \quad 6 \quad 9 \\
 \text{Divide by 2} \longrightarrow 1 \quad 3 \quad 3 \quad 9 \\
 \text{Divide by 3} \longrightarrow 1 \quad 1 \quad 1 \quad 3 \\
 \text{Divide by 3} \longrightarrow 1 \quad 1 \quad 1 \quad 1
 \end{array}$$

- 5 Now multiply the numbers you used to divide: $2 \times 3 \times 3 = 18$.
The LCD is 18.

The set of fractions now becomes:

$$\frac{1}{2} = \frac{9}{18}, \quad \frac{2}{3} = \frac{12}{18}, \quad \frac{5}{6} = \frac{15}{18}, \quad \frac{4}{9} = \frac{8}{18}$$



Let's do it again...

Find the LCD for each set of fractions.

1 $\frac{3}{5}, \frac{4}{7}, \frac{5}{9}, \frac{3}{10}$

2 $\frac{2}{3}, \frac{5}{6}, \frac{5}{12}, \frac{5}{9}$

3 $\frac{4}{21}, \frac{3}{7}, \frac{4}{9}$

4 $\frac{11}{12}, \frac{3}{4}, \frac{5}{6}$

Answers

1 630

2 36

3 63

4 12

Converting dissimilar fractions into fractions with a lowest common denominator makes comparing fractions much easier. This can help when deciding which medication strength is higher.

Using tablets of equal strength, is $\frac{4}{5}$ of a tablet more than $\frac{6}{7}$ of a tablet?

LCD = 35, so $\frac{4}{5}$ becomes $\frac{28}{35}$ and $\frac{6}{7}$ becomes $\frac{30}{35}$

Therefore, $\frac{6}{7}$ is greater than $\frac{4}{5}$



Remember: When comparing fractions with common denominators, the fraction with the largest numerator is the largest number.

Adding and subtracting fractions

We have seen that it is sometimes difficult to compare dissimilar fractions (think of it like trying to compare apples to oranges). Converting fractions to the LCD is a great way to allow us to compare apples with apples. When adding and subtracting fractions, we *must* convert them to the LCD because we cannot add dissimilar things, i.e. we cannot add apples to oranges! (Fig. 1.1).



Figure 1.1 Dissimilar things or units cannot be added together.

To add fractions:

- 1 First find the LCD
- 2 Express each fraction using the LCD
- 3 Add the numerators
- 4 Convert to a mixed number if necessary.

$$\frac{2}{3} + \frac{3}{4} \longrightarrow \text{LCD} = 12$$

$$\frac{2}{3} = \frac{8}{12}, \quad \frac{3}{4} = \frac{9}{12}$$

$$\frac{8}{12} + \frac{9}{12} = \frac{17}{12} = 1\frac{5}{12}$$

To subtract fractions:

- 1 First find the LCD
- 2 Express each fraction using the LCD
- 3 Subtract the numerators
- 4 Convert to a mixed number if necessary.

$$1\frac{3}{4} - \frac{5}{6} \longrightarrow \text{LCD} = 12$$

$$1\frac{3}{4} = \frac{7}{4} = \frac{21}{12}, \quad \frac{5}{6} = \frac{10}{12}$$

$$\frac{21}{12} - \frac{10}{12} = \frac{11}{12}$$



Let's do it again...

1 $\frac{2}{3} + \frac{5}{6}$

2 $\frac{5}{7} + \frac{3}{5}$

3 $\frac{7}{12} + \frac{3}{4} + \frac{3}{8}$

4 $\frac{21}{25} + \frac{3}{5} + \frac{7}{15}$

5 $\frac{8}{9} + \frac{2}{3}$

6 $\frac{11}{12} - \frac{2}{3}$

7 $\frac{7}{8} - \frac{5}{6}$

8 $\frac{23}{6} - \frac{3}{4}$

9 $\frac{9}{11} - \frac{2}{3}$

10 $\frac{65}{5} - \frac{1}{10}$

Answers

1 $1\frac{1}{2}$

2 $1\frac{11}{35}$

3 $1\frac{17}{24}$

4 $1\frac{68}{75}$

5 $1\frac{5}{9}$

6 $\frac{1}{4}$

7 $\frac{1}{24}$

8 $3\frac{1}{12}$

9 $\frac{5}{33}$

10 $12\frac{9}{10}$

Multiplying fractions

Unlike adding and subtracting, we do not need to find the lowest common denominator when multiply or dividing fractions. The numerator of one fraction is multiplied by the numerator of the second fraction and the denominator of the first is multiplied by the denominator of the second:

$$\frac{2}{3} \times \frac{4}{5} \longrightarrow \frac{2 \times 4}{3 \times 5} = \frac{8}{15}$$

If a fraction is multiplied by a whole number, think of the whole number as a fraction with 1 as the denominator:

$$\frac{2}{3} \times 4 \longrightarrow \frac{2 \times 4}{3 \times 1} = \frac{8}{3} \longrightarrow \frac{8}{3} = 2\frac{2}{3}$$

If multiplying mixed numbers, convert them to improper fractions before multiplying:

$$3\frac{4}{5} \times 12\frac{6}{7} \longrightarrow \frac{19}{5} \times \frac{90}{7} \longrightarrow \frac{19 \times 90}{5 \times 7} = \frac{1710}{35} = 48\frac{30}{35} = 48\frac{6}{7}$$



Let's do it again...

Multiply the following fractions:

$$1 \quad \frac{3}{7} \times \frac{5}{6} \quad 2 \quad \frac{13}{4} \times \frac{2}{3} \quad 3 \quad 1\frac{2}{5} \times 4\frac{5}{6} \quad 4 \quad \frac{9}{11} \times 4\frac{3}{4} \quad 5 \quad \frac{21}{8} \times 3\frac{2}{3}$$

Answers

$$1 \quad \frac{15}{42} \quad 2 \quad 2\frac{1}{6} \quad 3 \quad 6\frac{23}{30} \quad 4 \quad 3\frac{39}{44} \quad 5 \quad 12\frac{5}{6}$$

Dividing fractions

As in multiplication, we can divide fractions without worrying about converting them to their LCD. To divide fractions, simply invert the divisor (the number doing the dividing) and multiply:

$$\frac{2}{3} \div \frac{4}{5} \longrightarrow \frac{2}{3} \times \frac{5}{4} = \frac{10}{12} = \frac{5}{6}$$

To convince yourself that it is okay to do this inversion, consider one half of a pie that was to be shared by two people – in other words, the $\frac{1}{2}$ of a pie was divided by 2. You intuitively know that each person would receive $\frac{1}{4}$ of the pie, but this is how it would look (remember that $\frac{2}{1}$ is the same as 2):

$$\frac{1}{2} \div \frac{2}{1} \longrightarrow \frac{1}{2} \times \frac{1}{2} \left(\text{i.e. we have inverted } \frac{2}{1} \right) = \frac{1}{4}$$



Remember to convert mixed numbers to improper fractions before dividing.



Let's do it again...

Divide the following fractions:

1 $\frac{3}{7} \div \frac{5}{6}$

2 $\frac{13}{4} \div \frac{2}{3}$

3 $1\frac{2}{5} \div 4\frac{5}{8}$

4 $\frac{9}{11} \div 4\frac{3}{4}$

5 $\frac{22}{8} \div 3\frac{2}{3}$

Answers

1 $\frac{18}{35}$

2 $4\frac{7}{8}$

3 $\frac{42}{145}$

4 $\frac{36}{209}$

5 1

Complex fractions

A fraction in which either the numerator or denominator, or both, are themselves fractions is called a *complex fraction*. Since the line between the numerator and the denominator really means *divided by*, a complex fraction is simply one fraction divided by another.

$$\frac{\frac{2}{3}}{\frac{3}{4}} = \frac{2}{3} \div \frac{3}{4} \longrightarrow \frac{2}{3} \times \frac{4}{3} = \frac{8}{9}$$



Let's do it again...

Solve the following complex fractions

1 $\frac{\frac{4}{5}}{\frac{1}{2}}$

2 $\frac{\frac{13}{5}}{\frac{3}{4}}$

3 $\frac{\frac{8}{9}}{\frac{3}{7}}$

4 $\frac{\frac{2}{5}}{\frac{8}{2}}$

5 $\frac{\frac{22}{7}}{\frac{3}{2}}$

Answers

1 $1\frac{3}{5}$

2 $3\frac{7}{15}$

3 $2\frac{2}{27}$

4 $\frac{4}{25}$

5 $2\frac{2}{21}$

Decimals and Percentages

Learning Objectives

- What are decimals and percentages?
- The importance of zeros
- How to add and subtract decimals
- How to multiply and divide decimals
- How to round off decimals
- Converting fractions to decimals
- Converting decimals to fractions
- How to add and subtract percentages
- How to multiply and divide percentages

What is a decimal?

A decimal is simply a fraction in which the denominator is 10 or a power of 10 (*deci* is a latin root word that means one tenth, $\frac{1}{10}$). Instead of writing a fraction, we can express the denominator by using a *decimal point*. In this way, $\frac{1}{10}$ becomes 0.1. If we wanted to express the fraction $\frac{4}{10}$ as a decimal it would appear as 0.4. The denominator in a decimal fraction can be any power of ten: 10, 100, 1000, 10 000, etc. Each power of 10 has a place to the right of the decimal point for fractions whereas each whole number with a power of 10 has a place to the left of the decimal point (Fig. 2.1).

Using this system, any number with a denominator that has a power of 10 can be expressed as a decimal: $\frac{12}{100}$ becomes 0.12, $\frac{125}{1000}$ becomes 0.125, $\frac{32\,456}{10\,000}$ becomes 3.2456.

Zero in on zeros!



It is very important to include the zero to the left of the decimal point in numbers less than 1. Imagine reading a medication order for a dog that states: 'Give .1 mg intravenously every 8 hours.' The decimal point may be lost, especially with the notorious poor penmanship of veterinarians. It may be read as: 'Give 1 mg intravenously every 8 hours,' resulting in a 10 times overdose! The correct way to write the order is: 'Give 0.1 mg intravenously every 8 hours.'

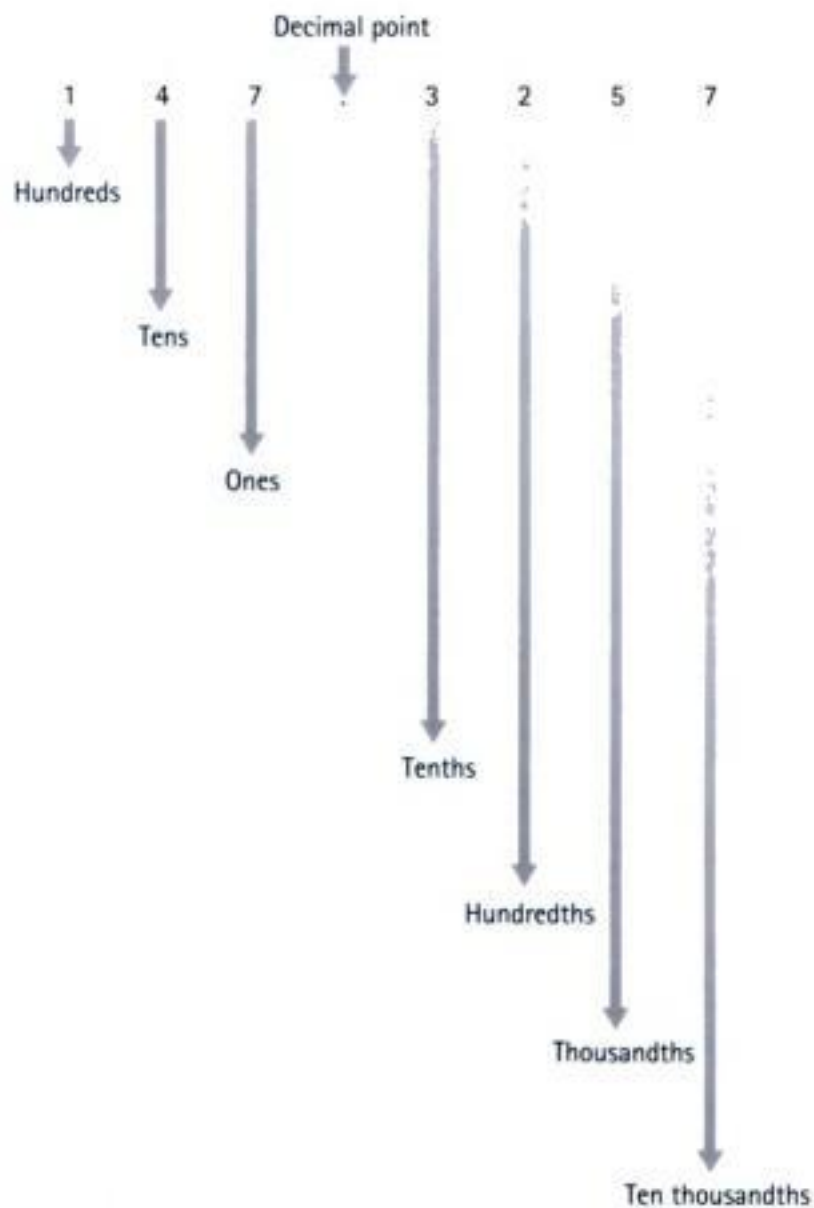


Figure 2.1 Powers of 10 on either side of the decimal point.

When zeros to the *right* of the decimal point do not appear in front of other numbers, they can be eliminated, e.g. 3.4500 can be written 3.45. The number 3.4507 must, of course, retain its zero.



Let's do it again...

Express the following fractions as decimals:

1 $\frac{33}{100}$

2 $\frac{345}{1000}$

3 $\frac{25}{10\,000}$

4 $\frac{35}{10}$

5 $\frac{8}{100}$

Answers

1 0.33

2 0.345

3 0.0025

4 3.5

5 0.08

Working with decimals

Adding and subtracting decimals

The only trick here is to line up the decimals correctly to insure proper placement. It is a good idea to use zeros to help you line up the numbers:

$$\begin{array}{r} 1.234 \\ + 0.310 \\ \hline 1.544 \end{array} \quad \begin{array}{r} 0.035 \\ + 5.600 \\ \hline 5.635 \end{array} \quad \begin{array}{r} 12.0020 \\ - 0.1235 \\ \hline 11.8785 \end{array}$$

Multiplying decimals

No need to line up decimal points with multiplication of decimals. The trick here is to ensure you have the correct number of decimal places in the product. This should equal the sum of the decimal places in the two numbers being multiplied.

$$\begin{array}{l} 5.5 \longrightarrow 1 \text{ decimal place from right} \\ \times 0.125 \longrightarrow 3 \text{ decimal places from right} \\ \hline 0.6875 \longrightarrow 4 \text{ decimal places (1 + 3)} \end{array}$$

$$\begin{array}{r} 10.75 \\ \times 5.0005 \\ \hline 53.755375 \end{array}$$

Dividing decimals

The number that is being divided is called the *dividend* while the number doing the dividing is called the *divisor*. The number that results is called the *quotient*.

$$\begin{array}{ccc} 8 & \div & 2 = 4 \\ \downarrow & & \downarrow \\ \boxed{\text{Dividend}} & & \boxed{\text{Divisor}} \quad \boxed{\text{Quotient}} \end{array}$$

When the divisor is a whole number, simply place the quotient's decimal point in the same place it appeared in the dividend:

$$\begin{array}{r} 5.3 \\ 2 \overline{)10.6} \end{array} \quad \begin{array}{r} 0.8052 \\ 125 \overline{)100.6500} \end{array}$$

If the divisor and the dividend are both decimals, we must convert the divisor to a whole number first. This done by moving the decimal point as far to the right as needed to get rid of it and then moving the dividend's decimal point the same number of places.

$$1.5 \overline{)10.05} \longrightarrow 15 \overline{)100.05} \longrightarrow 15 \overline{)100.5} \quad \begin{array}{r} 6.7 \\ 15 \overline{)100.5} \end{array}$$

$$0.005 \overline{)100.1} \longrightarrow 5 \overline{)100\ 100} \longrightarrow 5 \overline{)100\ 100}^{20\ 020}$$

In the last example, we had to add 2 zeros at the end of the dividend in order to move the decimal point over 3 places – the number of places it was moved to make the divisor a whole number.



Let's do it again...

Multiply or divide the following decimals.

- 1 4.5×6.75 2 0.1×45.5 3 12.075×0.01 4 5.01×100.25 5 3.5×1.005
 6 $5.05 \div 2$ 7 $10.75 \div 0.05$ 8 $100 \div 0.002$ 9 $\frac{10.8}{2.4}$ 10 $\frac{0.75}{5}$

Answers

- 1 30.375 2 4.55 3 0.12075 4 502.2525 5 3.5175
 6 2.525 7 215 8 50 000 9 4.5 10 0.15

Rounding off decimals

In clinical veterinary medicine we do not usually need to measure things to one thousandths or lower, so we can round off our decimals to the nearest hundredth or even the nearest tenth. To do this, we look at the number to right of the place to which we are rounding. If the number is 5 or greater, we bump up the last number by 1. If it is less than 5, the last number stays the same.

10.56 rounded to the nearest tenth becomes 10.6

10.54 rounded to the nearest tenth becomes 10.5

10.556 rounded to the nearest one hundredth becomes 10.56



Remember to take the number out one past the point of rounding in order to decide what to do with that last number.

Converting common fractions to decimals

A fraction can be converted into a decimal by simply dividing the numerator by the denominator. Remember to keep the zero to the left of the decimal point when converting proper fractions.

$$\frac{4}{10} = 4 \div 10 = 0.4, \quad \frac{4}{16} = 4 \div 16 = 0.25, \quad \frac{25}{200} = 25 \div 200 = 0.125$$



Remember to turn mixed numbers into improper fractions before converting them into decimals.

$$12\frac{1}{4} = \frac{49}{4} = 49 \div 4 = 12.25$$

$$7\frac{8}{9} = \frac{71}{9} = 71 \div 9 = 7.89 \text{ (rounded to nearest one hundredth)}$$

Converting decimals into fractions

This conversion is quite simple as we just need to remove the decimal point to give us the numerator and count the number of decimal places in the original number to find our denominator. Simplify the fraction if possible.

$$0.25 = \frac{25}{100} = \frac{1}{4}, \quad 0.005 = \frac{5}{1000} = \frac{1}{200}$$

Decimals greater than 1 are converted to a mixed number by treating the part of the number less than 1 as a proper fraction.

$$5.75 = 5\frac{75}{100} = 5\frac{3}{4}$$



Let's do it again...

Convert the following fractions into decimals and decimals into fractions.

1 $\frac{12}{16}$ 2 $\frac{25}{500}$ 3 0.005 4 52.4 5 2.025

Answers

1 0.75 2 0.05 3 $\frac{1}{200}$ 4 $52\frac{2}{5}$ 5 $2\frac{1}{40}$

Working with percentages

Percentages are used often in veterinary medicine. We may use 0.9% saline solution for intravenous use, 2.5% or 1.25% thiopentone for anesthesia induction, and a pulse oximeter gives us oxygen saturation in percent.

Think of the word *percent*; it literally means *per one hundred* (*cent* is one hundred in French). The expression 84% means '84 parts per one hundred parts'. We can express this as a decimal by dropping the percent sign and multiplying by $\frac{1}{100}$ or 0.01. When we do this, 84% becomes $\frac{84}{100}$ or 0.84. Going the other way, 0.34 becomes 34% and

$\frac{2}{10}$ becomes 20% ($\frac{2}{10} = \frac{20}{100}$). Remember to reduce the fractions after converting from a percent. In the examples above $\frac{84}{100}$ can be reduced to $\frac{21}{25}$ and $\frac{2}{10}$ becomes $\frac{1}{5}$.

We can convert fractions to percentages by converting them into a decimal fraction and then multiplying by 100:

- Divide the numerator by the denominator
- Multiply by 100.

$$\frac{3}{5} = 3 \div 5 = 0.6 \longrightarrow 0.6 \times 100 = 60\%$$

$$\frac{14}{25} = 14 \div 25 = 0.56 \longrightarrow 0.56 \times 100 = 56\%$$

$$4\frac{1}{5} = \frac{23}{5} = 23 \div 5 = 4.6 \longrightarrow 4.6 \times 100 = 460\%$$

Adding and subtracting percentages

Since all percentages are fractions with a denominator of 100, they can be added and subtracted without any other manipulations. For instance $23\% + 10\% = 33\%$. Let's convince ourselves:

$$23\% = \frac{23}{100}, \quad 10\% = \frac{10}{100}; \quad \frac{23}{100} + \frac{10}{100} = \frac{33}{100} = 33\%$$



Let's do it again...

1 $14\% + 2\%$

2 $45\% - 22\%$

3 $10.5\% + 20.4\%$

4 $67.8\% - 22.5\%$

5 $50\% - 0.5\%$

Answers

1 16%

2 23%

3 30.9%

4 45.3%

5 49.5%

Multiplying percentages

We can take any number and multiply it by a percent, or we can take a percent and multiply it by another percent. If I asked: 'What is 3 times 25%?' you would simply multiply 25 by 3 and reply '75%'. If I asked: 'What is 30% of 25%?' you would have a little more work on your hands! You should change one of the percentages to a decimal or a common fraction and then carry out the calculation:

$$30\% = 0.3, \quad 0.3 \times 25\% = 7.5\%$$

$$30\% = \frac{30}{100}, \quad \frac{30}{100} \times 25\% = \frac{750}{100}\% = 7.5\%$$



Let's do it again...

Multiply the following.

- 1 $67\% \times 0.5$ 2 $20\% \times 50\%$ 3 $1\% \times 75$ 4 $100\% \times 20\%$
 5 $0.5\% \times 25\%$

Answers

- 1 33.5% 2 10% 3 75% 4 20% 5 0.125%

Dividing percentages

The same technique can be applied to division of percentages. If the question involves more than one percentage, simply convert one percentage into a decimal or fraction then carry out the operation:

$$25\% \div 5 = 5\%$$

$$20\% \div 10\% = 20\% \div 0.1 = 200\% \left(\text{or } 20\% \div \frac{1}{10} = 20\% \times \frac{10}{1} = 200\% \right)$$



Making life simpler

If dividing one percentage by another, you can put them in the form of a fraction and cancel the percentages:

$$5\% \div 10\% \longrightarrow \frac{5\%}{10\%} \longrightarrow \frac{5}{10} = \frac{1}{2} = 50\%$$



Let's do it again...

Divide the following.

- 1 $48\% \div 2$ 2 $\frac{60\%}{3}$ 3 $25\% \div 5\%$ 4 $10\% \div 0.1\%$ 5 $\frac{50\%}{10\%}$

Answers

- 1 24% 2 22% 3 500% 4 10 000% 5 500%

Scientific Notation

Learning Objectives

- What is scientific notation?
- How to express numbers in scientific notation
- How to multiply and divide in scientific notation
- How to add and subtract in scientific notation

What is scientific notation?

Scientific notation is just a way of expressing very large or very small numbers in a simple form that makes it easier to perform calculations. To express a number in scientific notation we make it a multiple of 10. For example the number 100 can be expressed $1 \times 10 \times 10$ or 1×10^2 . The number 10 000 can be broken down to $1 \times 10 \times 10 \times 10 \times 10$ or 1×10^4 . When using multiples of 10, we call 10 the *base* and the number of times it is multiplied by itself, the *exponent*. In 1×10^2 , the exponent is 2 and in 1×10^4 , the exponent is 4.



Let's do it again...

Express the following numbers in scientific notation.

- 1 1000 2 100 000 3 1 000 000 4 10 5 10 000 000

Answers

- 1 1×10^3 2 1×10^5 3 1×10^6 4 1×10^1 5 1×10^7

Any number can be expressed in this way. Consider 159. How can we express this as a multiple of 10? We move the decimal point to the left until only one digit remains to the left. The exponent of the base 10 is equal to the number of places moved:

$$159 \longrightarrow 1.59 \times 10^2$$

Here are some more examples:

$$1245 \longrightarrow 1.245 \times 10^3$$

$$45\,678 \longrightarrow 4.5678 \times 10^4$$

$$630\,000 \longrightarrow 6.3 \times 10^5$$

Numbers smaller than zero can also be expressed in scientific notation but the exponent will be *negative*. The number 0.1 can be written 1×10^{-1} . Using a negative exponent means the number is multiplied by a fraction with a denominator that has a base of 10. In other words, 10^{-1} also means $\frac{1}{10}$. The number 0.001 can be written 1×10^{-3} or as $1 \times \frac{1}{1000}$ or as $1 \times \frac{1}{10} \times \frac{1}{10} \times \frac{1}{10}$.

Any number smaller than 1 can be expressed in scientific notation by moving the decimal point to the right so that one digit remains to the left of the decimal. The exponent is a negative number equal to the number of places moved. Here are some examples:

$$0.012 \longrightarrow 1.2 \times 10^{-2}$$

$$0.00365 \longrightarrow 3.65 \times 10^{-3}$$

$$0.000843 \longrightarrow 8.43 \times 10^{-4}$$



Let's do it again...

Express each number in scientific notation.

1 0.14

2 0.002854

3 1765

4 0.0000023

5 0.000385

Answers

1 1.4×10^{-1}

2 2.854×10^{-3}

3 1.765×10^3

4 2.3×10^{-6}

5 3.85×10^{-4}



Barking up the wrong tree

Be careful when working with numbers expressed in scientific notation. Those with negative exponents can fool you! Look at the number 1.345×10^{-4} . This really means $1.345 \times \frac{1}{10\,000}$ or, expressed another way, $\frac{1.345}{10\,000}$. It does *not* mean $\frac{1}{13\,450}$.

Multiplying with scientific notation

When multiplying two numbers expressed in scientific notation, just multiply the numbers and add the exponents to give you the final number:

$$(3 \times 10^3) \times (5 \times 10^2) = 15 \times 10^5 \text{ or more properly expressed as } 1.5 \times 10^6$$

Here are some more examples:

$$(2.5 \times 10^2) \times (1.5 \times 10^4) = 3.75 \times 10^6$$

2.5 × 1.5 = 3.75 2 + 4 = 6

$$(3 \times 10^5) \times (2 \times 10^{-3}) = 6 \times 10^2$$

$$(2 \times 10^{-3}) \times (4 \times 10^{-2}) = 8 \times 10^{-5}$$



Let's do it again...

1 $(1 \times 10^6) \times (4 \times 10^5)$ 2 $(2.3 \times 10^{-2}) \times (1.4 \times 10^6)$ 3 $(6 \times 10^3) \times (2.2 \times 10^{-9})$

Answers

1 4×10^{11}

2 3.22×10^4

3 1.32×10^{-5}

Dividing with scientific notation

As you might expect, when dividing numbers with scientific notation, we carry out the operation on the numbers that appear before the base 10 and then *subtract* the exponents. Be sure to subtract the exponent of the divisor from the exponent of the dividend. Here are some examples:

$$(2 \times 10^3) \div (1 \times 10^2) = 2 \times 10^1$$

Dividend Divisor 3 - 2 = 1 2 ÷ 1 = 2

$$(8 \times 10^7) \div (2 \times 10^4) = 4 \times 10^3$$

$$(6.6 \times 10^4) \div (2 \times 10^{-2}) = 3.3 \times 10^6$$



Let's do it again...

$$1 \quad (2.4 \times 10^{-4}) \div (1.2 \times 10^{-2}) \qquad 2 \quad \frac{2 \times 10^6}{1 \times 10^3} \qquad 3 \quad (4.8 \times 10^6) \div (2 \times 10^7)$$

Answers

$$1 \quad 2 \times 10^{-2} \qquad 2 \quad 2 \times 10^3 \qquad 3 \quad 2.4 \times 10^{-1}$$

Adding and subtracting with scientific notation

When multiplying and dividing, we were able to carry out these operations between two numbers that had different values for the exponents. When adding and subtracting however, we must convert the numbers so that the exponents have the *same value*. After adding the significant figures, the exponent used is the same as that which appears in the two numbers. Here is an example:

$$\text{Add: } (1 \times 10^5) + (3 \times 10^4)$$

$$\text{Step 1: } 1 \times 10^5 \longrightarrow 10 \times 10^4$$

$$\text{Step 2: } (10 \times 10^4) + (3 \times 10^4) = 13 \times 10^4 \text{ or } 1.3 \times 10^5$$

Note that we could have changed the other exponent:

$$3 \times 10^4 \longrightarrow 0.3 \times 10^5$$

$$(1 \times 10^5) + (0.3 \times 10^5) = 1.3 \times 10^5$$



Making life simpler

By changing the smaller number to the same format as the larger number, the answer will already be in the correct format, i.e. with one figure to the left of the decimal point.

Here are some more examples:

$$\text{Add: } (2.55 \times 10^5) + (1.2 \times 10^3)$$

$$1.2 \times 10^3 \longrightarrow 0.012 \times 10^5$$

$$(2.55 \times 10^5) + (0.012 \times 10^5) = 2.562 \times 10^5$$

Subtract: $(5 \times 10^2) - (3 \times 10^{-3})$

$$3 \times 10^{-3} \longrightarrow 0.00003 \times 10^2$$

$$(5 \times 10^2) - (0.00003 \times 10^2) = 4.99997 \times 10^2$$



Making life simpler

If in doubt when performing operations involving scientific notation, change the number to its regular form and carry on. For example:

$$(5 \times 10^4) - (3 \times 10^3) \text{ becomes } 50\,000 - 3\,000 = 47\,000 = 4.7 \times 10^4$$



Let's do it again...

1 $(4.3 \times 10^5) + (2.1 \times 10^2)$

2 $(6.75 \times 10^{-2}) - (2.6 \times 10^{-4})$

3 $(1.25 \times 10^3) + (4.25 \times 10^2)$

Answers

1 4.3021×10^5

2 6.724×10^{-2}

3 1.675×10^3

Ratio and Proportion

Learning Objectives

- What is a ratio?
- What is a proportion?
- Solving for x

What is a ratio?

A ratio is a way of demonstrating the *relationship between two numbers*. Ratios are used extensively in veterinary medicine. Think of an antibiotic tablet that is labeled as 100 mg. This implies that one tablet contains 100 mg of active ingredient, and can be expressed as:

1 tablet:100 mg or 100 mg:1 tablet

We can also express this relationship as a fraction:

$\frac{1 \text{ tablet}}{100 \text{ mg}}$ or $\frac{100 \text{ mg}}{1 \text{ tablet}}$

The concentration of liquid medication is often expressed as a ratio. The anaesthetic propofol comes in a concentration of 10 mg per millilitre (mL) and would appear as 10 mg/mL (10 mg per 1 mL).

What is a proportion?

A proportion demonstrates the *relationship between two ratios*. In a true proportion, the two ratios are equal. Using the 100 mg tablets, we can say if 1 tablet contains 100 mg, then 2 tablets contain 200 mg. We can express this:

1 tablet:100 mg = 2 tablets:200 mg or $\frac{1 \text{ tablet}}{100 \text{ mg}} = \frac{2 \text{ tablets}}{200 \text{ mg}}$

The fraction method is more commonly used to express ratios and proportions so we will use this from now on.

When setting up a ratio and proportion statement, we must ensure the order of the ratio on one side of the equal sign is the same as on

the other side. In the statement above, tablets are on top of ratios and mg are on the bottom. We cannot put tablets on top on one side and on the bottom on the other and expect both sides of the equation to be equal:

$$\frac{1 \text{ tablet}}{100 \text{ mg}} \neq \frac{200 \text{ mg}}{2 \text{ tablets}}$$



Remember to pay close attention to the equal sign. One side of the equation must equal the other side. Think of $\frac{1}{2}$ and $\frac{2}{4}$ – the numbers are different but the value is the same.

Using ratio and proportion to solve for x

Since one side of a ratio and proportion statement must equal the other side, if three values are supplied, we can use the relationship to determine the fourth value. Consider the question: 'If each tablet contains 100 mg, how many mg do two tablets contain?'

We set up the ratio and proportion statement:

$$\frac{1 \text{ tablet}}{100 \text{ mg}} = \frac{2 \text{ tablets}}{.x \text{ mg}}$$

In a true proportion the products of cross multiplication are equal therefore:

$$\begin{array}{cc} 1 \text{ tablet} & 2 \text{ tablets} \\ & \swarrow \quad \searrow \\ & \times \quad \times \\ & \swarrow \quad \searrow \\ 100 \text{ mg} & .x \text{ mg} \end{array}$$

$$(1 \text{ tablet})(.x \text{ mg}) = (2 \text{ tablets})(100 \text{ mg})$$

Recall from your early days of mathematics that whatever we do to one side of the equation, we can also do to the other side and not change the relationship. In the equation above, we can divide both sides by 1 tablet:

$$\frac{(1 \text{ tablet})(.x \text{ mg})}{1 \text{ tablet}} = \frac{(2 \text{ tablets})(100 \text{ mg})}{1 \text{ tablet}}$$

We can also cancel units that appear in the numerator and denominator:

$$\frac{(1 \text{ tablet})(.x \text{ mg})}{1 \text{ tablet}} = \frac{(2 \text{ tablets})(100 \text{ mg})}{1 \text{ tablet}}$$

$$.x \text{ mg} = (2)(100 \text{ mg})$$

$$x = 200 \text{ mg}$$



Let's do it again...

Determine the value of x in the following proportions.

$$1 \quad \frac{75 \text{ mg}}{5 \text{ mL}} = \frac{187.5 \text{ mg}}{x \text{ mL}}$$

$$2 \quad \frac{17 \text{ mg}}{3 \text{ tabs}} = \frac{42.5 \text{ mg}}{x \text{ tabs}}$$

$$3 \quad \frac{55 \text{ mg}}{1.1 \text{ mL}} = \frac{165 \text{ mg}}{x \text{ mL}}$$

$$4 \quad \frac{250 \text{ U}}{2.5 \text{ mL}} = \frac{30 \text{ U}}{x \text{ mL}}$$

$$5 \quad \frac{12.5 \text{ mg}}{1.2 \text{ mL}} = \frac{6.25 \text{ mg}}{x \text{ mL}}$$

Answers

$$1 \quad x = 12.5 \text{ mL}$$

$$2 \quad 7.5 \text{ tabs}$$

$$3 \quad 3.3 \text{ mL}$$

$$4 \quad 0.3 \text{ mL}$$

$$5 \quad 0.6 \text{ mL}$$

Dimensional Analysis

Learning Objectives

- What is dimensional analysis?
- How to identify conversion factors
- How to set up an equation using dimensional analysis

What is dimensional analysis?

Dimensional analysis sounds very technical but it is actually a very simple and logical method of converting units of measurement from one form to another. In chemistry courses, you may have used this method under the name *label factor method*. In the medical sciences, we often meet problems where we are dealing with different systems of measurement, and this method allows us to change the measurement type to fit the situation.

Consider giving a dog an antibiotic tablet. Somehow we have to convert the size of the dog to an equivalent size of tablet (Fig. 5.1). The first piece of information we need is the weight of the dog – we call this the *starting factor*. It is the unit of measurement that has to be converted to another unit. Secondly, we need to identify the units of measurement we wish to end up using – we call this the *answer unit*. In this case it is the number of tablets to give to the dog.

How do we arrive at the answer unit from the starting factor? We use one or a series of *conversion factors*. Conversion factors are ratios of units of measurement that have a true relationship and are expressed

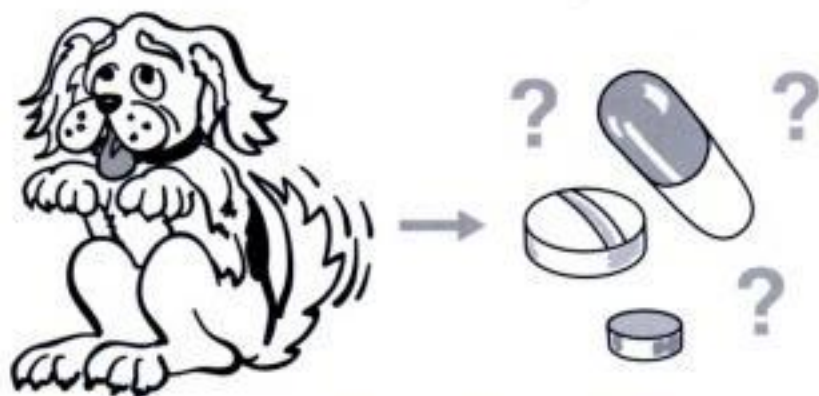


Figure 5.1 Tablet strength and patient size are inter-related.

as fractions with a numerator and denominator. An example of a conversion factor is 3 feet = 1 yard. As a ratio we would show this as:

$$\frac{3 \text{ feet}}{1 \text{ yard}}$$

Another example is: 'There are 1000 mg in 1 g':

$$\frac{1000 \text{ mg}}{1 \text{ g}}$$

Let's go back to our example of a dog requiring an antibiotic tablet. If our dog weighs 10 kg, we use this as our starting factor. The answer unit will be the number of tablets:

Weight (kg) \longrightarrow No. of tablets

To get from our starting factor to our answer unit, we need to multiply the starting factor by one or more conversion factors that serve as *bridges*. The first bridge we need is the dosage – in this case, it is 10 mg of antibiotic for every kg the dog weighs:

$$\frac{10 \text{ mg}}{1 \text{ kg}}$$

The second bridge is the amount of antibiotic in each tablet – in this case, each tablet contains 50 mg of antibiotic:

$$\frac{1 \text{ tablet}}{50 \text{ mg}}$$

Let's insert our bridges (conversion factors) in order to arrive at our destination:

$$10 \text{ kg} \times \frac{10 \text{ mg}}{1 \text{ kg}} \times \frac{1 \text{ tablet}}{50 \text{ mg}}$$



Remember we can simplify fractions and cancel out units that appear in the numerator and denominator.

So our equation becomes:

$$\begin{array}{c}
 \boxed{\text{Starting factor}} \\
 \downarrow \\
 10 \text{ kg} \times \frac{10 \text{ mg}}{1 \text{ kg}} \times \frac{1 \text{ tablet}}{50 \text{ mg}} = \frac{100 \text{ tablets}}{50} = 2 \text{ tablets} \\
 \begin{array}{ccc}
 \uparrow & \uparrow & \uparrow \\
 \boxed{\text{Conversion factors}} & & \boxed{\text{Answer unit}}
 \end{array}
 \end{array}$$

Dimensional analysis allows us to perform operations without memorising formulas and allows us to simplify equations so that a calculator is often unnecessary! It can be used in all sorts of situations involving measurements – not just in the clinic.



Many people were raised with and taught one system of measurement and then in later life faced the introduction of new systems. Dimensional analysis can allow us to convert from one to the other effortlessly (okay, with maybe just a little effort!).

If I fill up my car with 40 L of gasoline after having driven 400 km, how efficient is my car expressed in miles per gallon?

Starting factor: $\frac{\text{kilometres (km)}}{\text{litre (L)}}$ Answer unit: $\frac{\text{miles}}{\text{gallon}}$

Conversion factors: 1 gallon = 4.55 L 8 km = 5 miles

$$\frac{400 \text{ km}}{40 \text{ L}} \times \frac{4.55 \text{ L}}{1 \text{ gallon}} \times \frac{5 \text{ miles}}{8 \text{ km}} = \frac{9100 \text{ miles}}{320 \text{ gallons}} = \frac{28.4 \text{ miles}}{1 \text{ gallon}}$$

Identifying conversion factors

Conversion factors have values that are relative to each other. In other words, they represent a *ratio*. The relative value has to be true – you can't just make something up! Some standard conversion factors are:

- 12 inches = 1 foot
- 1000 mm = 1 m
- 60 s = 1 minute.

Other conversion factors are determined by the nature of the problem. If tablets come in 100 mg strength, then the conversion factor is 1 tablet = 100 mg. If the rate of fluid administration is supposed to be set at 10 mL per hour, then the conversion factor is 10 mL = 1 h.

The key is the relative value. Whether I give 1 tablet or 100 mg, as in the example above, I am giving the same amount. In the last example, with the passage of 1 hour, 10 mL will have been administered (conversely, if 10 mL have been administered, then 1 hour must have passed). Since the two values are relative, multiplying the starting factor by the conversion factor does not change the value of the starting factor but does change the way it looks. Thus we can convert a 10 kg dog into two 50 mg tablets!

Setting up the equation

Setting up an equation using dimensional analysis can be broken down into these 7 steps:

- 1 Identify the starting factor
- 2 Identify the answer units
- 3 Determine the conversion factors needed

- 4 Ensure the conversion factors are in the correct format to give you the desired answer unit
- 5 Cancel units that appear in both the numerator and denominator
- 6 Simplify the fractions
- 7 Complete the equation.



Barking up the wrong tree

When using conversion factors, it is very important to consider what to place in the numerator and what to place in the denominator. For instance, if we say each tablet is 100 mg, we can either express this as:

$$\frac{1 \text{ tablet}}{100 \text{ mg}} \text{ or } \frac{100 \text{ mg}}{1 \text{ tablet}}$$

How do we decide how to express the ratio? We always leave the units we want to end up with *on top*. If we are determining how many tablets to give, we use:

$$\frac{1 \text{ tablet}}{100 \text{ mg}}$$

If we are trying to determine how many mg to give, we use:

$$\frac{100 \text{ mg}}{1 \text{ tablet}}$$

Be sure to put your conversion factors in the correct format to give you the required answer unit.



Let's do it again...

Use dimensional analysis to solve the following problems.

- 1 A 5 kg cat requires $\frac{25 \text{ mg}}{\text{kg}}$ of medication that comes in a liquid strength of $\frac{10 \text{ mg}}{1 \text{ mL}}$. How many mL of liquid medication are you to give?
- 2 A visiting American client at a Canadian veterinary clinic wishes to pay her \$450 (Cdn) bill in US dollars. In each US dollar, there are 1.45 Canadian dollars. How much is her bill in US dollars?

Answers

$$1 \quad 5 \text{ kg} \times \frac{25 \text{ mg}}{\text{kg}} \times \frac{1 \text{ mL}}{10 \text{ mg}} = 12.5 \text{ mL} \qquad 2 \quad 450 \text{ Cdn} \times \frac{1 \text{ US}}{1.45 \text{ Cdn}} = 310.35 \text{ US}$$

Clinical Applications of Basic Principles

Let's see how everyday problems in a typical small animal practice can be solved using the concepts we have reviewed. Answers begin on page 33.

Questions

- 1 You must give a dog 250 mg of a medication that comes in tablets labeled 100 mg each. How many tablets will you give?
- 2 A dog weighs 60 kg and you tell the owner his dog should only weigh 50 kg. What fraction of its current weight must it lose to achieve the goal weight?
- 3 For the dog in question 2, what percent of its current weight (to the nearest tenth) does this represent?
- 4 A cat requires 50 mg of a liquid medication that has a strength of 150 mg per mL. What fraction of a mL should be given?
- 5 A dog on intravenous fluids has received 30% of the 500 mL initially in the i.v. bag. How many mL has it received?
- 6 If the dog in the question above weighs 25 kg, how many mL per kg of body weight has it received?
- 7 Tablets are 300 micrograms (μg) each and you must give 125 μg . What fraction of a tablet will you give?
- 8 A cat is to receive 90 kcal of a canned food at each meal. The food has a caloric density of 360 kcal per can. What fraction of a can should it receive at each meal?
- 9 A blood sample is diluted by placing 0.1 mL of the blood in a tube and filling the tube to the 20 mL mark with a solution. What percent of the solution represents whole blood?
- 10 Tablet A has a strength of 0.125 mg and tablet B has a strength of $\frac{1}{7}$ mg. Which tablet is stronger?
- 11 A clinic has 5250 patients of which 2020 are dogs, 2580 are cats, 400 are 'pocket pets' and the rest are birds. Determine the percentage of each category (answer to the nearest tenth).

- 12 If the same distribution in question 11 held true with 10 000 patients, how many pets would be in each category?
- 13 A dog ate $\frac{2}{3}$ of a cup of dry food in the morning, $\frac{1}{4}$ of a cup in the afternoon and $\frac{1}{2}$ of a cup in the evening. If the food has a caloric density of 350 kcal per cup, how many kcal did the dog eat in total (answer to nearest tenth).
- 14 A cat that swallowed a string needs to have surgery to remove part of its small intestine. If 15 cm are removed and the total length of the small intestine was 300 cm, what percent of intestine did it lose?
- 15 15 mL of an anaesthetic drug was drawn into a syringe. Initially, $\frac{1}{3}$ was injected followed by $\frac{1}{2}$ of the remainder. What fraction of the total drawn up did the patient receive?
- 16 When performing a complete blood count on a dog, you determine the leukocyte (white blood cell) total to be 5×10^3 cells per μL . If there are $1 \times 10^6 \mu\text{L}$ in every L, what was the count in cell per L? Hint: Set it up as a ratio and proportion:

$$\frac{5 \times 10^3 \text{ cells}}{1 \mu\text{L}} = \frac{x \text{ cells}}{1 \times 10^6 \mu\text{L}}$$

Use ratio and proportion equations to solve the following

- 17 A 5 kg cat needs amoxicillin at 22 mg/kg. How many mg of amoxicillin will you give?
- 18 A 45 kg dog needs prednisolone at 2.2 mg/kg. How many mg of prednisolone will you give?
- 19 A 20 kg dog needs 30 mg/kg of a medication which comes in 300 mg tablets. How many tablets will you give?
- 20 A 4 kg cat requires a liquid medication at 15 mg/kg. The liquid comes in a strength of 100 mg/mL. How many mL will you give?
- 21 A client wishes to pay her veterinary bill at a London surgery in travellers' cheques that are in US dollars. There are 1.8 US dollars to each British pound and her bill is £360. How many US dollars does she need?

Use dimensional analysis to solve the following

- 22 A 5 kg cat needs an antibiotic at a dose of 15 mg/kg. The antibiotic comes in liquid form at a concentration of 125 mg/5 mL. How many mL do you give?

- 23 A cat weighing 4.5 kg needs insulin at 1.5 international units (IU) per kg. The insulin comes in a strength of 10 IU per mL. How much insulin do you give (answer to nearest tenth of mL)?
- 24 What volume of fluid does a patient receive in 6 hours with a fluid rate of 30 mL/h?

Answers

$$1 \quad \frac{100 \text{ mg}}{1 \text{ tablet}} = \frac{250 \text{ mg}}{x \text{ tablets}}$$

$$(250 \text{ mg})(1 \text{ tab}) = (100 \text{ mg})(x \text{ tabs})$$

$$x \text{ tabs} = \frac{250 \text{ mg}}{100 \text{ mg}} = 2.5 \text{ tabs}$$

- 2 60 kg current weight – 50 kg goal weight = 10 kg weight loss

$$\frac{10 \text{ kg}}{60 \text{ kg}} = \frac{1}{6}$$

- 3 $\frac{1}{6} = 0.167$, $0.167 \times 100 = 16.7\%$

- 4 $\frac{150 \text{ mg}}{1 \text{ mL}} = \frac{50 \text{ mg}}{x \text{ mL}}$, $(150 \text{ mg})(x \text{ mL}) = (50 \text{ mg})(1 \text{ mL})$

$$x \text{ mL} = \frac{(50 \text{ mg})(1 \text{ mL})}{150 \text{ mg}}, \quad x = \frac{1}{3} \text{ mL}$$

- 5 $500 \text{ mL} \times 30\% = 500 \text{ mL} \times 0.3 \left(\frac{30}{100} \right) = 150 \text{ mL}$

$$\frac{30}{100} = 0.3 = 30\%$$

- 6 $\frac{150 \text{ mL}}{25 \text{ kg}} = \frac{x \text{ mL}}{1 \text{ kg}}$

$$(150 \text{ mL})(1 \text{ kg}) = (x \text{ mL})(25 \text{ kg})$$

$$x \text{ mL} = \frac{(150 \text{ mL})(1 \text{ kg})}{25 \text{ kg}} = 6 \text{ mL}$$

- 7 $\frac{125 \mu\text{g}}{300 \mu\text{g}} = \frac{5}{12}$

- 8 $\frac{90 \text{ kcal}}{360 \text{ kcal}} = \frac{1}{4}$

- 9 $\frac{0.1 \text{ mL}}{20 \text{ mL}} = 0.005$, $0.005 \times 100 = 0.5\%$

- 10 $0.125 \text{ mg} = \frac{125}{1000} = \frac{1}{8} \text{ mg}$
 $\frac{1}{7} \text{ mg} > \frac{1}{8} \text{ mg}$
- 11 $\frac{2020}{5250} = 0.3847, \quad 0.385 \times 100 = 38.5\% \text{ are dogs}$
 $\frac{2580}{5250} = 0.4914, \quad 0.491 \times 100 = 49.1\% \text{ are cats}$
 $\frac{400}{5250} = 0.0761, \quad 0.076 \times 100 = 7.6\% \text{ are 'pocket pets'}$
 $\frac{5250 - (2020 + 2580 + 400)}{5250} = 0.0476,$
 $0.048 \times 100 = 4.8\% \text{ are birds}$
- 12 $38.5\% \text{ dogs} \times 10\,000 \text{ patients} = 0.385 \times 10\,000 = 3850 \text{ dogs}$
 $49.1\% \text{ cats} \times 10\,000 \text{ patients} = 0.491 \times 10\,000 = 4910 \text{ cats}$
 $7.6\% \text{ pocket pets} \times 10\,000 \text{ patients} = 0.076 \times 10\,000$
 $= 760 \text{ pocket pets}$
 $4.8\% \text{ birds} \times 10\,000 \text{ patients} = 0.048 \times 10\,000 = 480 \text{ birds}$
- 13 $\frac{2}{3} + \frac{1}{4} + \frac{1}{2} = \frac{8}{12} + \frac{3}{12} + \frac{6}{12} = \frac{17}{12}$
 $\frac{17}{12} \text{ cup} \times \frac{350 \text{ kcal}}{\text{cup}} = 495.8 \text{ kcal}$
- 14 $\frac{15 \text{ cm}}{300 \text{ cm}} = 0.05, \quad 0.05 \times 100 = 5\%$
- 15 $\frac{1}{3} \times 15 \text{ mL} = 5 \text{ mL}, \quad \frac{1}{2} \times (15 \text{ mL} - 5 \text{ mL}) = 5 \text{ mL}$
 $\frac{(5 \text{ mL} + 5 \text{ mL})}{15 \text{ mL}} = \frac{2}{3}$
- 16 $\frac{5 \times 10^3 \text{ cells}}{1 \mu\text{L}} = \frac{x \text{ cells}}{1 \times 10^6 \mu\text{L}}$
 $(x \text{ cells})(1 \mu\text{L}) = (5 \times 10^3 \text{ cells})(1 \times 10^6 \mu\text{L})$
 $x = 5 \times 10^9 \text{ cells per L}$
- 17 $\frac{22 \text{ mg}}{1 \text{ kg}} = \frac{x \text{ mg}}{5 \text{ kg}}, \quad (22 \text{ mg})(5 \text{ kg}) = (x \text{ mg})(1 \text{ kg})$
 $x \text{ mg} = \frac{(22 \text{ mg})(5 \text{ kg})}{1 \text{ kg}} = 110 \text{ mg}$
- 18 $\frac{2.2 \text{ mg}}{1 \text{ kg}} = \frac{x \text{ mg}}{45 \text{ kg}}, \quad (2.2 \text{ mg})(45 \text{ kg}) = (x \text{ mg})(1 \text{ kg})$
 $x \text{ mg} = \frac{(2.2 \text{ mg})(45 \text{ kg})}{1 \text{ kg}} = 99 \text{ mg}$

$$19 \quad \frac{30 \text{ mg}}{1 \text{ kg}} = \frac{x \text{ mg}}{20 \text{ kg}}, \quad (30 \text{ mg})(20 \text{ kg}) = (x \text{ mg})(1 \text{ kg}), \quad x = 600 \text{ mg}$$

$$\frac{300 \text{ mg}}{1 \text{ tab}} = \frac{600 \text{ mg}}{x \text{ tabs}}$$

$$(600 \text{ mg})(1 \text{ tab}) = (300 \text{ mg})(x \text{ tabs}), \quad x = 2 \text{ tabs}$$

$$20 \quad \frac{15 \text{ mg}}{1 \text{ kg}} = \frac{x \text{ mg}}{4 \text{ kg}}, \quad x = 60 \text{ mg}$$

$$\frac{100 \text{ mg}}{1 \text{ mL}} = \frac{60 \text{ mg}}{x \text{ mL}}, \quad (60 \text{ mg})(1 \text{ mL}) = (100 \text{ mg})(x \text{ mL}), \quad x = 0.6 \text{ mL}$$

$$21 \quad \frac{1.8 \text{ US dollars}}{1 \text{ British pound}} = \frac{x \text{ US dollars}}{360 \text{ British pounds}}, \quad x = 648 \text{ US dollars}$$

22 Starting factor: 5 kg (weight of cat)

Answer unit: Number of mL

Conversion factors: $\frac{15 \text{ mg}}{1 \text{ kg}}$ (dosage), $\frac{5 \text{ mL}}{125 \text{ mg}}$ (strength of antibiotic)

$$5 \text{ kg} \times \frac{15 \text{ mg}}{1 \text{ kg}} \times \frac{5 \text{ mL}}{125 \text{ mg}} = 3 \text{ mL}$$

23 Starting factor: 4.5 kg (weight of cat)

Answer unit: Number of mL

Conversion factors: $\frac{1.5 \text{ IU}}{1 \text{ kg}}$ (dosage), $\frac{1 \text{ mL}}{10 \text{ IU}}$ (strength of insulin)

$$4.5 \text{ kg} \times \frac{1.5 \text{ IU}}{1 \text{ kg}} \times \frac{1 \text{ mL}}{10 \text{ IU}} = 0.7 \text{ mL}$$

24 Starting factor: 6 hours

Answer unit: Number of mL of fluid

Conversion factor: $\frac{30 \text{ mL}}{1 \text{ h}}$ (fluid rate)

$$6 \text{ h} \times \frac{30 \text{ mL}}{1 \text{ h}} = 180 \text{ mL}$$

Measurement Systems

Learning Objectives

- Review the metric system
- Convert values within the metric system
- Solve clinical problems using the metric system
- Review other common systems of measure
- Convert values from other systems to the metric system

The metric system

The metric system is the most commonly used system of measure in the world and is used almost exclusively within medical professions. It is based on the decimal system – using a base of 10. This makes calculations and conversions simple as it eliminates the need for proper fractions.

The three basic things we want to measure are weight, volume and length (Fig. 7.1).



Weight - basic unit is the gram (abbreviated g)



Volume - basic unit is the litre (abbreviated L)



Length - basic unit is the metre (abbreviated m)

Figure 7.1 Basic units of measurement for common variables.



Worlds apart

In the US the preferred spelling of litre is liter and that of metre is meter. In Canada both forms are encountered. Fortunately, the abbreviations are the same!

The basic unit of each measurement can be modified to indicate a larger or smaller quantity. This is accomplished by the addition of prefixes that carry a specific meaning (Table 7.1).

Table 7.1 Prefixes in measurement units. Commonly used units are shown in bold type.

Prefix	Symbol	Multiple of base unit	Weight	Volume	Length
Mega	M	1 000 000 (10^6)	Megagram (Mg)	Megalitre (ML)	Megametre (Mm)
Kilo	k	1000 (10^3)	Kilogram (kg)	Kilolitre (kL)	Kilometre (km)
Base Unit	-	1	Gram (g)	Litre (L)	Metre (m)
Deci	d	0.1 (10^{-1})	Decigram (dg)	Decilitre (dL)	Decimetre (dm)
Centi	c	0.01 (10^{-2})	Centigram (cg)	Centilitre (cL)	Centimetre (cm)
Milli	m	0.001 (10^{-3})	Milligram (mg)	Millilitre (mL)	Millimetre (mm)
Micro	μ or mc	0.000001 (10^{-6})	Microgram (μ g)	Microlitre (μ L)	Micrometre (μ m)

Converting within the metric system

The beauty of the metric system is its simplicity – we can all divide or multiply by 10! If we remember the commonly used units in the table, we can move from one unit to another. Let's say we want to change 1 cm into metres. We can see that 1 cm is 0.01 of a metre, or in other words there are 100 cm in 1 m. Moving from one to another is easily done by making *conversion factors* and employing dimensional analysis:

$$\begin{array}{c}
 \text{Conversion factor} \\
 \downarrow \\
 1 \text{ cm} \times \frac{1 \text{ m}}{100 \text{ cm}} = \frac{1 \text{ m}}{100} = 0.01 \text{ m} \leftarrow \text{Answer unit} \\
 \uparrow \qquad \qquad \qquad \swarrow \\
 \text{Starting factor} \qquad \text{Note that the cm units cancel each other}
 \end{array}$$

Now I would like to know how many mg are in a 2 g tablet:

Starting factor

$$2 \text{ g} \times \frac{1000 \text{ mg}}{1 \text{ g}} = 2000 \text{ mg}$$

Answer unit

Conversion factor

Here the g units cancel



Let's do it again...

- 1 How many cm are there in 1.8 km?
- 2 4 g equals how many μg ?
- 3 How many mL are there in 4.5 L?
- 4 A mouse weighs 30 g. How would you write this in kg?
- 5 How many L are there in 100 dL?

Answers

$$1 \quad 1.8 \text{ km} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{100 \text{ cm}}{1 \text{ m}} = 180\,000 \text{ cm}$$

$$2 \quad 4 \text{ g} \times \frac{10^6 \mu\text{g}}{1 \text{ g}} = 4 \times 10^6 \mu\text{g}$$

$$3 \quad 4.5 \text{ L} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 4500 \text{ mL}$$

$$4 \quad 30 \text{ g} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.03 \text{ kg}$$

$$5 \quad 100 \text{ dL} \times \frac{1 \text{ L}}{10 \text{ dL}} = 10 \text{ L}$$

Clinical applications

There are many problems encountered in veterinary practice that are simplified if you are comfortable moving around in the metric system.

Consider a 20 kg dog that requires 50 mg/kg of a medication that comes in 2 g tablets. How many tablets do we give?

We set the problem up using dimensional analysis:

$$\begin{array}{c}
 \text{Starting factor} \\
 \downarrow \\
 20 \text{ kg} \times \frac{50 \text{ mg}}{1 \text{ kg}} \times \frac{1 \text{ tablet}}{2 \text{ g}} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 0.5 \text{ tablet} \leftarrow \text{Answer unit} \\
 \uparrow \quad \uparrow \quad \nearrow \\
 \text{Conversion factors}
 \end{array}$$

Let's take a closer look at the conversion factors:

$$\frac{50 \text{ mg}}{1 \text{ kg}} = \text{dosage}$$

$$\frac{1 \text{ tablet}}{2 \text{ g}} = \text{strength of the medication}$$

$$\frac{1 \text{ g}}{1000 \text{ mg}} = \text{metric conversion factor}$$



Remember to arrange the conversion factors so that all the units except the desired answer units cancel out. In this case kg, mg, and g all appear once in the numerators and once in the denominators, cancelling each other. The only units left are tablets, which is what we want!

Dimensional analysis vs ratio and proportion

Many textbooks will use ratio and proportion to solve dosage calculation problems. This method requires more steps but, for some people, it may be preferred. Let's look at the same problem using ratio and proportion:

$$\text{Step 1: How many mg to give?} \quad \frac{50 \text{ mg}}{1 \text{ kg}} = \frac{x \text{ mg}}{20 \text{ kg}}, \quad x = 1000 \text{ mg}$$

$$\text{Step 2: How many grams do that equal?} \quad \frac{1000 \text{ mg}}{1 \text{ g}} = \frac{1000 \text{ mg}}{x \text{ g}}, \quad x = 1 \text{ g}$$

$$\text{Step 3: How many tablets do that equal?} \quad \frac{1 \text{ tablet}}{2 \text{ g}} = \frac{x \text{ tablets}}{1 \text{ g}}, \quad x = 0.5 \text{ tablet}$$

Dimensional analysis allows many steps to be incorporated into one equation, and if set up correctly, once all the cancelling is done, only the desired answer units are left at the end.



Let's do it again...

- 1 A 30 g mouse requires 200 $\mu\text{g}/\text{kg}$ of a medication that only comes in a strength of 1 mg/mL. How many mL do you give?
- 2 A horse requires intravenous fluids given at a rate of 500 mL/h. After 7 hours, how many litres will the horse receive?
- 3 A typical feline ovariohysterectomy (spay operation) requires 5 mL of isoflurane anaesthetic. If a veterinary clinic performs 200 such operations in a month, how many 2 dL bottles of isoflurane will they require?

Answers

$$1 \quad 30 \text{ g} \times \frac{200 \mu\text{g}}{1 \text{ kg}} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{1 \text{ mL}}{1 \text{ mg}} \times \frac{1 \text{ mg}}{1000 \mu\text{g}} = 0.006 \text{ mL}$$

$$2 \quad 7 \text{ h} \times \frac{500 \text{ mL}}{1 \text{ h}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 3.5 \text{ L}$$

$$3 \quad 200 \text{ ops} \times \frac{5 \text{ mL}}{1 \text{ op}} \times \frac{1 \text{ bottle}}{2 \text{ dL}} \times \frac{1 \text{ dL}}{100 \text{ mL}} = 5 \text{ bottles (op = operation)}$$

cc: a carbon copy of mL

Although the preferred metric measure for small volumes is millilitre (mL), you may see a drug order given in cubic centimeters (cc's). This is because 1 cc of water is equal to 1 mL at a temperature of 4°C. (Fig. 7.2).

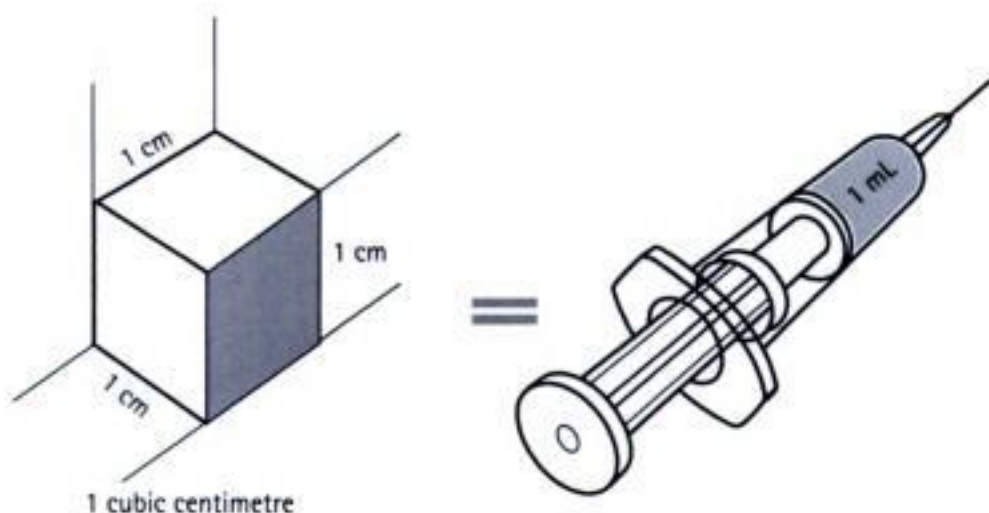


Figure 7.2 One cubic centimetre is equivalent to one millilitre.

Other systems of measure

Household system

Depending on the part of the world in which you live, the household system (Table 7.2) may be more familiar to animal owners than the metric system. This system uses droppers, teaspoons, tablespoons and cups for liquid volume. It is often combined with either the imperial system of measure (in the UK, Canada, Australia and New Zealand) or the United States Customary System (in the US). There may be times when you need to direct owners to use this system to administer over-the-counter medications or food supplements.

We can use dimensional analysis to convert within the household system, just as we did within the metric system, using conversion factors from the table below.

Converting between the household and metric system

It may be necessary to convert from one system to another. For instance, if you wanted an owner to administer 5 mL of a liquid anti-diarrhoea preparation to her small dog and she did not have an

Table 7.2 Household systems of measurement.

Household system (US)	Household system (imperial)
60 drops (gtt) = 1 teaspoon (tsp)	60 drops (gtt) = 1 teaspoon (tsp)
3 tsp = 1 tablespoon (tbs)	3 tsp = 1 tablespoon (tbs)
2 tbs = 1 ounce (oz)	2 tbs = 1 ounce (oz)
16 oz = 1 pint (pt)	20 oz = 1 pint (pt)
2 pt = 1 quart (qt)	2 pt = 1 quart (qt)
4 qt = 1 gallon (gal)	4 qt = 1 gallon (gal)

Table 7.3 Equivalencies for volume in different measurement systems.

Household system	Imperial system metric equivalent	US system metric equivalent
1 tsp	5 mL	5 mL
1 tbs	15 mL	15 mL
1 oz	28 mL	30 mL
1 cup	230 mL	240 mL
1 pint	570 mL	470 mL
1 quart	1.14 L	0.95 L
1 gallon	4.55 L	3.79 L

appropriate metric measuring device, you could tell her how to use a teaspoon measure (1 tsp). Now, it makes a difference where you are in the world as the imperial and US systems are different. Use Table 7.3 for the *approximate* conversions.

Fortunately, when it comes to weight and length, there is only one set of conversions (Table 7.4).

Metric	Household system	Household system	Metric system
1 g	0.033 ounce (oz)	1 ounce	30 g
1 kg	2.2 pounds (lb)	1 pound	0.454 kg
1 cm	0.39 inch	1 inch	2.54 cm
1 m	1.09 yard	1 foot	30.48 cm
1 km	0.625 mile	1 yard	91.44 cm
		1 mile	1.6 km

Let's go through a few problems to get comfortable moving between the systems!

An owner tells you his dog weighs 64 lb. How many kg does it weigh?

$$\begin{array}{c}
 \text{Starting factor} \\
 \downarrow \\
 64 \text{ lb} \times \frac{1 \text{ kg}}{2.2 \text{ lb}} = 29 \text{ kg} \leftarrow \text{Answer unit} \\
 \uparrow \\
 \text{Conversion factor}
 \end{array}$$

Here's another:

You are asked to give amoxicillin at a dose of 15 mg/kg to a cat that weighs 12 lb. How many mg of amoxicillin do you give?

$$\begin{array}{c}
 \text{Starting factor} \\
 \downarrow \\
 12 \text{ lb} \times \frac{1 \text{ kg}}{2.2 \text{ lb}} \times \frac{15 \text{ mg}}{1 \text{ kg}} = 82 \text{ mg} \leftarrow \text{Answer unit} \\
 \uparrow \\
 \text{Conversion factors}
 \end{array}$$



As always, remember to arrange your conversion factors so that the desired units are left in the answer!



Let's do it again...

- 1 You ask a client to give her dog 90 mL of water every hour. How many ounces does this represent in the US? In the UK?
- 2 You walk your dog 2 miles each day. How many km is this?
- 3 You are cutting disposable wrap for surgical packs and are asked to make them 1 yard long. How many cm is this?
- 4 A 2 lb ferret requires 10 mg/kg of a medication that comes in a strength of 1 mg/mL. How many mL should it receive?

Answers

$$1 \quad 90 \text{ mL} \times \frac{1 \text{ oz}}{30 \text{ mL}} = 3 \text{ oz (US)}, \quad 90 \text{ mL} \times \frac{1 \text{ oz}}{28 \text{ mL}} = 3.2 \text{ oz (UK)}$$

$$2 \quad 2 \text{ miles} \times \frac{1 \text{ km}}{0.625 \text{ miles}} = 3.2 \text{ km}$$

$$3 \quad 1 \text{ yard} \times \frac{91.44 \text{ cm}}{1 \text{ yard}} = 91.44 \text{ cm}$$

$$4 \quad 2 \text{ lb} \times \frac{1 \text{ kg}}{2.2 \text{ lb}} \times \frac{10 \text{ mg}}{1 \text{ kg}} \times \frac{1 \text{ mL}}{1 \text{ mg}} = 9.1 \text{ mL}$$

Oral Medication

Learning Objectives

- Types of oral medication
- Reading labels
- Calculating dosages

Types of oral medication

The majority of medications used in veterinary medicine are given by the oral route and can come in various forms: tablets, capsules, liquid, and powder. Tablets are manufactured with a specific amount of medication but can often be divided into smaller portions if needed. Capsules do not lend themselves to dividing the dose, whereas liquids and powders can often be administered in various increments.



The abbreviation for giving medication by mouth is p.o. (per os).

Some liquid medication is manufactured and stored in a powder form and then reconstituted with water to make a liquid. In this case, the concentration of the medication can vary according to the amount of water added – be sure to follow directions carefully!

Oral medication labels

Reading labels carefully is extremely important in order to prevent dosing errors. The *three-way safety check* is a method of ensuring the correct medication is used each time. Remember to check the label for the correct drug and dosage when:

- 1 You *remove* it from the pharmacy shelf
- 2 You *dispense* the medication
- 3 You *replace* the medication.

Examine the label shown in Fig. 8.1 for important information to check each time you handle medication.



Figure 8.1 Important information on the Metacam product packaging. (Reproduced by permission of Boehringer Ingelheim.)

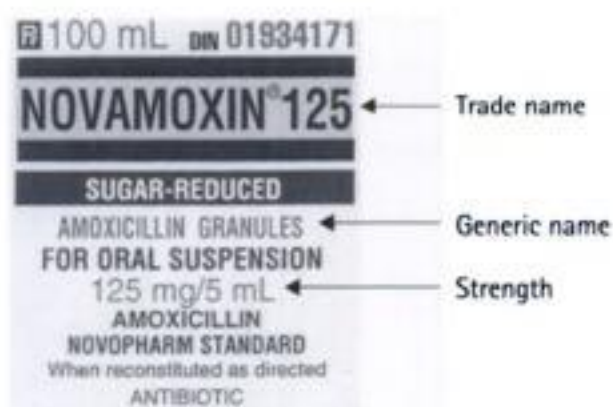


Figure 8.2 Label information on powdered medication for reconstitution. (Reproduced by permission of Novopharm Limited.)

Fig. 8.2 shows a label from a powdered medication that must be reconstituted before use. With the medication in Fig. 8.2, once the label directions are followed, you will have 100 mL of medication and each 5 mL will contain 125 mg. How much will each mL contain?

Using ratio and proportion: $\frac{5 \text{ mL}}{125 \text{ mg}} = \frac{1 \text{ mL}}{x \text{ mg}}, x = 25 \text{ mg}$

Using dimensional analysis: $1 \text{ mL} \times \frac{125 \text{ mg}}{5 \text{ mL}} = 25 \text{ mg}$

Let's use the two labels in Figs 8.1 and 8.2 to do the following problems.

A 10 lb cat needs amoxicillin 20 mg/kg twice daily. How many mL will you give at each dosing?

$$10 \text{ lb} \times \frac{1 \text{ kg}}{2.2 \text{ lb}} \times \frac{20 \text{ mg}}{1 \text{ kg}} \times \frac{5 \text{ mL}}{125 \text{ mg}} = 3.6 \text{ mL}$$

Notice how all the units except the desired answer units (mL) cancel out? The wonder of dimensional analysis!

Okay, we're on a roll, so let's do another ...

A 65 lb Labrador retriever requires 0.1 mg/kg of meloxicam once daily. How many mL should it receive?

$$65 \text{ lb} \times \frac{1 \text{ kg}}{2.2 \text{ lb}} \times \frac{0.1 \text{ mg}}{1 \text{ kg}} \times \frac{1 \text{ mL}}{1.5 \text{ mg}} = 1.97 \text{ mL}$$

Of course, it is not practical to measure to one hundredths of a mL, so you would give 2 mL. Note all the conversion factors that enable the desired answer units to appear in the answer.



Let's do it again...

Use the two labels in Figs 8.1 and 8.2 to solve these clinical problems.

- 1 A 10 kg spaniel cross requires 22 mg/kg of amoxicillin twice daily. How many mL are given at each treatment?
- 2 A 75 lb Doberman needs 0.15 mg/kg of meloxicam each morning. How many mL do you give?
- 3 A 6 lb cat is being treated for an abscess and needs 20 mg/kg of amoxicillin twice daily for 5 days. How many mL will have to be dispensed?

Answers

$$1 \quad 10 \text{ kg} \times \frac{22 \text{ mg}}{1 \text{ kg}} \times \frac{5 \text{ mL}}{125 \text{ mg}} = 8.8 \text{ mL}$$

$$2 \quad 75 \text{ lb} \times \frac{1 \text{ kg}}{2.2 \text{ lb}} \times \frac{0.15 \text{ mg}}{1 \text{ kg}} \times \frac{1 \text{ mL}}{1.5 \text{ mg}} = 3.4 \text{ mL}$$

$$3 \quad 6 \text{ lb} \times \frac{1 \text{ kg}}{2.2 \text{ lb}} \times \frac{20 \text{ mg}}{1 \text{ kg}} \times \frac{5 \text{ mL}}{125 \text{ mg}} \times \frac{2}{1 \text{ day}} \times 5 \text{ days} = 21.81 \text{ mL}$$

In this case, you would want to dispense at least 25 mL to ensure the client had enough medication to last.

Parenteral Medication

Learning Objectives

- What is parenteral administration?
- Types of syringe
- Reconstituting powders for injection
- Working with percent concentrations
- Administration of insulin
- Calculating dosages

What is parenteral administration?

The term *parenteral administration* refers to giving drugs 'in the space between the enteric canal and the surface of the body'. Essentially, this means injecting liquids with a needle into a vein (*intravenous*), into a muscle (*intramuscular*) or under the skin (*subcutaneous*). Abbreviations are:



Intravenous – i.v.

Intramuscular – i.m.

Subcutaneous – s.c. or s.q.

Types of syringe

The most commonly used syringe in small animal veterinary practice is the 3 mL (also known as the 3 cc) syringe (Fig. 9.1). This syringe is calibrated so that each increment equals 0.1 mL. Other sizes that are encountered are 5, 6, 10, and 12 mL syringes, in which each increment represents 0.2 mL. For smaller patients in which drug volumes are small, the tuberculin syringe is used: this is marked in 0.01 mL increments (Fig. 9.2). Occasionally a 20 mL, 30 mL, or 60 mL syringe is required. These are marked in 1 mL increments.

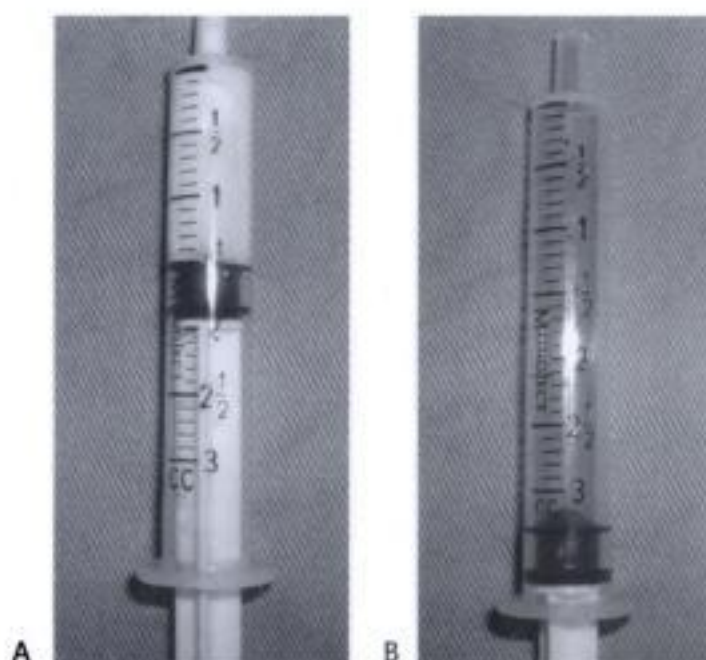


Figure 9.1 The 3 mL syringe is calibrated in 0.1 mL increments and marked with numbers every 0.5 mL. A reading is taken at the level of the top of the plunger. In **A**, the syringe plunger has been withdrawn to 1.5 mL of medication.

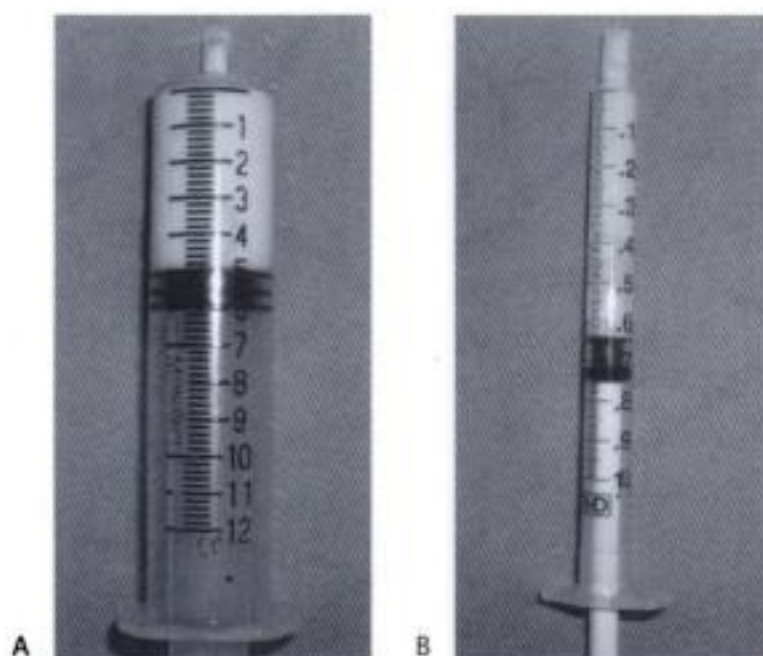


Figure 9.2 **A** A 12 mL syringe showing plunger withdrawal to the 5 mL mark. **B** A tuberculin syringe showing plunger withdrawal to the 0.63 mL mark.



Barking up the wrong tree

Be careful to use the correct syringe for the volume of medication you are administering. It is not accurate to measure 0.3 mL using a 12 mL syringe. A 3 mL or even a tuberculin syringe would be more appropriate.



Let's do it again...

What syringe size is appropriate for the following volumes?

- 1 1.5 mL 2 0.2 mL 3 4.6 mL 4 25 mL 5 2.6 mL

Answers

- 1 3 mL 2 1 mL (tuberculin) 3 6 mL 4 30 mL 5 3 mL

Reconstituting powders

Some injectable drugs are stored as powders and reconstituted just before use. Often, sterile water or saline is used for this purpose. The label will contain directions for reconstituting that will give you the required concentration of drug. On page 61 we will see how we can change the concentration of a liquid by adding less solvent (sterile water) or by diluting an existing solution.

Working with percent concentrations

Most injectable drugs are listed with their strength (concentration) listed in milligrams per millilitre (mg/mL). For instance, atropine is commonly found in a 0.5 mg/mL form. Other drugs, often in the powdered form, are listed as a percent concentration. Look at the label for thiopental in Fig. 9.3.

First of all, note that following the label directions will result in a solution of 1 g in 40 mL, giving a concentration of 2.5%. What does this



Figure 9.3 Thiopental (thiopentone) for reconstitution label. (Reproduced by permission of Abbott Laboratories/Abbott Animal Health Canada.)

mean? Remember that percent literally means 'per one hundred' so a concentration of 2.5% means that there are 2.5 parts of active drug for every 100 equivalent parts of solution. What is an 'equivalent part' you ask? One mL of water weighs 1 g and most medical solutions are nearly equivalent to water so we assume they also have a mass of 1 g per mL.



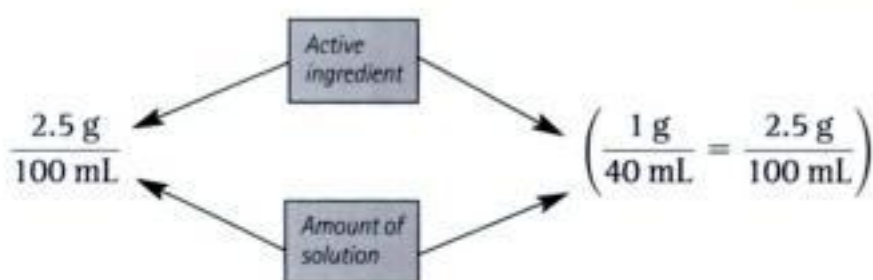
For most solutions, remember:

$$1 \text{ mL} = 1 \text{ cc} = 1 \text{ g}$$

$$1\% = 1 \text{ g}/100 \text{ mL}$$

$$10\% = 10 \text{ g}/100 \text{ mL (since 100 mL is the same as 100 g)}$$

In the example above, a 2.5% solution means there are 2.5 g of active ingredient in every 100 mL of solution. In other words:



Barking up the wrong tree

There is a temptation to think of 1 mL of water as weighing 1 mg as the words sound more similar than millilitre and gram. Don't get caught!

Let's try some problems using the thiopental label.

An 8 kg terrier usually requires 15 mg/kg of thiopental for anaesthetic induction (this is an injection given to anaesthetise an animal before using a gaseous anaesthetic). How much of the 2.5% drug will you draw up into a syringe?

$$8 \text{ kg} \times \frac{15 \text{ mg}}{1 \text{ kg}} \times \frac{100 \text{ mL}}{2.5 \text{ g}} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 4.8 \text{ mL}$$

Let's review this equation that uses dimensional analysis:

- The starting factor is the weight of the dog: kg
- The answer units are in mL as that is what you want to draw up
- The conversion factors are:
 - The dosage: 15 mg/kg
 - The concentration of the drug: 100 mL/2.5 g
 - The metric conversion of g to mg
- Using these conversion factors allows us to cancel units and leaves us with the desired answer units.



Barking up the wrong tree

If we had used the conversion factor 2.5 g/100 mL instead of 100 mL/2.5 g, we would not have arrived at the correct answer units. Placing mL on top in this conversion assured us it would come out in the answer unit once all the other units cancelled.



Let's do it again...

- 1 A 5 kg cat needs 12 mg/kg thiopental. How much 2.5% thiopental will you draw up?
- 2 25 mL of a 4% thiopental solution is drawn up. How many mg of drug does this represent?

Answers

$$1 \quad 5 \text{ kg} \times \frac{12 \text{ mg}}{1 \text{ kg}} \times \frac{100 \text{ mL}}{2.5 \text{ g}} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 2.4 \text{ mL}$$

$$2 \quad 25 \text{ mL} \times \frac{4 \text{ g}}{100 \text{ mL}} \times \frac{1000 \text{ mg}}{1 \text{ g}} = 1000 \text{ mg}$$



Solutions can be expressed as a weight/volume (w/v) percentage, as with the thiopental above, or as a volume/volume (v/v) percentage, such as a 2% hydrogen peroxide solution. This represents 2 mL of hydrogen peroxide in 100 mL of total solution. Remember it's the amount of active ingredient in the total final volume that gives us the percent concentration.

Administering insulin

Insulin is given to diabetic animals to replace the lack of natural insulin in their bodies. It is administered by clinical staff when a diabetic patient is in hospital but most often by the patient's owner at home. Insulin is measured in *international units* (IU) – a term that refers to a drug's *activity*, not its weight. Other drugs measured in this way include penicillin and heparin. Insulin comes in two common strengths: U-100, which has 100 units per mL, and U-40, which has 40 units per mL (Fig. 9.4).

Insulin must be administered with a specific type of syringe that is calibrated for the type of insulin used. U-100 syringes must *only* be used with U-100 insulin and U-40 syringes *only* with U-40 insulin (Fig. 9.5).

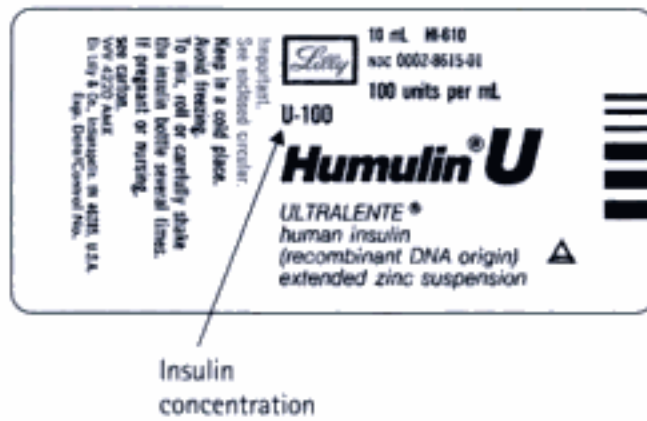


Figure 9.4 Humulin U-100 insulin labelling. (Reproduced by permission of Eli Lilly Canada Inc.)

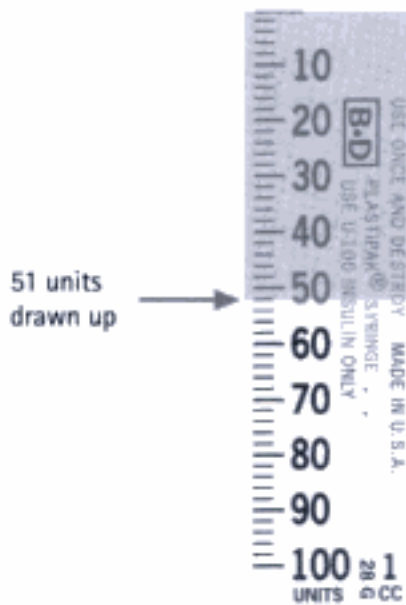


Figure 9.5 A U-100 syringe barrel showing a reading of 51 units on the measurement scale. Standard insulin syringes are either in 1 mL or 0.5 mL sizes, but the calibrations on both types are the same and always refer to the number of units drawn into the syringe.



Insulin syringes are either 1 mL or 0.5 mL in size but the calibrations always refer to the number of units drawn up into the syringe.



Barking up the wrong tree

What would happen if you used a U-100 syringe to draw up U-40 insulin? The U-40 insulin is $\frac{40 \text{ units/mL}}{100 \text{ units/mL}} = 40\%$ as strong as the U-100 insulin. Let's say you drew up 20 units of U-40 insulin with the U-100 syringe. You would actually have only 40% of 20 units, or 8 units.

Using a U-40 syringe for U-100 insulin would give you more insulin than you require, which could cause a severe reaction!

Let's try some clinical problems using insulin.

A 10 kg mixed breed dog needs 4 IU/kg of insulin twice daily. How much insulin will the owner draw up each time?

$$10 \text{ kg} \times \frac{4 \text{ IU}}{1 \text{ kg}} = 40 \text{ IU}$$

A 60 lb German shepherd requires 2 IU/kg of insulin twice daily. How much U-100 insulin will the owner need to use in 4 weeks?

$$60 \text{ lb} \times \frac{1 \text{ kg}}{2.2 \text{ lb}} \times \frac{2 \text{ IU}}{1 \text{ kg}} \times \frac{1 \text{ mL}}{100 \text{ IU}} \times 2 \times 28 = 30.5 \text{ mL}$$

Insulin dosage
Insulin strength
Days in 4 weeks

Weight of dog
Conversion to kg
Times per day
Total needed for 4 weeks

Notice once again that the conversion factor for the strength of the insulin is arranged so that the volume (mL) appears in the answer unit and all other units cancel.



Let's do it again...

- 1 A 12 lb cat needs 1 IU/kg of insulin once a day. Using U-40 insulin, how many units are given each day?
- 2 How many mL of U-100 insulin will be used in one week for a 35 lb Dachshund that is on a dose of 3 IU/kg twice daily?
- 3 If you accidentally used a U-40 syringe to draw up U-100 insulin. How many units would actually be contained in the syringe that is drawn to the 20 IU mark?

Answers

$$1 \quad 12 \text{ lb} \times \frac{1 \text{ kg}}{2.2 \text{ lb}} \times \frac{1 \text{ IU}}{\text{kg}} = 5.5 \text{ IU}$$

Note that the type of insulin does not affect the number of units given, only the number of mL.

$$2 \quad 35 \text{ lb} \times \frac{1 \text{ kg}}{2.2 \text{ lb}} \times \frac{3 \text{ IU}}{1 \text{ kg}} \times \frac{1 \text{ mL}}{100 \text{ IU}} \times 2 \times 7 = 6.7 \text{ mL}$$

$$3 \quad \frac{100 \text{ units/mL}}{40 \text{ units/mL}} \times 20 \text{ IU} = 50 \text{ IU}$$

Clinical Problems Using Dosage Calculations

Questions

- 1 4 mg = how many g?
- 2 5000 g = how many kg?
- 3 120 mL = how many L?
- 4 0.5 kg water = how many mL?
- 5 A 20 lb dog needs 30 mg/kg of medication. How many mg of medication do you give?
- 6 A 40 kg dog needs 0.5 mg/kg of a medication that comes in 10 mg tablets. How many tablets will you give?
- 7 A 30 g mouse needs 400 $\mu\text{g}/\text{kg}$ of a medication that comes in a liquid form with a strength of 0.1 mg/mL. How much will you give?
- 8 The dosage for a dog is 10 mg/kg. The dog weighs 25 kg and the medication comes in 100 mg tablets. How many do you give?
- 9 Mrs Smith's cat weighing 5 kg needs insulin at 2 IU/kg. The insulin comes in a strength of 40 IU/mL. How much insulin do you give?
- 10 How many grams of dextrose does 350 mL of a 50% dextrose solution contain?
- 11 A 3.5 kg cat needs 20 mg/kg of liquid antibiotic that comes in a strength of 15 mg/mL. How many mL do you give (answer to nearest tenth)?
- 12 How many mg of acepromazine are in 1.2 mL of a 10 mg/mL solution?
- 13 A 13 kg dog needs 40 mg/kg of an antibiotic that comes in 250 mg capsules. How many capsules do you give?
- 14 If an injectable drug has a concentration of 10 mg/mL, how would you express this as a percentage concentration?
- 15 A 22 kg dog needs 2 mg/kg of a drug that comes as a 5% solution. How many mL do you give?

Answers

$$1 \quad 4 \text{ mg} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 0.004 \text{ g}$$

$$2 \quad 5000 \text{ g} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 5 \text{ kg}$$

$$3 \quad 120 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 0.12 \text{ L}$$

$$4 \quad 0.5 \text{ kg} \times \frac{1 \text{ mL}}{1 \text{ g}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 500 \text{ mL}$$

$$5 \quad 20 \text{ lb} \times \frac{1 \text{ kg}}{2.2 \text{ lb}} \times \frac{30 \text{ mg}}{1 \text{ kg}} = 273 \text{ mg}$$

$$6 \quad 40 \text{ kg} \times \frac{0.5 \text{ mg}}{1 \text{ kg}} \times \frac{1 \text{ tab}}{10 \text{ mg}} = 2 \text{ tabs}$$

$$7 \quad 30 \text{ g} \times \frac{400 \mu\text{g}}{1 \text{ kg}} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{1 \text{ mL}}{0.1 \text{ mg}} \times \frac{1 \text{ mg}}{1000 \mu\text{g}} = 0.12 \text{ mL}$$

$$8 \quad 25 \text{ kg} \times \frac{10 \text{ mg}}{1 \text{ kg}} \times \frac{1 \text{ tab}}{100 \text{ mg}} = 2.5 \text{ tabs}$$

$$9 \quad 5 \text{ kg} \times \frac{2 \text{ IU}}{1 \text{ kg}} \times \frac{1 \text{ mL}}{40 \text{ IU}} = 0.25 \text{ mL}$$

$$10 \quad 350 \text{ mL} \times \frac{50 \text{ g}}{100 \text{ mL}} = 175 \text{ g, or } \frac{50 \text{ g}}{100 \text{ mL}} = \frac{x \text{ g}}{350 \text{ mL}}, x = 175 \text{ g}$$

$$11 \quad 3.5 \text{ kg} \times \frac{20 \text{ mg}}{1 \text{ kg}} \times \frac{1 \text{ mL}}{15 \text{ mg}} = 4.7 \text{ mL}$$

$$12 \quad 1.2 \text{ mL} \times \frac{10 \text{ mg}}{1 \text{ mL}} = 12 \text{ mg, or } \frac{10 \text{ mg}}{1 \text{ mL}} = \frac{x \text{ mg}}{1.2 \text{ mL}}, x = 12 \text{ mg}$$

$$13 \quad 13 \text{ kg} \times \frac{40 \text{ mg}}{1 \text{ kg}} \times \frac{1 \text{ capsule}}{250 \text{ mg}} = 2 \text{ capsules (you cannot split capsules)}$$

$$14 \quad \text{(i) } \frac{10 \text{ mg}}{1 \text{ mL}} \times \frac{1 \text{ g}}{1000 \text{ mg}} = \frac{0.01 \text{ g}}{1 \text{ mL}}, \text{ or}$$

$$\text{(ii) } \frac{0.01 \text{ g}}{1 \text{ mL}} = \frac{x \text{ g}}{100 \text{ mL}}, x = \frac{1 \text{ g}}{100 \text{ mL}} = 1\%$$

$$15 \quad 22 \text{ kg} \times \frac{2 \text{ mg}}{1 \text{ kg}} \times \frac{100 \text{ mL}}{5 \text{ g}} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 0.88 \text{ mL}$$

↑
5% = 5g/100mL
or 100mL/5g

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Total drug in bottle

$$5\% = \frac{5 \text{ g}}{100 \text{ mL}}, \quad \frac{5 \text{ g}}{100 \text{ mL}} = \frac{1 \text{ g}}{x \text{ mL}}, \quad x = 20 \text{ mL}$$

Concentration desired

Amount of diluent to add to 1 g in order to make a 5% solution

Let's see how a more concentrated form of the drug changes the volume we need to use. If the dose for a dog is 15 mg/kg, and we have a 50 kg dog, we would need:

$$50 \text{ kg} \times \frac{15 \text{ mg}}{1 \text{ kg}} \times \frac{100 \text{ mL}}{2.5 \text{ g}} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 30 \text{ mL} \quad \text{using the 2.5\% concentration}$$

$$50 \text{ kg} \times \frac{15 \text{ mg}}{1 \text{ kg}} \times \frac{100 \text{ mL}}{5 \text{ g}} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 15 \text{ mL} \quad \text{using the 5\% concentration}$$

When adding a diluent to a powder, the final volume is always a little more than the total volume of the diluent as the powder, even in solution, will add to the volume. When using larger volumes of diluent (more than 10 mL), this is not significant but when small volumes are used, the final volume can be quite different from the volume of the diluent alone. For instance, when 2.5 mL of diluent are added to 1 g of cefalozin antibiotic powder, the resultant volume is 3 mL and that makes the resultant concentration:

$$\frac{1 \text{ g}}{3 \text{ mL}} \times \frac{1000 \text{ mg}}{1 \text{ g}} = \frac{1000 \text{ mg}}{3 \text{ mL}}, \quad \frac{1000 \text{ mg}}{3 \text{ mL}} = \frac{x \text{ mg}}{1 \text{ mL}}, \quad x = 334 \text{ mg/mL}$$

Recall that in a volume/volume (v/v) solution it is the amount of active ingredient in the final volume that determines the concentration.

How would you make a 5% solution of hydrogen peroxide?

$$5\% = \frac{5 \text{ mL}}{100 \text{ mL}} = \frac{50 \text{ mL}}{1000 \text{ mL}} = \frac{1 \text{ mL}}{20 \text{ mL}} = \frac{25 \text{ mL}}{500 \text{ mL}}$$

If we wish to make 100 mL of solution, we take 5 mL of hydrogen peroxide and add diluent up to 100 mL final volume, in other words, add 95 mL of diluent. If we want 1000 mL of solution, we take 50 mL of hydrogen peroxide and add 950 mL of diluent.

Making weaker solutions from stock solutions

Many types of solutions that we use in the veterinary practice or research facility are concentrated to reduce the volume that needs to be shipped and stored. Before these *stock solutions* are used, they are

diluted to the appropriate concentration. Many disinfectant solutions are diluted before use.

There is a simple concept that is helpful in determining how to dilute solutions:

$$C_1 \times V_1 = C_2 \times V_2$$

C_1 = concentration of solution 1; V_1 = volume of solution 1;

C_2 = concentration of solution 2; V_2 = volume of solution 2.

This equation simply tells us that, in terms of the active ingredient, a small volume of a concentrated solution is equal to a large volume of diluted solution. This is like money; a small number of large denominations is equal to an appropriate large number of small denominations.

If we consider hydrogen peroxide, how much of a 10% concentration is equal to 1000 mL of a 1% concentration?

$$C_1 = 1\%; V_1 = 1000 \text{ mL}; C_2 = 10\%; V_2 = \text{unknown}$$

$$C_1 V_1 = C_2 V_2 \longrightarrow V_2 = \frac{C_1 V_1}{C_2}$$

$$V_2 = \frac{(1\%)(1000 \text{ mL})}{10\%}, \quad V_2 = 100 \text{ mL}$$

Therefore 100 mL of a 10% concentration has the same amount of active ingredient as 1000 mL of a 1% solution.

We can use this relationship to determine how to dilute a stock solution. We need to know the starting and final concentration and how much of the dilute solution we are making.

How would you make 250 mL of a 2% hydrogen peroxide using a 10% stock solution?

$$C_1 = 10\%; V_1 = \text{unknown}; C_2 = 2\%; V_2 = 250 \text{ mL}$$

$$C_1 V_1 = C_2 V_2 \longrightarrow V_1 = \frac{C_2 V_2}{C_1}$$

$$V_1 = \frac{(2\%)(250 \text{ mL})}{10\%}, \quad V_1 = 50 \text{ mL}$$

From our equation, we can see that 50 mL of a 10% solution will contain the same amount of active ingredient as 250 mL of a 2% solution. From this we conclude that we need to take 50 mL of our 10% *stock solution* and dilute it up to 250 mL (i.e. add 200 mL of diluent) in order to make our *working solution*.

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Working with mixed solutions



Occasionally, mixtures of drugs are used in one solution, sometimes call a *cocktail*. The concentration of each drug in the final solution must be constant in order to administer the correct dose to the patient. A challenging problem can be to make up such a cocktail, especially if the ingredient concentrations are changed from the original 'recipe'.

Look at the following recipe for 'Premix'. What is the final concentration of each ingredient?

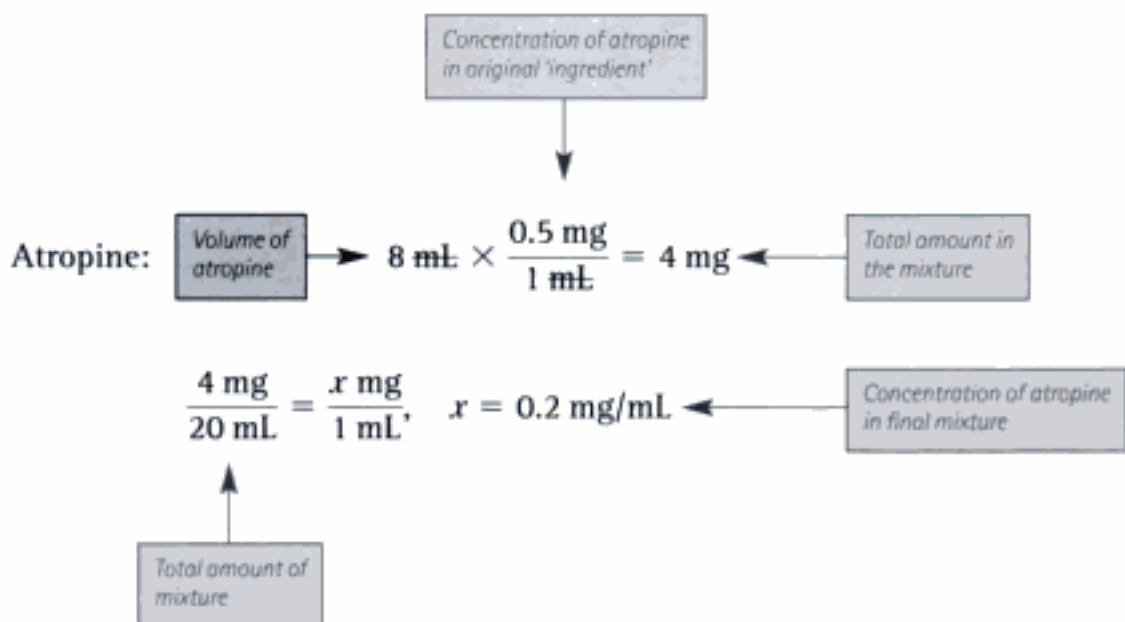
'Premix': an anaesthetic premedication cocktail

Atropine sulfate: 8 mL of a 0.5 mg/mL solution

Acepromazine: 2 mL of a 10 mg/mL solution

Meperidine: 4 mL of a 100 mg/mL solution

Sterile saline: 6 mL added to give final volume



Acepromazine: $2 \text{ mL} \times \frac{10 \text{ mg}}{1 \text{ mL}} = 20 \text{ mg}, \quad \frac{20 \text{ mg}}{20 \text{ mL}} = \frac{x \text{ mg}}{1 \text{ mL}}, \quad x = 1 \text{ mg/mL}$

Meperidine: $4 \text{ mL} \times \frac{100 \text{ mg}}{1 \text{ mL}} = 400 \text{ mg}, \quad \frac{400 \text{ mg}}{20 \text{ mL}} = \frac{x \text{ mg}}{1 \text{ mL}}, \quad x = 20 \text{ mg/mL}$

These calculations tell us the final concentration of each of the ingredients in the final solution. No matter how much of the solution we make up, it must contain these final concentrations.

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- 2 Just when we think we have it all figured out, someone tells us that the only form of acepromazine we have available is in a concentration of 25 mg/mL. How will this change our recipe for making 25 mL of the cocktail?

We know we need 25 mg of acepromazine in the total 25 mL of the cocktail so how much of the stronger drug do we need?

$$25 \text{ mg} \times \frac{1 \text{ mL}}{25 \text{ mg}} = 1 \text{ mL}$$

Diagram illustrating the calculation of the volume of drug required:

- Total drug needed** (25 mg) is multiplied by the **Concentration of drug** ($\frac{1 \text{ mL}}{25 \text{ mg}}$) to determine the **Volume of drug required** (1 mL).

Since we only need 1 mL of this stronger acepromazine, our recipe now looks like this:

Butorphanol:	5 mL
Acepromazine:	1 mL
Atropine:	10 mL
<i>Total volume of drugs:</i>	16 mL

In order to make our total volume equal 25 mL and maintain the desired final concentration of each drug, we must add 9 mL of saline as a diluent. This represents the extra 1.5 mL of saline we have to add since we are using 1.5 mL less of the stronger acepromazine compared to the original weaker acepromazine.



Barking up the wrong tree

If we just used 7.5 mL of saline, as in the first recipe, our total volume would only be 23.5 mL and each drug would be more concentrated in the final solution:

Butorphanol:	$\frac{50 \text{ mg}}{23.5 \text{ mL}} = 2.13 \text{ mg/mL}$, instead of 2 mg/mL
Acepromazine:	$\frac{25 \text{ mg}}{23.5 \text{ mL}} = 1.06 \text{ mg/mL}$, instead of 1 mg/mL
Atropine:	$\frac{5 \text{ mg}}{23.5 \text{ mL}} = 0.21 \text{ mg/mL}$, instead of 0.2 mg/mL

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Take 6 mL of the 5% thipentone and add 9 mL of sterile diluent to make 15 mL of a 2% solution.

- 2 The original cocktail has 4 mL of acepromazine with a concentration of 10 mg/mL for a total of 40 mg of the drug in the cocktail. Using the new, stronger acepromazine (25 mg/mL) as a stock solution, we would need:

$$40 \text{ mg} \times \frac{1 \text{ mL}}{25 \text{ mg}} = 1.6 \text{ mL of acepromazine}$$

Since this is 2.4 mL less than the original amount of stock solution, we need to add 10.4 mL of saline as a diluent, instead of just 8 mL, to maintain our final cocktail volume at 30 mL, thus keeping all our final concentrations the same.

- 3 $C_1V_1 = C_2V_2$

$$C_1 = 15 \text{ mg/mL}, V_1 = \text{unknown}; C_2 = 0.5 \text{ mg/mL}; V_2 = 10 \text{ mL}$$

$$V_1 = \frac{C_2V_2}{C_1}, V_2 = \frac{(0.5 \text{ mg/mL})(10 \text{ mL})}{(15 \text{ mg/mL}), V_1 = 0.33 \text{ mL}$$

Take 0.33 mL of the stock solution and add 9.67 mL of diluent to make 10 mL of working solution.

- 4 $C_1V_1 = C_2V_2$

$$C_1 = 10\%; V_1 = \text{unknown}; C_2 = 0.6\%; V_2 = 30 \text{ mL}$$

$$V_1 = \frac{C_2V_2}{C_1}, V_1 = \frac{(0.6\%)(30 \text{ mL})}{(10\%)}, V_1 = 1.8 \text{ mL}$$

In order to make 30 mL of working solution, 28.2 mL of diluent would be needed (30 mL - 1.8 mL).

- 5 $C_1V_1 = C_2V_2$

$$C_1 = 1\%; V_1 = \text{unknown}; C_2 = 5 \text{ mg/dL}; V_2 = 50 \text{ mL}$$

Since we need to ensure the same units in the equation, we can either convert C_2 into a percent concentration or convert C_1 into a weight by volume concentration. Let's make C_2 into a percent:

$$\frac{5 \text{ mg}}{1 \text{ dL}} \times \frac{1 \text{ dL}}{100 \text{ mL}} \times \frac{1 \text{ g}}{1000 \text{ mg}} = \frac{0.005 \text{ g}}{100 \text{ mL}} = 0.005\%$$

↑
Leaving the answer in grams per 100 mL gives us the percent concentration as per the definition of percent: number of grams per 100 mL of solution

$$V_1 = \frac{C_2V_2}{C_1}, V_1 = \frac{(0.005\%)(50 \text{ mL})}{(1\%)}, V_1 = 0.25 \text{ mL}$$

Take 0.25 mL of the stock solution and add 49.75 mL of diluent to make 50 mL of a 1% working solution.

- 6 In this problem the amount of working solution is not specified so we must decide how much to make in order to give us V_1 . Let's make 60 mL.

$$C_1V_1 = C_2V_2$$

$$C_1 = 450 \text{ mg/mL}; V_1 = \text{unknown}; C_2 = 15 \text{ mg/mL}; V_2 = 60 \text{ mL}$$

$$V_1 = \frac{C_2V_2}{C_1}, \quad V_1 = \frac{(15 \text{ mg/mL})(60 \text{ mL})}{(450 \text{ mg/mL})}, \quad V_1 = 2 \text{ mL}$$

Take 2 mL of the stock solution and add 58 mL of diluent to make 60 mL of working solution.

- 7 We can see from Table 12.1 that we need 1 mL of the ketamine stock solution and 2 mL of the diazepam stock solution; therefore we need to add 7 mL of diluent to bring us up to the 10 mL final volume of the cocktail.

Table 12.1

Drug	Cocktail concentration of drug	Total drug in cocktail	Stock concentration of drug	Volume of drug needed from stock
Ketamine	10 mg/mL	$10 \text{ mL} \times \frac{10 \text{ mg}}{1 \text{ mL}} = 100 \text{ mg}$	100 mg/mL	1 mL
Diazepam	1 mg/mL	$10 \text{ mL} \times \frac{1 \text{ mg}}{1 \text{ mL}} = 10 \text{ mg}$	5 mg/mL	2 mL

Intravenous Fluids

Learning Objectives

- Understanding rates of fluid administration
- Determining how to calculate flow rates
- Using fluid administration sets
- Determining how to calculate drip rates
- Intravenous pumps

Intravenous fluid administration

Intravenous (i.v.) fluids are used to provide water, electrolytes, energy and, often, medication to patients. This is frequently necessary when oral administration is not appropriate or insufficient to meet the patient's needs. One example would be a puppy suffering from parvovirus enteritis, which can cause severe vomiting and diarrhoea leading to dehydration. Attempting to give water and medicine orally is ineffective as it simply causes more vomiting and will not be absorbed.

There are many different types of i.v. fluids but all are administered through a catheter (needle) placed in a vein. They must be administered at an appropriate rate to meet the patient's needs and yet not too quickly to cause fluid overload.

Flow rates

A flow rate implies a volume of a substance delivered over time in which the substance being delivered is the numerator of the fraction and time is the denominator. In veterinary medicine the two most common flow rates are mL of i.v. fluids per hour (mL/h) and L of oxygen per minute (L/min) during anaesthesia. Rates can be described in more than one way. Intravenous fluid rates can be described as mL/h, mL/min, or mL/24 h (i.e. volume delivered in one day). We can also describe i.v. fluid rates based on the weight of the patient – mL/kg/unit of time. An example would be an order to provide an i.v. fluid rate during surgery of 10 mL/kg/h. In other words, for every

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Let's do a few more problems adding some other factors.

A 10 kg dog needs 10 mL/kg every hour during surgery. Using a 10 gtt/mL i.v. set, how will you set the rate in gtt/min?

$$10 \text{ kg} \times \frac{10 \text{ mL}}{\text{kg} \cdot \text{h}} \times \frac{10 \text{ gtt}}{1 \text{ mL}} \times \frac{1 \text{ h}}{60 \text{ min}} = \frac{16.7 \text{ gtt}}{1 \text{ min}}$$

Of course, it is impossible to count 0.7 of a drip, so we always round up or down the number of drips. In this case we would set the drip rate at 17 gtt/min.

A 4 kg cat requires 50 mL/kg every 24 hours to maintain its hydration. Using a 60 gtt/mL i.v. set, how will you set the rate in gtt/min?

$$4 \text{ kg} \times \frac{50 \text{ mL}}{\text{kg} \cdot 24 \text{ h}} \times \frac{60 \text{ gtt}}{1 \text{ mL}} \times \frac{1 \text{ h}}{60 \text{ min}} = \frac{8.3 \text{ gtt}}{1 \text{ min}} = 8 \text{ gtt/min}$$

This conversion factor is the prescribed rate – for every 24 hours, give 50 mL per kg



Let's do it again...

- 1 A patient is to receive 40 mL per hour of fluids. Using a 60 gtt/mL set, how will you set the rate in gtt/min?
- 2 A 45 kg dog requires maintenance fluids at 50 mL/kg every 24 hours. Using a 10 gtt/mL set, how will you set the rate in gtt/min?
- 3 You are asked to give fluids of 120 mL/kg-24 h to a 3.5 kg cat. How will you set the rate in gtt/min using a 60 gtt/mL set?

Answers

$$1 \quad \frac{40 \text{ mL}}{\text{h}} \times \frac{60 \text{ gtt}}{\text{mL}} \times \frac{1 \text{ h}}{60 \text{ min}} = \frac{40 \text{ gtt}}{\text{min}}$$

$$2 \quad 45 \text{ kg} \times \frac{50 \text{ mL}}{\text{kg} \cdot 24 \text{ h}} \times \frac{10 \text{ gtt}}{\text{mL}} \times \frac{1 \text{ h}}{60 \text{ min}} = \frac{15.6 \text{ gtt}}{\text{min}}; \text{ set it at } 16 \text{ gtt/min}$$

$$3 \quad 3.5 \text{ kg} \times \frac{120 \text{ mL}}{\text{kg} \cdot 24 \text{ h}} \times \frac{60 \text{ gtt}}{\text{mL}} \times \frac{1 \text{ h}}{60 \text{ min}} = \frac{17.5 \text{ gtt}}{\text{min}}; \text{ set it at } 18 \text{ gtt/min}$$

Constant Rate Infusions

Learning Objectives

- What is meant by constant rate infusion
- Determining rates of drug infusion
- Determining amount of drug to add to fluids

Constant rate infusion

In most cases, medications are administered at set intervals throughout the day. For example a dog may receive an antibiotic injection every 8 hours. The level of medication in the patient will rise to a peak and then start to fall as the body metabolises and excretes it. The faster this occurs, the more often the medication must be given in order to ensure therapeutic levels throughout the day. If the medication is given intravenously at a constant rate, the levels in the body stay the same at all times. This is important for some drugs used in intensive care situations and during anaesthesia. Examples of such drugs include metoclopramide, used to control vomiting, and lidocaine, used to control an irregular heartbeat. The dosage for these drugs is described as an amount delivered per kilogram of body weight per unit of time. For instance, the prescribed rate of metoclopramide infusion is 1–2 mg/kg-24 h.

Determining infusion rates

Using the prescribed dosage, we can calculate how much drug to infuse over a period of time. We start by determining the weight of the drug and then, taking into account the concentration of the drug, we calculate the volume of drug to use.

If a 10 kg dog requires 2 mg/kg of metoclopramide every 24 hours, how much drug do you infuse in 24 hours?

$$10 \text{ kg} \times \frac{2 \text{ mg}}{\text{kg} \cdot 24 \text{ h}} = \frac{20 \text{ mg}}{24 \text{ h}}$$

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We would add 16.7 mL of the drug to 483.3 mL (500 – 16.7) of i.v. fluids and then administer the combination at the rate prescribed:

$$\frac{240 \text{ mL}}{24 \text{ h}} = \frac{10 \text{ mL}}{\text{h}}$$

If we do not have an infusion pump available and are using a 60 gtt/mL i.v. set, the drip rate would be:

$$\frac{10 \text{ mL}}{1 \text{ h}} \times \frac{60 \text{ gtt}}{1 \text{ mL}} \times \frac{1 \text{ h}}{60 \text{ min}} = \frac{10 \text{ gtt}}{\text{min}}$$

We can check our answer by working backwards:

In 240 mL of fluid (the amount administered in 24 hours), we have 8 mL of drug. The concentration of the drug is 1 mg/mL so we have 8 mg of the drug given in 24 hours.

The weight of the patient is 4 kg, so we are giving 2 mg/kg every 24 hours.



These problems can be quite complex so it is worth checking your answer in this fashion before adding the drug.



Let's do it again...

- 1 A 10 kg dog requires a drug to be given by continuous infusion at a rate of 1 mg/h using a maintenance fluid rate of 50 mL/kg over 24 hours. How many mg of drug are to be added to 1 L of fluids?
- 2 A 10 kg dog is receiving fluids at a rate of 40 mL/h. It needs a drug added to 500 mL of fluids so that it receives 2 mg/kg each hour. The drug has a strength of 2%. What volume of drug will you add?
- 3 A 5 kg diabetic cat needs a constant infusion of insulin of 0.1 units/kg each hour. It is on maintenance fluids of 60 mL/kg every 24 hours and a 60 gtt/mL drip set is in use. The insulin concentration is 40 units/mL. How many mL of insulin will you add to a 250 mL bag of fluids?

Answers

- 1 Amount of drug needed in 24 hours:

$$10 \text{ kg} \times \frac{1 \text{ mg}}{\text{kg-h}} \times 24 \text{ h} = 240 \text{ mg}$$

Volume of fluid needed in 24 hours:

$$10 \text{ kg} \times \frac{50 \text{ mL}}{\text{kg} \cdot 24 \text{ h}} = \frac{500 \text{ mL}}{24 \text{ h}}$$

In 500 mL of fluid, you would need 240 mg of drug, therefore in 1 L (1000 mL), you would need 480 mg of drug.

2 Volume of drug needed in 1 h:

$$10 \text{ kg} \times \frac{2 \text{ mg}}{\text{kg} \cdot \text{h}} \times \frac{100 \text{ mL}}{2 \text{ g}} \times \frac{1 \text{ g}}{1000 \text{ mg}} = \frac{1 \text{ mL}}{\text{h}}$$

2% = 2 g for every 100 mL

Volume of fluid to be given in 1 hour: 40 mL

Volume of drug added to 1000 mL:

$$\frac{1 \text{ mL}}{40 \text{ mL}} = \frac{x \text{ mL}}{500 \text{ mL}}, \quad x = 12.5 \text{ mL}$$

Add 12.5 mL of drug to 487.5 mL of fluid and infuse at a rate of 40 mL/h.

3 Volume of insulin needed in 24 hours:

$$5 \text{ kg} \times \frac{0.1 \text{ units}}{\text{kg} \cdot \text{h}} \times 24 \text{ h} \times \frac{1 \text{ mL}}{40 \text{ units}} = 0.3 \text{ mL}$$

Volume of fluid needed in 24 hours:

$$5 \text{ kg} \times \frac{60 \text{ mL}}{\text{kg} \cdot 24 \text{ h}} = \frac{300 \text{ mL}}{24 \text{ h}}$$

Volume of insulin per 250 mL:

$$\frac{0.3 \text{ mL}}{300 \text{ mL}} = \frac{x \text{ mL}}{250 \text{ mL}}, \quad x = 0.25 \text{ mL}$$

Dilutions

Learning Objectives

- What is a dilution?
- Determining the final concentration in a dilution
- Dilution series
- Serial dilutions
- Immunology applications
- Microbiology applications
- Haematology applications

What is a dilution?

A dilution refers to a *weakened solution*. We have seen that some solutions used in veterinary practice come in a concentrated form (stock solution) and must be diluted before use (working solution). Other examples of using dilutions include performing a complete blood count in which the sample is diluted, cells are counted, and then the actual number of cells in the undiluted sample is calculated by *extrapolation*.

Microbiology applications include diluting a sample and counting the number of bacterial colonies formed and extrapolating back to the original sample. In immunology, the number of antibodies in serum is determined by a series of diluted serum samples. In order to perform these calculations we need to understand the relationship between a diluted sample and the original sample.

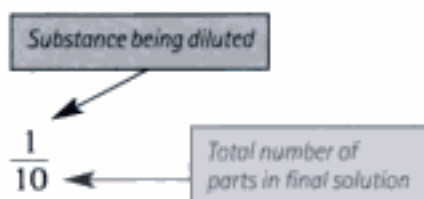


The preferred method of describing a dilution is: *the number of parts of the substance being diluted in the total number of parts in the final product*.

For instance, if I take 1 part serum and dilute it so that the total number of parts is 10, I have made a one-in-ten dilution. I may do this by taking 1 mL of serum and adding 9 mL of saline or I may take 10 mL of serum and add 90 mL of saline. In the first instance, I would have 10 mL

of a one-in-ten dilution of serum, and in the second I would have 100 mL.

Dilutions are written as fractions with the substance being diluted as the numerator and the total volume of the solution as the denominator:



In this example, the dilution is $\frac{1}{10}$ or we could also express this as 0.1 or 10^{-1} . Generally, the dilution is expressed so that the numerator is one. If we took 5 parts of serum and diluted it with 5 parts of saline, the dilution would be $\frac{5}{10}$ but we would express this as $\frac{1}{2}$.



Barking up the wrong tree

You may see dilutions expressed as a ratio. For instance, in the $\frac{1}{10}$ serum in saline example above there is 1 part serum to 9 parts saline, or a 1:9 serum-to-saline ratio. Be careful not to confuse these two descriptions of the same solution.

Determining dilution concentrations

If we know the original concentration of a solution and how the solution is diluted, we can determine the final concentration of the diluted solution:



Original concentration \times *Dilution* = *Final concentration*

$$OC \quad \times \quad D \quad = \quad FC$$

If we use the $\frac{1}{10}$ serum sample, the original concentration is 100%, the dilution is $\frac{1}{10}$ and so the final concentration is:

$$100\% \times \frac{1}{10} = 10\%$$



Let's do it again...

- 1 A 10% saline solution is diluted $\frac{1}{10}$. What is the final concentration?
- 2 A solution that was diluted $\frac{1}{5}$ has a concentration of 10%. What was the original concentration?
- 3 If a drug with a concentration of 100 mg/mL is diluted $\frac{1}{20}$, what is the final concentration?
- 4 A stock solution with a concentration of 70% is diluted and the working solution has a concentration of 3.5%. How was it diluted?

Answers

- 1 $OC \times D = FC$, $10\% \times \frac{1}{10} = 1\%$
- 2 $OC \times D = FC$, $OC = \frac{FC}{D}$, $OC = 10\% \div \frac{1}{5}$, $OC = 10\% \times \frac{5}{1} = 50\%$
- 3 $OC \times D = FC$, $100 \text{ mg/mL} \times \frac{1}{20} = 5 \text{ mg/mL}$
- 4 $OC \times D = FC$, $D = \frac{FC}{OC}$, $D = \frac{3.5\%}{70\%} = \frac{1}{20} = 0.05 = 5 \times 10^{-2}$. (All are expressions of the same number.)

Dilution series

In some applications, we would like to make a series of dilutions, rather than just a single dilution. There are two ways in which to do this. We can go to the original solution each time – *independent dilutions* – or we can use the first dilution to make a second dilution – *dependent dilutions*.

Independent dilutions

Let's say we have a serum sample and we want to make a $\frac{1}{5}$, a $\frac{1}{10}$, and a $\frac{1}{100}$ dilution. To accomplish this with independent dilutions we would:

- 1 Take 1 part serum and dilute up to 5 parts with saline = $\frac{1}{5}$
- 2 Take 1 part serum and dilute up to 10 parts with saline = $\frac{1}{10}$
- 3 Take 1 part serum and dilute up to 100 parts with saline = $\frac{1}{100}$.

Dependent dilutions

If we want to make the same dilutions but only want to use the serum once, we can make dependent dilutions:

- 1 Take 1 part serum and dilute up to 5 parts with saline = $\frac{1}{5}$

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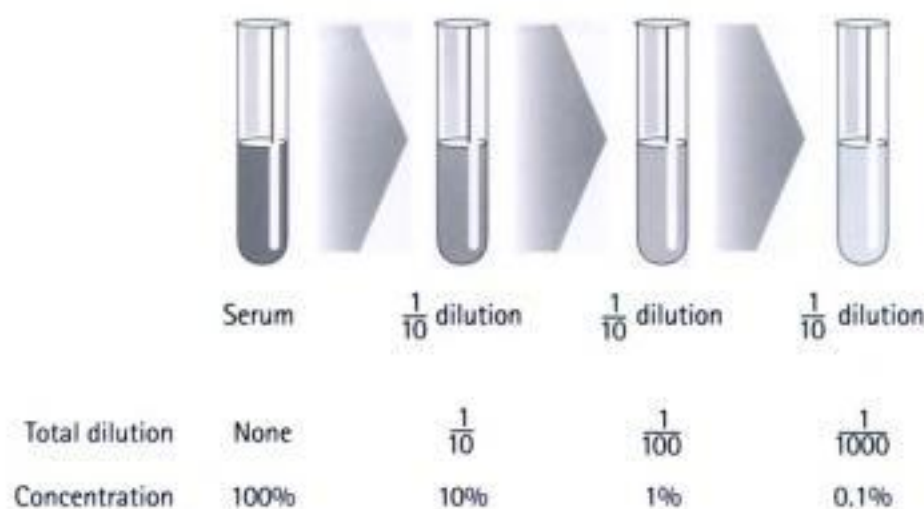


Figure 15.1 Successive dilutions of $\frac{1}{10}$.

is often used to describe a serial dilution. In this example, we have a 10-fold dilution of serum. Sometimes, the first dilution is different than the rest so that if the first dilution in our example had been $\frac{1}{2}$, we would call it a 10-fold dilution that started at 2.

Once again, by knowing the original concentration and the dilutions, we can determine the concentration of the sample at any step along the way (Fig. 15.1).

Let's say we had a drug that came in a very concentrated form that was used for horses and we wanted to make a diluted form for use in birds. We could use a serial dilution to accomplish this.

How would you make a serial dilution for ivermectin 10 mg/mL so that the final concentration was 0.1 mg/mL?

From our equation: $OC \times dilution = FC$, we determine that the dilution has to be:

$$Dilution = \frac{FC}{OC} = \frac{0.1 \text{ mg/mL}}{10 \text{ mg/mL}} = \frac{1}{100}$$

This can be accomplished in two steps using a $\frac{1}{10}$ serial dilution (Fig. 15.2).

It is possible to perform this dilution in just one step (a $\frac{1}{100}$ dilution) but it is difficult to be accurate when measuring small amounts. If we were only making 10 mL of the final drug, we would have to measure 0.1 mL to do it in one step whereas if we do it in two steps our smallest measure would be 1 mL.

Immunology applications

A *titre* is the term used for measuring the number of antibodies in a serum sample and is used to determine if a patient has been exposed to a particular microorganism or a vaccine. A titre is determined by

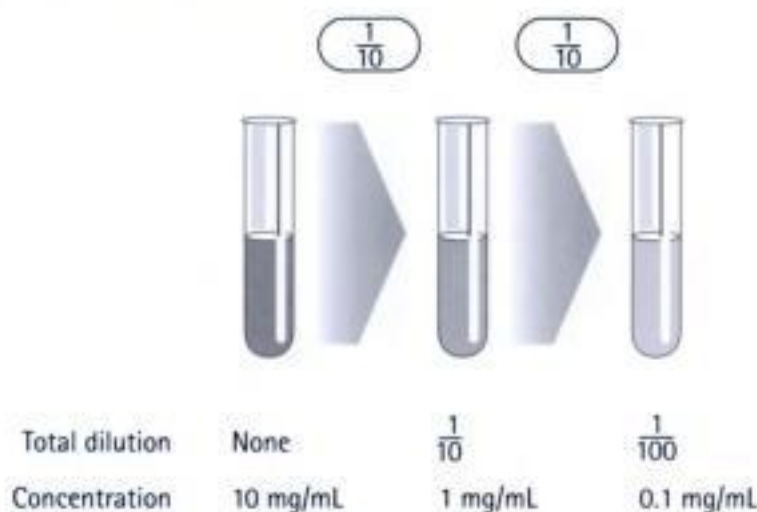


Figure 15.2 Two successive $\frac{1}{10}$ dilution steps.

setting up a serial dilution of a serum sample and then placing into each sample a known amount of antigen tied to a molecule that causes a reaction in the solution. The titre is the greatest dilution producing a positive response.



Say a 2-fold serial dilution of serum is set up and a positive reaction is observed in the $\frac{1}{2}$ and $\frac{1}{4}$ dilutions but not in the other dilutions. The titre is $\frac{1}{4}$ – the greatest dilution producing a positive reaction. Sometimes a titre is reported as the reciprocal of the dilution – in this case 4. A high titre (a very dilute sample) indicates a strong response by the immune system.



Let's do it again...

- 1 Starting with a tube of a 50% solution, what is the concentration in tube number 5 if the solution undergoes a 10-fold serial dilution?
- 2 A 4-fold dilution is carried out on a drug. The concentration after four steps is 0.05 mg/mL. What was the original concentration?
- 3 A 5-fold serial dilution of serum is set up and the last positive reaction to an antigen is found in the fourth tube. What is the titre? (Count the first tube as the first dilution.)

Answers

$$1 \quad OC \times \text{dilution (dilution 1} \times \text{dilution 2} \dots) = FC$$

$$50\% \times \left(\frac{1}{10} \times \frac{1}{10} \times \frac{1}{10} \times \frac{1}{10} \right) = 50\% \times \frac{1}{10\,000} = 50\% \times 10^{-4}$$

$$= 5 \times 10^{-3}\% = 0.005\%$$

$$2 \quad OC \times D = FC; \quad OC = \frac{FC}{D} = \frac{0.05 \text{ mg/mL}}{\left(\frac{1}{4} \times \frac{1}{4} \times \frac{1}{4} \times \frac{1}{4}\right)} = \frac{0.05 \text{ mg/mL}}{\left(\frac{1}{256}\right)}$$

$$= 0.05 \text{ mg/mL} \times 256 = 12.8 \text{ mg/mL}$$

$$3 \quad \text{Total dilution} = \text{dilution 1} \times \text{dilution 2} \times \text{dilution 3} \times \text{dilution 4}$$

$$= \frac{1}{5} \times \frac{1}{5} \times \frac{1}{5} \times \frac{1}{5} = \frac{1}{625}$$

The titre is 1/625 (or often expressed as 625).

Microbiology applications

One method to determine how susceptible a microorganism is to an antibiotic is called the *broth dilution susceptibility test*. This involves a series of test tubes with dilutions of an antibiotic. A standardised amount of an organism is inoculated into the tubes. The first tube in which there is *no* growth of the organism, evidenced by a clear solution, is the minimum concentration of antibiotic required to inhibit growth. Note the similarity to the titre test in immunology. Here the positive reaction is indicated by no growth of the organism and thus a clear solution (Fig. 15.3).

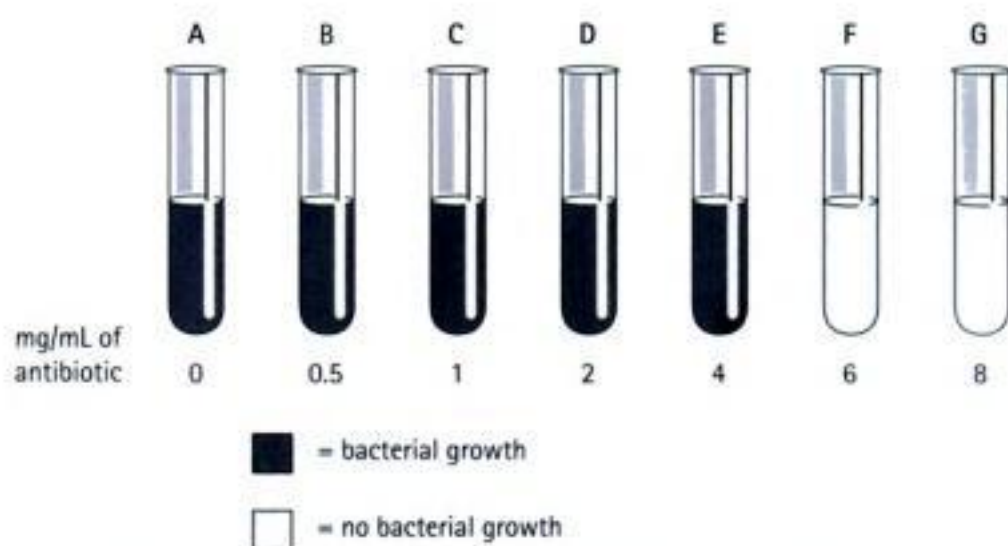


Figure 15.3 A broth dilution susceptibility test. Tube G has an antibiotic concentration of 8 mg/mL. A series of dilutions of antibiotic is performed and then a standard amount of organism is inoculated into each of tubes A–G. Tube F, with 6 mg/mL antibiotic, demonstrates the minimum inhibitory concentration (MIC) of antibiotic for this organism since the next dilution below it allows bacterial growth to occur.

A solution of 20 mg/mL of an antibiotic is diluted $\frac{1}{2}$, then rediluted $\frac{1}{2}$. This is the last clear solution of the antibiotic. What is the MIC?

$$(OC = 20 \text{ mg/mL}) \times \left(\text{Dilution} = \frac{1}{2} \times \frac{1}{2} = \frac{1}{4} \right) = (FC = 5 \text{ mg/mL})$$

The MIC is 5 mg/mL.

Another application in microbiology is performing colony counts on a microorganism broth culture. A very small volume of the broth culture is plated onto a culture medium using a *loop* that holds a standard volume. After 24–48 hours, the number of *colony forming units* (*cfu*) is counted. Each colony represents one original bacterium.

It is often necessary to dilute the broth culture before plating it out otherwise too many colonies will form, making counting difficult. We take this dilution, along with the volume of the diluted broth culture that is plated, into account when determining the number of colony forming units per litre (*cfu/L*).

A bacterial culture is diluted $\frac{1}{1000}$ (10^{-3}) and then 0.05 mL of this diluted sample is plated onto a culture plate. After 48 hours, 75 *cfu* are counted. What was the concentration of organisms (*cfu/L*) in the original culture?

Original concentration \times *dilution* = *final concentration*

We are looking for the original concentration so we can rearrange the above equation:

$$\text{Original concentration} = \frac{\text{final concentration}}{\text{dilution}}$$

$$\text{Final concentration} = \frac{75 \text{ cfu}}{0.05 \text{ mL}}, \text{ Dilution} = \frac{1}{1000}$$

$$\text{Original concentration} = \frac{\left(\frac{75 \text{ cfu}}{0.05 \text{ mL}} \right)}{\left(\frac{1}{1000} \right)}$$



Remember: when dividing by a fraction, simply multiply by the reciprocal. In this case, dividing by $\frac{1}{1000}$ is the same as multiplying by 1000.

$$\text{Original concentration} = \frac{75 \text{ cfu}}{0.05 \text{ mL}} \times \frac{1000}{1} = \frac{75\,000 \text{ cfu}}{0.05 \text{ mL}} = \frac{1\,500\,000 \text{ cfu}}{1 \text{ mL}}$$

This gives us the number of *cfu* per mL but we need to report it in *cfu* per L, so let's use some dimensional analysis:

$$\frac{1\,500\,000 \text{ cfu}}{1 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = \frac{1\,500\,000\,000}{1 \text{ L}}$$

Such a large number is best expressed in scientific notation:
 1.5×10^9 cfu/L.

Haematology applications

As a veterinary technician or nurse, one of the most commonly encountered diagnostic tests is the complete blood count (CBC). This involves taking a sample of blood and estimating the number of red blood cells, white blood cells and the number of each type of white blood cell. The concentration of cells in the blood is very high so we need to dilute the blood sample in order to count a smaller number and then extrapolate back to the original sample.

Dilution is carried out by drawing a set quantity of blood into a pipette and adding a known amount of diluent. There are several types of diluting pipettes but the most common one creates a $\frac{1}{100}$ dilution. Once the blood is diluted, a standard volume of the diluted sample is examined under the microscope and the number of cells counted. The result is a number of cells in a volume of sample – a concentration.

Haemocytometers

How do we ensure a standard volume is used each time? A special microscope slide called an haemocytometer is used, the most common of which is called the *Neubauer haemocytometer*. This slide has an area marked with various sizes of squares (see Fig. 15.4) and it is also 0.1 mm in depth. This allows a set volume (area \times depth) to be scanned and the number of cells counted.

In reality, most red cell counts are performed with a machine called a *Coulter counter* and only the white cells are counted with a haemocytometer. Let's try a problem involving white cell counts:

A blood sample is diluted $\frac{1}{100}$ and then four 'W' areas are counted on the Neubauer haemocytometer. A total of 50 cells are counted. What is the white cell count?

We can use the equation for determining the concentration of a sample that has been diluted:

$$\text{Original concentration} \times \text{dilution} = \text{final concentration}$$

In these problems we are looking for the original concentration so we can rearrange the equation:

$$\text{Original concentration} = \frac{\text{final concentration}}{\text{dilution}}$$

$$OC = \frac{\left(\frac{50 \text{ cells}}{4 \times 1 \text{ mm} \times 1 \text{ mm} \times 0.1 \text{ mm}} \right)}{\left(\frac{1}{100} \right)}$$

Number of cells counted in four 'W' squares that each have a volume of 1 mm × 1 mm × 0.1 mm

Dilution of original sample

$$OC = \frac{\left(\frac{50 \text{ cells}}{0.4 \text{ mm}^3} \right)}{\left(\frac{1}{100} \right)}$$

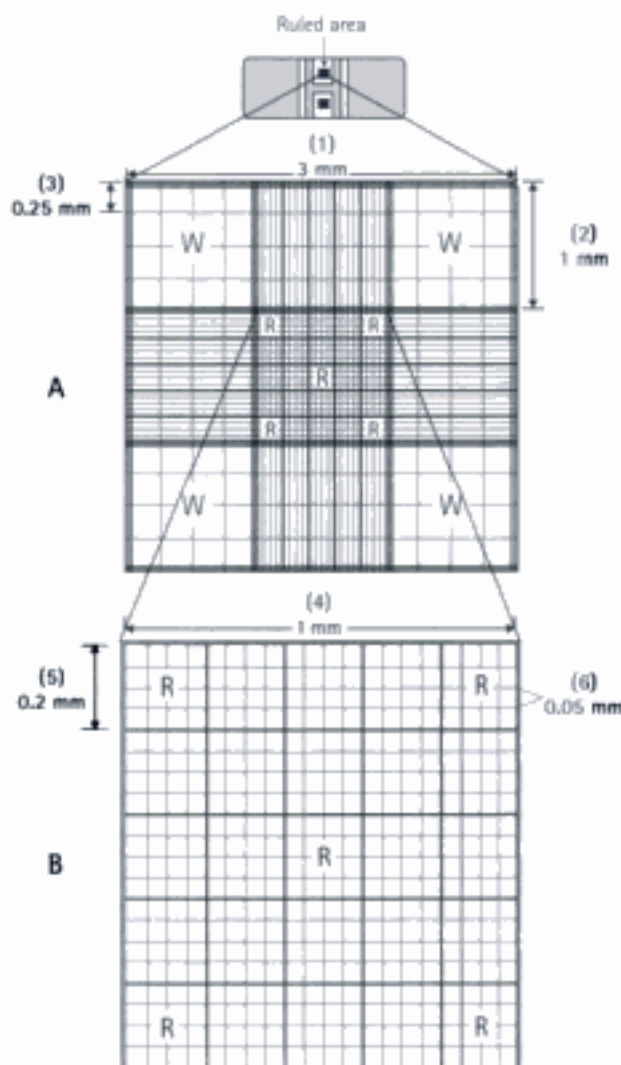


Figure 15.4 The Neubauer haemocytometer counting area is divided into 9 large squares, each measuring 1 mm × 1 mm (or 1 mm²). These larger squares are designated 'W' and are used to count white blood cells. If 4 of these squares are used, and the number of white cells in them counted, then the volume used is: 4 × 1 mm² × 0.1 mm (depth) = 0.4 mm³.

The central square is divided into 25 smaller squares, designated 'R', and are used to count red blood cells. Each R square measures 0.2 mm × 0.2 mm = 0.04 mm². If 5 R squares are counted, then the volume used is: 5 × 0.04 mm² × 0.1 mm (depth) = 0.02 mm³.

We know that 1 cc = 1 mL, therefore 1 mm³ = 1 μL:

$$\frac{1 \text{ cm}^3}{1 \text{ mL}} \times \frac{1 \text{ mL}}{1000 \mu\text{L}} \times \frac{1000 \text{ mm}^3}{1 \text{ cm}^3} = \frac{1 \text{ mm}^3}{1 \mu\text{L}}$$

Rearrange the equation by multiplying by the reciprocal of the denominator:

$$OC = \frac{50 \text{ cells}}{0.4 \text{ mm}^3} \times \frac{100}{1}$$

$$OC = \frac{5000 \text{ cells}}{0.4 \text{ mm}^3} = \frac{12\,500 \text{ cells}}{1 \text{ mm}^3} \leftarrow \text{Concentration of the original blood sample}$$

In most laboratories, white cells are reported in the number of cells per litre. How do we change our value to this standard reporting method? Dimensional analysis of course!

$$\frac{12\,500 \text{ cells}}{1 \text{ mm}^3} \times \frac{1 \text{ mm}^3}{1 \mu\text{L}} \times \frac{1\,000\,000 \mu\text{L}}{1 \text{ L}} = \frac{12\,500\,000\,000 \text{ cells}}{1 \text{ L}}$$

We would use scientific notation to express such a large number, so it becomes:

$$1.25 \times 10^{10} \text{ cells/L}$$

There is another convention that says all white cell counts should be reported in such a way that the exponent is always 9. This allows the clinician to just look at the numbers to the left of the decimal point and he or she can make a quick comparison with normal values. Our white cell count expressed this way would be:

$$12.5 \times 10^9 \text{ cells/L}$$

Similarly, all red cell counts are reported with 12 as the exponent, e.g. 6.5×10^{12} cells/L.



Worlds apart

These conventions may differ in your part of the world. Always convert your white and red cell counts to correspond to local norms in order to make comparison with normal values.



Let's do it again...

- 1 Six 'W' squares are scanned and 66 white cells are counted. The blood sample had been diluted $\frac{1}{100}$. What is the white cell count (cells/L)?
- 2 Four 'R' squares are scanned and 80 red cells are counted. The blood sample had been diluted $\frac{1}{100}$. What is the red cell count?

Answers

$$1 \quad OC = \frac{\left(\frac{66 \text{ cells}}{6 \times 1 \text{ mm} \times 1 \text{ mm} \times 0.1 \text{ mm}} \right)}{\left(\frac{1}{100} \right)} = \frac{66 \text{ cells}}{0.6 \text{ mm}^3} \times \frac{100}{1} = \frac{6600 \text{ cells}}{0.6 \text{ mm}^3}$$

$$= 1.1 \times 10^4 \text{ cells/mm}^3$$

$$= 1.1 \times 10^{10} \text{ cells/L} = 11 \times 10^9 \text{ cells/L}$$

$$2 \quad OC = \frac{\left(\frac{80 \text{ cells}}{4 \times 0.2 \text{ mm} \times 0.2 \text{ mm} \times 0.1 \text{ mm}} \right)}{\left(\frac{1}{100} \right)} = \frac{80 \text{ cells}}{0.016 \text{ mm}^3} \times \frac{100}{1}$$

$$= \frac{8000 \text{ cells}}{0.016 \text{ mm}^3}$$

$$= 5 \times 10^5 \text{ cells/mm}^3 = 5 \times 10^{11} \text{ cells/L} = 0.5 \times 10^{12} \text{ cells/L}$$



When using the equation: $OC \times \text{dilution} = FC$ and you are trying to find the OC , rearrange the equation into: $OC = FC \times \text{dilution factor}$, where *dilution factor* is the reciprocal of the dilution. For example, when the dilution is $\frac{1}{100}$, the dilution factor is 100. When the dilution is 10^{-3} , the dilution factor is 1000.

Clinical Problems Using Dilutions

Questions

- 1 A 7% solution is diluted $\frac{1}{100}$. What is the final concentration?
- 2 How much serum would be present in 25 mL of a $\frac{1}{5}$ dilution?
- 3 A stock solution contains 200 g/L. What dilution is necessary to prepare a working standard containing 5 mg/100 mL?
- 4 You are given a series of 10 tubes, each of which contains 5 mL of diluent. To the first tube is added 1 mL of serum, and a serial dilution using 1 mL is carried out on the remaining tubes. What is the serum concentration in tubes 4 and 8?
- 5 You want to make 30 mL of a $\frac{1}{500}$ dilution of urine in water. How much diluent will it take?
- 6 Forty five colonies are found on a blood agar plate after inoculating 0.5 mL of the 10^{-4} dilution onto the plate. What is the concentration of the original solution (cfu per mL).
- 7 In order to determine the quantity of bacteria in a water sample, 2 L of water were put through a filter that the organisms cannot pass through. When the filter was cultured 15 colonies were counted. What is the concentration of organisms in the water?
- 8 A blood sample was first diluted $\frac{1}{100}$ then 91 white cells were counted in four 'W' areas. What is the white cell count?
- 9 A blood sample was first diluted $\frac{1}{20}$ then 140 cells were counted in five 'W' squares. What is the white cell count?
- 10 You need to dilute a drug from its original concentration of 100 mg/mL to a concentration of 0.1 mg/mL. The smallest volume you can measure accurately is 0.5 mL and the largest volume you can make at one time is 10 mL. With these restrictions, how would you make your diluted drug?

Answers

- 1 $OC \times dilution = FC$
 $7\% \times \frac{1}{100} = \frac{7}{100} = 0.07\%$

$$2 \quad \frac{1}{5} = \frac{x}{25 \text{ mL}}, x = 5 \text{ mL}$$

Dilution is a ratio of 1 part serum to 5 parts total solution

$$3 \quad OC = 200 \text{ g/L}, FC = 5 \text{ mg/100 mL}$$

$$OC \times \text{dilution} = FC, \text{ Dilution} = \frac{FC}{OC}$$

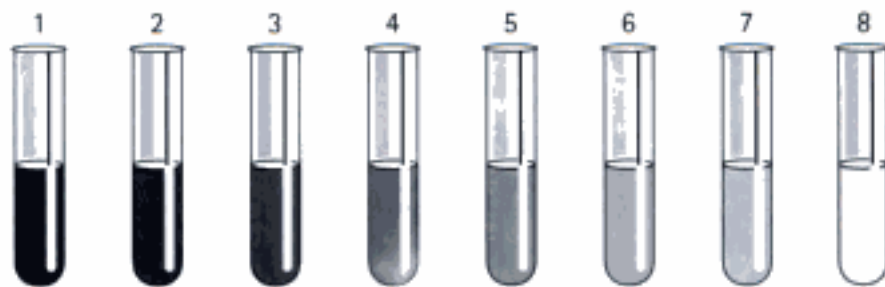
Since our *OC* and *FC* are in different units, we need to convert one of them into units that are the same as the other:

$$\frac{200 \text{ g}}{1 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1000 \text{ mg}}{1 \text{ g}} = \frac{200 \text{ mg}}{1 \text{ mL}}$$

$$\frac{200 \text{ mg}}{1 \text{ mL}} = \frac{x \text{ mg}}{100 \text{ mL}}, x = \frac{20\,000 \text{ mg}}{100 \text{ mL}}$$

$$\text{Dilution} = \frac{\left(\frac{5 \text{ mg}}{100 \text{ mL}}\right)}{\left(\frac{20\,000 \text{ mg}}{100 \text{ mL}}\right)} = \frac{1}{4000}$$

4 The serum began as a 100% solution and in this 6-fold serial dilution it became 0.077% by the 4th tube and 0.00006% by the 8th tube (Fig. 16.1).



Dilution	$\frac{1}{6}$	$\frac{1}{36}$	$\frac{1}{216}$	$\frac{1}{1296}$	$\frac{1}{7776}$	$\frac{1}{46656}$	$\frac{1}{279936}$	$\frac{1}{1679616}$
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Concentration	16.7%	2.6%	0.46%	0.077%	0.0129%	0.00021%	0.00036%	0.00006%
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Figure 16.1 Dilutions for Q4.

5 If the total volume is 30 mL it must have the same ratio as the $\frac{1}{500}$ dilution:

$$\frac{1}{500} = \frac{x}{30 \text{ mL}}, x = 0.06 \text{ mL}$$

If only 0.06 mL of the 30 mL is urine, then (30 - 0.06) 29.94 mL is diluent.

$$6 \quad OC \times \text{dilution} = FC, \quad OC = \frac{FC}{\text{dilution}}$$

$$OC = \frac{\left(\frac{45 \text{ cfu}}{0.5 \text{ mL}}\right)}{\left(\frac{1}{10\,000}\right)}, \quad OC = \frac{90 \text{ cfu}}{1 \text{ mL}} \times 10\,000 = \frac{900\,000 \text{ cfu}}{1 \text{ mL}}$$

$$OC = 9 \times 10^5 \text{ cfu/mL}$$

7 $\frac{15 \text{ cfu}}{2 \text{ L}} = \frac{x}{1 \text{ L}}$, $x = 7.5 \text{ cfu/L}$. Sometimes, it's not too complicated!

8 $OC = FC \times \text{dilution factor}$ (reciprocal of the dilution)

$$OC = \frac{91 \text{ cells}}{4 \times 1 \text{ mm} \times 1 \text{ mm} \times 0.1 \text{ mm}} \times 100 = \frac{9100 \text{ cells}}{0.4 \text{ mm}^3}$$

$$\frac{9100 \text{ cells}}{0.4 \text{ mm}^3} \times \frac{1 \text{ mm}^3}{1 \mu\text{l}} \times \frac{1\,000\,000 \mu\text{L}}{1 \text{ L}} = \frac{9\,100\,000\,000 \text{ cells}}{0.4 \text{ L}}$$

$$= \frac{22\,750\,000\,000}{1 \text{ L}}$$

$$OC = 22.75 \times 10^9 \text{ cells/L}$$

9 $OC = FC \times \text{dilution factor}$ (reciprocal of the dilution)

$$OC = \frac{140 \text{ cells}}{5 \times 1 \text{ mm} \times 1 \text{ mm} \times 0.1 \text{ mm}} \times 20 = \frac{2800 \text{ cells}}{0.5 \text{ mm}^3}$$

$$OC = \frac{2800 \text{ cells}}{0.5 \text{ mm}^3} \times \frac{1 \text{ mm}^3}{1 \mu\text{l}} \times \frac{1\,000\,000 \mu\text{l}}{1 \text{ L}}$$

$$= \frac{2\,800\,000\,000 \text{ cells}}{0.5 \text{ L}} = \frac{5\,600\,000\,000 \text{ cells}}{1 \text{ L}}$$

$$OC = 5.6 \times 10^9 \text{ cells/L}$$

10 This is a tricky problem so let's take it one step at a time.

The dilution we require is: $\frac{FC}{OC} = \frac{0.1 \text{ mg/mL}}{100 \text{ mg/mL}} = \frac{1}{1000}$

The greatest dilution we can make is limited by the smallest and largest volumes we can use. The smallest volume is 0.5 mL and the largest is 10 mL.

Therefore the greatest dilution we can make in one step is:

$$\frac{0.5 \text{ mL}}{10 \text{ mL}} = \frac{1}{20}$$

Using a $\frac{1}{20}$ dilution as the largest dilution, how do we get to a dilution of $\frac{1}{1000}$?

We could do it several ways:

We could do 3 dilutions of $\frac{1}{10}$ ($\frac{1}{10} \times \frac{1}{10} \times \frac{1}{10} = \frac{1}{1000}$), or $\frac{1}{20} \times \frac{1}{10} \times \frac{1}{5}$ or any combination to give us a $\frac{1}{1000}$ dilution within our limitations.

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Anaesthesia and Nutrition Applications

Learning Objectives

- Calculating anaesthesia gas flow rates
- Calculating nutritional requirements

Anaesthesia gas flow rates

We have performed some calculations for injectable anaesthetic agents such as pentothal. Generally, these agents are used to take the patient from an awake or sedated state to a state of general anaesthesia and then a gaseous agent is administered to keep them anaesthetised. The gas is administered through an endotracheal tube directly into the lungs where it crosses into the bloodstream and finds its way to the brain. The gas is delivered by a vaporiser that has a carrier gas (usually oxygen) passed over it.

The amount of anaesthetic gas delivered to the patient is a function of the vaporiser setting and the flow rate of carrier gas. Setting the vaporiser is simply a matter of dialing the correct percent of anaesthetic agent but calculating the flow rate is a little more complex. Flow rates are based on the patient's size and also on the type of anaesthetic protocol. Some protocols, such as mask induction, require a high flow rate while others, such as maintenance on a closed circuit, require a low flow of carrier gas. We will leave it to the appropriate anaesthesia textbook to explain the different protocols but will use some examples to make you comfortable with the calculations.

The flow rate recommended for use just after an injectable agent has been used is equal to the *respiratory minute volume (RMV)*. The RMV is equal to the *tidal volume* (the volume of a normal inhalation) multiplied by the *respiratory rate*, which averages about 20 breaths per minute. The tidal volume varies with the size of the animal and is calculated at about 10 mL/kg.

Calculate the correct anaesthesia gas flow rate following injectable induction for a 20 kg dog.

$$\begin{aligned}
 \text{Flow rate} &= \text{respiratory minute volume} \\
 &= \text{tidal volume} \times \text{respiratory rate} \\
 &= 10 \text{ mL/kg} \times 20/\text{min}
 \end{aligned}$$

$$= 20 \text{ kg} \times \frac{10 \text{ mL}}{1 \text{ kg}} \times \frac{20}{\text{min}} = \frac{4000 \text{ mL}}{\text{min}}$$

The flow rate recommended for mask induction (where no injectable agent is used) is 30 times the tidal volume.

Calculate the flow rate required for mask induction of a 4 kg cat.

$$\begin{aligned} \text{Flow rate} &= 30 \times \text{tidal volume} \\ &= 30 \times 10 \text{ mL/kg} \\ &= 4 \text{ kg} \times \frac{10 \text{ mL}}{\text{kg}} \times 30 = 1200 \text{ mL (per minute)} \end{aligned}$$

Flow rate calculations can vary according to the anaesthetic protocol and there is considerable leeway for the clinician's own judgment, but dimensional analysis is a good tool for coming up with the correct amount.

Nutritional calculations

Veterinary technicians are often required to calculate the nutritional needs of patients, both for normal activity and for therapeutic situations such as recovering from illness. The basis for nutritional calculations is determining *energy requirements* of the patient. This assumes that a *balanced diet* is fed – this means that once the energy requirements are determined, all other nutrients will be present in the correct amounts.

The unit used for determining energy requirements is the *calorie*, which is defined as the amount of energy needed to raise 1 mL of water from 14.5°C to 15.5°C. There are 1000 calories in 1 kilocalorie (kcal). The energy density of foods is determined by dividing the kcal present in the food by the weight of the food (kcal/gram).

Animals require varying levels of nutrition depending on their physical state. A healthy cat sitting in a kennel requires much less energy than one chasing mice outside. We need a system to determine these different needs.

Resting energy requirement

This term is used for the energy needs of a healthy animal at rest in a thermoneutral environment – in other words in a warm kennel. The RER is calculated by using the *ideal body weight* of the patient in the formula:

$$30 \times \text{BW (in kg)} + 70$$

For a 10 kg dog, the RER would be:

$$30 \times 10 \text{ kg} + 70 = 370 \text{ kcal}$$

The RER is then adjusted based on the activity level or therapeutic needs of the patient. Table 17.1 is one suggested guide for multiplying factors to use on the RER.

Active or therapeutic state	Multiply RER by:
Maintenance	1.2
Growth	1.5–2
Moderate activity	1.25
Very active	2
Weight loss	0.8
Pregnant (last trimester)	1.3
Lactating (peak)	3–4
Post surgery	1.5
Major infection	2



Worlds apart

There are different systems for calculating the basic requirements for energy needs. Some use the term *metabolisable energy requirements* (MER) for the needs of a healthy animal at rest while others use the term *resting energy requirements* (RER). Consult a nutritional reference for your needs and apply the principles presented below.



Let's do it again...

- 1 What are the energy requirements for a 22 kg Labrador retriever that runs 10 km with its owner every day?
- 2 How much energy does an obese 7 kg cat that should weigh 4 kg require?
- 3 Calculate the energy needs of a 60 lb German shepherd following surgery to stabilise a torn ligament in its knee joint.

Answers

- 1 Energy = $2 \times \text{RER}$
 $= 2 \times [(30 \times 22 \text{ kg}) + 70]$
 $= 1460 \text{ kcal}$

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Statistics and Quality Control

Learning Objectives

- Understanding measures of central tendency
- Understanding distribution, ranges and variance
- Calculating standard deviation
- Using statistics in quality control

Measures of central tendency

Whenever we are presented with a lot of information, it's nice to be able to summarise it somehow – to 'get to the heart of the matter' or see a 'snapshot' in order to be able to understand the essence of the information quickly. Working with numerical information is no different; we like to get an *average* value to help us understand it. An average reduces many individual pieces of information to a single 'typical' value. While we all have a general idea what *average* means, there are actually three different types of average used scientifically.

Mean

The mean is the arithmetical average of a set of values – to get the mean, add up all the values and divide by the number of values. It can be expressed as:

$$\text{Mean} = \frac{\sum x}{n}$$

If we had test scores of 60, 65, 70, 75, 80 then the mean would be:

$$\text{Mean} = \frac{60 + 65 + 70 + 75 + 80}{5} = 70$$

The mean is the most reliable of the averages when the values we are evaluating form a *normal distribution* (see p. 105).

Median

The median is the number that divides the data in half, with the same number of values appearing on either side of the median. For example, if the scores on an exam are: 60, 65, 70, 75, 80, 85, 90 then the median score is 75 as there are three scores on either side. On another exam the scores are: 60, 60, 65, 68, 72, 78, 78, 80, 90. The median score here is 72 as there are four scores on either side.

What if there is an even number of values, so that there is no 'middle' value? In this case the two middle values are added together and divided by two. Here's another set of test scores: 65, 68, 70, 74, 80, 85. In this case 70 and 74 are the two middle scores so the median is $\frac{(70 + 74)}{2} = 72$.

The median is useful to describe a set of values that do not form a normal distribution but is *skewed*, i.e. more values occur toward one end of the distribution than the other (Fig. 18.1).

An example of using the median to describe a set of values could be found in a class of veterinary technicians, in which the age of the students may vary from, e.g. 17 to 57. Let's say this is your class and most of your classmates are between 18 and 24 but there are two people who are in their 30s and one in their 50s. The graph of the distribution of the ages of the class would resemble the one in Fig. 18.1. The mean value of the class would be pulled higher by the three more mature class members but it would not really be a good picture of the age of most of the class members. In this case the median would describe the class age more accurately.

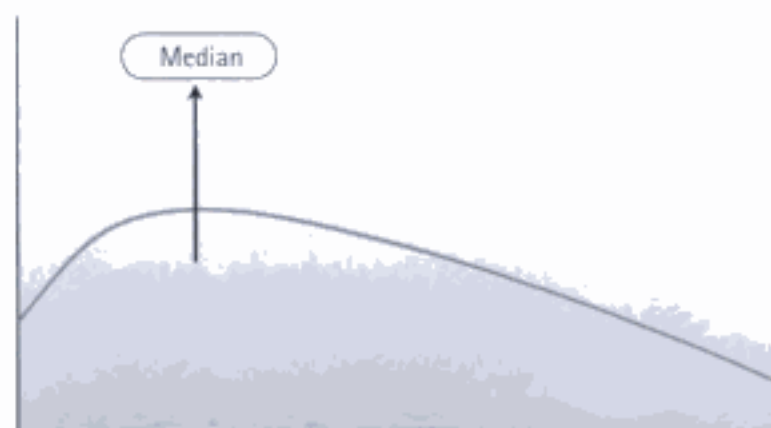


Figure 18.1 This is a skewed set of data: more values occur toward one end of the distribution than the other.

Mode

The mode is the value that occurs most often. This is the easiest value to find but it can be misleading. The mode is not used often in the clinical setting.

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squaring technique, followed by finding the square root. Let's look at an example to illustrate this.

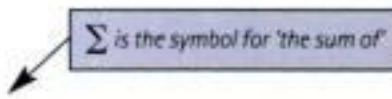
12 healthy dogs had their blood glucose measured and the values are listed in Table 18.1.

The mean value is:

$$\frac{[3.8 + 4.1 + 4.3 + 2.9 + 3.2 + 4.6 + 4.3 + 3.9 + 4.9 + 3.8 + 4.1 + 5.1]}{12}$$

Mean (\bar{x}) = 4.08. Let's round to the nearest one-tenth and call the mean 4.1

The next step (Table 18.2) is to total the squares of the deviation from the mean:



$$\sum(x - \bar{x})^2 = 4.44$$

We then divide this total by the number of values minus one ($n - 1$). The reason for using one less than the total number of values is due to a statistical parameter known as *degrees of freedom*. This is related

Table 18.1 Blood glucose results from 12 dogs.

Dog	1	2	3	4	5	6	7	8	9	10	11	12
Glucose (mmol/L)	3.8	4.1	4.3	2.9	3.2	4.6	4.3	3.9	4.9	3.8	4.1	5.1

Table 18.2 Squares of deviation from the mean blood glucose result.

Value (x)	Mean (\bar{x})	Variation from mean ($x - \bar{x}$)	Square of variation ($(x - \bar{x})^2$)
3.8	4.1	-0.3	0.09
4.1	4.1	0	0
4.3	4.1	+0.2	0.04
2.9	4.1	-1.2	1.44
3.2	4.1	-0.9	0.81
4.6	4.1	+0.5	0.25
4.3	4.1	+0.2	0.04
3.9	4.1	-0.2	0.04
4.9	4.1	+0.8	0.64
3.8	4.1	-0.3	0.09
4.1	4.1	0	0
5.1	4.1	1	1
			$\sum(x - \bar{x})^2 = 4.44$

to the fact that since we used the original values to come up with the mean, and *then* used the mean to come up with another value, we have used up 'one degree of freedom' and must therefore subtract 1 from the number of values. (You don't need to worry about the statistical theory behind this.)

This number is called the variance s^2 and can be expressed as:

$$\frac{\sum(x - \bar{x})^2}{(n - 1)}$$

In this case:

$$s^2 = \frac{4.44}{11} = 0.40$$

Since we used the *square* of the differences between the mean and each value to determine the variance, if we now take the *square root* of the variance, we arrive at the standard deviation, abbreviated s :

$$s = \sqrt{s^2}, \quad s = \sqrt{0.40} = 0.63$$

If we look back at the stages of getting to this value, we see that the complete formula for the standard deviation can be shown as:

$$s = \sqrt{\frac{\sum(x - \bar{x})^2}{(n - 1)}}$$

Given this set of healthy dogs, we have determined the mean blood glucose value is 4.1 mmol/L, with a standard deviation of 0.64 mmol/L. If we were to measure another dog's blood glucose and find it to be 6.3 mmol/L we would now know that the value is too high to be considered normal as it falls beyond two standard deviations of the mean (more of this later).



Let's do it again...

Find the mean and standard deviation for the following.

- 1 A set of exam scores: 48, 51, 53, 59, 61, 66, 70, 71, 76, 78, 81, 82, 88, 91, 99.
- 2 Ages of students in a class: 17, 18, 19, 19, 20, 20, 20, 21, 21, 22, 22, 23, 25, 25, 26, 34, 48.
- 3 White cell counts in healthy cats (all are $\times 10^9$ cells per litre): 5.2, 3.9, 4.5, 6.3, 6.8, 7.9, 4.9, 10.2, 9.3, 11.4, 12.5, 8.1, 6.7.

Answers

- 1 The data are given in Table 18.3.

Table 18.3 Exam scores (question 1).

Value (x)	Mean (\bar{x})	Variation from mean ($x - \bar{x}$)	Square of variation ($(x - \bar{x})^2$)
48	71.6	-23.6	556.96
51	71.6	-20.6	424.36
53	71.6	-18.6	345.96
59	71.6	-12.6	158.76
61	71.6	-10.6	112.36
66	71.6	-5.6	31.36
70	71.6	-1.6	2.56
71	71.6	-0.6	0.36
76	71.6	4.4	19.36
78	71.6	6.4	40.96
81	71.6	9.4	88.36
82	71.6	10.4	108.16
88	71.6	16.4	268.96
91	71.6	19.4	376.36
99	71.6	27.4	750.76
			$\sum(x - \bar{x}) = 3285.60$

$$s = \sqrt{\frac{\sum(x - \bar{x})^2}{(n - 1)}}, \quad s = \sqrt{\frac{3285.60}{14}}, \quad s = 15.32$$

The mean test score is 71.6 with a standard deviation of 15.32.

- 2 The data are given in Table 18.4.

Table 18.4 Student ages (question 2).

Value (x)	Mean (\bar{x})	Variation from mean ($x - \bar{x}$)	Square of variation ($(x - \bar{x})^2$)
17	23.5	-6.5	42.63
18	23.5	-5.5	30.57
19	23.5	-4.5	20.52
19	23.5	-4.5	20.52
20	23.5	-3.5	12.46
20	23.5	-3.5	12.46
20	23.5	-3.5	12.46
21	23.5	-2.5	6.40
21	23.5	-2.5	6.40
22	23.5	-1.5	2.34
22	23.5	-1.5	2.34
23	23.5	-0.5	0.28
25	23.5	1.5	2.16
25	23.5	1.5	2.16
26	23.5	2.5	6.10
34	23.5	10.5	109.63
48	23.5	24.5	598.81
			$\sum(x - \bar{x}) = 888.24$

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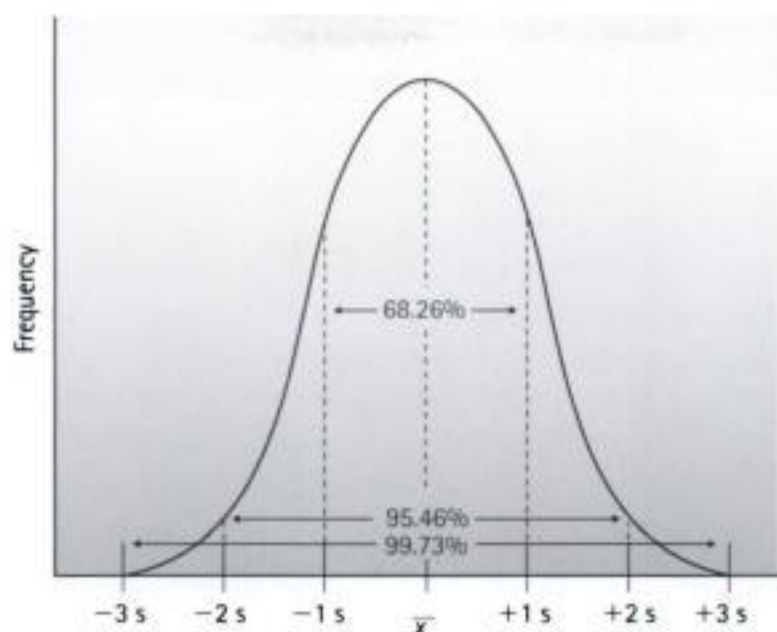


Figure 18.4 The curve of normal distribution.

When considering a value derived from a clinical test, we can compare it to a normal curve and see if it is within an acceptable range. For most clinical tests, a value that falls within ± 2 standard deviations is considered normal. The normal curve was first created using data from a large set of healthy individuals and then determining the mean and standard deviation. Let's look at an example.

A laboratory was setting up its reference ranges for sodium values in healthy dogs. One hundred dogs were sampled and the mean value was 145 mmol/L with a standard deviation of 2.5 mmol/L. What was the reference range for healthy dogs?

If the reference range is ± 2 standard deviations then the reference range is:

$$145 - (2 \times 2.5) = 140 \text{ mmol/L} \quad \text{to} \quad 145 + (2 \times 2.5) = 150 \text{ mmol/L}$$

If a dog's blood was found to have a value of 135 mmol/L of sodium, it would be considered abnormally low.



Barking up the wrong tree

If a value falls below two standard deviations on a clinical test it is considered abnormal but, in fact, it may be normal for that individual. Remember that ± 2 standard deviations encompasses 95.46% of the 'normal' values. It may be that this 'abnormal' value is one of the 4.54% *outside* of the two standard deviations. This is why it is important to look at the patient as well as the clinical test results!

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tested on the chemistry analyser. The results were tabulated and a mean and standard deviation calculated, as shown in Table 18.6.

The control solution has an assigned value of 4.5 mmol/L. Each day, it is measured and a value recorded. Since the procedure and equipment are going to have *some* random variability, we must determine the mean of the values and the standard deviation for our laboratory.

The mean is calculated to be 4.6 mmol/L with a standard deviation of:

$$s = \sqrt{\frac{(x - \bar{x})^2}{N - 1}}$$

$$s = \sqrt{\frac{3.37}{30}} = 0.34$$

With this information, we can create our Levey-Jennings chart that we can start using in April.

Table 18.6 Blood glucose test control figures (March).			
Day	(x)	(x - \bar{x})	(x - \bar{x}) ²
1	4.6	0	0
2	4.4	-0.2	0.04
3	4.8	0.2	0.02
4	4.5	-0.1	0.01
5	3.9	-0.7	0.49
6	5.1	0.5	0.25
7	5.0	0.4	0.16
8	4.9	0.3	0.09
9	3.9	-0.7	0.49
10	4.4	-0.2	0.04
11	4.7	0.1	0.01
12	4.5	-0.1	0.01
13	5.0	0.4	0.16
14	5.1	0.5	0.25
15	4.4	-0.2	0.04
16	4.3	-0.3	0.09
17	4.7	0.1	0.01
18	4.8	0.2	0.04
19	4.3	-0.3	0.09
20	4.7	0.1	0.01
21	4.1	-0.5	0.25
22	5.0	0.5	0.25
23	4.8	0.2	0.04
24	4.3	-0.3	0.09
25	4.7	0.1	0.01
26	4.3	-0.3	0.09
27	4.9	0.3	0.09
28	4.2	-0.4	0.16
29	4.2	-0.4	0.04
30	4.7	0.1	0.01
31	4.8	0.2	0.04
	$\bar{x} = 4.6$		$\sum(x - \bar{x})^2 = 3.37$

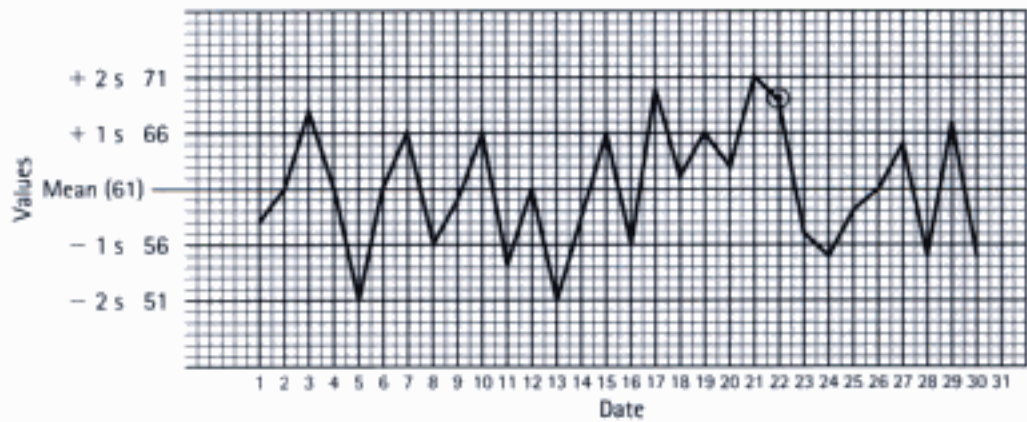


Figure 18.6 A shift: from the 17th until the 22nd there are six consecutive readings above the mean.

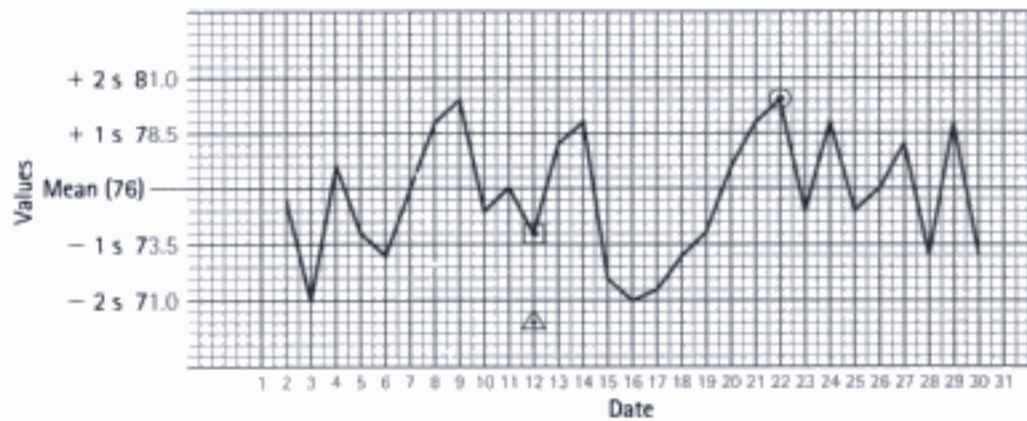


Figure 18.7 A trend: showing a consecutive increase in readings for 7 days between the 16th and 22nd.

In the month of April, we will test our control solution on our equipment. If the reading is between 3.92 and 5.28 (4.6 ± 2 standard deviations), then we say the test is in control and we can carry on measuring blood samples that day. If the control solution falls below or above this range, we must repeat it; if it is still outside the range, we must determine why the test is out of control.

There are two other situations in which a test may be considered out of control: when the control test results have a number of values in a row that fall on one side of the mean, or when a series of consecutive values forms a line in one direction. We call the first case a *shift* – the mean has shifted up or down; the second case is called a *trend* – there is something causing the values of the control solution to increase or decrease each day. The acceptable number of consecutive values on one side of the mean or the number going in one direction varies in each laboratory but six is a commonly used number, i.e. action must be taken when six such readings are obtained. Figs 18.6 and 18.7 illustrate a shift and a trend.



You may find some variation on the detail of quality control procedures as used from laboratory to laboratory, but remember two things about testing: your test result is only as reliable as the test itself and always look at the patient – not just the numbers!

Index

- A**
Addition and subtraction
 decimals, 11
 fractions, 4–5
 percentages, 14
 scientific notation, 20–1
Anaesthesia, 99–100
Answer unit, 27
- B**
Base, 17
Bell curve, 105
Bridges, 28
Broth dilution susceptibility test, 89
- C**
Central tendency, 103–4
Cocktails, 63–6
Colony forming units, 90
Common denominator, 3–4
Complex fractions, 7
Conversion factors
 dimensional analysis, 27, 29
 metric system, 48–9
Coulter counter, 91
- D**
Decimal point, 9
Decimals, 9–13
 adding and subtracting, 11
 conversion of fractions to, 12–13
 conversion to fractions, 13
 definition, 9
 dividing, 11–12
 multiplying, 11
 rounding off, 12
 zeros, 9–10
Degrees of freedom, 107–8
Denominator, 1
Dilution factor, 94
Dilutions, 83–94
 clinical problems, 95–7
 definition, 83–4
 dependent, 85–6
 dilution concentrations, 84–5
 haematology applications, 91–4
 immunology applications, 87–9
 independent, 85
 microbiology applications, 89–91
 serial, 86–7
 see also Solutions
Dimensional analysis, 27–30
 clinical applications, 32–3
 conversion factors, 29
 definition, 27–9
 metric system, 40–1
Dividend, 11
Dividing
 decimals, 11–12
 fractions, 6–7
 percentages, 15
 scientific notation, 19–20
Divisor, 11
Dosage calculations, 57–8
Drip rates, 73–5
- E**
Exponent, 17
Extrapolation, 83
- F**
Flow rates, 71–3
Fluid administration sets, 73
Fractions, 1–7
 adding and subtracting, 4–5
 common denominator, 3–4
 complex, 7
 conversion of decimals to, 13
 conversion to decimals, 12–13
 converting, 1–2
 definition, 1
 dividing, 6–7
 improper, 1
 multiplying, 5–6
 proper, 1
 reducing, 2–3
- H**
Haematology, 91–4
Haemocytometers, 91–4
Household measurement system, 42
 conversion with metric system, 42–3
- I**
Ideal body weight, 101
Immunology, 87–9
Improper fractions, 1
Infusions, constant rate, 77–81
 adding drugs to, 78–81
 infusion rates, 77–8
Insulin, 53–5
International units, 53
Intravenous fluids, 71–5
 drip rates, 735
 flow rates, 71–3
 fluid administration sets, 73
- L**
Label factor method, 27
Labels
 oral medication, 45–6
 Pentothal, 59
Levey-Jennings chart, 112–13
Lowest common denominator, 3
- M**
Mean, 103
Measurement systems, 37–44
Median, 104
Metabolisable energy
 requirement, 100
Metric system, 37–41
 clinical applications, 39–40
 conversion with household measurement system, 42–3
 conversion within, 38–9
 cubic centimetres, 41
 dimensional analysis vs ratio and proportion, 40–1
Microbiology, 89–91
Mixed numbers, 1
Mode, 104
Multiplying
 decimals, 11
 fractions, 5–6
 percentages, 14–15
 scientific notation, 18
- N**
Neubauer haemocytometer, 91, 92
Normal distribution, 103, 105–11
 standard deviation, 106–10
 variance, 105–6
Numerator, 1
Nutrition, 100–2
- O**
Oral medication, 45–7
 labels, 45–6

P

- Parenteral medication, 49–55
 - definition, 49
 - insulin, 53–5
 - percent concentrations, 51–2
 - reconstituting powders, 51–2
 - types of syringes, 49–51

Percentages, 13–15

- adding and subtracting, 14
- dividing, 15
- multiplying, 14–15
- parenteral administration, 51–2

Proper fractions, 1**Proportion, 23–5**

- clinical applications, 32
- metric system, 40–1

Q**Quality control, 112–14**

- see also Statistics

Quotient, 11**R****Range, 105****Ratio, 23–5**

- clinical applications, 32
- metric system, 40–1

Respiratory minute volume, 99**Respiratory rate, 99****Resting energy requirement,**

- 100, 101–2

S**Scientific notation, 17–21**

- adding and subtracting, 20–1
- definition, 17–18
- dividing, 19–20
- multiplying, 18

Serial dilutions, 86–7**Shift, 114****Skew, 104****Solutions, 59–66**

- clinical problems, 67–9
- mixed solutions (cocktails), 63–6

single ingredient, 59–60

stock solutions, 60–2

working solutions, 61

see also Dilutions

Standard deviation, 106–10**Starting factor, 27****Statistics, 103–14**

- central tendency, 103–4
- normal distribution, 105–11

Syringes, 49–51

- insulin, 53–4

T**Three-way safety check, 45****Tidal volume, 99****Titre, 87****Trend, 114****V****Variance, 105–6**

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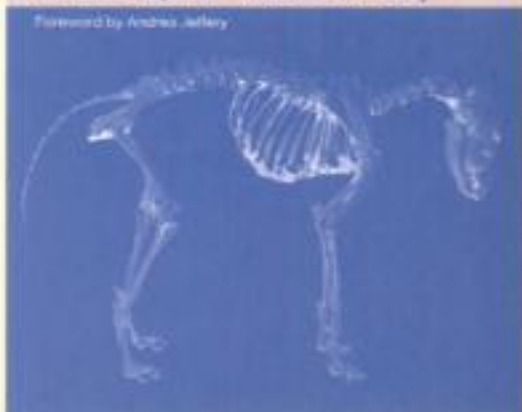
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Dosage Calculations for Veterinary Nurses and Technicians is designed to explain common mathematical principles in veterinary terms. The author uses a commonsense approach to clinical situations faced by every student and qualified practitioner, highlighting common errors and providing tips for avoiding potential pitfalls. Drawing upon his extensive experience, Terry Lake also provides a method of conversion that simplifies equations and removes the necessity of memorising formulae. This extremely useful text takes the student from the secure ground of decimals and percentages, through to the uncharted terrain of statistics and dimensional analysis – all in an easily accessible and user-friendly style.

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