Are you ready for S218?

This item contains selected online content. It is for use alongside, not as a replacement for the module website, which is the primary study format and contains activities and resources that cannot be replicated in the printed versions.

Contents

1 Introduction

If you are intending to study S218, you will want to make sure that you have the necessary background knowledge and skills to be able to enjoy the module fully and to give yourself the best possible chance of completing it successfully.

This session is intended to help you find out whether or not you are ready for S218.

Please read through these notes carefully, and work through the questions.

Key point

S218 is a 60-credit module, and it is recommended you spend an average of 20 hours per study week over the 31 weeks of the presentation.

At Level 2 the depth of knowledge expected is greater than at Level 1.

You can find advice about planning your study time and time management within the 'Study Skills' section in StudentHome. If you would like additional advice about workload, please contact your Student Support Team.

1.1 Foundations

The first two weeks of S218 have been allocated to review a number of important concepts in chemistry that you will need to be familiar with when starting out on S218 – this block is titled Foundations.

Each topic covered will be developed further during the course of the module.

The first assignment in S218 is an interactive computer-marked assignment (iCMA) which directly tests these introductory topics, and you will be asked to reflect on your readiness to study in the first tutor-marked assignment (TMA 01).

So, when you work through Section 5 of this resource, if there are a few topics you feel you need to brush up on don't worry – these will be covered again in the Foundations block, along with other chemistry topics that are covered in Level 1 science modules.

There are notes throughout this session indicating when topics are covered in Foundations, and if they are covered in more depth later in the module.

2 Module profile

S218 is a 60-credit Level 2 module that explores a range of fundamental concepts chemistry, together with a number of contemporary topics.

S218 is a compulsory module in R59 BSc (Hons) in Chemistry, and S34 (Professional Certificate in Chemistry).

The module is completely online comprising text, interactive media, audio-visual, collaborative and independent activities.

No residential schools or face-to-face laboratory work are required to successfully complete the module.

2.1 Skills developed

Students studying S218 are expected to develop:

- a sound knowledge and understanding of essential concepts across inorganic, organic, physical, and analytical chemistry, designed to underpin OU Level 3 study in the subject
- a familiarity with basic coding and its applications in chemistry
- investigative skills through a series of on-screen experiments
- communication skills
- problem-solving skills
- collaborative skills.

In order to do well in the assignments (TMAs) and the EMA in this module, you will need to demonstrate:

- the ability to write concisely in order to answer factual or evaluative questions or summarise a piece of text in your own words
- the ability to organise and present material in a logical progression of linked points in a clear and concise manner to produce longer written reports
- a basic mathematical competence and ability to extract information from data presented in various formats (such as tables and graphs)
- the ability to search for, analyse and interpret information from a range of sources.

We expect you to have proficient IT skills such that you can follow module guidance to complete online experiments and use word processing and other software to prepare your assignments for online submission. This includes using software for drawing molecules, but note that you are not expected to be familiar with drawing packages.

3 Suggested prior study

Key point

Before starting this module, we strongly recommend that you have completed an OU Science Level 1 module.

S218 assumes you understand some basic scientific and mathematical concepts, and study skills at least equivalent to this level.

These modules include: S111 *Questions in science* and S112 *Science: concepts and practice*.

As an alternative, you should, fairly recently, have taken and obtained good marks in modules equivalent to GSCE, A-level or a Level 3 vocational qualification standard in science, including chemistry.

4 General study skills

It is expected that you will already have achieved some degree of competency in the study skills listed below.

- An ability to organise your study time and pace it.
- An ability to analyse tasks and plan how to tackle them.
- A willingness to learn from feedback provided.

You should be able to:

- read effectively to distinguish relevant from irrelevant or redundant information and analyse data from scientific text and images
- locate and consult a range of online module materials (including video, audio and interactive activities) in order to obtain information and clarify complex ideas
- synthesise information, including being able to identify arguments and alternative interpretations.

4.1 Writing skills

You should be able to:

Present information *in your own words*, in a range of formats, e.g. reports or short answers to questions, based on information and data extracted from module materials and scientific texts, making references where appropriate, and ensuring that arguments, ideas and information are presented in a logical sequence.

4.2 Collaborative skills

You should be able to:

- work as part of a team in collaborative activities
- share information via online forums.

4.3 Computing skills

You should be familiar with:

- word processing software such as Microsoft Word for completing tutor-marked assignments (TMAs)
- how to search the web for information and resources
- using online forums
- online tutorial software.

4.4 Coding skills

Basic coding skills for chemists using the Python programming language are introduced in S218. You are not expected to have experience in this area prior to beginning the module.

5 Chemistry topics

This section summarises some key areas of chemistry you should be familiar with before you begin your study of S218.

Read through each section and attempt the self-assessment questions.

5.1 Elements, atoms, molecules and compounds

An element is a substance that cannot be broken down into simpler components by a chemical reaction.

Each element is composed of a single type of atom. For example, the element hydrogen consists of hydrogen atoms.

Every atom has a nucleus at its centre which consists of protons and neutrons. The nucleus is surrounded by particles known as electrons. Protons are positively charged, neutrons have no charge and electrons are negatively charged. Protons and neutrons each have approximately the same mass, whereas the mass of an electron is much smaller, and in fact negligible.

An atom has no overall electrical charge because the number of protons in an atom equals the number of electrons.

Some common elements exist as diatomic molecules, e.g. the gases oxygen $(\mathrm{O_2})$, hydrogen $(\mathrm{H_2})$, nitrogen $(\mathrm{N_2})$ and chlorine $(\mathrm{Cl_2})$, which each contain two identical atoms bonded together by covalent interactions.

Atoms of different elements may combine to form a more complex structure called a compound, e.g. sodium chloride (NaCl). In each case, the chemical formula of the compound indicates the relative numbers of the different atoms that combine together in its formation.

Thinking ahead

The structure of atoms and chemical bonding is covered in the Foundations block.

- How many atoms of nitrogen are there in a molecule of nitrogen gas $(\mathrm{N_2})$?
- The subscript ‘2’ in $(\mathrm{N_2})$ indicates that there are two nitrogen atoms.

- What are the relative numbers of the three different atoms, hydrogen (H), phosphorus (P) and oxygen (O), in the compound phosphoric acid $(\mathrm{H_3PO_4})$?
- The symbol for phosphorus has no subscript, so there is only one atom of phosphorus. However, the symbol for hydrogen has the subscript ‘3’, so there are three atoms of hydrogen indicated in the chemical formula. Similarly, the symbol for oxygen has the subscript ‘4’, so there are four atoms of oxygen indicated in the chemical formula. The

relative number of atoms indicated by the chemical formula is therefore 3 hydrogen: 1 phosphorous: 4 oxygen.

5.2 Chemical reactions

In a chemical reaction, reactants are converted into different substances called products.

In order for a chemical reaction to occur, the reactant molecules must collide with sufficient kinetic energy. Most chemical reactions do not therefore occur spontaneously at any measurable rate because they cannot overcome this energy barrier.

A reaction with a large energy barrier can be made possible by introducing a catalyst, a substance that increases the rate of a reaction, but is not itself used up during the reaction.

Thinking ahead

Chemical reactions are covered in the Foundations block.

- Identify two factors that can increase the rate of collision of reactant molecules and thus speed up a chemical reaction.
- The rate of collision of molecules can be increased by:
  - increasing the concentration of the molecules
  - increasing the temperature which gives the molecules more kinetic energy, so they move faster and interact more often.

5.3 The mole

The mole is the SI unit of amount of substance and given the symbol mol.

The mole is used to quantify the number of atoms or molecules (or formula units) involved in a reaction or contained in a volume of gas or solution.

The relative atomic mass in grams of every element contains exactly the same number of atoms.

This number is called Avogadro's constant, and it has a value
$N_\mathrm{A} = 6.022 \times 10^{23}$ atoms per mole or $N_\mathrm{A} = 6.022 \times 10^{23}\,\mathrm{mol}^{-1}$.

The mass of a mole of a substance is obtained by adding together the relative atomic masses of all of the atoms in the formula unit, and following this by the unit of mass, g (grams).

Concentrations of solutions are commonly expressed as the number of moles of solute dissolved in $1\,\mathrm{dm}^3$ of solution $(\mathrm{mol\,dm}^{-3})$.

Where dm stands for decimetre $= 0.1\,\mathrm{m}$.

In litres (L), $1\,\mathrm{dm}^3 = 1\,\mathrm{L}$.

Thinking ahead

The mole and concentration are covered in the Foundations block, with plenty of practice calculations.

- $9.8\,\mathrm{g}$ of sulfuric acid $(\mathrm{H_2SO_4})$ is dissolved in water so that the total volume is $250\,\mathrm{cm^3}$.

  Express the concentration of the resulting solution in $\mathrm{mol\,dm^{-3}}$ (the relative atomic masses of the elements concerned are $\mathrm{H} = 1$, $\mathrm{S} = 32$; $\mathrm{O} = 16$).

- The molar mass of $\mathrm{H_2SO_4}$ corresponds to the sum of the relative atomic masses of two hydrogen atoms, one sulfur atom and four oxygen atoms; expressed in grams this is $(1 \times 2) + 32 + (16 \times 4) = 98\ \mathrm{g})$.

  Therefore, $9.8\,\mathrm{g}$ corresponds to $0.1\,\mathrm{mol}$.

  This amount is dissolved in $250\,\mathrm{cm^3}$, which is $= 0.25\,\mathrm{dm^3}$ of solution. Since the concentration is the amount (in moles) dissolved in $1\ \mathrm{dm^3}$ of solution, the concentration of this solution is $4 \times 0.1 = 0.4\,\mathrm{mol\,dm^{-3}}$.

5.4 Chemical equations

Chemical equations are written showing the reactants on the left-hand side and the products on the right-hand side.

Reactants and products are connected by an arrow indicating the direction of the reaction.

As *atoms are neither created nor destroyed during chemical reactions*, the number of atoms of each type, present on one side of the equation, must be the same as the number of each type on the other side, i.e. the equation must be balanced.

Take a look at an example:

$$\mathrm{Na\,(s) + Cl_2\,(g) \rightarrow NaCl\,(s)} \qquad \text{(R1)}$$

R1 is not balanced, there are two atoms of chlorine on the left-hand side but only one on the right-hand side.

The equation is balanced as shown.

$$\mathrm{2Na\,(s) + Cl_2\,(g) \rightarrow 2NaCl\,(s)} \qquad \text{(R2)}$$

The physical states of reactants and products are denoted by suffixes:

(s) for solid

(l) for liquid

(g) for gas

(aq) for aqueous solution.

- Balance the following equation for the combustion of heptane, C_7H_{16}.

$$C_7H_{16}\,(l) + O_2\,(g) \rightarrow CO_2\,(g) + H_2O\,(g) \qquad (R3)$$

- $$C_7H_{16}\,(l) + 11O_2\,(g) \rightarrow 7CO_2\,(g) + 8H_2O\,(g) \qquad (R4)$$

On each side of the reaction there are seven carbon atoms, sixteen hydrogen atoms and twenty-two oxygen atoms.

Thinking ahead

Chemical equations (including plenty of practice examples) are covered in the Foundations block.

6 Mathematical skills for S218

S218 assumes that you have the ability to:

- add, subtract, multiply, and divide
- use a scientific calculator
- manipulate decimals and fractions
- calculate values to the required number of significant figures.

You will also be expected to be familiar with:

- scientific notation
- handling data in appropriate units
- drawing graphs
- rearranging equations
- fractions and percentages
- trigonometric functions
- logarithmic and exponential functions.

Struggling with maths?

If you do have problems with any of these topics and feel you want to brush up on your maths skills, note that mathematics tutorials/workshops will take place at the start of the module, and then midway during the presentation.

You will also find 'Maths for science' supporting material on the Resources page of the module website.

6.1 Scientific (powers of ten) notation

There is a very wide range of magnitudes of numbers involved in scientific data.

For instance, the distance to the nearest star is 40 000 000 000 000 000 metres, whereas the time taken by light to travel 100 metres is 0.000 000 33 seconds. It is clearly not convenient to express very large or very small numbers like these with lots of zeros.

A more manageable form, known as scientific notation, uses the fact that large (or small) numbers are generated by multiplying several tens together; the number of tens being indicated by a superscript called 'the power'. This is also known as standard form.

Thus:

$$10 = 10^1$$ ('ten to the power one')

$$100 = 10 \times 10 = 10^2$$ ('ten to the power two')

$$1\,000\,000 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 10^6$$ ('ten to the power six').

For example, in this module you'll come across equations which include the value of the speed of light in a vacuum.

The speed of light in a vacuum is approximately $300\,000\,000\ \mathrm{m\,s^{-1}}$, in other words

$$3 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \, \mathrm{m \, s^{-1}} = 3 \times 10^8 \, \mathrm{m \, s^{-1}}$$

Numbers less than 1 can be expressed in a similar way; for example $0.1 = 1/10 = 1/10^1$, which is written as 10^{-1}.

And, $0.0001 = 1/10\,000 = 1/(10 \times 10 \times 10 \times 10) = 1/10^4$, which is written as 10^{-4}.

6.1.1 Multiplying and dividing using standard notation

When *multiplying* values expressed using powers of 10, the powers must be *added*. For example, 1000×100 becomes $10^3 \times 10^2 = 10\,(3 + 2) = 10^5 = 100\,000$.

In order to raise a power by a further power, the powers must be multiplied. For example, $(10^3)^4 = 10^{(3 \times 4)} = 10^{12}$.

When *dividing* using powers of 10 you *subtract* the indices.

- Express the following numbers using scientific (powers of 10) notation:

  i. 8 970
  ii. 0.0046
  iii. 234×10^2
  iv. 0.27

- i. 8.97×10^3

  ii. 4.6×10^{-3}

  iii. 2.34×10^4

  iv. 2.7×10^{-1}

- Evaluate the following using scientific notation:

  i. $10^3 \times 10^5$

  ii. $10^{-2} \times 10^4$

- i. 10^8

  ii. 10^2

6.2 Physical quantities and units

A physical quantity is a property that can be measured.

All measured quantities must have units associated with them.
The units used in science are based on SI units.

In the SI system, all units are related to seven base units:

- length is measured in metres (m)
- time in seconds (s)
- mass in kilograms (kg)
- amount in moles (mol)
- temperature in kelvin (K)
- electric current in amperes (A)
- luminous intensity in candelas (cd).

Study note
As a chemist you are not likely to come across the last two on the list.

An example of the use of SI units is the recording of velocity:

If 1000 metres are travelled in 50 seconds, the velocity is given by:
$1000\,\mathrm{m}/50\,\mathrm{s} = 20\,\mathrm{ms}^{-1}$.

6.2.1 Derived units

Some units derived from these base units have special names. Table 1 shows the units you will come across in S218.

Table 1 Derived units

physical quantity	unit	symbol	equivalent in SI base units
frequency	hertz	Hz	s^{-1}
energy	joule	J	$\mathrm{kg\,m^2\,s^{-2}}$
force	newton	N	$\mathrm{kg\,m\,s^{-2}}$
power	watt	W	$\mathrm{kg\,m^2\,s^{-3}} \equiv \mathrm{J\ s^{-1}}$
pressure	pascal	Pa	$\mathrm{kg\,m^{-1}\,s^{-2}} \equiv \mathrm{J\ m^{-3}}$
electric charge	coulomb	C	$\mathrm{A\,s}$
electric potential difference	volt	V	$\mathrm{kg\,m^2\,s^{-3}\,A^{-1}} \equiv \mathrm{J\ A^{-1}\,s^{-1}}$

Study note

The symbol $\equiv$ means 'identical to'. This is different from the equals (=) sign, which shows that the values either side of it are the same.

Prefixes

Units can be used with standard prefixes that enable large and small values to be written more efficiently. Table 2 shows those you will come across most often.

Table 2 Examples of prefixes

prefix name	symbol	10^n	meaning
giga	G	10^9	1000 000 000
mega	M	10^6	1000 000
kilo	k	10^3	1000
hecto	h	10^2	100
deca	da	10^1	10
–	–	10^0	1
deci	d	10^{-1}	0.1
centi	c	10^{-2}	0.01
milli	m	10^{-3}	0.001
micro	μ	10^{-6}	0.000 001
nano	n	10^{-9}	0.000 000 001
pico	p	10^{-12}	0.000 000 000 001

You will have met kilo-, for example, in kilogram and kilometre.

6.2.2 Calculations and units

When carrying out a calculation involving physical quantities, the operation (for example, multiplication or division) is carried out on the units as well as the numbers.

For example the value of $\mathrm{K_w}$ is determined by multiplying the value of the concentration of $\mathrm{OH^-}$ ions with that of the concentration of $\mathrm{H^+}$ ions.

If concentration is expressed in units of mols per decimetre cubed, or $\mathrm{mol\ dm^{-3}}$, the unit of $\mathrm{K_w}$ is $(\mathrm{mol\,dm^{-3}}) \times (\mathrm{mol\,dm^{-3}})$; in other words, $(\mathrm{mol\,dm^{-3}})^2$ or $\mathrm{mol^2\,dm^{-6}}$.

Study note

$\mathrm{K_w}$ is the equilibrium constant of water, representing the extent to which molecules of water dissociate (break up) into the ions $\mathrm{H^+}$ and $\mathrm{OH^-}$.

Thinking ahead

In S218, equilibrium constants are covered in Foundations and later in the Thermodynamics block.

6.3 Recording data graphically

The significance of trends in data is often seen more clearly when those data are presented in the form of a graph.

There are two types of variable (a property that can change).

- The *independent* variable is the variable being tested (this is what you change during the experiment, i.e. what is under *your* control).
- The *dependent* variable is the variable you are measuring (i.e. it is affected by the changes you make during the experiment).

Key point

The independent variable is always on the *x*-axis (horizontal line) and the dependent variable on the *y*-axis (vertical line).

Thinking again about velocity, for example:

If you plot distance travelled against time (as in Figure 1) the graph produced allows you to calculate velocity.

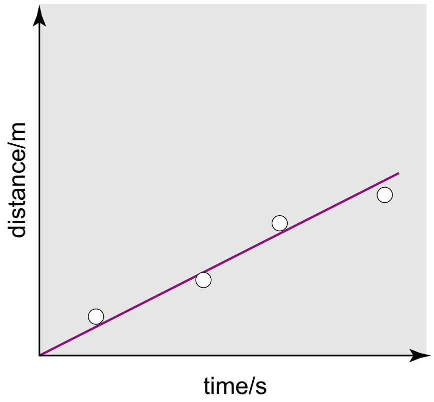

Figure 1 Distance (on the vertical, *y*, axis) plotted against time (on the horizontal, *x*, axis)

Figure 1 is a linear plot (with *y* plotted against *x*) that is, it's a straight line, or has a constant slope.

A linear plot is represented by an equation of the form:

$y = mx + c$,

where *m* is the proportionality constant which corresponds to the slope (gradient) of the straight line, and *c* is the value of the intercept of the line with the *y*-axis.

In Figure 1, $c = 0$, because the line cuts the vertical axis at the value $y = 0$ and the horizontal axis at $x = 0$.

The slope (gradient), *m*, is given by: $(y_1 - y_2) / (x_1 - x_2)$

where (x_1, y_1) and (x_2, y_2) are the coordinates of any two points on the line.

The unit of the physical quantity corresponding to the slope is obtained as follows (using the example in Figure 1):

$$\frac{\text{distance/m}}{\text{time/s}^{-1}} = \text{velocity } (\text{ms}^{-1})$$

The fact that it is a linear plot means that the velocity is constant.

6.3.1 Non-linear graphs

Not all graphs are straight lines.

Figure 2 illustrates the progress of the chemical reaction (R5):

$$S_2O_8{}^{2-}(aq) + 2I^-(aq) \longrightarrow 2SO_4{}^{2-}(aq) + I_2(aq) \quad \text{(R5)}$$

The graph was produced by plotting the concentration of one of the reactants against time. Don't worry about the chemistry at this point – it's the shape of the graph that's important here.

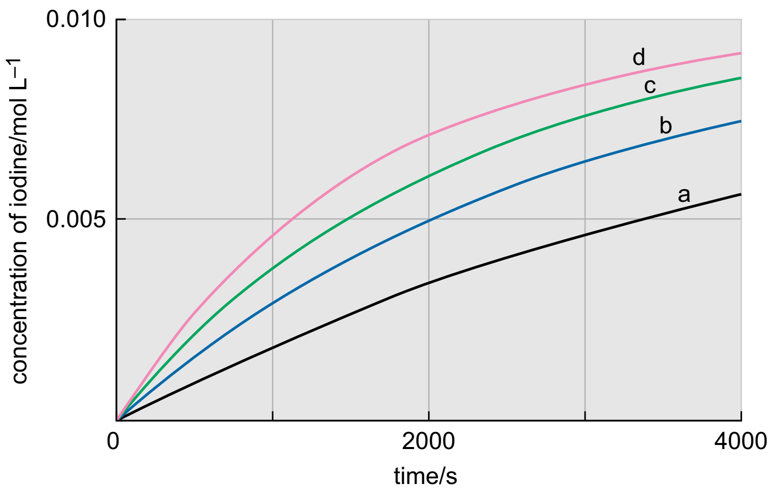

Figure 2 The progress of reaction R5

In Figure 2, the concentration of one of the products (I_2) is measured four different initial concentrations of ${S_2O_8}^{2-}$.

In the graph, the early part of each reaction progress curve approximates to a straight line. For example, curve (a) from 0 to $1500\,s$, and curve (d) from 0 to $400\,s$.

For all four lines the value of *c* is 0 because they all cut the *y*-axis (showing the concentration of iodine) at the point where the value of *y* is zero.

Experimental data will not normally lie exactly in a straight line, and a 'best-fit' line should be drawn, in which the data points are scattered evenly above and below the line. The gradient of such a line can be calculated by selecting two points on the line and dividing the difference in their corresponding *y* values by the difference in their *x* values.

Thinking ahead

You will be extracting data from graphs of this type in the Kinetics block. This will also give you an opportunity to practise your coding skills developed earlier in the module.

- With reference to Figure 2, and the reaction:

$$ {S_2O_8}^{2-}(aq) + 2I^-(aq) \rightarrow 2{SO_4}^{2-}(aq) + I_2(aq) \qquad \text{(R5)} $$

Does the speed (rate) of the reaction increase or decrease as the concentration of ${S_2O_8}^{2-}(aq)$ ions increases?

- The rate of reaction can be defined as the rate at which the concentration of a product increases, or the concentration of a reactant decreases.

In Figure 2 you can measure the rate of reaction by measuring the rate at which the concentration of one of the products, iodine, increases. As the initial concentration of

$S_2O_8{}^{2-}$ ions increases, the curves are steeper at short times; this means that the rate of the reaction increases.

6.4 Rearranging equations

Consider the equation:

$$a = \sqrt{\frac{b}{c}}$$

But suppose that, instead of knowing b and c and wanting to find c, you know a and b and want to find c.

The best way to proceed is to rearrange the equation to make c the subject of the equation, where the word 'subject' is used to mean the term written by itself, usually to the left of the equals sign.
In other words an equation that starts $c =$

There are many different methods taught for rearranging equations, and if you are happy with a method you have learnt previously, it is probably best to stick with it.
However you could do it this way:

$\sqrt{\frac{b}{c}}$ means you take the square root of b/c so squaring both sides gives you:

$$a^2 = b/c$$

And multiplying both sides of the equation by c gives you:

$$b = a^2c$$

- The density of a cubic crystal, ρ, is given by $\rho = M/V$ where M is the mass of atoms or ions in one cell of the crystal of volume V. For a cubic cell of side, r, write the volume in terms of r, and rearrange the equation $\rho = M/V$ to make r the subject. (*Hint:* the volume of a cube of side r is r^3).

- The volume of a cube of side r is r^3

  Hence $\rho = M/r^3$.

  Multiplying both sides by r^3 gives:

  $\rho \times r^3 = M$.

  Dividing each side by ρ gives:

  $r^3 = M/\rho$

Now r is on the left-hand side, but it is cubed so you need to take the cube root:

$r = (M/\rho)^{\frac{1}{3}}$.

Thinking ahead

In S218 you'll look at calculations of this type in the Structure and bonding block.

6.5 Fractions and percentages

Consider how you would calculate a certain fraction or percentage of a given number.

For example, 75% of 300 means ${}^{75}/{}_{100} \times 300 = 225$.

- What is 8% of 400?
- 8% of 400 is:
  $(8/100) \times 400 = 8 \times 4 = 32$.

6.6 Trigonometric functions

These are functions such as sine and cosine.

They can be defined in terms of a triangle as follows: for all triangles, the internal angles add up to 180°. A triangle with one internal angle equal to 90° (i.e. a right angle) is known as a right-angled triangle.

The side opposite the right angle in a right-angled triangle is known as the hypotenuse.

For a right-angled triangle:

$$\cos\theta = \text{adjacent}/\text{hypotenuse}$$

$$\sin\theta = \text{opposite}/\text{hypotenuse}$$

$$\tan\theta = \text{opposite}/\text{adjacent}$$

Thinking ahead

You'll be using trigonometric functions in the Structure and bonding block.

6.7 Significant figures

Calculations using scientific measurements often result in an answer with a large number of decimal places, particularly if you use a calculator. You then need to decide how many ‘significant figures’ to quote in the final answer.

Significant figures really just mean the most important digits – the ones you are most certain of. It is important not to quote your answer to more significant figures than the data you are working with.

When conducting an experiment, significant figures represent the accuracy to which your experiment was carried out.

In straightforward cases, the number of significant figures in a number is found simply from counting the number of digits.

In the number 23 509, the 2 is the most significant digit, because it tells us that the number is twenty thousand and something. 3 is the next most significant and then 5. If, as in this case, a zero appears between two significant digits, it is also counted as a significant digit. The last significant digit here is 9.

So the number 23 509 has five significant figures.

For the number 0.000324, the zeros at the beginning act only as place holders (they are there to place the decimal point in the correct location) so the 3 is the most significant digit, because it tells us that the number is 3 ten thousandths and something. The 2 is the next most significant and then the 4.

So the number 0.000324 has three significant figures.

6.7.1 Trailing zeros

‘Trailing zeros’ are zeros at the end of a number.

They are only considered significant if they are at the end of a number with a decimal point in it.

For example, the number 95 has two significant figures (9 and 5) but the number 95.00 has four (9, 5, zero, zero). This convention relates to the investigator’s confidence in the precision of a measurement – a measurement of 95.00 metres is claiming to be more precise than one of 95 metres.

The number 0.0500 has three significant figures (5, zero and zero).

Trailing zeros at the end of a whole number however are not considered significant (because they act as placeholder). For example the number 25 000 only has two significant figures, 2 and 5. This can sometimes lead to confusion about whether the number means exactly 25 000, or an approximation of ‘twenty-five thousand and something’ to two significant figures. If you wanted to express the exact number 25 000 to, for example, three significant figures it’s best to turn it into a power of ten: 2.50×10^4 so that it’s clear what you mean.

6.7.2 Rounding significant figures

The rules for rounding significant figures are as follows:

If the next number is 5 or more you should round up but if it is less than 5 you should not round up.

So, the number 58 567 expressed to three significant figures would be 58 600, or as a power of ten, 5.86×10^4.

Study note

As a rule of thumb, when multiplying and dividing numbers, the number of significant figures in the result of a calculation should be the same as the value with the fewest significant figures used in the calculation.

For example, if the length of a flower bed is $4.5\,\mathrm{m}$ and its width is $1.09\,\mathrm{m}$, then the calculated area is $4.5\,\mathrm{m} \times 1.09\,\mathrm{m} = 4.905\,\mathrm{m}^2$. However, since the length of $4.5\,\mathrm{m}$ is measured only to two significant figures (4 and 5), you would only be justified in quoting the area to two significant figures, so you would round the calculated value to $4.9\,\mathrm{m}^2$.

- How many significant figures (sig. figs.) are there in the following numbers?

  i. 5644
  ii. 5600
  iii. 5.06

- i. 4 sig. figs.
  ii. 2 sig. figs.
  iii. 3 sig. figs.

- Rewrite the following numbers to the stated number of significant figures:

  i. 36 373 to three significant figures.
  ii. 0.008248 to three significant figures.

- i. 36 400
  ii. 0.00825

6.8 Logarithmic and exponential functions

You will find two types of logarithms on your calculator, denoted by ‘log’ and ‘ln’. $\log\,\mathrm{x}$ is the power to which you have to raise 10 to obtain the number x.

So $\log\,100 = 2$ because $100 = 10^2$.

The powers do not have to be whole numbers. For example to three sig. figs. $2 = 10^{0.301}$ and therefore $\log\,2 = 0.301$.

An important use of $\log\,\mathrm{x}$ is in determining pH values.

pH tells you how acidic a solution is and is defined by $\mathrm{pH} = -\log\,[\mathrm{H}^+]$, where $[\mathrm{H}^+]$ represents the concentration of hydrogen ions in a solution.

Thinking ahead

You will look at pH calculations in the Foundations block.

It is worth noting that:

- it is not possible to obtain the logarithm to base 10 of a negative number, or of zero; if you try this on your calculator it will produce an error message
- you can obtain logarithms of pure numbers only; you cannot obtain the logarithm of a quantity possessing units. Strictly, if a quantity possesses units, then it should be divided by those units before taking the logarithm.

$\ln\ x$ is the power to which you have to raise the number e to obtain the number x. Where e to four significant figures is 2.718.

Check that you can use your calculator to raise e to various powers. You are likely to be using a button labelled ‘ex ’ in order to do this; the ‘EXP’ button has a totally different use. There is a need to take particular care over the meaning of ‘e’, ‘EXP’ and ‘exp’ since ‘exp’ is sometimes used to mean ‘e to the power’.

- What is the value of $e^{0.5}$ to 2 significant figures?

- $$e^{0.5} = 1.6487212707001281468486507878142 = 1.6$$ (to 2 significant figs)

- What is the value of $\ln(0.5)$ to 2 significant figures?

- $$\ln(0.5) = -0.69314718055994530941723212145818 = -0.69$$ (to 2 significant figs)

Study note

If you are still unsure about whether or not S218 is the right module for you, we advise you to seek further help and advice from the Student Support Team (SST) for Undergraduate Science. Contact details for the SST can be found on StudentHome.

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