Retrieval questions

You need to be confident about the definitions of terms that describe measurements and results in Biology.

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many answers as you can. Check and repeat.

Practical science key terms

When is a measurement valid?	when it measures what it is supposed to be measuring
When is a result accurate?	when it is close to the true value
What are precise results?	when repeat measurements are consistent/agree closely with each other
What is repeatability?	how precise repeated measurements are when they are taken by the *same* person, using the *same* equipment, under the *same* conditions
What is reproducibility?	how precise repeated measurements are when they are taken by *different* people, using *different* equipment
What is the uncertainty of a measurement?	the interval within which the true value is expected to lie
Define measurement error	the difference between a measured value and the true value
What type of error is caused by results varying around the true value in an unpredictable way?	random error
What is a systematic error?	a consistent difference between the measured values and true values
What does zero error mean?	a measuring instrument gives a false reading when the true value should be zero
Which variable is changed or selected by the investigator?	independent variable
What is a dependent variable?	a variable that is measured every time the independent variable is changed
Define a fair test	a test in which only the independent variable is allowed to affect the dependent variable
What are control variables?	variables that should be kept constant to avoid them affecting the dependent variable

1 Magnification

To look at small biological specimens you use a microscope to magnify the image that is observed. The microscope was developed in the 17th century. Anton van Leeuwenhoek used a single lens and Robert Hooke used two lenses. The lenses focus light from the specimen onto your retina to produce a magnified virtual image. The magnification at which observations are made depends on the lenses used.

1.1 Calculating the magnifying power of lenses

Lenses each have a magnifying power, defined as the number of times the image is larger than the real object. The magnifying power is written on the lens.

To find the magnification of the virtual image that you are observing, multiply the magnification powers of each lens used. For example, if the eyepiece lens is ×10 and the objective lens is ×40 the total magnification of the virtual image is 10 × 40 = 400.

Practice questions

1 Calculate the magnification of the virtual image produced by the following combinations of lenses:

a objective ×10 and eyepiece ×12

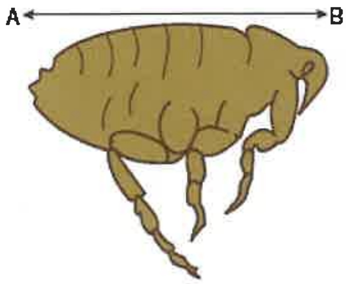
b objective ×40 and eyepiece ×15

1.2 Calculating the magnification of images

Drawings and photographs of biological specimens should always have a magnification factor stated. This indicates how much larger or smaller the image is compared with the real specimen.

The magnification is calculated by comparing the sizes of the image and the real specimen. Look at this worked example.

The image shows a flea which is 1.3 mm long. To calculate the magnification of the image, measure the image (or the scale bar if given) on the paper (in this example, the body length as indicated by the line A–B).



For this image, the length of the image is 42 mm and the length of the real specimen is 1.3 mm.

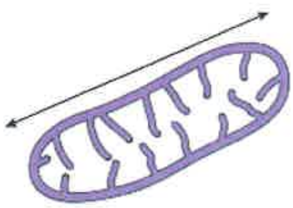
$$\text{magnification} = \frac{\text{length of image}}{\text{length of real specimen}} = 42/1.3 = 32.31$$

The magnification factor should therefore be written as ×32.31

Remember: Use the same units. A common error is to mix units when performing these calculations. Begin each time by converting measurements to the same units for both the real specimen and the image.

Practice question

2 Calculate the magnification factor of a mitochondrion that is 1.5 μm long.



1.3 Calculating real dimensions

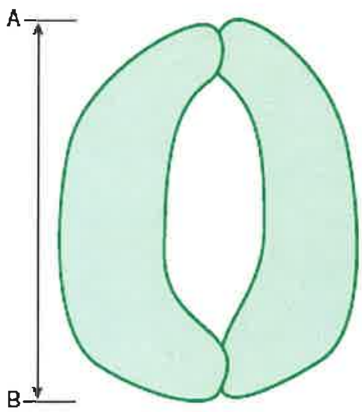
Magnification factors on images can be used to calculate the actual size of features shown on drawings and photographs of biological specimens. For example, in a photomicrograph of a cell, individual features can be measured if the magnification is stated. Look at this worked example.

The magnification factor for the image of the open stoma is ×5000.

This can be used to find out the actual size of any part of the cell, for example, the length of one guard cell, measured from A to B.

Step 1: Measure the length of the guard cell as precisely as possible. In this example the image of the guard cell is 52 mm long.

Step 2: Convert this measurement to units appropriate to the image. In this case you should use μm because it is a cell.



So the magnified image is 52 × 1000 = 52 000 μm

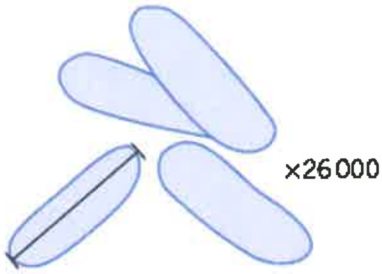
Step 3: Rearrange the magnification equation to get:

real size = size of image/magnification = 52 000/5000 = 10.4

So the real length of the guard cell is 10.4 μm.

Practice question

3 Use the magnification factor to determine the actual size of a bacterial cell.



2 Percentages and uncertainty

A percentage is simply a fraction expressed as a decimal. It is important to be able to calculate routinely, but is often incorrectly calculated in exams. These pages should allow you to practise this skill.

2.1 Calculating percentages as proportions

To work out a percentage, you must identify or calculate the total number using the equation:

$$\text{percentage} = \frac{\text{number you want as a percentage of total number}}{\text{total number}} \times 100\%$$

For example, in a population, the number of people who have brown hair was counted.

The results showed that in the total population of 4600 people, 1800 people had brown hair.

The percentage of people with brown hair is found by calculating:

$$\frac{\text{number of people with brown hair}}{\text{total number of people}} \times 100$$

$$= \frac{1800}{4600} \times 100 = 39.1\%$$

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Practice questions

1 The table below shows some data about energy absorbed by a tree in a year and how some of it is transferred.

Energy absorbed by the tree in a year	3 600 000 kJ/m^2
Energy transferred to primary consumers	2240 kJ/m^2
Energy transferred to secondary consumers	480 kJ/m^2

Calculate the percentage of energy absorbed by the tree that is transferred to

a primary consumers **b** secondary consumers.

2 One in 17 people in the UK has diabetes.

Calculate the percentage of the UK population that have diabetes.

2.2 Calculating the percentage change

When you work out an increase or a decrease as a percentage change, you must identify, or calculate, the total original amount:

$$\% \text{ increase} = \frac{\text{increase}}{\text{original amount}} \times 100$$

$$\% \text{ decrease} = \frac{\text{decrease}}{\text{original amount}} \times 100$$

Remember: When you calculate a percentage change, use the total *before* the increase or decrease, not the final total.

Practice questions

3 Convert the following mass changes as percentage changes.

Sucrose conc. / mol dm^{-3}	Initial mass / g	Final mass / g	Mass change / g	Percentage change in mass
0.9	1.79	1.06		
0.7	1.86	1.30		
0.5	1.95	1.70		
0.3	1.63	1.76		
0.1	1.82	2.55		

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GCSE → Level 3 transition
Student sheet

Atoms, ions, and compounds

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many answers as you can. Check and repeat.

What does an atom consist of?	a nucleus containing protons and neutrons, surrounded by electrons
What are the relative masses of a proton, neutron, and electron?	1, 1, and $\frac{1}{1836}$ respectively
What are the relative charges of a proton, neutron, and electron?	+1, 0, and -1 respectively
How do the number of protons and electrons differ in an atom?	they are the same because atoms have neutral charge
How does the number of protons differ between atoms of the same element?	it does not differ – all atoms of the same element have the same number of protons
What is the proton number / atomic number of an element?	the number of protons in the atom's nucleus of an element
What is the mass number of an element?	number of protons + number of neutrons
What is an isotope?	an atom with the same number of protons but different number of neutrons
What is the equation for relative isotopic mass?	relative isotopic mass = $\frac{\text{mass of an isotope}}{\frac{1}{12}^{\text{th}} \text{ mass of 1 atom of } ^{12}\text{C}}$
What is the equation for relative atomic mass (A_r)?	relative atomic mass = $\frac{\text{weighted mean mass of 1 atom}}{\frac{1}{12}^{\text{th}} \text{ mass of 1 atom of } ^{12}\text{C}}$
What is the equation for relative molecular mass (M_r)?	relative molecular mass = $\frac{\text{average mass of 1 molecule}}{\frac{1}{12}^{\text{th}} \text{ mass of 1 atom of } ^{12}\text{C}}$
What is an ion?	an atom or group of atoms with a charge (a different number of electrons to protons)
Define the term cation	a positive ion (atom with fewer electrons than protons)
Define the term anion	a negative ion (atom with more electrons than protons)
What is the function of a mass spectrometer?	it accurately determines the mass and abundance of separate atoms or molecules, to help us identify them
What is a mass spectrum?	the output from a mass spectrometer that shows the different isotopes that make up an element

Maths skills

1 Core mathematical skills

A practical chemist must be proficient in standard form, significant figures, decimal places, SI units, and unit conversion.

1.1 Standard form

In science, very large and very small numbers are usually written in standard form.

Standard form is writing a number in the format $A \times 10^x$ where A is a number from 1 to 10 and x is the number of places you move the decimal place.

For example, to express a large number such as 50 000 mol dm^{-3} in standard form, A = 5 and x = 4 as there are four numbers after the initial 5.

Therefore, it would be written as 5×10^4 mol dm^{-3}.

To give a small number such as 0.000 02 Nm^2 in standard form,

A = 2 and there are five numbers before it so x = −5.

So it is written as 2×10^{-5} Nm^2.

Practice questions

1 Change the following values to standard form.

a boiling point of sodium chloride: 1413 °C

b largest nanoparticles: $0.0\,001\times10^{-3}$ m

c number of atoms in 1 mol of water: 1806×10^{21}

2 Change the following values to ordinary numbers.

a 5.5×10^{-6} **b** 2.9×10^{2} **c** 1.115×10^{4} **d** 1.412×10^{-3} **e** 7.2×10^{1}

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Applied Science

1.2 Significant figures and decimal places

In chemistry, you are often asked to express numbers to either three or four significant figures. The word significant means to 'have meaning'. A number that is expressed in significant figures will only have digits that are important to the number's precision.

It is important to record your data and your answers to calculations to a reasonable number of significant figures. Too many and your answer is claiming an accuracy that it does not have, too few and you are not showing the precision and care required in scientific analysis.

For example, 6.9301 becomes 6.93 if written to three significant figures.

Likewise, 0.000 434 56 is 0.000 435 to three significant figures.

Notice that the zeros before the figure are *not* significant – they just show you how large the number is by the position of the decimal point. Here, a 5 follows the last significant digit, so just as with decimals, it must be rounded up.

Any zeros between the other significant figures are significant. For example, 0.003 018 is 0.003 02 to three significant figures.

Sometimes numbers are expressed to a number of decimal places. The decimal point is a place holder and the number of digits afterwards is the number of decimal places.

For example, the mathematical number pi is 3 to zero decimal places, 3.1 to one decimal place, 3.14 to two decimal places, and 3.142 to three decimal places.

Practice questions

3 Give the following values in the stated number of significant figures (s.f.).

a 36.937 (3 s.f.) **b** 258 (2 s.f.) **c** 0.043 19 (2 s.f.) **d** 7 999 032 (1 s.f.)

4 Use the equation:

number of molecules = number of moles × 6.02 × 10^{23} molecules per mole

to calculate the number of molecules in 0.5 moles of oxygen. Write your answer in standard form to 3 s.f.

5 Give the following values in the stated number of decimal places (d.p.).

a 4.763 (1 d.p.) **b** 0.543 (2 d.p.) **c** 1.005 (2 d.p.) **d** 1.9996 (3 d.p.)

Foundations of Physics

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many answers as you can. Check and repeat.

What is a physical quantity?	a property of an object or of a phenomenon that can be measured
What are the S.I. units of mass, length, and time?	kilogram (kg), metre (m), second (s)
What base quantities do the S.I. units A, K, and mol represent?	current, temperature, amount of substance
List the prefixes, their symbols and their multiplication factors from pico to tera (in order of increasing magnitude)	pico (p) 10^{-12}, nano (n) 10^{-9}, micro (μ) 10^{-6}, milli (m) 10^{-3}, centi (c) 10^{-2}, deci (d) 10^{-1}, kilo (k) 10^{3}, mega (M) 10^{6}, giga (G) 10^{9}, tera (T) 10^{12}
What is a scalar quantity?	a quantity that has magnitude (size) but *no* direction
What is a vector quantity?	a quantity that has magnitude (size) *and* direction
What is the difference between distance and displacement?	distance is a scalar quantity displacement is a vector quantity
What does the Greek capital letter Δ (delta) mean?	'change in'
What is the equation for average speed in algebraic form?	$v = \frac{\Delta x}{\Delta t}$
What is instantaneous speed?	the speed of an object over a very short period of time
What does the gradient of a displacement–time graph tell you?	velocity
How can you calculate acceleration and displacement from a velocity–time graph?	acceleration is the gradient displacement is the area under the graph
Write the equation for acceleration in algebraic form.	$a = \frac{\Delta v}{\Delta t}$
What do the letters *suvat* stand for in the equations of motion?	s = displacement, u = initial velocity, v = final velocity, a = acceleration, t = time taken
Write the four *suvat* equations.	$v = u + at$ $s = ut + \frac{1}{2}at^2$ $s = \frac{1}{2}(u+v)t$ $v^2 = u^2 + 2as$
Define *stopping distance*	the total distance travelled from when the driver first sees a reason to stop, to when the vehicle stops
Define *thinking distance*	the distance travelled between the moment when you first see a reason to stop to the moment when you use the brake
Define *braking distance*	the distance travelled from the time the brake is applied until the vehicle stops
What does *free fall* mean?	when an object is accelerating under gravity with no other force acting on it

Applied Science

Maths skills

1 Measurements

1.1 Base and derived SI units

Units are defined so that, for example, every scientist who measures a mass in kilograms uses the same size for the kilogram and gets the same value for the mass. Scientific measurement depends on standard units – most are *Système International* (SI) units. Every measurement must give the unit to have any meaning. You should know the correct unit for physical quantities.

Base units

Physical quantity	Unit	Symbol
length	metre	m
mass	kilogram	kg
time	second	s

Physical quantity	Unit	Symbol
electric current	ampere	A
temperature difference	Kelvin	K
amount of substance	mole	mol

Derived units

Example:

$$\text{speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

If a car travels 2 metres in 2 seconds:

$$\text{speed} = \frac{2\text{ metres}}{2\text{ seconds}} = 1\frac{\text{m}}{\text{s}} = 1\text{m/s}$$

This defines the SI unit of speed to be 1 metre per second (m/s), or 1 m s^{-1} ($s^{-1} = \frac{1}{s}$).

Practice questions

1 Complete this table by filling in the missing units and symbols.

Physical quantity	Equation used to derive unit	Unit	Symbol and name (if there is one)
frequency	period^{-1}	s^{-1}	Hz, hertz
volume	length^3		–
density	mass ÷ volume		–
acceleration	velocity ÷ time		–
force	mass × acceleration		
work and energy	force × distance		

1.2 Significant figures

When you use a calculator to work out a numerical answer, you know that this often results in a large number of decimal places and, in most cases, the final few digits are 'not significant'. It is important to record your data and your answers to calculations to a reasonable number of significant figures. Too many and your answer is claiming an accuracy that it does not have, too few and you are not showing the precision and care required in scientific analysis.

Numbers to 3 significant figures (3 s.f.):

3.62 25.4 271 0.0147 0.245 39 400

(notice that the zeros before the figures and after the figures are *not* significant – they just show you how large the number is by the position of the decimal point).

Numbers to 3 significant figures where the zeros *are* significant:

207 4050 1.01 (any zeros between the other significant figures *are* significant).

Standard form numbers with 3 significant figures:

9.42×10^{-5} 1.56×10^{8}

If the value you wanted to write to 3.s.f. was 590, then to show the zero was significant you would have to write:

590 (to 3.s.f.) or 5.90×10^{2}

Practice questions

2 Give these measurements to 2 significant figures:

a 19.47 m **b** 21.0 s **c** 1.673×10^{-27} kg **d** 5 s

3 Use the equation:

$$\text{resistance} = \frac{\text{potential difference}}{\text{current}}$$

to calculate the resistance of a circuit when the potential difference is 12 V and the current is 1.8 mA. Write your answer in kΩ to 3 s.f.

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1.3 Uncertainties

When a physical quantity is measured there will always be a small difference between the measured value and the true value. How important the difference is depends on the size of the measurement and the size of the uncertainty, so it is important to know this information when using data.

There are several possible reasons for uncertainty in measurements, including the difficulty of taking the measurement and the resolution of the measuring instrument (i.e. the size of the scale divisions).

For example, a length of 6.5 m measured with great care using a 10 m tape measure marked in mm would have an uncertainty of 2 mm and would be recorded as 6.500 ± 0.002 m.

It is useful to quote these uncertainties as percentages.

For the above length, for example,

$$\text{percentage uncertainty} = \frac{\text{uncertainty}}{\text{measurement}} \times 100$$

$\text{percentage uncertainty} = \frac{0.002}{6.500} \times 100\% = 0.03\%$. The measurement is 6.500 m ± 0.03%.

Values may also be quoted with absolute error rather than percentage uncertainty, for example, if the 6.5 m length is measured with a 5% error,

the absolute error = 5/100 × 6.5 m = ±0.325 m.

Practice questions

4 Give these measurements with the uncertainty shown as a percentage (to 1 significant figure):

a 5.7 ± 0.1 cm **b** 450 ± 2 kg **c** 10.60 ± 0.05 s **d** 366 000 ± 1000 J

5 Give these measurements with the error shown as an absolute value:

a 1200 W ± 10% **b** 330 000 Ω ± 0.5%

6 Identify the measurement with the smallest percentage error. Show your working.

A 9 ± 5 mm **B** 26 ± 5 mm **C** 516 ± 5 mm **D** 1400 ± 5 mm

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GCSE → Level 3
Student sheet

2 Standard form and prefixes

When describing the structure of the Universe you have to use very large numbers. There are billions of galaxies and their average separation is about a million light years (ly). The Big Bang theory says that the Universe began expanding about 14 billion years ago. The Sun formed about 5 billion years ago. These numbers and larger numbers can be expressed in standard form and by using prefixes.

2.1 Standard form for large numbers

In standard form, the number is written with one digit in front of the decimal point and multiplied by the appropriate power of 10. For example:

- The diameter of the Earth, for example, is 13 000 km.
  13 000 km = 1.3 × 10 000 km = 1.3×10^4 km.
- The distance to the Andromeda galaxy is 2 200 000 light years = 2.2 × 1 000 000 ly = 2.2×10^6 ly.

2.2 Prefixes for large numbers

Prefixes are used with SI units (see Topic 1.1) when the value is very large or very small. They can be used instead of writing the number in standard form. For example:

- A kilowatt (1 kW) is a thousand watts, that is 1000 W or 10^3 W.
- A megawatt (1 MW) is a million watts, that is 1 000 000 W or 10^6 W.
- A gigawatt (1 GW) is a billion watts, that is 1 000 000 000 W or 10^9 W.

Prefix	Symbol	Value
kilo	k	10^3
mega	M	10^6

Prefix	Symbol	Value
giga	G	10^9
tera	T	10^{12}

For example, Gansu Wind Farm in China has an output of 6.8×10^9 W. This can be written as 6800 MW or 6.8 GW.

Practice questions

1 Give these measurements in standard form:

a 1350 W **b** 130 000 Pa **c** 696 × 10^6 s **d** 0.176 × 10^{12} C kg^{-1}

2 The latent heat of vaporisation of water is 2 260 000 J/kg. Write this in:

a J/g **b** kJ/kg **c** MJ/kg

2.3 Standard form and prefixes for small numbers

At the other end of the scale, the diameter of an atom is about a tenth of a billionth of a metre. The particles that make up an atomic nucleus are much smaller. These measurements are represented using negative powers of ten and more prefixes. For example:

- The charge on an electron = 1.6×10^{-19} C.
- The mass of a neutron = $0.016\,75 \times 10^{-25}$ kg = 1.675×10^{-27} kg (the decimal point has moved 2 places to the right).
- There are a billion nanometres in a metre, that is 1 000 000 000 nm = 1 m.
- There are a million micrometres in a metre, that is 1 000 000 μm = 1 m.

Prefix	Symbol	Value
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}

Prefix	Symbol	Value
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}

Practice questions

3 Give these measurements in standard form:

a 0.0025 m **b** 160×10^{-17} m **c** 0.01×10^{-6} J **d** 0.005×10^{6} m **e** 0.00062×10^{3} N

4 Write the measurements for question 3a, c, and d above using suitable prefixes.

5 Write the following measurements using suitable prefixes.

a a microwave wavelength = 0.009 m

b a wavelength of infrared = 1×10^{-5} m

c a wavelength of blue light = 4.7×10^{-7} m

3 Rearranging equations

Sometimes you will need to rearrange an equation to calculate the answer to a question. For example, if you want to calculate the resistance *R*, the equation:

potential difference (*V*) = current (*A*) × resistance (Ω) or $V = I R$

must be rearranged to make *R* the subject of the equation:

$$R = \frac{V}{I}$$

When you are solving a problem:

- Write down the values you know and the ones you want to calculate.
- you can rearrange the equation first, and then substitute the values

  or

- substitute the values and then rearrange the equation

3.1 Substitute and rearrange

A student throws a ball vertically upwards at 5 m s^{-1}. When it comes down, she catches it at the same point.

Calculate how high it goes.

step 1: Known values are:

- initial velocity u = 5.0 m s^{-1}
- final velocity v = 0 (you know this because as it rises it will slow down, until it comes to a stop, and then it will start falling downwards)
- acceleration $a = g = -9.81$ m s^{-2}
- distance s = ?

Step 2: Equation:

(final velocity)^2 − (initial velocity)^2 = 2 × acceleration × distance

or $v^2 - u^2 = 2 \times g \times s$

Substituting: $(0)^2 - (5.0 \text{ m s}^{-1})^2 = 2 \times -9.81 \text{ m s}^{-2} \times s$

$0 - 25 = 2 \times -9.81 \times s$

Step 3: Rearranging:

$-19.62\,s = -25$

$$s = \frac{-25}{-19.62} = 1.27 \text{ m} = 1.3 \text{ m (2 s.f.)}$$

Practice questions

1 The potential difference across a resistor is 12 V and the current through it is 0.25 A. Calculate its resistance.

2 Red light has a wavelength of 650 nm. Calculate its frequency. Write your answer in standard form.

(Speed of light = 3.0×10^8 m s^{-1})