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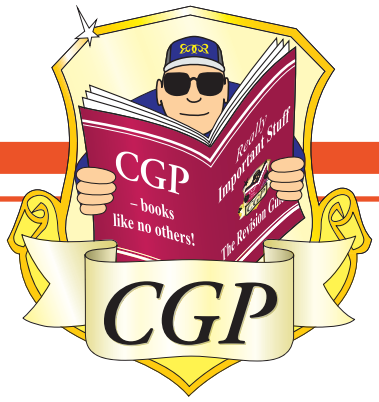
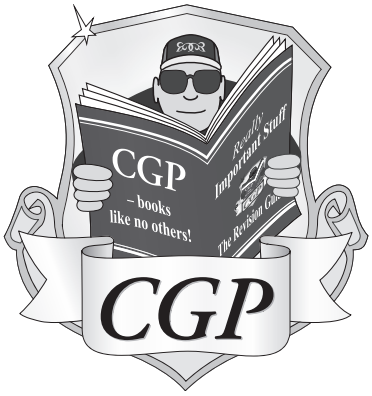


GCSE Chemistry

For AQA (Grade 9-1)

The Workbook

Higher Level



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AQA GCSE Chemistry is full of amazing facts to learn, but that's not all — you'll also need to apply your knowledge to brand new scientific situations.

It's a challenge, but this CGP Workbook will make your life easier. We've packed it with questions to test your understanding of all the key topics, so you'll be a GCSE Chemistry guru by the end of it.

And as the final part of the recipe, we've mixed in just the right amount of helpful warm-ups and expert tips. It's the perfect formulation!

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Contents

☑ Use the tick boxes to check off the topics you've completed.

Atoms and Elements

There's no escaping atoms, in chemistry books or in life... They're everywhere.

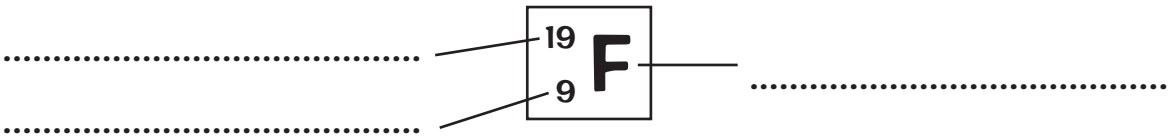
Warm-Up

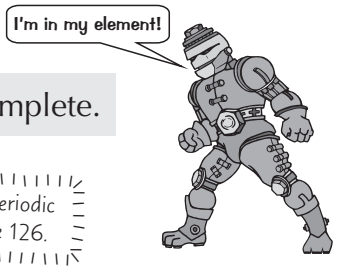
All substances are made of atoms. Atoms are tiny, with a radius of just 0.1 nanometres. They're made up of even smaller particles — protons, neutrons and electrons.

Complete the passage below by writing the correct words in the gaps:

Atoms always have a charge of ..... . An atom which has lost or gained electrons is called an ..... . A neutral atom has the same number of electrons and ..... . If an electron is added to a neutral atom, the atom becomes ..... charged.

Atoms can be represented by their nuclear symbol. This shows the atomic number, the mass number and the element symbol of the atom. Label the atomic number, mass number and element symbol on the nuclear symbol of fluorine shown below:





Q1 **Table 1** contains information about some elements. **Table 1** is incomplete.

Complete **Table 1** below using a periodic table.

You'll find a periodic table on page 126.

Table 1

Element	Symbol	Mass Number	Number of Protons	Number of Electrons	Number of Neutrons
Sodium	Na	.....	11	.....	.....
.....	.....	16	8	8	8
Neon	.....	.....	10	10	10
.....	Ca	.....	.....	20	20

Q2 **Figure 1** shows part of the structure of a neutral atom with a mass number of 11.

a) What is the name for the part of the atom shown in **Figure 1** that is shaded grey?

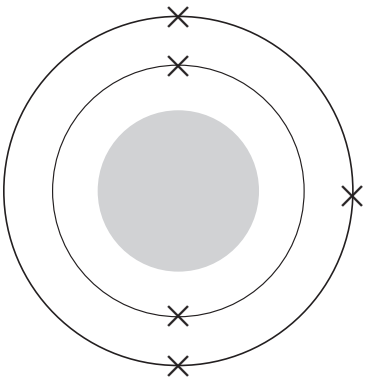
.....

b) **Figure 1** is incomplete.
The atom's electrons are shown on **Figure 1** using ×.
Complete **Figure 1** by adding the correct numbers of protons and neutrons, using:
- ● to represent protons,
- ■ to represent neutrons.

c) Use a periodic table to identify the element shown in **Figure 1**.

.....

Figure 1



Q3 The nuclear symbols for four atoms are shown below.

$^{12}_{6}C$ $^{4}_{2}He$ $^{14}_{6}C$ $^{14}_{7}N$

a) Circle the **two** atoms which are isotopes of each other.

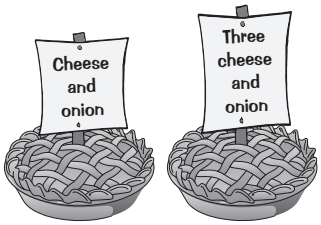
b) Explain your answer.

.....

.....

Q4 Gallium can exist as two stable isotopes: Ga-69 and Ga-71.

60.1% of gallium atoms are Ga-69 atoms, and the rest are Ga-71 atoms.
Calculate the relative atomic mass of gallium to 3 significant figures.



Piesotopes

relative atomic mass = ...

Which element has the funniest isotopes? Helium — ^{3}He ^{4}He...

Remember, it's the number of protons in an atom that determines which element it is. So atoms of the same element always have the same number of protons, but might have a different number of neutrons — if they do, they're isotopes.

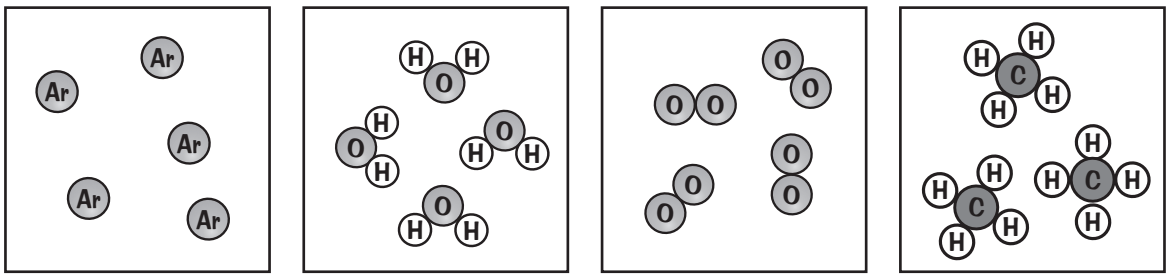
Compounds and Chemical Equations

Unluckily for you, elements don't just keep themselves to themselves...

Warm-Up

Compounds are formed when two or more elements combine in a chemical reaction. The atoms of the elements are present in fixed proportions and held together by chemical bonds. Compounds can only be converted back into elements by chemical reactions.

Look at the following diagrams of substances. Circle the boxes that contain a compound.



Compounds can be represented by formulas using the symbols of the elements from which they are made.

Draw lines to match the names of the compounds below with their formulas.

calcium chloride	carbon dioxide	hydrochloric acid	sodium hydroxide
CO_2	NaOH	HCl	$CaCl_2$

Q1 Ernest put some hot sodium (Na) into a gas jar containing chlorine (Cl_2). The sodium burst into flames and a white solid was formed.

a) Complete **Figure 1** to show the reaction that took place.

Figure 1

b) Give the chemical name of the product formed in this reaction.

.....

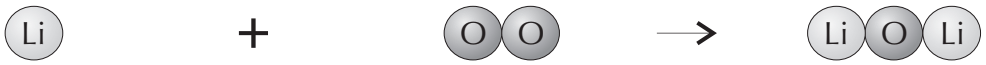
c) Write a balanced symbol equation for the reaction.

.....

Q2 Write word equations and balanced symbol equations for the unbalanced picture equations below.

You can draw more pictures to help you balance the unbalanced ones.

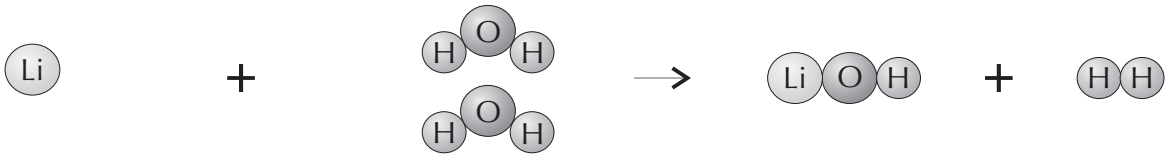
a)



i) Word equation: .....

ii) Symbol equation: .....

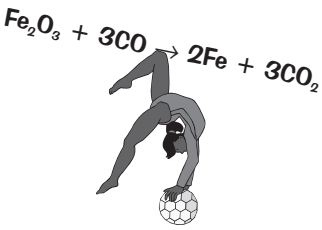
b)



i) Word equation: .....

ii) Symbol equation: .....

Q3 Balance these equations by adding in whole numbers.



a) N_2 + ... H_2 → ..... NH_3

b) ..... Fe + ... O_2 → ..... Fe_2O_3

c) ..... NH_3 + ... O_2 → ..... NO + ... H_2O

Q4 Sodium hydrogen carbonate is an ingredient in a number of foods.

a) i) Baking powder contains sodium hydrogen carbonate.

Sodium hydrogen carbonate ($NaHCO_3$) can be produced by reacting sodium carbonate (Na_2CO_3) with water (H_2O) and carbon dioxide (CO_2). Write the balanced equation for this reaction.

.....

ii) Using the formulas of the substances in this reaction, explain how you can tell that a new compound has been formed.

.....

.....

b) Sherbet sweets contain sodium hydrogen carbonate and citric acid. When mixed with the water in saliva, these react to produce bubbles of carbon dioxide, creating a fizzing sensation. Water and sodium citrate are also produced.

Balance the equation for this reaction:

..... $NaHCO_3$ + $C_6H_8O_7$ → ..... CO_2 + ... H_2O + $Na_3C_6H_5O_7$

Sodium and chlorine went on a date — they really bonded...

Balancing equations can be tricky. It might help you to keep a running total of how many of each type of atom you have on each side as you try different numbers in the equation. When both sides match, you'll know you've balanced it.

Mixtures and Chromatography

If you mix two substances that don't react you get... a mixture (creative name, huh?).

Warm-Up

A mixture is made up of two or more substances that are not chemically joined together.

Tick the statements below which are true:

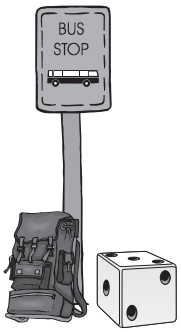
- ☐ **A The parts of a mixture can be either elements or compounds.**
- ☐ **B The chemical properties of a substance are changed if it is part of a mixture.**
- ☐ **C Mixtures can be separated by carrying out chemical reactions, producing new substances in the process.**

One method for separating mixtures is chromatography.

Q1 John did a paper chromatography experiment to investigate the dyes contained in different coloured sweets. His results are shown in **Table 1**.

Table 1

Colour of sweet	Distance travelled by dyes (mm)		
Brown	10	17	18
Red	18	–	–
Green	10	17	–
Orange	10	18	26
Blue	17	–	–



a) Which of the sweets in **Table 1** definitely contains a mixture of dyes?

.....

b) Explain how you can tell.

.....

.....

.....

.....

Q2 Magnesium reacts with dilute acid, but copper does not. Sophie has a mixture of small pieces of copper and magnesium.

Explain what would happen if Sophie added dilute hydrochloric acid to the mixture.

.....

.....

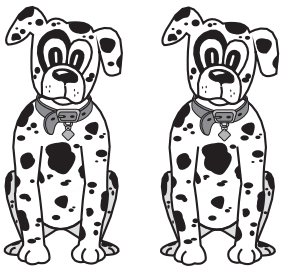
.....

PRACTICAL

Q3 Elena wanted to find out which of five dyes could be present in a particular black ink.

Elena was asked to suggest a method. This is the method she suggested:

1. **Take a piece of filter paper. Draw a horizontal pencil line near the bottom.**
2. **Add spots of the dyes to the line at regular intervals.**
3. **Put the paper into a beaker of water with the line just touching the water.**
4. **Repeat these steps with a spot of the black ink on a second piece of filter paper, and put this paper into a beaker of ethanol.**
5. **Place a lid on each beaker, and wait for the solvents to travel to the top of the paper.**
6. **Compare the positions of the spots created by the black ink with those created by the dyes.**



Spot the difference.

Identify **two** problems with this method. For each problem, suggest how you would alter the method to carry out the experiment correctly.

You can assume Elena takes sensible safety precautions.

Problem 1 .....

.....

Correction .....

.....

.....

Problem 2 .....

.....

Correction .....

.....

.....

Why is chromatography so popular? Everyone wants to do it for the 'gram...

There'll be more on chromatography later, but for now make sure you've really nailed how to carry it out. Exactly what you're asked to investigate could vary, so whether you're planning your own experiment or describing a method in an exam, always make sure that what you've suggested doing will get you the results you need.

PRACTICAL

More Separation Techniques

Didn't think you were getting away with learning just the one, did you?

Warm-Up

Chromatography is one physical process for separating mixtures, but there are several others you can use depending on what's in the mixture you want to separate. You need to know about simple distillation, fractional distillation, crystallisation and filtration.

Which of the following types of mixture can filtration be used to separate?

☐ **A liquids** ☐ **B soluble solid and liquid** ☐ **C insoluble solid and liquid**

Q1 Mei is using crystallisation to obtain a sample of solid potassium nitrate.

She begins by gently heating potassium nitrate solution in an evaporating dish until crystals start to form. Describe how she should complete the process.

.....

.....

.....

.....

Q2 The boiling points of methanol and propanol are 65 °C and 97 °C, respectively.

The apparatus shown in **Figure 1** was used to separate a mixture of methanol and propanol. **Table 1** shows the contents of the flask and the beaker at different temperatures.

Figure 1

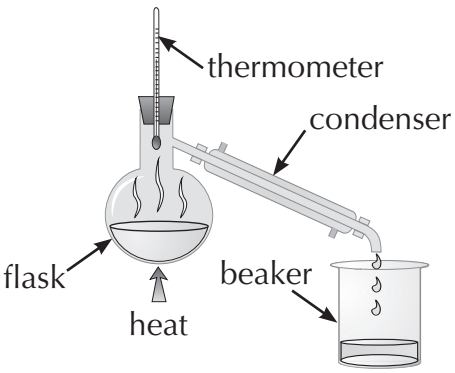


Table 1

Temperature on thermometer	Contents of the flask	Contents of the beaker
.....	Propanol	Methanol
.....	Both liquids	No liquid
.....	No liquid	Both liquids

Complete **Table 1** using the temperatures in the box below.

40 °C	75 °C	110 °C

Q3 Sodium chloride dissolves in water, but not in ethanol.
Sodium chloride has a melting point of 801 °C and a boiling point of 1413 °C.
Ethanol has a melting point of –114 °C and a boiling point of 78 °C.

a) Suggest a method which would separate a mixture of sodium chloride and ethanol, but **not** a mixture of sodium chloride and water. Explain your answer.

.....

.....

.....

.....

.....

b) Suggest a method which would separate a mixture of sodium chloride and water and would **also** separate a solution of sodium chloride and ethanol. Explain your answer.

.....

.....

c) Why can't crystallisation be used to produce a sample of sodium chloride and a sample of water from a mixture of sodium chloride and water?

.....

Q4 **Table 2** lists the boiling points of three compounds.

Table 2

Name	Formula	Boiling point (°C)
diethyl ether	$C_4H_{10}O$	35
THF	C_4H_8O	66
ethyl ethanoate	$C_4H_8O_2$	77

Suggest why a mixture of THF and ethyl ethanoate is more difficult to separate than a mixture of diethyl ether and ethyl ethanoate.
Explain how this affects the technique that can be used to separate the mixtures.

.....

.....

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.....

.....

Just don't do it by text, whatever you do...

Phew, I feel like separating myself from this book after all of that. If you found that you kept getting your techniques mixed up in these questions, read over your notes again until it all becomes crystal clear and have another go.

The History of the Atom

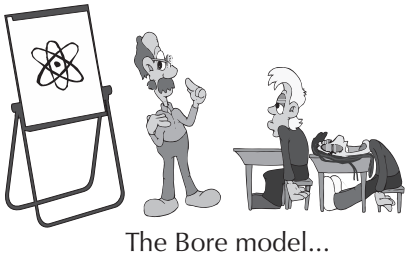
I know it says history, but I promise there's no essay-writing involved.

Warm-Up

Over the past two hundred years, changes in the theory of atomic structure have come about as a result of new experimental evidence.

Write the numbers 1-4 in the boxes next to the following landmark theories to show the order in which they were developed.

The nuclear model		**Bohr's nuclear model**	
Tiny solid spheres		**The plum pudding model**	



The Bore model...

The theory changed further when scientists found evidence that the nucleus was made up of two types of smaller particles — protons and neutrons.

Who discovered the neutron?

.....

Q1 For each of the following discoveries, describe the model of the atom that existed at the time of the discovery, and the new model that was proposed as a result of the discovery.

a) The discovery of the electron.

.....

.....

.....

.....

b) When alpha particles are fired at a thin sheet of gold, some are deflected more than expected, including being deflected backwards.

.....

.....

.....

.....

.....

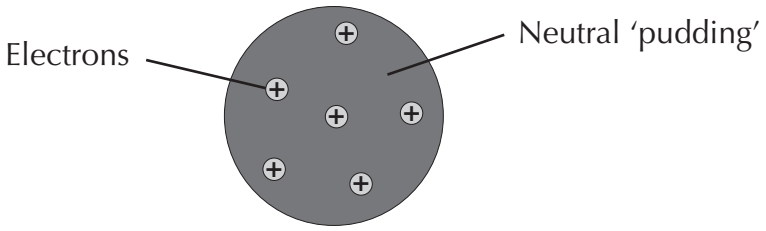
.....

.....

Q2 Dylan and Zara draw diagrams to represent different models of the atom.

a) **Figure 1** shows Dylan's labelled diagram of the plum pudding model. Dylan has made two mistakes in his diagram. Identify these mistakes and describe how Dylan should correct them.

Figure 1



Mistake 1: .....

.....

Correction: .....

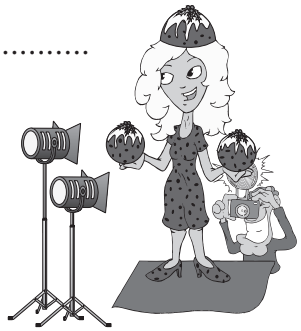
.....

Mistake 2: .....

.....

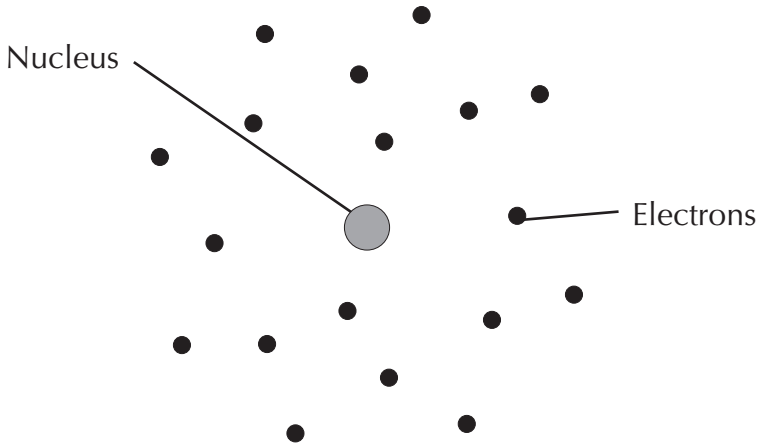
Correction: .....

.....



b) Zara is drawing the Bohr model of the atom. **Figure 2** shows her incomplete diagram. Complete **Figure 2** so that it shows the Bohr model.

Figure 2



All this talk of pudding is making me hungry...

It's really important you don't just learn how the model of the atom changed over time; you also need to know why. It's a classic example of the scientific method in action — a theory can only last as long as it can explain all available evidence.

Electronic Structure

Ok, so electrons are found in shells, but how are they arranged?

Warm-Up

In an atom, electrons always move around the nucleus in fixed shells. These shells are sometimes called energy levels. The shells closest to the nucleus have the lowest energy — electrons occupy these shells first.

There is a set maximum number of electrons allowed in each shell. Complete the table below by writing the numbers of electrons allowed in the first three shells.

Shell	Maximum number of electrons
1st	.....
2nd	.....
3rd	.....

The electronic structure of an element tells you how many electrons an atom of that element has in each shell. It can be shown as a diagram or as numbers.

When you're drawing or writing the electronic structure of an element, you first need to find out the total number of electrons that an atom of that element has. How can you do this?

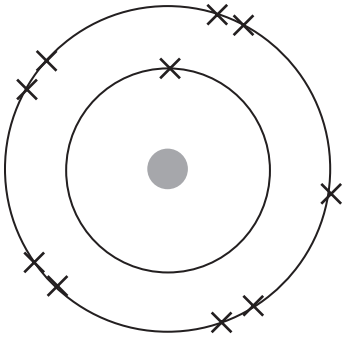
.....

.....

.....

Q1 **Figure 1** incorrectly shows the electronic structure of neon.

Figure 1



a) Describe what is wrong with **Figure 1**.

.....

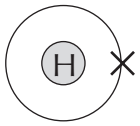
.....

.....

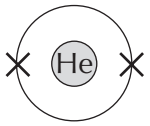
b) Write the correct electronic structure for neon as numbers.

.....

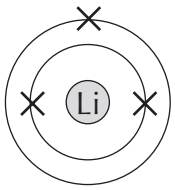
Q2 Complete the full electronic structures for the elements below. The first three have been done for you.



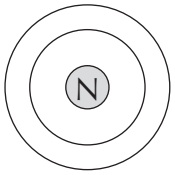
Hydrogen



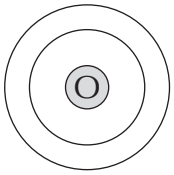
Helium



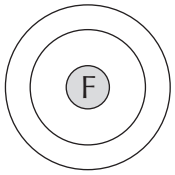
Lithium



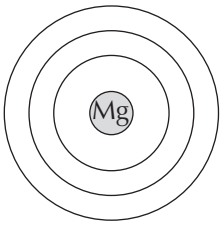
a) Nitrogen



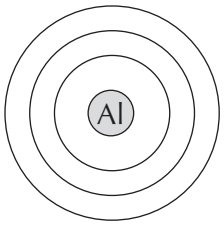
b) Oxygen



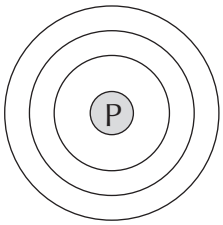
c) Fluorine



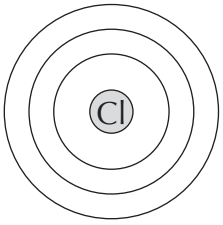
d) Magnesium



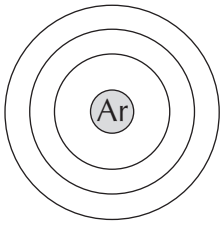
e) Aluminium



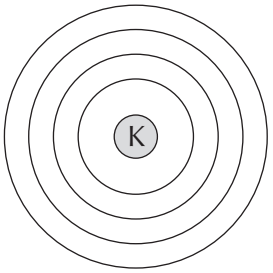
f) Phosphorus



g) Chlorine

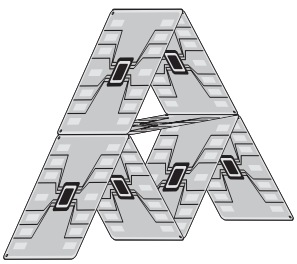


h) Argon



i) Potassium

Q3 Electronic structures can also be used to represent the arrangement of electrons in ions.



a) A potassium atom loses an electron to form a potassium ion. Write the electronic structure of a potassium ion.

.....

b) An oxygen atom gains two electrons to form an oxygen ion. Write the electronic structure of an oxygen ion.

.....

What did chemists wear in the 80s? Shell suits...

Ok, so this looks like an unfamiliar and slightly scary topic, but when you break it down it's just about following a set of simple rules. As long as you remember to fill your shells one at a time and not overfill them, life's a beach.

The Periodic Table

It's more than just a pretty poster on your classroom wall...

Warm-Up

The periodic table was developed by chemists to help them understand patterns in the properties of elements. Use the words in the box below to complete the following passage about the periodic table. You may need to use some words more than once.

groups	reactivity	electrons	atomic number
atomic mass	periods	atoms	protons

Early periodic tables were produced by placing the elements in order of ..... , but in the modern periodic table the elements are arranged in order of ..... . The columns in the table are called ..... and the rows are called ..... . Elements with similar properties are found in the same ..... in the periodic table. These elements all have the same number of ..... in their outer shell, and so all react in a similar way.

In early periodic tables, some elements were placed in the wrong groups. Describe the two things Dmitri Mendeleev did to make sure elements were in the correct group.

1. .....

.....

2. .....

.....

Q1 Select from the elements below to answer the following questions.

iodine nickel phosphorus sodium radon krypton calcium

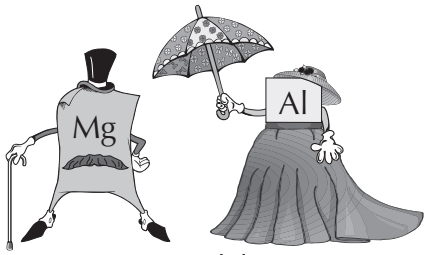
a) Which **two** elements are in the same group?

..... and .....

b) Name **two** elements which are in Period 3.

..... and .....

c) Name an element in Group 1. .....



A period drama

d) Name an element with seven electrons in its outer shell. .....

e) Name **one** non-metal which is not in Group 0. .....

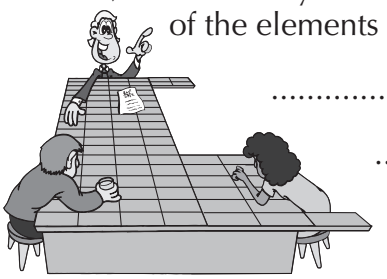
Q2 **Table 1** shows some information about selected elements from the periodic table.

Table 1

Name	Group number	Period number	Electronic structure
.....	4	.....	2, 4
.....	.....	3	2, 8, 4
Boron	3	.....	2, 3
.....	6	.....	2, 8, 6
Beryllium	.....	2	2, 2

a) Complete **Table 1**.

b) What do you notice about how the group and period numbers of the elements relate to their electronic structures?



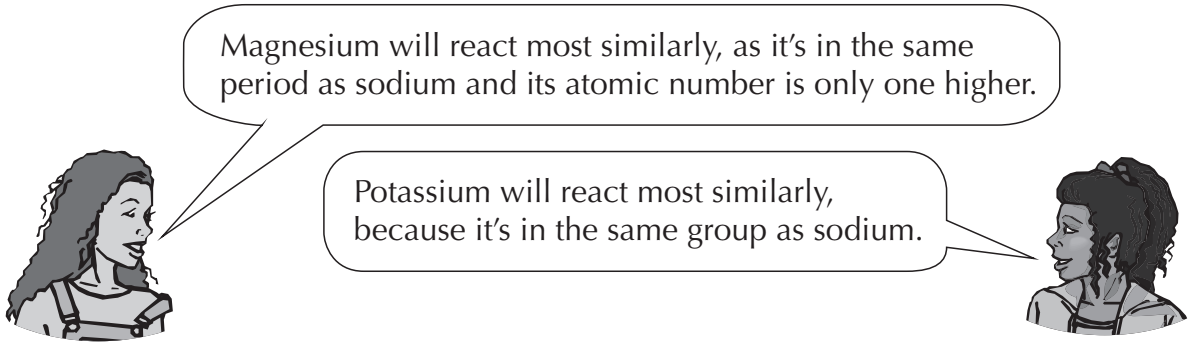
.....

.....

.....

Q3 Beth and Aaliyah are investigating the reactions of sodium, potassium and magnesium with water.

They start by adding a piece of sodium metal to water. The sodium melts and whizzes around the surface of the water as it reacts to form a gas and a colourless solution. Beth and Aaliyah predict which of the other metals will react most similarly to the sodium.



Beth Aaliyah

Who is correct? Explain why she is correct.

.....

.....

.....

Why couldn't hydrogen enter the battle of the bands? It's not in a group...

The periodic table is a really handy way of displaying a load of information about the elements. You'll get given a copy in the exam, but it's worth getting familiar with it now so you can extract the information you need when you need it.

Metals and Non-Metals

Doom, death, thrash, folk, Viking... I know my metals.

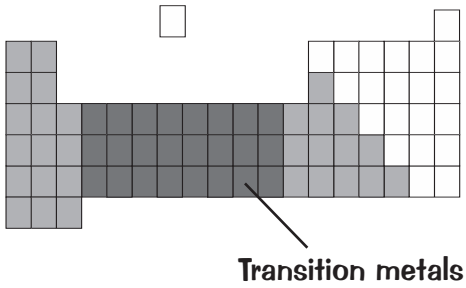
Warm-Up

Non-metals are found at the far right and top of the periodic table.
They tend to either share or gain electrons to get a full outer shell.
Metals are elements found to the left and towards the bottom of the periodic table.

Circle the correct words to complete the following passage about metals.

Metals to the left of the periodic table have **many** / **few** electrons to remove in order to be left with a full outer shell. Metals towards the bottom of the periodic table have outer electrons which are **close to** / **far away from** the nucleus and so feel a **stronger** / **weaker** attraction to it. This means that **not much** / **a lot of** energy is needed to remove electrons from the metal.

Transition metals are found in the middle of the periodic table. They have the properties expected of typical metals, but also have some special properties of their own.



Q1 **Table 1** shows the properties of four elements found in the periodic table.

Table 1

Element	Melting point (°C)	Density (g/cm^3)	Electrical conductivity
A	1084	8.90	Excellent
B	1064	19.3	Excellent
C	115	2.07	Very poor
D	1536	7.87	Very good

a) Which **three** of the elements in **Table 1** are most likely to be metals?

.....

b) Explain why the other element is least likely to be a metal.

.....

.....

.....

Q2 In the experiment shown in **Figure 1** some identically sized rods of different materials (A, B, C and D) were heated at one end and temperature sensors were connected to the other ends. The graph in **Figure 2** shows the results of the experiment.

Figure 1

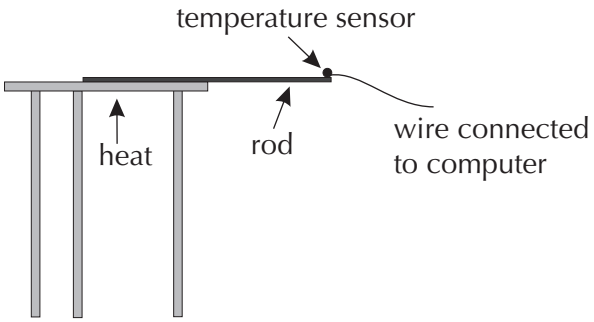
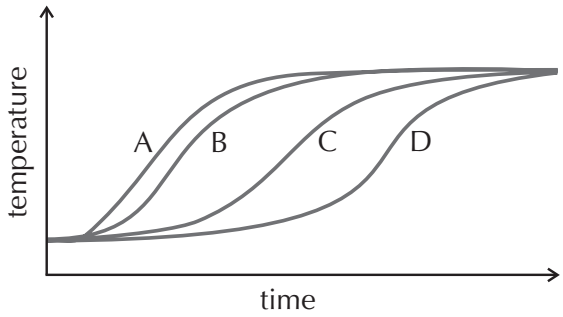
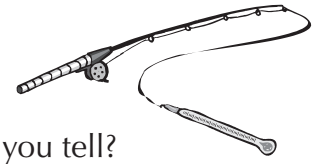


Figure 2



a) Which **two** rods do you think were made from metals?

.....



b) Which of the metals was the best conductor of heat? How can you tell?

.....

.....

Q3 **Table 2** gives some data for five elements.

Table 2

Element	Melting point (°C)	Density (g/cm^3)	Conducts electricity as solid?	Colour of oxide (at 20 °C)
A	1455	8.9	Yes	Green
B	44	1.82	No	White
C	3550	3.51	No	Colourless
D	1536	7.87	Yes	Red
E	98	0.97	Yes	White

a) i) Identify the elements in **Table 2** that are transition metals.

.....

ii) Explain your answers.

.....

.....

b) Give a use for **one** named transition metal.

.....

These questions will really test your metal...

If you're struggling to remember the properties of metals, try linking them to some of the things you use them for in everyday life. For example, metals are used to make saucepans because they have high melting points (so won't melt all over your hob) and are good conductors of heat (so your food actually gets cooked).

Group 1 Elements

Time to look at one of the groups from the periodic table in more detail...

Warm-Up

The elements in Group 1 are known as the alkali metals.
They each have one electron in their outer shell, which makes them highly reactive.

Circle the correct words to complete the passage below about alkali metal reactions.

It doesn't take much energy for alkali metals to lose their outer shell electron, and so they readily form **1+** / **1–** ions. Because they form ions so easily, alkali metals always form **covalent** / **ionic** compounds. They react with water to produce **hydrogen** / **oxygen** gas and a **hydroxide** / **chloride** solution.

Q1 The elements of Group 1 display trends in their properties.

Choose an element from the box below to answer each of the following questions.
Use the periodic table to help you.

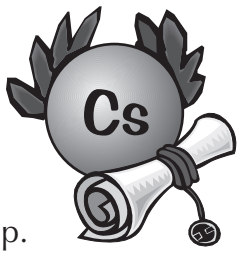
rubidium	sodium	potassium	lithium	francium	caesium

a) Which element has the highest relative atomic mass?

.....

b) Which element is the least reactive element?

.....



c) The melting points of the Group 1 metals decrease down the group.
Which element has a higher melting point than sodium?

.....

Q2 Alkali metals should be stored under oil.

A scientist finishes working with a sodium sample and puts it in a jar.
He forgets to add oil to the jar. When he next wants to use the sample,
he notices that the surface has changed from a shiny silver to a dull grey.
Explain what has happened to the sodium.

.....

.....

.....

Q3 A piece of lithium is heated in chlorine gas.

a) Write a word equation for the reaction that takes place.

.....

b) Write a balanced symbol equation for the reaction. Include state symbols.

.....

Q4 Archibald dropped samples of three different alkali metals, **A**, **B** and **C**, into bowls of water. Each sample has the same mass and surface area. In each case, the metal reacted with the water and disappeared.

a) The time taken for each metal to disappear is shown in **Table 1**.

Table 1

Metal	Time taken to disappear (s)
A	27
B	8
C	42

i) Which of the metals in **Table 1** is the most reactive? How can you tell?

.....

.....

ii) The three metals used were lithium, sodium and potassium. Use the results in **Table 1** to deduce the identity of metals **A**, **B** and **C**.

A = ... **B** = ... **C** = ...

b) i) What products were formed in the reaction between sodium and water?

.....

ii) Archibald says: "The amount of time taken for rubidium to disappear in water will be shorter than for metal **A**, but longer than for metal **B**". Is his statement correct? Explain your answer in terms of the arrangements of electrons in the metals.

.....

.....

.....

.....

.....

Want to hear a joke about potassium? K...

Luckily for you, the reactions of Group 1 elements with water and with chlorine follow the same patterns. So if you know the word and balanced symbol equations for one Group 1 element, you actually know them all. All you need to do is swap out the name or symbol of the Group 1 element with whichever one you need. Simple.

Group 7 Elements

Skip over Groups 2-6 — Group 7's the next one you need to know about.

Warm-Up

The elements of Group 7 are known as the halogens. The halogens are non-metals that exist as molecules which are pairs of atoms. Just like in Group 1, there are trends in the properties of the elements as you move down Group 7.

Write the halogens from the box below in order of increasing relative molecular mass.

Iodine	Fluorine	Bromine	Astatine	Chlorine

....

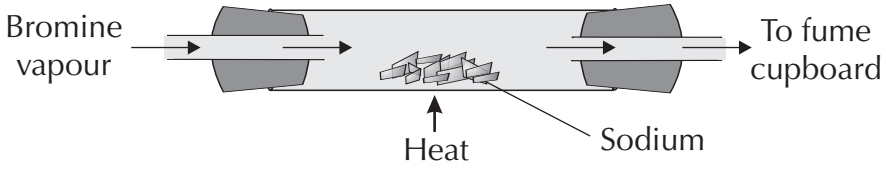
Lowest M_r **Highest M_r**

Draw lines to match the first three halogens to their melting points.

Chlorine	**Bromine**	**Fluorine**
–7 °C	**–220 °C**	**–101 °C**

Q1 Sodium metal was reacted with bromine vapour using the apparatus shown in **Figure 1**. New white crystals were formed during the reaction.

Figure 1



a) What type of bonding is present in the white crystals?

.....

b) The reaction in **Figure 1** was repeated under the same conditions, first using iodine instead of bromine, and then using chlorine. For each of these reactions, state whether it would be faster or slower than the reaction shown in **Figure 1**, giving a reason for your answer.

i) The reaction between sodium and iodine vapour.

.....

ii) The reaction between sodium and chlorine gas.

.....

Q2 Fluorine, F_2, reacts with hydrogen, H_2, to form hydrogen fluoride, HF.

a) i) What type of bond is present in hydrogen fluoride?

.....

ii) Explain why this type of bond is formed.

.....

.....

b) Fluorine reacts explosively with hydrogen at low temperatures. Iodine reacts slowly and incompletely with hydrogen when heated strongly. Explain this difference in reactivity in terms of the arrangement of electrons in fluorine and iodine atoms.

.....

.....

.....

Q3 Equal volumes of bromine water were added to two separate test tubes, each containing a different potassium halide solution. The observations are shown in **Table 1**.

Table 1

Solution	Observations
potassium chloride	no reaction
potassium iodide	reaction took place

a) Explain these observations.

.....

.....

.....

.....

b) Write a balanced symbol equation, including state symbols, for the reaction with potassium iodide solution.

$Br_{2(aq)}$ + ... → ..... + ...

c) Would you expect a reaction between:

i) bromine water and potassium astatide solution? .....

ii) bromine water and potassium fluoride solution? .....

I'm just an average kind of guy — I'm the bro-mean...

You won't need to remember individual melting or boiling points of any of the elements, but you could be asked to predict some of them using given information, so make sure you understand how they change as you move down the group.

Group 0 Elements

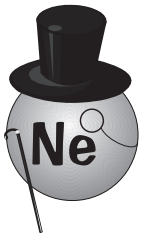
What comes after Group 7? Group 0 of course...

Warm-Up

The Group 0 elements are also known as the noble gases. They are found on the far right of the periodic table and are all unreactive gases at room temperature.

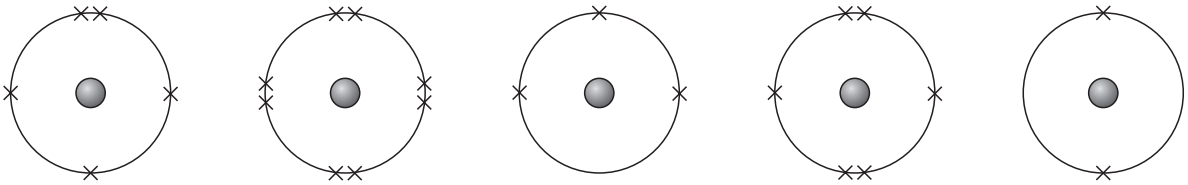
Tick the statements below which are true:

- ☐ **A The noble gases are non-metals.**
- ☐ **B The noble gases exist as molecules made of pairs of atoms.**
- ☐ **C The noble gases have full outer electron shells.**
- ☐ **D The noble gases easily form both positive and negative ions.**



Q1 **Figure 1** shows the outer shell electron arrangements of five atoms, **A**-**E**.

Figure 1



a) Which of the five atoms could be Group 0 elements?

.....

b) Explain your answer.

.....

.....

Q2 Some light bulbs contain a thin metal filament. If these bulbs were filled with air, oxygen would react with the filament causing it to burn away. To avoid this, the light bulbs are filled with argon.

Explain why argon is suitable for this use.
You should refer to the arrangement of the electrons in an argon atom in your answer.

.....

.....

.....

.....

Q3 There are trends in the properties of the Group 0 elements.

a) i) Complete **Table 1** using the numbers provided to show the relative atomic masses and the boiling points of the Group 0 elements.

Table 1

4 –246 –186 40

Element	Relative atomic mass	Boiling point (°C)
Helium	.....	–269
Neon	20	.....
Argon	.....	.....

ii) The melting points of the elements increase moving down Group 0. Argon is a solid at –200 °C. Predict the state of krypton at –200 °C. Explain your prediction.

Prediction: .....

Explanation: .....

.....

.....

b) The densities of the Group 0 elements increase as you go down Group 0. **Table 2** shows the densities of helium and argon at 20 °C.

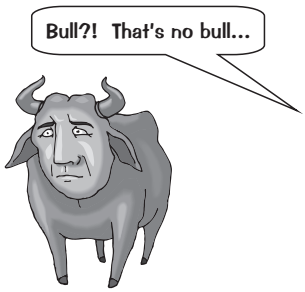


Table 2

Element	Density (g/cm^3)
Helium	0.0002
Argon	0.0018

Predict the density of neon.

.....

Q4 Mariya tries to burn a sample of neon gas with oxygen. Nothing happens.

Explain why, in terms of the arrangement of the electrons in neon.

.....

.....

.....

.....

Trying to think of a joke for this page, but my wit and creativity argon...

So, surprise surprise, the Group O elements show trends in their properties, just like the elements in Groups 1 and 7. Thankfully, they don't follow any of the trends that I did back in the noughties, and they are much easier to predict.

Ions and Ionic Bonding

Ions sound pretty space age. They're even more exciting than that, believe me.

Warm-Up

Ions are charged atoms, or groups of atoms. They form when atoms gain or lose electrons to get a full outer shell of electrons. This gives them the same electronic structure as a noble gas.

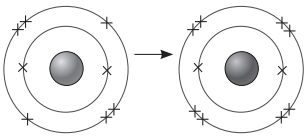
A metal atom can transfer the electrons it loses to a non-metal atom. The ions which form as a result of these electrons being transferred can bond due to electrostatic attraction — this is ionic bonding. Dot and cross diagrams can be used to show an ionic compound's electronic structure.

Circle the correct words to complete the passage below.

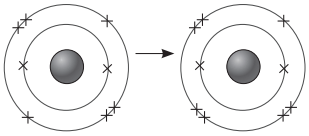
Elements in Group 1 and Group 2 are **metals** / **non-metals** which **gain** / **lose** electrons to form **positive** / **negative** ions. Elements in Groups 6 and 7 are **metals** / **non-metals** which **gain** / **lose** electrons to form **positive** / **negative** ions.

Q1 Which of the following diagrams shows an oxide ion forming from an oxygen atom?

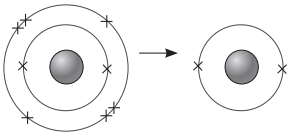
☐ **A**



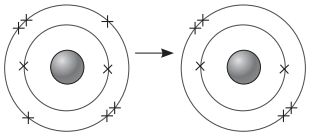
☐ **B**



☐ **C**



☐ **D**



Q2 Different atoms need to gain or lose different numbers of electrons to get a full outer shell.

a) How many electrons do the following elements need to lose in order to get a full outer shell? Write your answers in the boxes.

lithium ☐ calcium ☐ potassium ☐

b) How many electrons do the following elements need to gain in order to get a full outer shell? Write your answers in the boxes.

sulfur ☐ chlorine ☐ fluorine ☐

Q3 Rhodium is an element which can form 3+ ions.
Is rhodium a metal or a non–metal? Explain your answer.

.....

.....

Q4 Iodine and chlorine react together to form a compound with the formula ICl.
Iodine and chlorine do not form ionic bonds with each other in iodine chloride.
Explain why iodine and chlorine do not form ionic bonds with each other.

.....

.....

.....

Q5 Potassium selenide, K_2Se, is an ionic compound. Potassium (K) is in Group 1 and selenium (Se) is in Group 6. Draw a dot and cross diagram to show the bonding in potassium selenide. You only need to draw the outer shells of electrons.
Include all charges.

Q6 Argon is a noble gas in Group 0 of the periodic table. It's very stable but scientists have found a way to make argon lose one electron.
The resulting argon ions are used in certain types of laser.

a) Draw a diagram to show the electronic structure of an argon ion.
You only need to draw the outer shell electrons. Include the charge of the ion.

b) Which atom has the same electronic structure as an argon ion?

.....

I'll happily ion your shirts — there's a charge though...

These ideas can seem a bit confusing at first, but with practice, they definitely get easier. Make sure you get loads of practice at drawing dot and cross diagrams and that you can describe how ionic bonds are formed.

Ionic Compounds

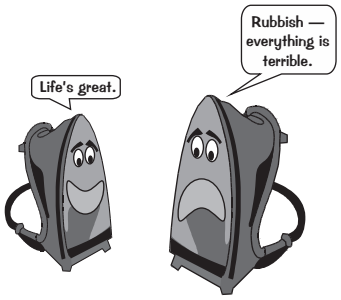
Ironic compounds are contrary to what you'd expect. Luckily, ionic compounds are simpler...

Warm-Up

In an ionic compound, oppositely charged ions are held together closely by very strong electrostatic forces of attraction. The strong forces of attraction between ions give ionic compounds similar properties.

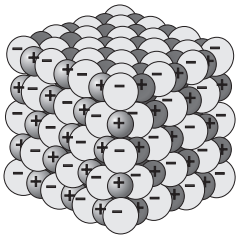
Tick the box next to each statement that is true.

- ☐ **A Ionic compounds conduct electricity in all states.**
- ☐ **B Ionic compounds only conduct electricity when molten.**
- ☐ **C Ionic compounds have high melting points.**
- ☐ **D Ionic compounds don't melt.**

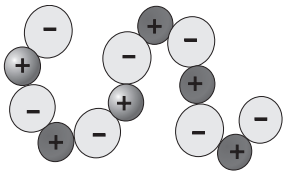


Q1 Diagrams can be used to represent the structures of chemical substances.

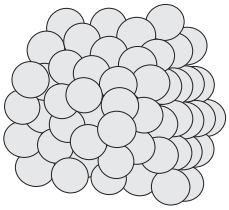
a) Lithium chloride has a similar structure to sodium chloride. Which of the following diagrams could be used to represent the bonding in solid lithium chloride?



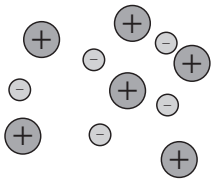
☐ **A**



☐ **B**



☐ **C**



☐ **D**

b) What type of structure does solid lithium chloride have?

.....

c) Give the limitations of using a ball and stick model to represent the structure of lithium chloride compared to using the model you chose in part a).

.....

.....

.....

.....

Q2 Some elements and the ions they form are shown below.

beryllium, Be^{2+}	potassium, K^{+}	iodine, I^{-}	sulfur, S^{2-}

Write the formulas of four ionic compounds which can be made using just these elements.

1. ..... 2. .....

3. ..... 4. .....

Q3 Potassium chloride is an example of a salt found in the sea. Johan carries out an experiment to find out if potassium chloride conducts electricity. He tests the compound when it's solid and when it's dissolved in water.

a) Circle the correct options in **Table 1** to show Johan's expected results.

Table 1

	When solid	When dissolved in water
Conducts electricity?	Yes / No	Yes / No

b) Explain your answers to part a).

.....

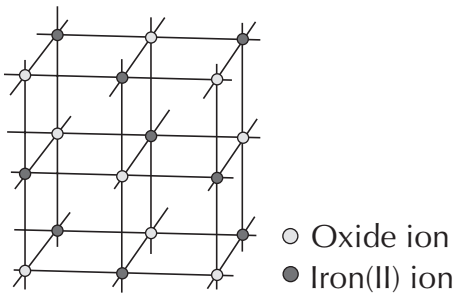
.....

.....

Q4 **Figure 1** shows the structure of iron(II) oxide. In forming the compound, the iron atoms lost two electrons each.

Use **Figure 1** to work out the empirical formula of iron(II) oxide. Show your working in the space below.

Figure 1



Empirical formula of iron(II) oxide: .....

One giant ionic salad — no tomato but plenty of lattice please...

If you're told a compound is ionic, you can usually predict its physical properties. So whether you have sodium chloride, bismuth oxychloride or even sodium tetrahydridoborate, you know it's probably going to have a high boiling point.

Covalent Bonding

Share your chocolate with a stranger. If they share some with you too, you've formed a bond.

Warm-Up

Covalent bonds are formed when atoms share electrons in bonds.

A covalent bond forms between...

...a metal atom and a non-metal atom. ☐ **... two non-metal atoms.** ☐

...two metal atoms. ☐ **...an ion and a non-metal.** ☐

The positively charged nuclei are attracted to the shared pair of electrons through electrostatic forces. Covalent bonds are very strong.

Each atom will form enough covalent bonds to...

...empty its outer shell of electrons. ☐ **...fill its outer shell of electrons.** ☐

Dot and cross diagrams can be used to show the covalent bonds in a molecule.

Cross Dot

Q1 Silicon has the electronic structure 2, 8, 4. Use this information to predict the maximum number of covalent bonds one atom of silicon will form in a simple molecule. Explain your answer.

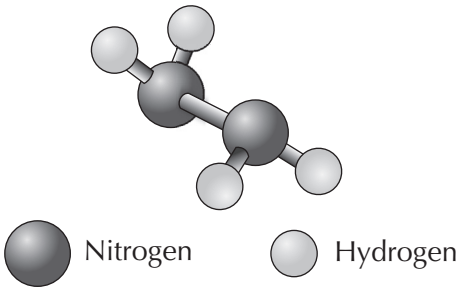
.....

.....

.....

Q2 **Figure 1** shows a molecule of hydrazine.

Figure 1



a) Write down the molecular formula of hydrazine.

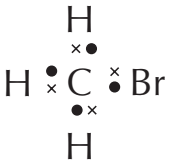
.....

b) Give **two** advantages of using the model shown in **Figure 1** to represent the structure of hydrazine over using a dot and cross diagram.

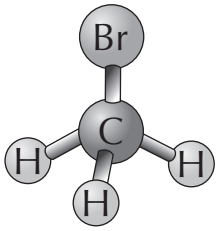
.....

.....

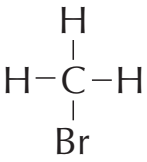
Q3 Which of the following diagrams does not represent the structure of bromomethane, CH_3Br?



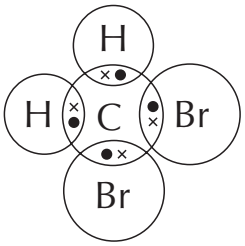
☐ **A**



☐ **B**



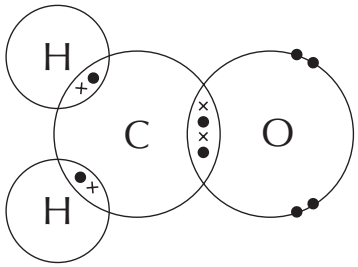
☐ **C**



☐ **D**

Q4 The bonding in formaldehyde is represented in **Figure 2**.

Figure 2



a) What is the molecular formula of formaldehyde?

.....

b) How many covalent bonds has carbon formed in formaldehyde?

.....

c) Draw the displayed formula of formaldehyde in the space below.

Remember — one covalent bond is shown by one line in the displayed formula.

d) What information is given by **Figure 2** that is not given by the displayed formula of formaldehyde?

.....

.....

Terrible covalent bonding jokes — best not to be shared....

Covalent bonds are the bread and butter of a lot of chemistry, so you've got to make sure you understand them well. Make sure you can explain how they form. Practise drawing dot and cross diagrams too — they're pretty important.

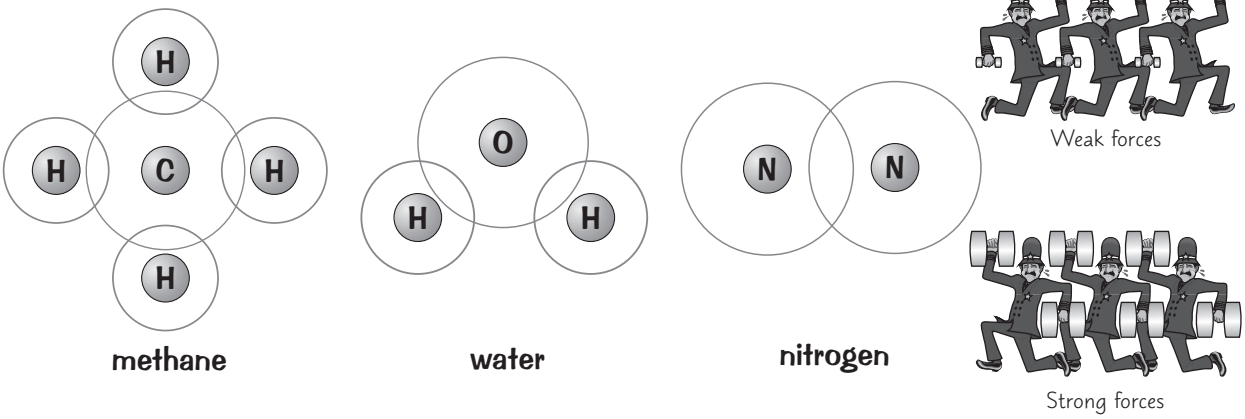
Simple Molecular Substances

Simple by name, simple by nature. And with practice, answering these questions will be simple too.

Warm-Up

Simple molecular substances are made up of molecules containing a small number of atoms joined by covalent bonds. The forces of attraction between these molecules are generally very weak, but they get stronger as molecules get larger.
Simple molecular compounds can be represented using dot and cross diagrams.

Complete the dot and cross diagrams of the simple molecular compounds shown below.



Q1 **Table 1** shows some properties of four substances.

Table 1

Substance	Melting Point (°C)	Conducts electricity when liquid?
A	1085	yes
B	1650	no
C	–39	yes
D	–102	no

a) Substance **A** is not a simple molecular substance.
How can you tell this using **Table 1**?

.....

.....

b) Which substance is a simple molecular substance? Explain your answer.

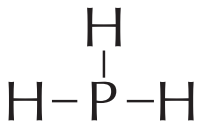
.....

.....

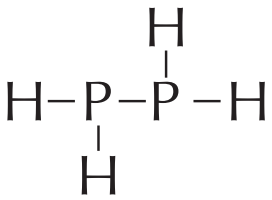
Q2 Phosphane and diphosphane are simple molecular substances. Their displayed formulas are shown in **Figure 1**.

Figure 1

phosphane



diphosphane



a) Phosphane has a similar structure and bonding to ammonia. Draw a dot and cross diagram to represent the bonding in phosphane. You only need to draw the outer shell electrons.

b) Ammonia (NH_3) has a higher melting point than diphosphane. Why is this surprising?

You don't need to know why ammonia has a higher melting point. Just apply what you know about melting in simple molecular substances.

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c) A scientist has a sample of phosphane gas and a sample of diphosphane gas. Both samples are kept at the same temperature. The scientist cools both samples at the same rate. Which sample would you expect to turn into a liquid first? Explain your answer.

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Don't make me remember all this — ammonia wee lad...

Luckily, there's not a lot you need to remember. You just need to know what the key properties of simple molecular substances are. Make sure you can apply what you know, and you'll be able to tackle any old question thrown at you.

Polymers and Giant Covalent Structures

Polymers are really repetitive — with enough practice, you should be an expert. Off you go...

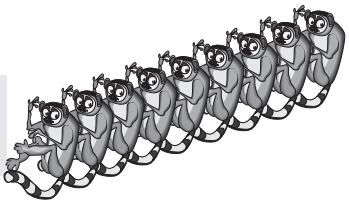
Warm-Up

Polymers are long molecules in which the atoms are all covalently bonded.
Small repeating units make up the long polymer.
Giant covalent structures are large networks of atoms which are all covalently bonded.

Complete the passage below by adding in the correct missing words.

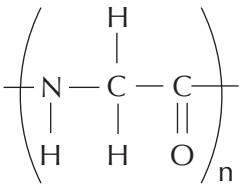
intermolecular forces solid ionic repeating units covalent liquid

Polymers are chains of ..... . Polymers have stronger ..... between them than simple ..... molecules. This means they're usually ..... at room temperature.



Q1 Poly(glycine) is a polymer made from the amino acid, glycine. The displayed formula of the repeating unit is shown in **Figure 1**.

Figure 1

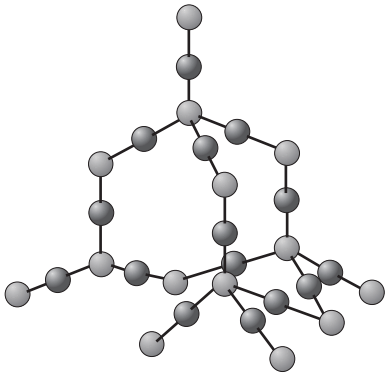


Write the molecular formula of poly(glycine).

.....

Q2 **Figure 2** shows part of the structure of substance **X**.

Figure 2



Substance **X** contains two types of atom.
Each atom forms four covalent bonds.

a) Predict the state of substance **X** at room temperature.

.....

b) Tick the correct box to complete the following sentence.

Substance **X** must be made up of...

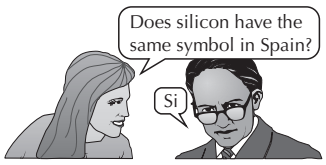
...two metals. ☐ ...two non-metals. ☐ ...a metal and a non-metal. ☐

Q3 Carbon is directly above silicon in Group 4 of the periodic table.
Table 2 shows the boiling points of both silicon dioxide and carbon dioxide.

If something sublimes it turns straight from a solid into a gas.

Table 2

Compound	Boiling Point (°C)
carbon dioxide	–78 (sublimes)
silicon dioxide	2230



Explain the difference in the boiling points of carbon dioxide and silicon dioxide.

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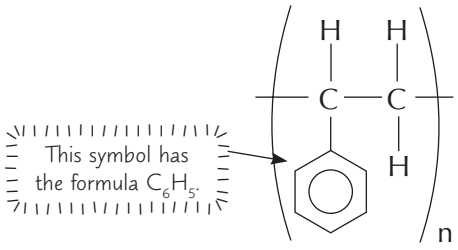
Q4 The structure of poly(styrene) is shown in **Figure 2**.

What is the molecular formula of the repeating unit?

.....

Figure 2



This symbol has the formula C_6H_5.

Q5 Propene, C_3H_6, is a gas at room temperature.
Propene can polymerise to form poly(propene).

a) Write down the molecular formula of poly(propene).

.....

b) Predict whether poly(propene) is a solid, liquid or gas at room temperature.
Explain your answer.

.....

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Polymers — they're really repetitive...

Some of these questions were a little tricky and were supposed to make you think a bit about what you know. If you're asked to explain melting or boiling temperatures, think about intermolecular forces and bonding between molecules.

Allotropes of Carbon

Diamonds are everyone's best friend. The other allotropes are pretty nifty too. See for yourself.

Warm-Up

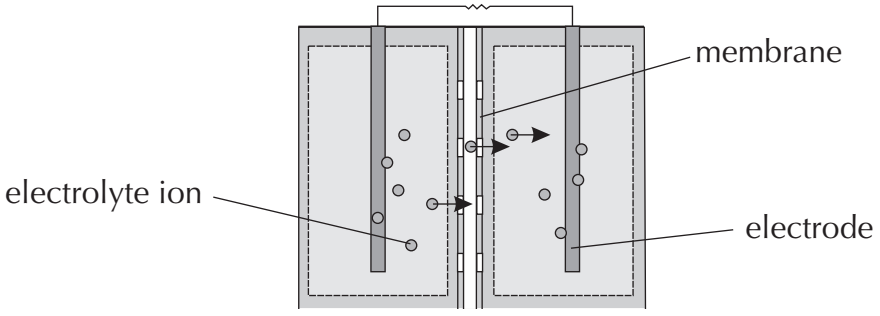
Allotropes are different structural forms of the same element in the same physical state. Carbon has several allotropes. These include diamond, graphite, graphene and the various fullerenes, such as carbon nanotubes.

Complete this table showing the properties of several allotropes of carbon.

Allotrope	Structure	Conducts electricity?
.....	giant covalent	no
.....	layers of carbon atoms arranged in hexagons with no covalent bonds between layers	.....
.....	single layer of carbon atoms arranged in hexagons	.....
.....	molecules of carbon shaped like hollow balls or cylinders	cylindrical molecules conduct electricity

Q1 **Figure 1** shows a diagram of a battery. Some carbon allotropes can be used to make the electrodes in batteries. Electrodes make up part of the electrical circuit.

Figure 1



a) Why isn't diamond a suitable carbon allotrope choice for making electrodes?

.....

b) The electrodes in some batteries are made from graphite. The performance of such batteries can be improved by replacing the graphite electrodes with metal electrodes coated with a very thin layer of another carbon allotrope.

Suggest the identity of this carbon allotrope. Explain your suggestion.

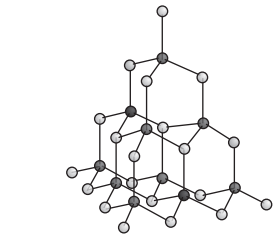
.....

.....

Q2 Boron nitride is a compound made from boron and nitrogen atoms.
Scientists are interested in boron nitride because it forms structures, called polymorphs, which are very similar to the structures of some carbon allotropes. The polymorphs of boron nitride therefore have very similar properties to these carbon allotropes.

a) The polymorph c-boron nitride is a hard material and so is often used as a cutting tool. Its structure is shown in **Figure 2**. Use your knowledge of carbon allotropes to suggest why c-boron nitride is used as a cutting tool.

Figure 2



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b) i) The polymorph h–boron nitride is a soft and slippery material which is often used as a lubricant. Its structure is shown in **Figure 3**. Use your knowledge of carbon allotropes to suggest why h-boron nitride is used as a lubricant.

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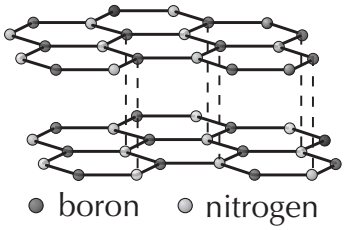
Figure 3



ii) h–boron nitride has a similar structure to a carbon allotrope which conducts electricity. However, h–boron nitride does not conduct electricity. Suggest a difference between h-boron nitride and this carbon allotrope which could explain this. Explain your answer.

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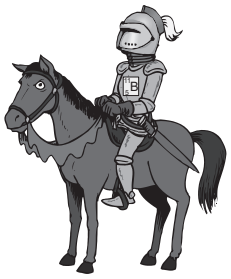


My friend prefers oval cut diamonds. My personal favourite is Neil...

Diamond is pretty hard, but with plenty of practice, you should soon find questions on carbon structures pretty easy. Make sure you can recognise the structures of the different allotropes and that you can explain their properties too.

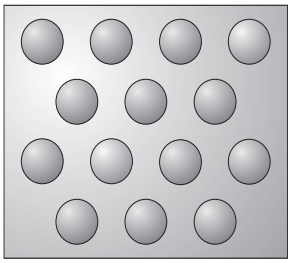
Metallic Bonding

Seeing as you're (probably) such a fan, here are even more questions about bonding. Such a treat.

Warm-Up

Metals are elements which are good conductors.
At room temperature, they are solid (except mercury) and malleable.
Metals have a giant structure. The outer shell electrons of metal atoms are delocalised (they're free to move around).
The structure is held together by strong electrostatic attraction between these delocalised electrons and positively charged metal ions. Alloys are solid mixtures of metals.

The diagram on the right represents the bonding in sodium.
Complete the diagram by adding delocalised electrons and charges on sodium ions.



Q1 Read the following statements about metals. Tick all the statements which are true.

- ☐ **A** The properties of metals mean they are good for insulating buildings.
- ☐ **B** All alloys are malleable as layers of atoms can easily slide over each other.
- ☐ **C** Metals conduct electricity because the electrons are held in fixed positions.
- ☐ **D** Pure metals are softer than alloys because layers of atoms can slide over each other.

Q2 Copper is often used as a material for gas piping. When bought, copper pipes are long and straight, but are then bent into the shapes required. Suggest why pure copper is used for this purpose, rather than a copper alloy?

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Q3 Household radiators are used to warm rooms and are often made from certain metals. What property of these metals enables them to warm a room? Explain why metals have this property.

.....

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Q4 Solder is an alloy of the metals lead and tin. Kuba is carrying out an experiment to compare the hardness of a piece of lead with the hardness of a piece of solder.

Kuba first scratches the surface of the lead with solder and records his observations. He then scratches the surface of the solder with the lead. A scratch mark is left on the surface of one of the pieces but not on the other.

Harder materials leave scratch marks on softer materials. Suggest which material, lead or solder, has been marked? Explain your answer referring to the structure of each material.

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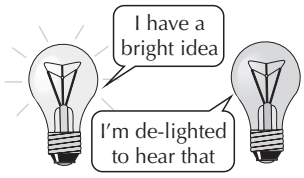
Q5 Incandescent light bulbs contain a thin metal wire called a filament. Filaments are often made from the metal tungsten. Passing electricity through the filament causes it to get hot and produce light.



a) Tungsten has a very high melting point which allows it to reach the temperatures necessary to produce light without melting. With reference to bonding, explain why metals can reach high temperatures without melting.

.....

.....

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b) Give **one** other property which makes tungsten a suitable material for use as a light bulb filament. Explain this property.

.....

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Pure metal's the best music — mixed metal's really alloying...

There isn't loads to learn when it comes to metallic bonding. It's important to be able to relate properties of metals and alloys to the bonding within them though. And make sure you don't confuse metallic bonding with the other types....

States of Matter and Changing State

Like teleporting from Alaska to Texas — one moment you're frozen and the next you've melted...

Warm-Up

There are three states of matter — solids, liquids and gases. A substance's state depends on the strength of the forces of attraction between its particles.
Particle theory is a model which can be used to explain how the particles in a material behave in each of these states. In particle theory, atoms, molecules or ions in a material are thought of as small, solid, inelastic spheres.
It's a useful model, but it has its limitations.

Sketch the arrangement of the particles in a solid, liquid and gas in the boxes below. Draw each particle as a small circle.

Solid **Liquid** **Gas**

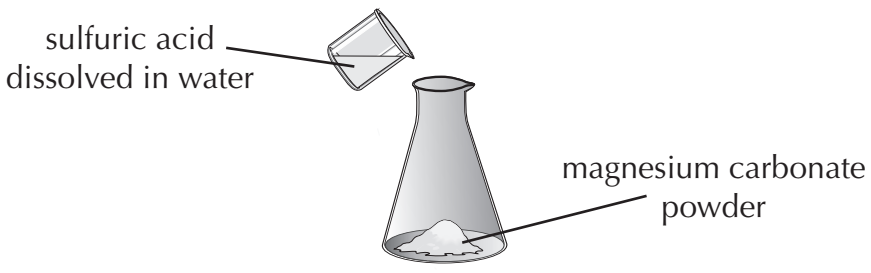
Q1 **Table 1** shows some information about a number of compounds. Fill in the empty row in **Table 1** with the correct state of each compound at room temperature (20 °C).

Table 1

Substance	Water	Sulfur	Mercury	Silica
Melting Point (°C)	0	115	–39	1713
Boiling Point (°C)	100	445	357	2950
State at Room Temperature	.....	.....	.....	.....

Q2 **Figure 1** shows an experiment in which sulfuric acid (H_2SO_4) is reacted with magnesium carbonate ($MgCO_3$).

Figure 1



Use **Figure 1** to complete the equation below by adding in state symbols.

$$MgCO_{3\,.....} + H_2SO_{4\,.....} \rightarrow MgSO_{4(aq)} + CO_{2(g)} + H_2O_{(l)}$$

Q3 **Table 2** shows the melting and boiling points of three compounds. **Table 3** does not.

Table 2

Compound	Melting Point (°C)	Boiling Point (°C)
propane	–188	–42
propanol	–126	97
glycerol	18	290

Table 3

a) Which of the compounds in **Table 2** are solid at 0 °C?

.....

b) Which of the compounds in **Table 2** freezes at the highest temperature?

.....

c) Which of the compounds in **Table 2** condenses at the lowest temperature?

.....

d) A scientist has a sample of propane in his lab. He stores it in a freezer at –190 °C. However, his freezer breaks and the temperature slowly rises to 20 °C. With reference to the forces between the propane particles, explain the changes in the arrangement of propane particles as the temperature rises.

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e) Why can't particle theory explain the difference in the melting points of glycerol and propane?

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Boil the kettle will you — set those particles free...

Particle theory is likely to crop up a lot in chemistry, so it's dead important you understand it all really well. And make sure you can interpret melting and boiling points to work out the state of a substance at a certain temperature.

Nanoparticles and their Uses

They're really, really, really, really small. But they're really, really, really cool — trust me...

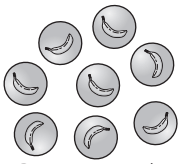
Warm-Up

Particles can be categorised based on their diameter. Nanoparticles consist of only a few hundred atoms and they have a large surface area to volume ratio. This gives them very different properties to the material when it's in bulk. These properties mean nanoparticles have lots of useful potential applications, so lots of research is being done to understand nanoparticles.

Give two examples of ways that nanoparticles can be used.

1. .....

2. .....



Bananoparticles

Q1 **Table 1** shows some information about three differently-sized particles of the same material.

Table 1

Particle	Particle Width (m)	Particle Width (nm)
1	3.4×10^{-6}	.....
2	4.0×10^{-8}	40
3	6.4×10^{-10}	.....

To convert a measurement from m to nm, multiply by 10^9.

a) Complete the boxes in **Table 1**.

b) Which of the following statements are true?

- ☐ **A** **1, 2** and **3** are all nanoparticles.
- ☐ **B** Only **2** is a nanoparticle.
- ☐ **C** **2** and **3** are nanoparticles.
- ☐ **D** Only **3** is a nanoparticle.

c) Calculate the surface area to volume ratio of particle **2**, assuming that the particle is a cube. Show your working in the space below.

Surface area to volume ratio = ... nm^{-1}

Q2 Titanium dioxide (TiO_2) catalyses a reaction which can break down the organic matter which makes up dirt. TiO_2 nanoparticles are used to coat self-cleaning windows for this purpose.

Suggest why TiO_2 nanoparticles are used to catalyse this reaction rather than bulk TiO_2.

.....

.....

.....

Q3 **Table 2** shows some useful properties of different nanoparticles.


Quantum Dot

Table 2

Type	Useful properties
Quantum dots (QDs)	• Can conduct electricity under the right conditions. • Glow brightly in various colours.
Magnetic nanoparticles (MNPs)	• Can be easily removed from liquids using magnets. • Generate heat when a magnetic field is applied.

a) Nanoparticles have potential applications in the diagnosis and treatment of cancer. They could be made to bind to tumours so that tumours can easily be seen by doctors.

Use **Table 2** to suggest which of the nanoparticles would be the most appropriate for this use. Explain your answer.

.....

.....

b) MNPs could be used to kill cancer cells. This would involve injecting MNPs into the body where they would be absorbed by tumours. A magnetic field would then be applied to generate enough heat to kill the cell.
Why might people worry about injecting MNPs into the body?

.....

.....

c) Nanoparticles could also be used to remove unwanted chemicals in drinking water. However, nanoparticles are too small to be caught by most conventional water filters. Many people are concerned about the presence of nanoparticles in drinking water.

Use **Table 2** to suggest why MNPs could be a good choice of nanoparticle to use in water treatment?

.....

.....

You say bulk is better — I say na–no way...

There's no doubt that nanoparticles are really exciting, but they also have their downsides. For all the benefits they bring, there are risks associated with them. They must all be considered before everyone goes nanoparticle crazy....

Relative Formula Mass and the Mole

Not the catchiest title for an adventure story, but then I suppose this is a chemistry book...

Warm-Up

The relative formula mass of a compound is calculated by adding together the relative atomic masses of all the atoms in the compound's molecular formula.

A substance's relative formula mass tells you the mass in grams of one mole of that substance. The mole is a unit used in chemistry to measure amounts.

Tick each type of particle below that can be measured in moles.

☐ **atoms** ☐ **molecules** ☐ **ions** ☐ **electrons**

One mole of a substance is the amount of that substance in which the number of particles is equal to the Avogadro constant. What is the value of the Avogadro constant?

.....

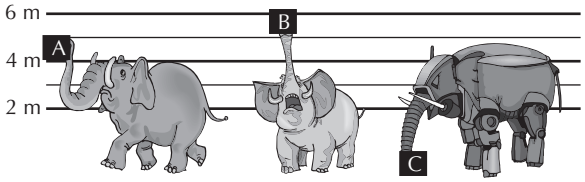
Q1 Use a periodic table to help identify the elements **A**, **B** and **C**.

Element **A** has an A_r of 4.
Element **B** has an A_r 3 times that of element **A**.
Element **C** has an A_r 4 times that of element **A**.

Element **A** = ...

Element **B** = ...

Element **C** = ...



Q2 The equation below shows a reaction between element **X** and water.

$$2X + 2H_2O \rightarrow 2XOH + H_2$$

The relative atomic mass, A_r, of H = 1 and of O = 16.
The total M_r of the products is 114. What is element **X**?

element X = ...

Q3 Calculate the percentage mass of the following elements in ammonium nitrate, NH_4NO_3.

To find the percentage by mass of an element use the following formula:

$$\% \text{ mass} = \frac{A_r \times \text{number of atoms of that element}}{M_r \text{ of the compound}} \times 100$$

Relative atomic masses (A_r): N = 14, H = 1, O = 16

a) Nitrogen

percentage mass =..... %

b) Oxygen

percentage mass = ... %

Q4 A pharmacist is synthesising aspirin, $C_9H_8O_4$, as part of a drugs trial. After the experiment, the pharmacist calculates that she has made 12.4 moles of aspirin. What mass of aspirin has the pharmacist made?

Relative atomic masses (A_r): C = 12, H = 1, O = 16

mass = ... g

Q5 A scientist finds a sample vial whilst clearing out a cupboard in the lab. The label on the vial says that it contains 0.075 moles of an unknown metal oxide.

a) The sample weighs 3.0 g. Calculate the M_r of the metal oxide.

M_r = ...

b) Which of these compounds could be the metal oxide?

☐ **A** Fe_2O_3 ☐ **B** MgO ☐ **C** CaO ☐ **D** Na_2O

What do chemists eat for brunch? Smashed Avogadro on toast...

Number of moles = mass in g ÷ M_r. You need to learn that equation and then practise using and rearranging it until you can do so standing on your head in a tank full of piranhas. Not that it'll be all that helpful to you there....

Conservation of Mass

Pretty straightforward these pages, but it's important stuff, so best get stuck in now, eh?

Warm-Up

The law of conservation of mass states that no atoms are created or destroyed during a chemical reaction. So no mass is lost or gained — mass is conserved.

Look at the equation below for the formation of magnesium hydroxide from magnesium oxide and water. Complete the table to show the numbers of each type of atom on each side of the equation.

$$MgO + H_2O \rightarrow Mg(OH)_2$$

Type of atom	Number of each type of atom	
	in reactants	in products
Mg	.....	.....
O	.....	.....
H	.....	.....

What do you notice about the numbers of atoms on each side?

.....

.....

Q1 When iron wool burns, the iron reacts with oxygen in the air to form iron oxide. There are no other products of the reaction.

4.4 g of iron wool is burnt, producing 6.3 g of iron oxide.
What mass of oxygen did the iron react with?

mass = ... g

Q2 The balanced symbol equation below shows a reaction between potassium and water.

$$2K + 2H_2O \rightarrow 2KOH + H_2$$

a) Use relative formula masses to show that mass is conserved during this reaction.

Relative atomic masses (A_r): K = 39, H = 1, O = 16

.....

.....

.....

.....

b) Explain why the potassium hydroxide and hydrogen produced by this reaction have the same total mass as the potassium and water that reacted.

.....

.....

.....

.....

PRACTICAL

Q3 A scientist added 6 g of zinc carbonate and 53 g of dilute sulfuric acid to a strong conical flask. The following reaction took place:

$$ZnCO_{3(s)} + H_2SO_{4(aq)} \rightarrow ZnSO_{4(aq)} + CO_{2(g)} + H_2O_{(l)}$$

When the reaction was complete, the scientist recorded the total mass of the products in the flask. She repeated the experiment. The results for both her experiments are shown in **Table 1**.

Table 1

Experiment	Total mass of reactants / g	Total mass of products / g
1	59	59
2	59	57

In one experiment, the scientist immediately sealed the conical flask with a bung following the addition of the reactants. In the other experiment, the conical flask was left open.

a) Use **Table 1** to identify whether the flask was open in experiment **1** or experiment **2**.

.....

b) Explain your answer.

.....

.....

.....

.....

Q4 Tim heats copper with sulfur to form copper sulfide in three separate experiments. In each experiment, all of the copper reacts with all of the sulfur to form copper sulfide.

Copper sulfide is the only product formed in this reaction.

Complete **Table 2** to show the masses of the reactants and products involved in each experiment.

Table 2

Experiment	Mass of copper / g	Mass of sulfur / g	Mass of copper sulfide / g
1	63.5	32	.....
2	31.75	.....	.....
3	3.175	.....	.....

My uncle's a marine biologist — he's into the conservation of bass...

It doesn't matter whether you're looking at the M_r values or the actual reacting masses — mass is always conserved in reactions. If it looks like any's gone missing, go back and make sure you've considered all the products of the reaction.

The Mole and Equations

Gets about a bit this mole... Comes in dead handy for balancing reaction equations though.

Warm-Up

In a balanced symbol equation, the big numbers in front of the chemical formulas tell you how many moles of each reactant and product there are in the reaction.

Look at the equation for the combustion of lithium below and then complete the sentences by writing in the correct numbers of moles.

$$4Li + O_2 \rightarrow 2Li_2O$$

In this reaction, ... of lithium and ..... of oxygen react together to form ..... of lithium oxide.

You can work out what these big numbers should be if you know the masses of the reactants and products that took part in the reaction.

Q1 6.2 g of sodium oxide, Na_2O, reacts completely with 7.3 g of hydrochloric acid, HCl, to form 11.7 g of sodium chloride, NaCl, and 1.8 g of water, H_2O.

a) Complete **Table 1** by calculating the relative formula masses and the number of moles of hydrochloric acid, sodium chloride and water.

Relative atomic masses (A_r): Na = 23, O = 16, H = 1, Cl = 35.5

Table 1

Substance	Na_2O	HCl	NaCl	H_2O
M_r	62	.....	.....	.....
Number of moles	0.1	.....	.....	.....

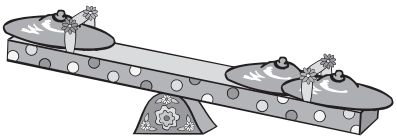
b) Use your answers to part a) to balance the symbol equation for the reaction between sodium oxide and hydrochloric acid.

..... Na_2O + ... HCl → ..... NaCl + H_2O

Q2 A scientist produces 12.6 g of nitric acid, HNO_3, by completely reacting 13.8 g of nitrogen dioxide, NO_2, with 1.8 g of water, H_2O. The reaction also produces 3.0 g of nitrogen oxide, NO.

Relative formula masses (M_r): HNO_3 = 63, NO_2 = 46, H_2O = 18, NO = 30

Use these masses to work out the balanced symbol equation for the reaction between nitrogen dioxide and water.



Balanced symbol equation:

..... + ... → ..... + ...

Q3 Incomplete combustion takes place when a fuel burns in insufficient oxygen. How the reaction equation is balanced depends on the amount of oxygen present.

Ibrahim is investigating the incomplete combustion of the hydrocarbon butane, C_4H_{10}. He burns 2.9 g of butane in oxygen. Carbon, carbon monoxide and water are produced. Ibrahim suggests the following reaction equation:

$$C_4H_{10} + 3O_2 \rightarrow 3C + CO + 5H_2O$$

The reaction produced 4.2 g of carbon monoxide.
Is Ibrahim's suggested equation correct? Explain your answer.

Relative atomic masses (A_r): C = 12, H = 1, O = 16

.....

.....

.....

.....

Why are moles so good at times tables? They just love moletiplication...

These sorts of calculations can be fiddly, but as long as you follow the steps and work through them systematically, you should be ok. Make sure you set out your working so that it's clear to both you and whoever is marking your work.

Limiting Reactants

I say we stop imposing boundaries and just let those reactants do what they jolly well please...

Warm-Up

A chemical reaction generally stops when one of the reactants is used up.
This reactant is called the LIMITING REACTANT.

Select the correct words from the box to complete the sentences below.

quickly	inversely	in excess	not	directly	slowly

The amount of product formed is ..... proportional to the amount of limiting reactant. All the other reactants are added ..... to make sure that the limiting reactant is used up.

Q1 Sodium sulfate (Na_2SO_4) is made by reacting sodium hydroxide (NaOH) with sulfuric acid (H_2SO_4). Water is also produced. The balanced symbol equation for this reaction is shown below:

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

Relative atomic masses (A_r): Na = 23, O = 16, H = 1, S = 32

a) What mass of sodium hydroxide is needed to produce 75 g of sodium sulfate when reacted with excess sulfuric acid?

mass of NaOH = ... g

b) What mass of water is formed when 50 g of sulfuric acid reacts with excess sodium hydroxide?

mass of H_2O = ... g

c) When 12 g of sodium hydroxide reacts with 10 g of sulfuric acid, which reactant is the limiting reactant? Show your working.

Limiting reactant = ...

Q2 Eilidh measured the rate of a reaction. She added 1 g of calcium carbonate powder to 100 cm^3 of dilute hydrochloric acid. The equation for the reaction that took place is shown below.

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$$

a) Eilidh measured the reaction rate by recording how the mass of the mixture changed over time. After two minutes there was still some powder left at the bottom of the flask, but the mass of the reaction mixture had stopped changing.

i) State which reactant is the limiting reactant

.....

ii) Explain your answer to part i).

.....

.....

b) Eilidh is going to repeat the experiment. This time she plans to add half as much of the limiting reactant. What will happen to the amount of calcium chloride produced? Explain your answer.

.....

.....

Q3 Iron oxide is reduced to iron inside a blast furnace using carbon. There are three stages involved.

Stage A	$C + O_2 \rightarrow CO_2$
Stage B	$CO_2 + C \rightarrow 2CO$
Stage C	$3CO + Fe_2O_3 \rightarrow 2Fe + 3CO_2$

If 10 g of carbon are used in stage B, and all the carbon monoxide produced gets used in stage C, what mass of CO_2 is produced in stage C? Give your answer to 2 significant figures.

Relative atomic masses (A_r): C = 12, O = 16, Fe = 56

mass of CO_2 = ... g

Biscuits — the limiting reactant in any revision session...

You often won't need to worry about whether a reactant is limiting or not, but it's still important to understand the definition, and how the amount of product formed can be affected. The main thing though is feeling confident calculating how much product you'll get from a given amount of (limiting) reactant, and vice versa. So better keep practising.

Gases and Solutions

No, not that kind of solution, I'm afraid. If I gave you the answers now, it would spoil the fun.

Warm-Up

At a fixed temperature and pressure, a given number of moles of any gas will always occupy the same volume.

What volume does one mole of any gas occupy at room temperature and pressure?

.....

Concentration is a measure of the amount of a substance dissolved in a certain volume of solution. The amount of the substance can be given as a mass or a number of moles.

Write down the formula you would you use to calculate concentration if you were told that a certain mass of a substance had dissolved in a given volume.

.....

What formula would you use to calculate concentration if you were given the number of moles of a substance that had dissolved instead of the mass?

.....

The higher the concentration, the larger the amount of the dissolved substance there is in a given volume of solution.

Q1 Ammonium sulfate, $(NH_4)_2SO_4$, is a soluble salt often used as a fertiliser.

Erin is preparing a solution of ammonium sulfate. She dissolves 2.6 g of ammonium sulfate in 1.8 dm^3 of water. What is the concentration of the solution in g/dm^3?

concentration = ... g/dm^3

Q2 450 cm^3 of a sodium carbonate solution contains 0.18 moles of sodium carbonate.

Calculate the concentration of the solution in mol/dm^3.

The units for concentration are g/dm^3 or mol/dm^3. If you're given a volume in cm^3, convert it to dm^3 by dividing by 1000.

concentration = ... mol/dm^3

Q3 Calculate the volume, in dm^3, of 16.5 g of carbon dioxide (CO_2) gas at room temperature and pressure.

Relative atomic masses (A_r): C = 12, O = 16

volume = ... dm^3

Q4 Sujit produces a 250 cm^3 solution of copper sulfate with a concentration of 32 g/dm^3.

What mass of copper sulfate does Sujit's solution contain?

mass = ... g

Q5 In a car engine, the temperature is high enough for nitrogen, N_2, and oxygen, O_2, from the air to react together to form nitric oxide, NO. The nitric oxide produced can go on to react with more oxygen to form nitrogen dioxide, NO_2. The equations for these reactions are shown below.

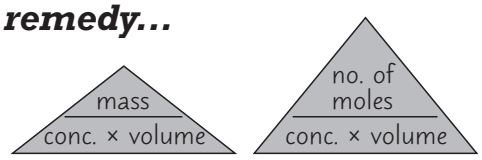
$$N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$$
$$2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)}$$

Calculate the volume of NO_2 produced if 20 dm^3 of nitrogen reacts with excess oxygen in the engine. You may assume that both reactions take place at the same temperature and pressure.

volume = ... dm^3

I've heard peppermint tea is an excellent natural remedy...

Make sure you're super-comfortable using and rearranging the formulas for concentration — you'll need them again very soon. Practice makes perfect, and if you find formula triangles helpful, you might want to use them here.



Concentration Calculations

If my working is correct, my concentration levels have been averaging 54% so far this section...

Warm-Up

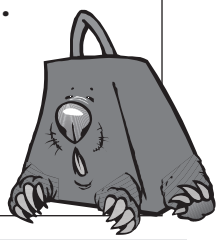
A titration is an experiment used to find the volumes of two solutions that react together completely. You can use these volumes, along with the concentration of one of the solutions and the reaction equation, to calculate the concentration of the other solution.

Usually a titration experiment is repeated several times and then the mean volume that reacted is calculated. There is always an uncertainty in the mean value.

Which of the following is not a cause of this uncertainty?

See pages 56 and 57 for more on titrations.

- ☐ **A Random error when measuring the volumes.**
- ☐ **B Using the wrong concentration for the solution of known concentration.**
- ☐ **C Limits in the resolution of the measuring equipment used.**



To convert a concentration in mol/dm³ to a concentration in g/dm³, just multiply by the M_r of the solute. To go the other way, you'll need to divide by the M_r.

Q1 The concentration of a sodium hydroxide solution, NaOH, is to be determined by titration with hydrochloric acid, HCl. 25 cm³ of NaOH solution required 20 cm³ of 0.1 mol/dm³ HCl solution to neutralise it. The equation for the reaction that took place is shown below:

$$NaOH + HCl \rightarrow NaCl + H_2O$$

Work out the concentration of the NaOH in g/dm³ using the steps outlined below.

a) How many moles of HCl are present in 20 cm³ of 0.1 mol/dm³ solution?

moles of HCl = ... mol

b) Complete the following sentence:

From the reaction equation, ... mole(s) of HCl reacts with ..... mole(s) of NaOH.

c) Use your answers to a) and b) to work out how many moles of NaOH there are in 25 cm³ of NaOH.

moles of NaOH = ... mol

d) What is the concentration of the sodium hydroxide solution in moles per dm³?

concentration = ... mol/dm³

e) What is the concentration of the sodium hydroxide solution in grams per dm³?

Relative atomic masses (A_r): Na = 23, O = 16, H = 1, Cl = 35.5

concentration = ... g/dm³

PRACTICAL

Q2 Tia is investigating the concentration of ammonia, NH_3, in a cleaning solution.
She performs a titration experiment to determine the volume of 1.00 mol/dm^3 hydrochloric acid solution, HCl, that reacts completely with 25.00 cm^3 of the cleaning solution.

Tia repeats her experiment five times. Her results are shown in **Table 1**.

Table 1

Repeat	1	2	3	4	5
Volume of HCl / cm^3	41.20	41.10	41.10	41.15	41.10

a) i) Find the mean volume of hydrochloric acid needed to react completely with the cleaning solution.

mean volume = ... cm^3

ii) What is the uncertainty of this mean volume?

uncertainty = ... cm^3

b) The equation for the reaction between ammonia and hydrochloric acid is shown below:

$$NH_3 + HCl \rightarrow NH_4Cl$$

i) Use the reaction equation and your answer to part a) i) to calculate the concentration, in mol/dm^3, of ammonia in the cleaning solution. Give your answer to 3 significant figures.

concentration = ... mol/dm^3

ii) Use your answer to part b) i) to find the concentration of the ammonia in g/dm^3.

Relative atomic masses (A_r): N = 14, H = 1, Cl = 35.5

concentration = ... g/dm^3

You'll need all your concentration to find these solutions...

These types of calculations can look daunting, but once again, as long as you break them down into manageable steps and work through them carefully, you should be all right. Just don't forget to convert all your volumes into dm^3 first.

Atom Economy and Percentage Yield

The end is in sight — of this section anyway... Just two more pages of calculations left.

Warm-Up

The atom economy (or atom utilisation) of a reaction is a measure of the amount of the reactants that end up as useful products. It helps to give an indication of how much waste a process produces, and so of how 'green' that process is.

Atom economy is one of several factors considered when choosing the most appropriate reaction to produce a particular product. Select the correct words from the box to complete the following passage about another important consideration.

percentage	lost	yield	lower	theoretical	higher

The amount of product you get from a reaction is known as the ..... .

The more reactants you start with, the ..... it will be.

The ..... yield compares how much you actually get to the ..... yield.

Q1 Copper oxide can be reduced to copper by heating it with carbon.

copper oxide + carbon → copper + carbon dioxide

$2CuO + C \rightarrow 2Cu + CO_2$

Relative formula masses: CuO = 79.5, C = 12, Cu = 63.5, CO_2 = 44

a) i) What is the useful product in this reaction?

.....

ii) Calculate the atom economy of the reaction.

atom economy = ... %

iii) Calculate what percentage of the starting materials are wasted.

percentage wasted = ... %

b) A scientist investigated this reaction in her laboratory. Her maximum theoretical yield is calculated to be 7.2 g of copper metal, but she found that she only obtained 4.4 g. What was the percentage yield of this reaction?

percentage yield = ... %

Q2 Titanium chloride ($TiCl_4$) can be reduced to titanium using magnesium or sodium.

a) Calculate the atom economy for the reaction with magnesium and for the reaction with sodium. Relative atomic masses (A_r): Ti = 48, Cl = 35.5, Mg = 24, Na = 23

i) With magnesium: $TiCl_4 + 2Mg \rightarrow Ti + 2MgCl_2$

atom economy = ... %

ii) With sodium: $TiCl_4 + 4Na \rightarrow Ti + 4NaCl$

atom economy = ... %

b) A chemical company wants to start producing titanium metal from titanium chloride ($TiCl_4$) as sustainably and profitably as possible.

Use your answers to part a) to suggest whether they should carry out the reduction with magnesium or with sodium. Explain why choosing this method could make the process more sustainable and profitable.

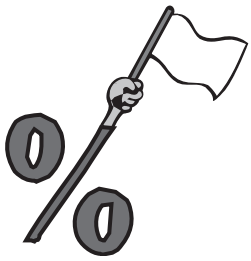
.....

.....

.....

.....

Q3 When heated, calcium carbonate decomposes to form calcium oxide and carbon dioxide. The equation for this reaction is shown below.



$$CaCO_3 \rightarrow CaO + CO_2$$

In an industrial reaction, 68.00 kg of calcium carbonate decomposed to form 28.56 kg of calcium oxide, CaO. Calculate the percentage yield of calcium oxide.

Relative atomic masses (A_r): Ca = 40, C = 12, O = 16

Percentage yield = ... %

There are 10 virtual cows in my theoretical field...

The atom economy for a particular reaction is fixed — it doesn't take into account reaction conditions and you just need the balanced reaction equation to work it out. The percentage yield, on the other hand, is likely to be different every time you carry out a reaction, because it depends on the exact conditions under which the reaction took place.

Acids, Bases and Titrations

Acids and bases are pretty vital to this section, so you had better get to grips with what these are.

Warm-Up

Acids are substances with a pH of less than 7 and bases are substances with a pH of greater than 7. Alkalis are bases which dissolve in water.
Titrations allow you to find the exact amount of acid needed to react with a given quantity of alkali (or vice versa). This data can then be used to work out the concentration of the acid or alkali.


Acid bass

Complete each of the following sentences with a single word.

a) Solutions which are not acidic or alkaline are said to be .....

b) A neutral substance has a pH of .....

c) Universal indicator gradually changes ..... over a broad range of pH.

Q1 Ant stings hurt because of the formic acid they contain.

Table 1

Substance	pH
lemon juice	3.0
baking soda	9.0
milk	6.5

a) **Table 1** shows the pH measurements of some household substances. Suggest a substance from **Table 1** that could be used to relieve the discomfort of an ant sting.

.....

b) Explain your answer.

.....

Q2 Indra has two solutions, **P** and **Q**. One of these solutions is acidic. The other is an alkali. Indra mixes solution **P** with universal indicator. The solution turns orange.

a) Is solution **P** acidic or alkaline?

.....

b) Complete the following passage using some of the words in the box below.

atoms	hydrogen	blue	neutralisation	green	hydroxide	water	ions

When solution **P** is mixed with solution **Q** a ..... reaction occurs.

Hydrogen ..... in solution **P** react with .....

ions in solution **Q**. When these react, ... is formed.

When all of solution **P** has reacted with all of solution **Q**, universal indicator

turns ..... .

PRACTICAL

Q3 Antacid tablets contain bases to neutralise the excess stomach acid that causes indigestion. Funmi carried out some titrations to work out how much base is in antacid tablets **A-E**. **Figure 1** shows the method Funmi used and **Table 2** shows her results.

Figure 1

1. Dissolve tablet A in 10 cm^3 distilled water.
2. Put some 0.01 mol/dm^3 hydrochloric acid (HCl) in a burette. Read off the volume added to the burette.
3. Gradually add HCl to the antacid tablet solution until the end-point is reached.
4. Write down how much acid is left in the burette.
5. Work out the volume of acid that was used to react with all the antacid tablet solution.
6. Repeat method for tablets B-E.

Table 2

	Tablet				
	A	B	C	D	E
Initial burette reading / cm^3	35.2	31.0	14.1	32.6	35.6
Final burette reading / cm^3	50.0	46.9	37.5	49.3	42.2
Volume of HCl used / cm^3	14.8	.....	.....	.....	.....

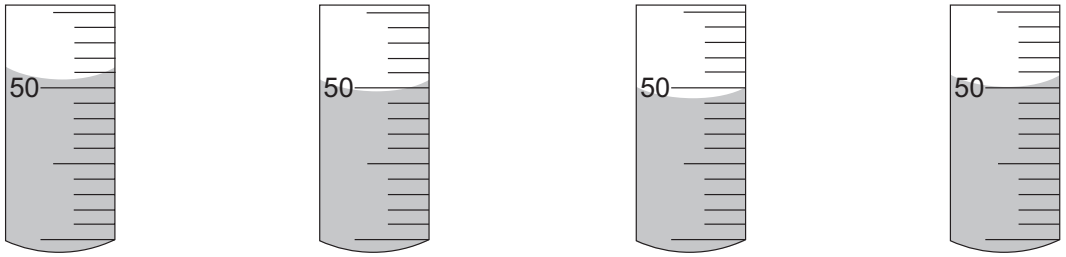
Burettes measure from the top to the bottom, so when filled to the top of the scale, the scale reads zero.

a) Complete **Table 2** by working out the volume of acid required to react with all of the base in each tablet. Tablet **A** has been done for you.

b) Which tablet contains the smallest amount of base?

.....

c) Funmi's final burette reading for her first titration was 50.0 cm^3. Which of the following diagrams correctly shows the level of acid when this measurement was taken?



A ☐ **B** ☐ **C** ☐ **D** ☐

d) i) Why is a rough titration often carried out first in titration experiments?

.....

.....

ii) What should Funmi do to increase the accuracy of her results?

.....

.....

.....

Ordered lithium diisopropylamide. Barman asked, "Why the long base?"...

It's really important that you know how to read the volume of liquid in a burette correctly. Oddly enough, if you read the volume the same wrong way in each titration, your results may be pretty precise, but they won't be very accurate.

Strong Acids and Weak Acids

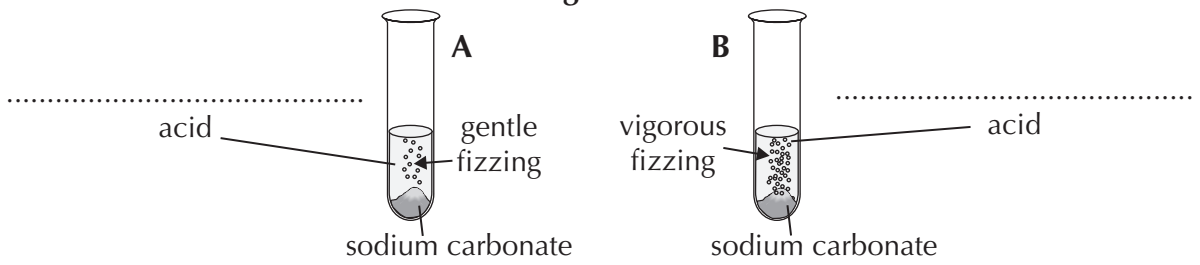
Time to keep your ion this page and dissociate yourself from distractions of sugary snacks and TV.

Warm-Up

Acids can be strong or weak. An acid's strength tells you what proportion of acid molecules ionise in water. The pH of an acid is not a measure of acid strength, it measures the concentration of hydrogen ions in water.

Q1 Zoe put equal masses of sodium carbonate into two test tubes **A** and **B**. She added 50 cm^3 of hydrochloric acid to one test tube and 50 cm^3 of citric acid to the other test tube. Both acids had the same concentration. **Figure 1** shows what Zoe observed. Label the acid added to each test tube.

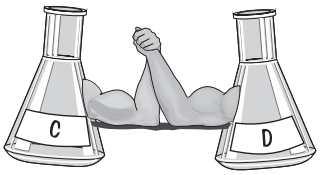
Figure 1



Q2 Wojciech has prepared 0.1 mol/dm^3 solutions of acid **C** and of acid **D**. He measures the pH of both acids and records the results in **Table 1**.

Table 1

Acid	pH
Acid **C**	3
Acid **D**	1



a) Which acid, **C** or **D**, is the strongest? How you can tell?

.....

b) Wojciech says, "The pH of acid **C** is three times bigger than the pH of acid **D**, so the hydrogen ion concentration of acid **C** must be three times smaller than that of acid **D**."

Is Wojciech correct? Explain your answer.

.....

.....

.....

.....

I once saw some sulfuric acid doing press-ups with its little finger...

Increasing the concentration of hydrogen ions in an acid leads to a decrease in pH — it becomes more acidic.
And, unsurprisingly, decreasing the concentration of hydrogen ions leads to an increase in pH — it becomes less acidic.

Reactions of Acids

My first reaction to these questions was a long sigh. You just have to crack on sometimes, though.

Warm-Up

Acids react with bases and alkalis in neutralisation reactions.

Metal oxides and hydroxides are bases which react with acids to form...

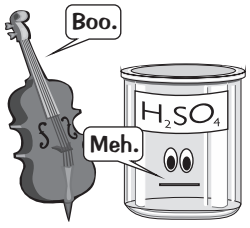
...a salt and carbon dioxide ☐ **...a salt and water** ☐

Draw lines to join the salt to the correct acid and base that can be used to make it.

Salt	Acid	Base
potassium sulfate	nitric acid	magnesium hydroxide
copper chloride	sulfuric acid	copper oxide
magnesium nitrate	hydrochloric acid	potassium hydroxide

You can make soluble salts in the lab by reacting an acid with an insoluble base.

Q1 **A**, **B** and **C** are symbol equations for reactions in which salts are formed.



A $CuO_{(s)} + H_2SO_{4(aq)} \rightarrow CuSO_{4(aq)} + H_2O_{(l)}$

B $2NaOH_{(aq)} + H_2SO_{4(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)}$

C $Pb(NO_3)_{2(aq)} + H_2SO_{4(aq)} \rightarrow PbSO_{4(s)} + 2HNO_{3(aq)}$

Which equation (A, B or C) refers to the formation of a salt:

a) in an acid/alkali reaction? ☐ b) from an insoluble base? ☐

Q2 Some solid magnesium oxide was added to hydrochloric acid (HCl) solution in a test tube. The reactants and the products are shown below, but the equation is **not** balanced. **X** is a mystery product.

Mg has a 2+ charge.
O has a 2– charge.
Cl has a 1– charge.

$$MgO_{(s)} + HCl_{(aq)} \rightarrow X_{(aq)} + H_2O_{(l)}$$

a) i) Give the chemical formula of substance X.

.....

ii) Write the full balanced symbol equation for the above reaction. Include state symbols.

.....

b) When solid magnesium oxide was added to a substance, **S**, magnesium sulfate and water were formed. Name substance **S**.

.....

Q3 Amir was investigating how he could restore a tarnished copper ornament. He obtained two copper compounds and looked at the effect of reacting them with dilute hydrochloric acid (HCl). **Table 1** shows Amir's observations.

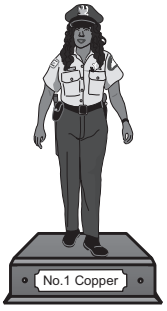


Table 1

Compound Tested	Formula	Colour	Observations
copper carbonate	$CuCO_3$	green	fizzed and dissolved to form a blue solution
copper hydroxide	$Cu(OH)_2$	blue	dissolved slowly to form a blue solution

Amir tested a part of the copper ornament with hydrochloric acid and it fizzed.

a) i) Suggest which compound from **Table 1** is most likely to be present on the surface of the ornament.

.....

ii) Write a balanced equation for the reaction between this compound and hydrochloric acid.

.....

b) Give the formula of the salt produced by the reaction between copper hydroxide and nitric acid.

.....

PRACTICAL

Q4 Zinc sulfate is a soluble salt that can be made by the reaction between sulfuric acid, H_2SO_4, and insoluble zinc oxide, ZnO.

a) Write a balanced chemical equation, including state symbols, for the reaction between sulfuric acid and zinc oxide.

.....

b) Outline how you could prepare a pure, dry sample of zinc sulfate in the lab from sulfuric acid and zinc oxide.

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Phhheeww — an appropriate reaction to finishing this page...

There's quite a lot to learn in this section. Make sure you can predict the salt that will form when an acid reacts with a base. You need to know how you actually use acids and bases to go about making soluble salts in the lab too.

The Reactivity Series

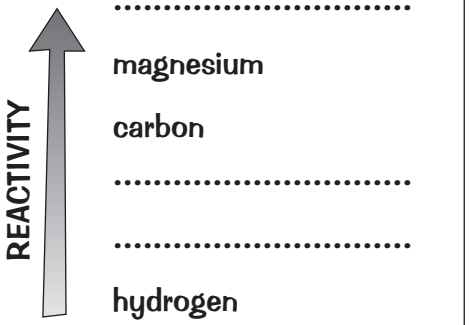
Ah, my favourite series. In the absence of a streaming subscription, here are some questions...

Warm-Up

The reactivity series is a list of metals in order of their reactivity. How metals react with both acids and water tells you about their reactivity. Carbon and hydrogen are non-metals which are often included in the reactivity series.

Fill in the gaps in the reactivity series on the right using the elements in the boxes below.

copper | iron | zinc | potassium

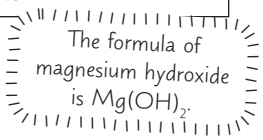


Q1 Sammy investigated the reactions of some metals with water. He recorded his observations in **Table 1**.

Table 1

Metal added to water	Observation
Lithium	Very vigorous reaction during which lithium disappears. Lots of bubbles in the water.
Calcium	Bubbles in the water, calcium disappears.
Magnesium	No bubbles in the water, a few bubbles on the magnesium.
Copper	No bubbles, no change to copper.

a) Magnesium can react with water to form magnesium hydroxide and a gas. Give the balanced symbol equation for this reaction.



.....

b) Sammy predicts that no bubbles will be produced if he adds potassium to water. Explain why he is wrong.

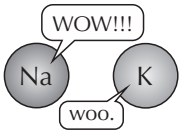
.....

.....

c) Based on their reactions with water, put lithium, calcium and magnesium in order from most reactive to least reactive.

Most reactive .... Least reactive

d) Sammy says, "Lithium forms positive ions less easily than calcium". Is Sammy correct? Explain your answer.



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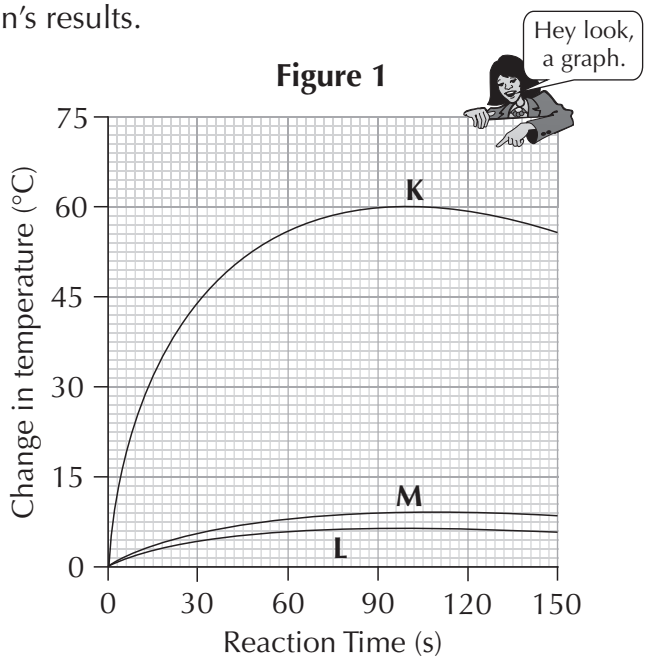
PRACTICAL

Q2 Jenson carried out some experiments to investigate the reactivity of metals.

He placed samples of three powdered metals (**K**, **L** and **M**) into hydrochloric acid and measured the change in temperature over 150 seconds.
Figure 1 shows Jenson's results.

Figure 1



a) Write the three metals, **K**, **L** and **M**, in order, from most reactive to least reactive.

Most reactive .... Least reactive

b) The products of the reactions between hydrochloric acid and metals **K**, **L** and **M** are magnesium chloride, zinc chloride and iron chloride. Deduce the identity of **M** and write a balanced symbol equation for the reaction of **M** with hydrochloric acid.

.....

.....

c) Which of the following is the independent variable in Jenson's experiment?

- ☐ **A** Reaction time
- ☐ **B** Temperature
- ☐ **C** The metal used in the reaction
- ☐ **D** The type of acid used

d) Give **three** variables that need to be controlled for this experiment to be a fair test.

1. .....

2. .....

3. .....

Compare your friends' reactivity by pranking them...

You might be given the results of an experiment in which metals are reacted with acid and water. You'll have to use the results to put the metals in order of reactivity. More reactive metals will react more vigorously than less reactive metals.

Separating Metals from Metal Oxides

Not all metals can just be plucked out of the ground. Many need extracting from their ore first.

Warm-Up

You can't simply dig up most metals as pure elements from the ground. They have often reacted with oxygen in the air to form oxides from which they must be extracted.

Complete the passage using the words in the box below.
You do not need to use all of the words.

electrolysis	reduction	oxidation	more	below	above	less

Carbon can be used to extract metals that are ..... it in the reactivity series. Oxygen is removed from the metal oxide in a process called ..... . Other metals have to be extracted using ..... because they are ..... reactive than carbon.

Q1 Imagine that three new metals, antium, bodium and candium have been discovered.

Use the information in **Table 1** to put these metals in order of reactivity relative to carbon.

Table 1

Metal	Extraction method
Antium	Found as the metal itself
Bodium	Can't be extracted by reduction with carbon
Candium	Candium oxide reacts with carbon to form candium and carbon dioxide

1. .....

Carbon

2. .....

3. .....

Q2 Different metals were discovered at different times throughout history. In general, more reactive metals were discovered much more recently than less reactive metals. Very unreactive metals, such as gold, were discovered in ancient times.

a) Suggest an explanation for the link between a metal's date of discovery and its reactivity.

.....

.....

.....

.....

.....

b) Silver is found in the Earth as the metal itself.
What does this suggest about the reactivity of silver?

.....

Q3 Copper may have been formed when someone accidentally dropped some copper ore into a wood fire. When the ashes were cleared away some copper was left.

Explain how dropping the ore into the fire led to the extraction of copper.

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Wood contains carbon.

Q4 Aluminium and carbon can both be used to extract iron from iron oxide, Fe_2O_3.

a) The balanced equation for an aluminothermic reaction is shown below:

$$Fe_2O_3 + 2Al \rightarrow Al_2O_3 + 2Fe$$

i) Which element or compound is oxidised in this reaction, and which is reduced?

Oxidised: .....

Reduced: .....

ii) How can you tell?

.....

.....

b) Write a balanced symbol equation for the reaction that takes place when iron is extracted from iron oxide using carbon.

.....

c) Explain why carbon can be used to extract iron from its ore but cannot be used to extract aluminium.

.....

.....

.....

.....

d) Obtaining aluminium from its ore for use in the extraction of iron is expensive. Why is this?

.....

Iron and oxygen were inseparable friends — until carbon came along...

If a metal is less reactive than carbon, you can use carbon to extract it. If a metal is more reactive than carbon, then you'll need to use other methods, like electrolysis, to extract it. If you're separating a metal from its ore, you're reducing it.

Redox Reactions

Redox is short for reduction and oxidation. Probably good if you know that before you move on...

Warm-Up

Reduction and oxidation involves the transfer of electrons.
Reduction and oxidation take place at the same time in redox reactions.
Reduction is the gain of electrons and oxidation is the loss of electrons.

Displacement reactions are redox reactions in which a more reactive metal displaces a less reactive metal from its compound. Ionic equations can be used to show which substances are oxidised and which are reduced.

Printing restrictions sadly prevent me from bringing you a "red ox" on this page. Please be amused by this grey goat instead.

Q1 A student carries out a displacement reaction by reacting magnesium with an aqueous solution of iron(II) chloride ($FeCl_2$) to produce magnesium chloride and iron.

a) Write the ionic equation for the reaction of magnesium with iron(II) chloride. Include state symbols.

.....

b) This is a redox reaction. Identify which species is oxidised and which is reduced. Explain your answer.

.....

.....

c) Copper is a brown metal and copper(II) sulfate is blue in solution.
Aluminium is a shiny grey metal and aluminium sulfate is colourless in solution.

Predict the student's observations when pure aluminium reacts with copper(II) sulfate.

.....

.....

Q2 Magnesium ribbon reacted with sulfuric acid in a redox reaction. Complete the passage using the words in the box below.

lost	reduced	oxidised	a different	gained	the same

Magnesium ..... electrons so magnesium was ..... .

Hydrogen ions ..... electrons so these ions were ..... .

Both processes happened at ..... time so this is a redox reaction.

OIL RIG — whatever you do, don't forget this...

The crucial thing to remember is that oxidation is loss and reduction is gain. The electrons lost by one species in oxidation are the same electrons gained by another species in reduction. I'll say it again — don't forget OIL RIG.

Electrolysis

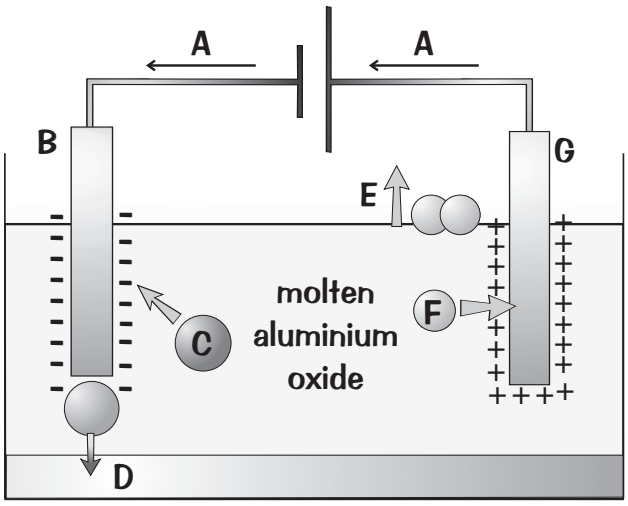
Passing a current through me would probably cause a reaction. It's pretty similar with salts too...

Warm-Up

Electrolysis uses an electrical current to cause a chemical reaction. The electrical current is passed through an electrolyte (a molten or dissolved ionic compound).
Positive ions in the electrolyte move towards the negative electrode and negative ions in the electrolyte move towards the positive electrode. The ions form uncharged elements which are discharged from the electrolyte.

The diagram below right, shows an aluminium oxide electrolysis cell.
Write the letters A-G in the boxes below to show what each label represents in the diagram.

negative electrode	
molten aluminium	
oxide ion, O^{2-}	
positive electrode	
flow of electrons	
aluminium ion, Al^{3+}	
oxygen gas	



Q1 A company has built a new plant which extracts aluminium from its ore using electrolysis.

a) Explain why the company melts the aluminium oxide ore before electrolysing it.

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b) Aluminium oxide has a high melting point so lots of energy is required to melt it. What can the company do to reduce the cost of heating aluminium oxide?

.....

c) The company often has to replace one of the electrodes.
Which electrode must they replace? Explain why they must replace this electrode.

.....

.....

Q2 This question is about the electrolysis of molten and dissolved ionic substances.

a) i) Name the product that forms at the anode when concentrated lithium chloride solution is electrolysed.

.....

ii) When electrolysis is complete, lithium hydroxide (LiOH) remains in solution. Explain why this happens. Refer to reactivity in your answer.

.....

.....

.....

iii) Complete the balanced half equation for the reaction at the negative electrode.

..... $^{+}$ + ... $e^- \rightarrow$ .....

b) i) Which products are obtained at each electrode when molten potassium bromide is electrolysed? Tick **one** row.

Tick		Anode	Cathode
☐	**A**	bromine	potassium
☐	**B**	potassium	bromine
☐	**C**	bromine	potassium hydroxide
☐	**D**	bromide ions	potassium ions

ii) Which half equation below represents the reaction happening at the anode when molten potassium bromide is electrolysed?

☐ **A** $Br^+ + e^- \rightarrow Br$

☐ **B** $K^{2+} + 2e^- \rightarrow K$

☐ **C** $2Br^- \rightarrow Br_2 + 2e^-$

☐ **D** $K^+ + e^- \rightarrow K$

iii) Is the reaction occurring at the anode an example of reduction or oxidation? Explain your choice.

.....

c) Write down the half equation for the reaction occurring at the cathode when a solution of copper sulfate ($CuSO_4$) is electrolysed. Include state symbols.

.....

Electrolysis — a very current topic...

Aluminium's the big one here — make sure you know how the electrolysis of aluminium oxide works. It'll help knowing which electrode the electrolysis products form at too. Remember PANCakes — positive anode, negative cathode.

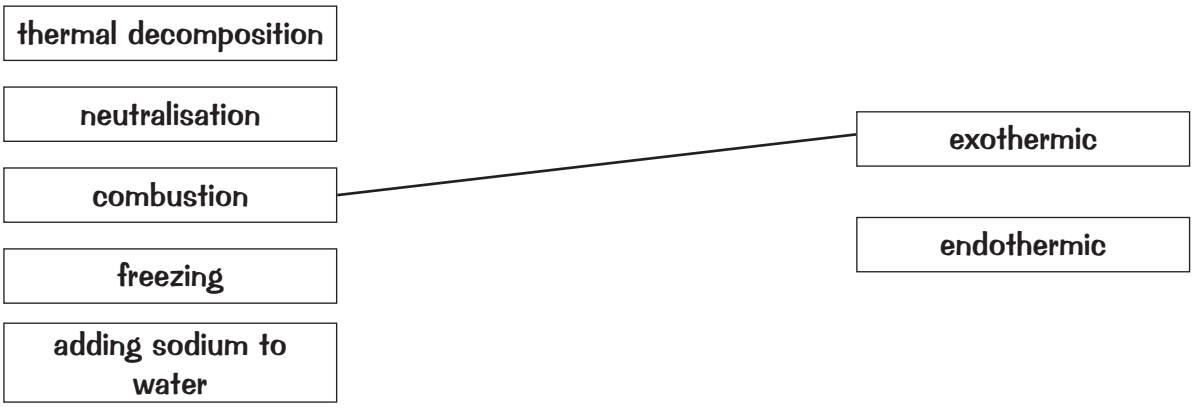
Exothermic and Endothermic Reactions

Time to practise stuff on energy changes in chemical reactions. I bet you're dead excited...

Warm-Up

Exothermic reactions give out energy, usually in the form of heat.
This causes the temperature of the surroundings to increase.
Endothermic reactions take in energy from the surroundings.
This means that the temperature of the surroundings decreases.

Draw lines to match the reactions or processes below to the correct label on the right.
One has been done for you.



Q1 The reaction profiles in **Figure 1** represent the energy changes in five chemical reactions.

For parts a) – d), write the letter of the graph(s) matching the description.
Assume all the axes have the same scale.

a) An exothermic reaction.

.....

b) An endothermic reaction.

.....

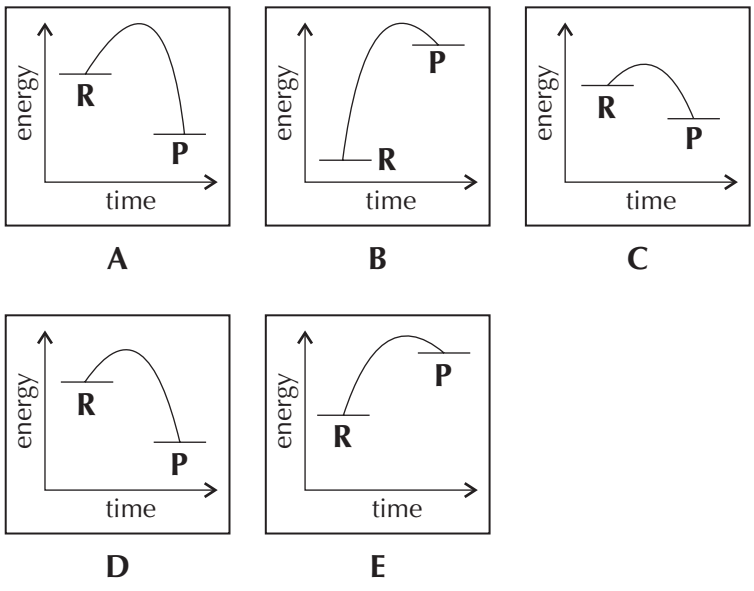
c) The reaction with the largest activation energy.

.....

d) The reaction which needs the smallest amount of energy to start.

.....

Figure 1



Key: **R** = reactants, **P** = products

PRACTICAL

Q2 Lorna investigated the temperature change during a neutralisation reaction. She added 50 cm^3 of a solution of a base at room temperature to 25 cm^3 of an acid solution in a polystyrene cup. She put a lid on the cup, and used a data logger to measure the temperature of the reaction mixture over five seconds.

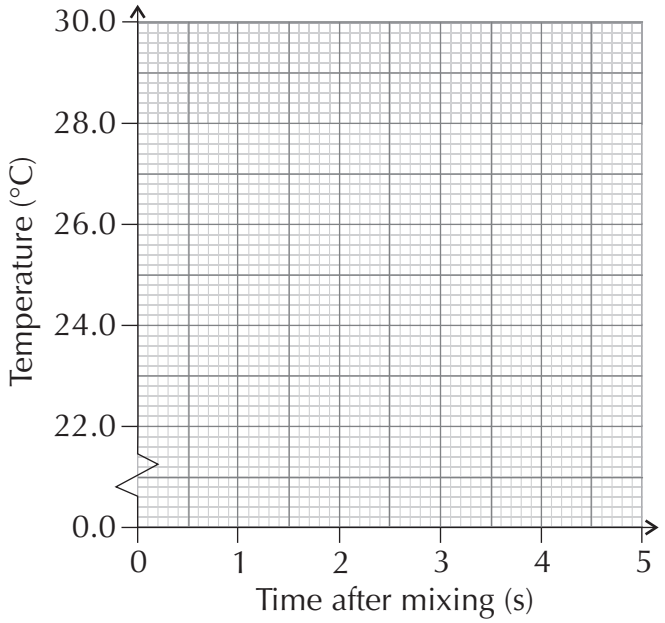
Table 1

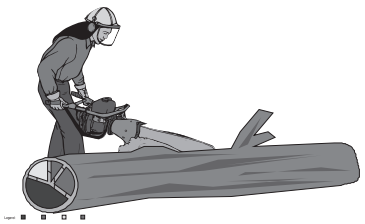
Time after mixing (s)	0	1	2	3	4	5
Temperature (°C)	22.0	27.4	29.2	29.4	29.0	28.2

A data logger is an instrument used to automatically record data such as temperature and pH.

a) On **Figure 2**, draw a graph of Lorna's results, shown in **Table 1**. Include a curve of best fit.

Figure 2





b) The data logger recorded a maximum temperature of 29.4 °C. Calculate the maximum temperature change of the reaction. Show your working.

Temperature change = ... °C

c) Use your answer to b) to explain whether the reaction is endothermic or exothermic.

.....

.....

d) Rahul repeats Lorna's experiment keeping all variables the same, but he forgets to put the lid on his polystyrene cup. Will the maximum temperature change measured by Rahul be higher or lower than that measured by Lorna? Explain your answer.

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A nice mug of coffee — that's my morning activation energy...

This stuff shouldn't be too tough but it can be easy to get caught out. Remember that energy isn't made or destroyed. If a reaction loses energy, it gives the energy to the surroundings — this is why you get warm when you sit by a fire.

Bond Energies

Get your calculator ready for this one — and your pillows. You might need a sleep afterwards...

Warm-Up

Chemical reactions can be exothermic or endothermic.
Energy changes in reactions are caused by bonds breaking and forming.

Circle the correct words to complete each of the sentences below.

a) Energy must be supplied to **break** / **form** bonds.

b) Energy is released when bonds are **broken** / **formed**.

c) Bond breaking is an **exothermic** / **endothermic** process.

d) Bond forming is an **exothermic** / **endothermic** process.

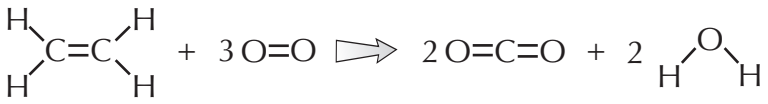
You will need to use the bond energies in **Table 1** to answer Q1 and Q3.

Table 1

Bond	N–N	C–H	O=O	C=O	O–H	C–C	N–H	C=C
Bond energy (kJ/mol)	158	412	498	805	463	348	391	602

Q1 The equations below show the complete combustion of ethene.

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$



Using the relevant bond energies given in **Table 1**, calculate:

a) The energy required to break the bonds in the reactants.

Energy = ... kJ/mol

b) The energy released when bonds form in the products.

Energy = ... kJ/mol

c) The overall energy change for the reaction.

Energy = ... kJ/mol

Q2 ATP is a product of aerobic respiration in many organisms.
ATP undergoes a reaction in which energy is released into the cell.
This energy then powers that cell. A word equation for the reaction is shown below.

ATP → ADP + phosphate

Using the information provided, explain the difference between the total bond energy in the ATP and the total bond energy in the ADP and phosphate.

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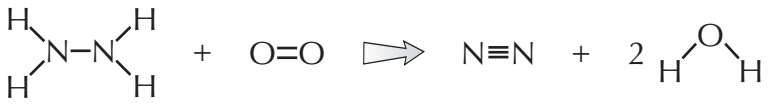
Q3 Hydrazine is a chemical used as a rocket fuel.

The box below shows how hydrazine undergoes a combustion reaction with oxygen.

$$N_2H_4 + O_2 \rightarrow N_2 + 2H_2O$$



The overall energy change for the reaction is –577 kJ/mol.
Using the information in **Table 1**, calculate the energy of the N≡N bond.

Use everything you know to write an equation, which you can then rearrange to find the missing N≡N bond energy.

N≡N bond energy = ... kJ/mol

Breaking the bond between me and my bed — a VERY endothermic process.

Bond energy calculations are hard to get your head around at first, but practising them will help you. You will always be given all of the values you need to answer a question, so you don't need to memorise any specific bond energies.

Cells, Batteries and Fuel Cells

This page is called Phillip. Phillip's great. Phillip will help you to learn stuff. Treat Phillip well.

Warm-Up

Cells are systems which produce electricity from chemical reactions. All types of cell have two electrodes and an electrolyte (a liquid). You need to know about two types of cell — electrochemical cells and fuel cells. Several cells connected together are called a battery.

Use words from the box below to complete the gaps in the following passage about electrochemical cells. You will need to use some words more than once.

charge electrodes voltmeter electrolyte

Electrochemical cells contain two different ..... which are in contact with the ..... solution. Ions in this solution can react with the ..... . This creates a ..... difference between the ..... . A metal wire connecting the ..... creates a circuit. A ..... can be used to measure the voltage.

Q1 New cars are being developed which run on batteries and on hydrogen fuel cells.

a) Explain how using hydrogen fuel cell cars could help reduce the amount of air pollution in cities.

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.....

b) When an electric car's battery runs out, it is recharged by applying an external electrical current.

i) Why does an electric car's battery stop producing electricity when it runs out?

.....

.....

ii) Explain how applying an external current recharges the car's battery.

.....

.....

PRACTICAL

Q2 A scientist is investigating electrochemical cells. She sets up cells with different combinations of electrodes and electrolytes and measures the voltage of each cell. **Table 1** shows the scientist's results.

Table 1

Electrolyte	Electrode **A**	Electrode **B**	Voltage (V)
1	zinc	iron	+0.32
1	zinc	copper	+1.10
2	zinc	iron	+0.28
2	zinc	copper	+1.06

a) Calculate the voltage of a battery that is formed by connecting all of the cells in **Table 1** in series. Show your working.

Voltage = ...V

b) The scientist sets up another cell, where electrode **A** is copper, electrode **B** is iron, and electrolyte **1** is used.

i) If electrode **A** is more reactive than electrode **B**, the voltage is positive.
If electrode **A** is less reactive than electrode **B**, the voltage is negative.
Is the voltage of the new cell positive or negative? Explain your answer.

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ii) Calculate the voltage of this cell. Show your working.

Voltage = ...V

c) Another scientist sets up a cell, where electrode **A** is magnesium, electrode **B** is copper and electrolyte **2** is used. Magnesium is more reactive than zinc. Which of the following could be the voltage of this cell? Tick **one** box.

☐ **A** +0.54 ☐ **C** –1.39

☐ **B** +2.67 ☐ **D** +0.06

Cells and batteries — they're re-volting things...

This stuff on cells and batteries can be a bit confusing, but it gets easier with practice. You might be asked to interpret stuff from tables. Take your time, read the question, underline the important bits and Robert's your mum's brother...

Rates of Reaction

Get your skates on — this section's all about speed. Well, sort of anyway...

Warm-Up

The rate of reaction is how fast reactants are used up and products are made. Collision theory explains the rate of reaction. The rate is affected by how frequently particles collide. The rate of reaction also depends on particles colliding with enough energy — the activation energy — to react.

The four statements below are about rates of reaction. Circle the correct words from each pair to complete the sentences.

a) The **higher** / **lower** the temperature, the faster the rate of reaction.

b) A **higher** / **lower** concentration or pressure will reduce the rate of reaction.

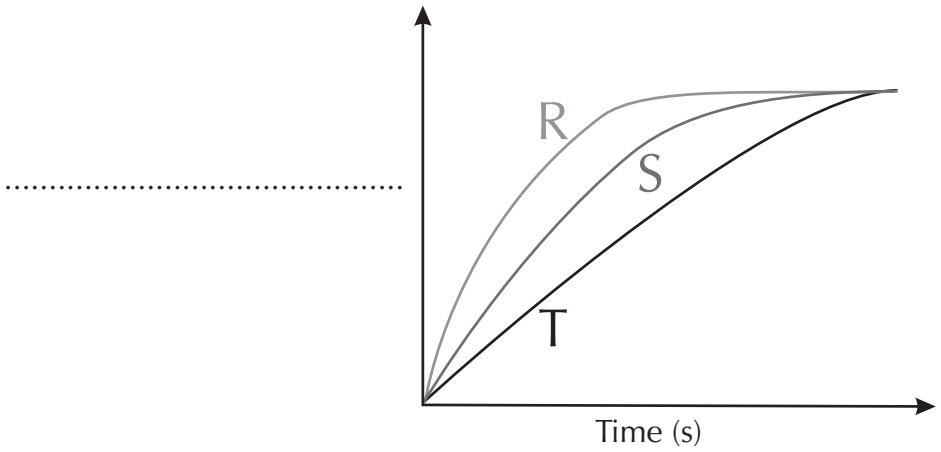
c) A smaller surface area of solid reactants **increases** / **decreases** the rate of reaction.

d) A catalyst **does** / **doesn't** change the rate of reaction.

PRACTICAL

Q1 A student measured the volume of gas (in cm^3) produced in a reaction to find out which of three catalysts (**R**, **S** or **T**) was most effective. **Figure 1** is a graph of her results.

Figure 1



a) Label the y-axis on the dotted lines above.

b) i) Which curve (**R**, **S**, or **T**) represents the reaction using the most effective catalyst? Circle the correct letter on the graph.

ii) Explain your choice with reference to how catalysts change the rate of reaction.

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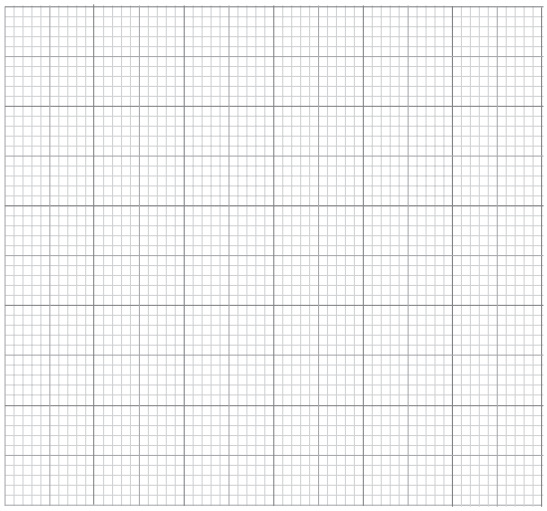
PRACTICAL

Q2 Saz measured the volume of carbon dioxide produced during a reaction between 5 g of marble chips and 100 cm^3 of hydrochloric acid. She then repeated the experiment keeping all but one of the variables the same. **Table 1** shows the results of both reactions.

Table 1

Time (s)	Volume of CO_2 (cm^3)	
	Reaction 1	Reaction 2
10	14	24
20	25	42
30	36	57
40	46	69
50	54	77
60	62	80
70	70	80
80	76	80
90	80	80
100	80	80

Figure 2



a) Plot the data from **Table 1** onto the grid in **Figure 2**.
Draw each reaction as a separate curve and label the axes.

b) Which reaction is faster? Explain your answer with reference to part a).

.....

c) Suggest **three** factors which Saz could have changed to change the rate of reaction.

1. .....

2. .....

3. .....

Q3 Ivona is an explorer. She gets lost while exploring in the jungles of Cumbria. Ivona decides to light a fire using her trusty lighter and some large chunks of wood that she finds in the jungle. The wood burns in a combustion reaction with oxygen in the air.

Use collision theory to explain why the fire will burn more quickly if she chops the wood into smaller chunks before burning it.

.....

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.....

Collision theory has its uses — never find yourself cold in a jungle again...

Changing some things will affect the frequency of the collisions between reactant particles and this means the rate of reaction will change. This isn't how catalysts increase the rate though — don't let yourself get caught out.

PRACTICAL

Measuring Rates of Reaction

This section's all about measuring speeds. Like a speed camera, but loads more exciting. Super.

Warm-Up

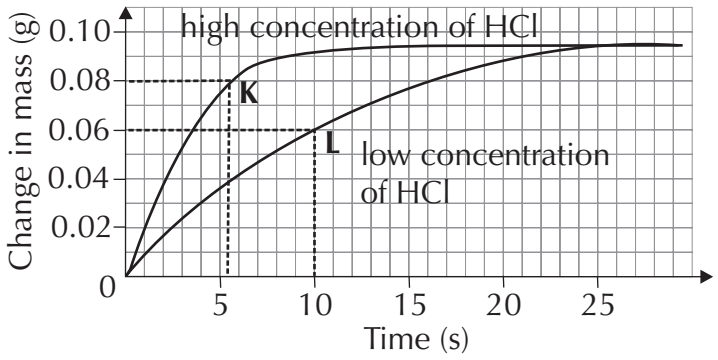
The rate of reaction can be measured in several ways. You can time how long it takes for a precipitate to form, or for a colour change to occur. Alternatively, you can measure the change in mass or the volume of gas given off at regular intervals.

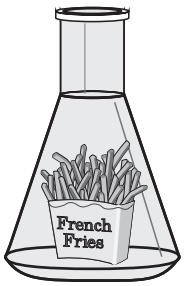
Tick all of the statements below that are true.

- ☐ **A** Change-of-mass experiments give very subjective results.
- ☐ **B** The more gas given off during a given time interval, the faster the reaction.
- ☐ **C** Measuring a change in turbidity with the naked eye gives very accurate results.
- ☐ **D** There are no hazards in measuring the volume of gas given off in an experiment.

Q1 Em investigated the rate of a reaction between marble chips and hydrochloric acid. She recorded the mass of the reaction mixture at regular intervals and calculated the change in its mass from the start of the reaction. She then repeated the experiment, changing only the concentration of hydrochloric acid. The results are shown in **Figure 1**.

Figure 1





a) Which of the following options represents a valid conclusion that can be drawn from **Figure 1** about the reaction between hydrochloric acid and marble chips? Tick **one**.

- ☐ **A** The reaction rate depends on the temperature of the reactants.
- ☐ **B** Increasing the concentration of the acid has no effect on the rate of reaction.
- ☐ **C** The reaction rate depends on the acid concentration.
- ☐ **D** The reaction rate depends on the mass of the marble chips used.

b) Calculate the mean rate of reaction between the origin and point **L** on the graph. Give your answer to one significant figure.

Mean rate = ... g/s

c) How might Em calculate the rate of reaction at point **K**?

.....

Q2 Ari reacted 5 g of calcium with five different concentrations of hydrochloric acid. She measured the volume of gas produced during the first minute of each reaction and repeated each measurement three times. **Table 1** shows her results.

Table 1

Hydrochloric acid concentration (mol/dm^3)	Volume of gas produced (cm^3)			Mean volume of gas produced (cm^3)
	Experiment 1	Experiment 2	Experiment 3	
2.0	92	96	93	.....
1.5	63	65	65	.....
1.0	44	47	31	.....
0.5	20	22	21	.....


Acid concentration

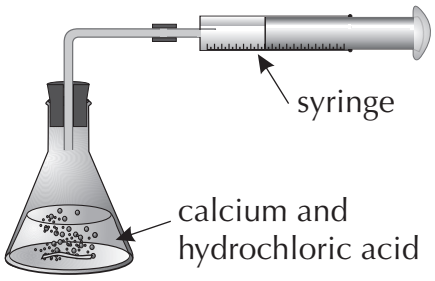
a) Circle the anomalous result in **Table 1**.

b) Complete the final column in **Table 1**, ignoring any anomalous results. Give your answers to one decimal place.

c) Circle the concentration of hydrochloric acid in **Table 1** that produced the fastest rate of reaction.

Figure 2 shows part of Ari's experimental set-up.

Figure 2



d) Name **one** other key piece of apparatus needed for this experiment that is not shown in **Figure 2**.

.....

e) Suggest what may have caused the anomalous result.

.....

Anomalous — that's an odd word...

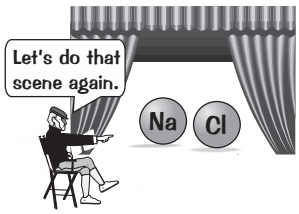
You should be a whizz at this stuff now. It's all data and tables and numbers — sounds like maths. Bubbles, gases and colour changes in chemistry hopefully have you more excited than maths though. I think.... maybe.... not.... um, okay.

Reversible Reactions

Some questions about going backwards now — it'd be great if this page beeped to warn you...

Warm-Up

Some reactions can go backwards — the products can react with each other to re-form the reactants. When the concentration of products and reactants stop changing, a reversible reaction is at equilibrium.



A rehearsable reaction

Tick any of the statements below that are false.

- ☐ **A** Equilibrium is the point at which the product and reactant concentrations are equal.
- ☐ **B** Endothermic reactions are always reversible.
- ☐ **C** Equilibrium is the point at which the rate of reaction is equal in both directions.
- ☐ **D** Equilibrium reactions only occur in liquids.

Q1 Mo did an experiment to investigate reversible reactions. Pink hydrated cobalt(II) chloride was heated over a Bunsen burner. **Figure 1** shows what Mo wrote about the experiment:

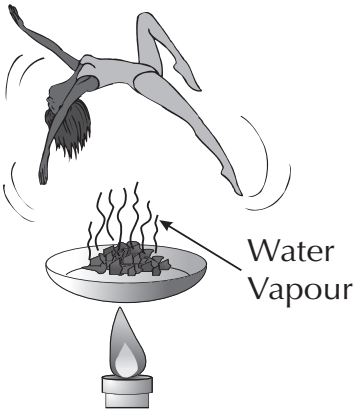


Figure 1

When I heated up pink cobalt(II) chloride water appeared and the salt dissolved, forming a blue solution. I evaporated some of the water and let the blue salt crystallise. I then added some water back to it. It went pink again and got really hot.

'Anhydrous' means 'without water'.
'Hydrated' means 'containing water'.

a) Predict the word equation for the reaction.

..... ⇌ ..... + ...
....

b) This reaction is reversible, but does not reach equilibrium.
Which of the following explains why? Tick the correct box.

- ☐ **A** The reverse reaction needs more energy than the forward reaction releases.
- ☐ **B** The reverse reaction has a higher activation energy than the forward reaction.
- ☐ **C** The reactions do not occur in a closed system.
- ☐ **D** The reverse reaction occurs at a faster rate than the forward reaction.

Q2 The equation for making ethanol from ethene and steam is given below. **Table 1** shows how the percentage of ethanol at equilibrium changes with pressure, at a fixed temperature.

$$C_2H_{4(g)} + H_2O_{(g)} \rightleftharpoons C_2H_5OH_{(g)}$$

Table 1

Pressure (atm)	20	30	40	50	60	70	80	90	100
% ethanol at equilibrium	20	24	28	32	38	43	48	54	59

a) How many molecules are there on the left-hand side of the equation?

.....

b) What happens to the amount of reactants at equilibrium when the pressure is increased? Explain this observation.

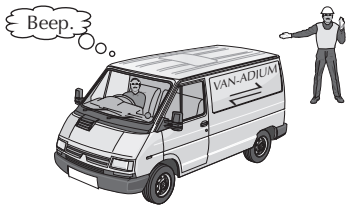
.....

.....

.....

.....

Q3 When ammonium chloride is heated, it decomposes into ammonia and hydrogen chloride. The reaction is reversible.



$$NH_4Cl_{(s)} \rightleftharpoons NH_{3(g)} + HCl_{(g)}$$

Two students are trying to work out the best conditions to favour the forward reaction. The first student suggests a temperature of 375 °C and a pressure of 1 atmosphere. The second student suggests a temperature of 250 °C and a pressure of 5 atmospheres.

Using your knowledge of equilibrium reactions, deduce which conditions are more favourable for the forward reaction. Explain your answer.

.....

.....

.....

.....

.....

.....

Some like it hot — and others don't...

For the questions on this page, you will have used Le Chatelier's Principle. This basically explains why reversible reactions at equilibrium are just quite fussy. Try changing anything and they kick off and try to stop you making that change.

Hydrocarbons and Fractional Distillation

Hydrocarbons come in many different sizes, which can be separated using fractional distillation.

Warm-Up

Hydrocarbons are found in crude oil and are made up of only carbon and hydrogen atoms. The properties of hydrocarbons change as their carbon chains get longer.

Circle the correct words to complete the following sentences.

Crude oil is formed mainly from ancient **plankton** / **coral** that was buried in mud.

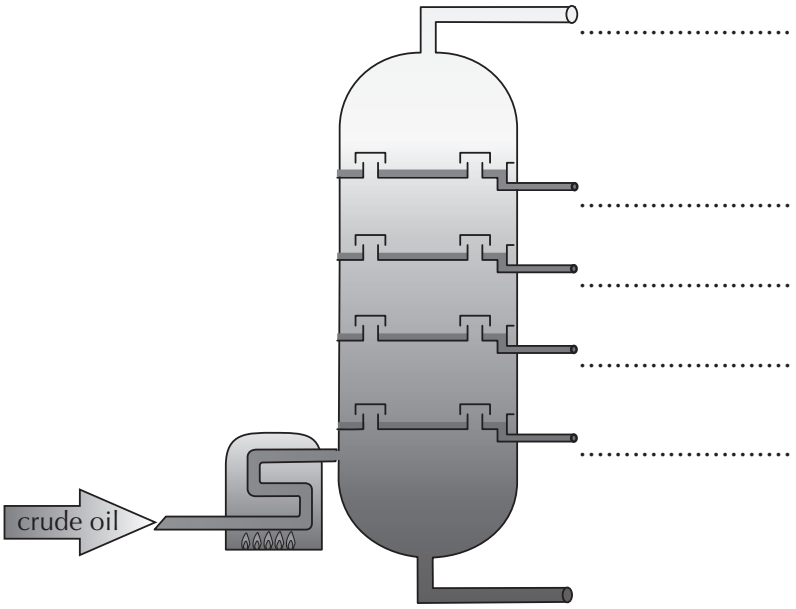
Crude oil is a **mixture** / **compound** of different molecules.

Most of the compounds in crude oil are **carbohydrate** / **hydrocarbon** molecules.

Crude oil is a **renewable** / **finite** resource.

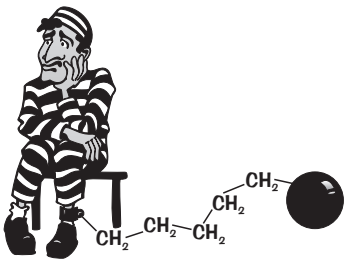
Q1 **Figure 1** shows a fractionating column used to separate hydrocarbon fractions. Label the diagram with the hydrocarbon molecules in the box below to show where you would expect each of them to drain out of the column.

Figure 1



Hydrocarbon Molecules

C_8H_{18} $C_{20}H_{42}$ $C_{40}H_{82}$ C_3H_8 $C_{15}H_{32}$



Q2 Engine oil is made up of hydrocarbons.

a) Engine oil needs to be viscous so that it can coat engine parts well. Do the hydrocarbons in engine oil have long or short carbon chains?

.....

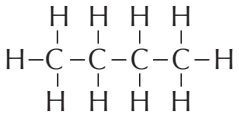
b) Engines get very hot when they are in use. Why would oil containing short-chain hydrocarbons be less suitable for use as a lubricant in a hot engine than long-chain hydrocarbons?

.....

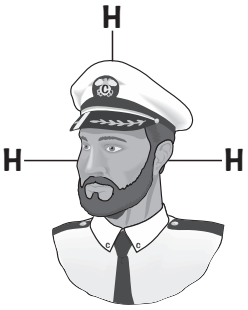
.....

Q3 **Table 1** gives the name, chemical formula and structure of some alkanes. Complete the table by filling in the gaps.

Table 1

Name	Chemical formula	Structure
ethane	.....	
.....	C_3H_8	
.....	.....	

Q4 Heptane and triacontane are two molecules that are present in two of the fractions produced by the fractional distillation of crude oil.



Captane

Table 2 shows the boiling points of these two molecules.

Table 2

Hydrocarbon	Chemical formula	Boiling point (°C)
Heptane	C_7H_{16}	98
Triacontane	$C_{30}H_{62}$	450

a) Write a balanced symbol equation for the complete combustion of heptane.

.....

b) Which of these two hydrocarbons will drain off lower down the fractionating column? Explain why this is, with reference to the boiling points of the hydrocarbons.

.....

.....

.....

.....

A cowboy with C_9H_{20} — the man with nonane...

Fractional distillation is an early stage in the processing of crude oil. It separates hydrocarbons from each other according to their chain length. These fractions are then processed further into different materials that are useful to us.

Uses and Cracking of Crude Oil

Crude oil is vital for many things that we rely on in modern life — so let's crack on with it...

Warm-Up

Cracking is a process used to produce more useful molecules from fractions of crude oil.

Tick the boxes to finish the following sentences.

There is a high demand for...

...short-chain fractions of crude oil. ☐ **...long-chain fractions of crude oil** ☐

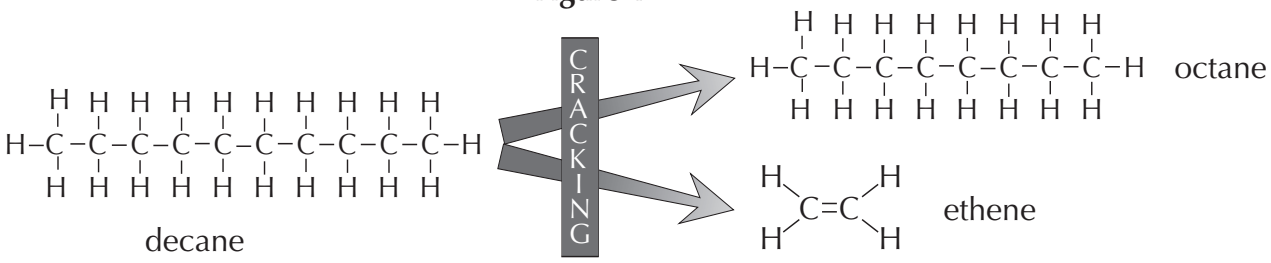
Cracking involves heating hydrocarbons with a catalyst to...

...form long-chain hydrocarbons from shorter ones. ☐

...break long-chain hydrocarbons into shorter ones. ☐

Q1 **Figure 1** is a diagram of decane being cracked into octane and ethene.

Figure 1



a) Write out the symbol equation for this process.

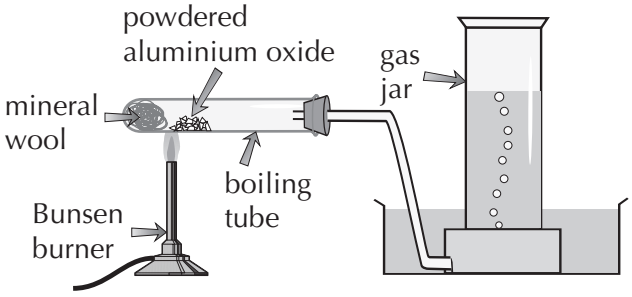
..... → ..... + ...

b) In another reaction, decane is cracked to form hexane (C_6H_{14}) and ethene. Write the balanced symbol equation for this reaction.

..... → ..... + ...

Q2 The apparatus in **Figure 2** can be used to crack a liquid hydrocarbon.

Figure 2



a) Suggest where the liquid hydrocarbon would be in the experimental set-up.

.....

b) What is the role of aluminium oxide?

.....

c) What types of hydrocarbons collect as gases in the gas jar?

.....

Q3 Use the words below to fill in the gaps in the paragraph.

alkenes **long** **shorter** **crude oil** **polymers** **solvents**

Alkanes from ..... can be used to make ..... and lubricants.

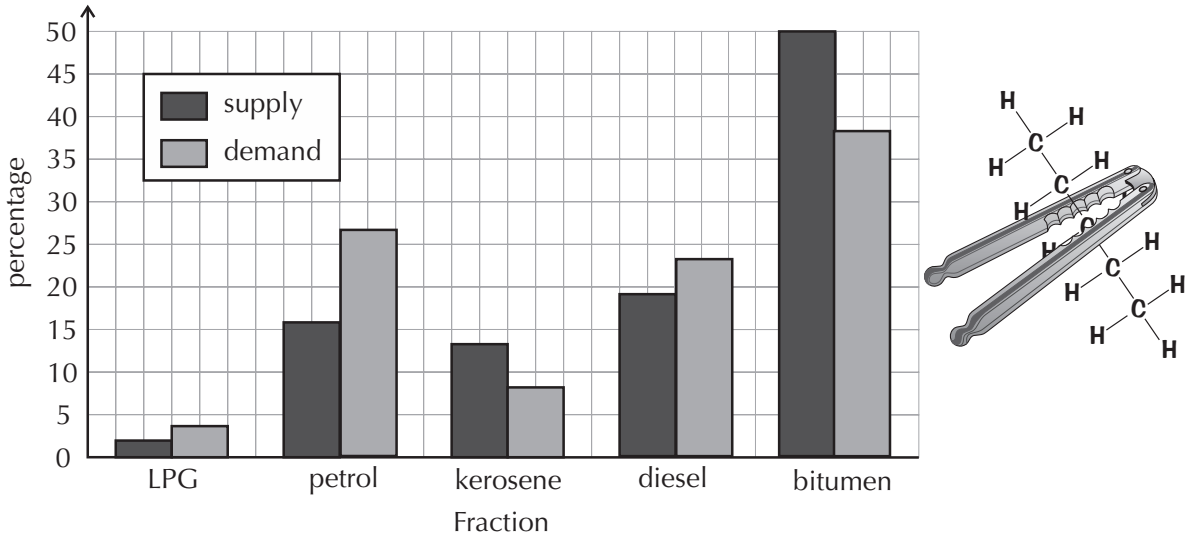
..... chain alkanes can be cracked to produce alkanes with .....

chains, which make better fuels . Cracking also produces .....

which can be used as the starting material to make ..... .

Q4 Horatio owns a crude oil refinery. He records the amount of each fraction that's present in a sample of crude oil and compares it against how much of each fraction his customers want. The results are shown in **Figure 3**.

Figure 3



a) Which fractions in this sample of crude oil are in excess (more is produced than can be sold)?

.....

.....

b) Explain how cracking will help Horatio match the levels of supply to the levels of demand.

.....

.....

c) Suggest how else cracking can benefit crude oil companies economically.

.....

.....

Heating hydrocarbons with steam — great craic...

Hydrocarbons can be cracked using a catalyst — this, surprisingly, is called catalytic cracking. Alternatively, hydrocarbons can be cracked by heating them to really high temperatures with steam — this is called, you guessed it, steam cracking.

Alkenes and their Reactions

As long as you're not saturated with chemistry and you're *all keen* to carry on, it's time for alkenes.

Warm-Up

Alkenes are unsaturated hydrocarbons that contain a C=C double bond.
This double bond makes them much more reactive than alkanes.
The general formula of alkenes is C_nH_{2n}.

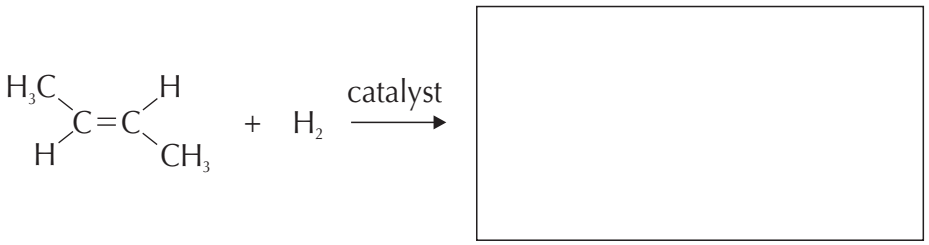
Write down the formulas of the following alkenes.

pentene: ..... propene: ..... ethene: .....

hexene (6 carbons): ..... dodecene (12 carbons): .....

Q1 **Figure 1** shows a reaction between but-2-ene and hydrogen.

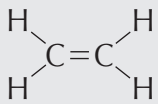
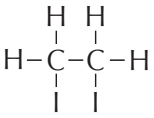
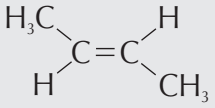
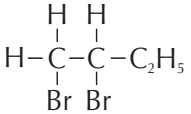
Figure 1

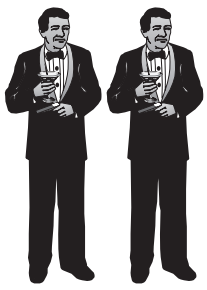


Draw the product of this reaction in the box in **Figure 1**.

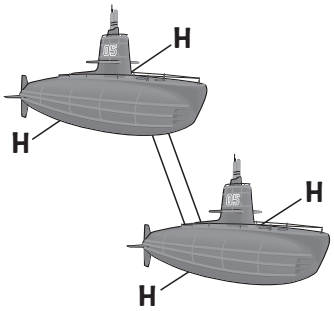
Q2 **Table 1** shows the product formed when the given alkene reacts with a halogen. Complete the table by drawing the displayed formulas of the missing products and the missing alkene.

Table 1

Alkene	I_2	Br_2
		
		
		



Q3 Otis wants to produce propanol from an alkene.



a) Draw the alkene Otis should use.

b) Write the word equation for the reaction he should use.

.....

PRACTICAL

Q4 Wei has two samples, **X** and **Y**. One sample is butane and the other sample is butene. Wei puts each sample into a separate boiling tube.

a) Wei has a bottle of bromine water. Describe how she could use the bromine water to identify which sample, **X** or **Y**, is butane and which is butene.

.....

.....

.....

.....

.....

b) An addition reaction takes place between butene and bromine.
Describe what happens to the butene molecule during this reaction.

.....

.....

c) i) Wei burns the butene sample in air. An incomplete combustion reaction takes place.
Complete the following equation showing the incomplete combustion of butene.

$$C_4H_8 + ... O_2 \rightarrow ..... CO + 2C + ... H_2O$$

ii) Describe what Wei will observe during this reaction.

.....

Addition reactions — when calculators give you a rash...

Alkenes are really reactive, especially compared to alkanes, which means they can be used to produce different compounds. An alkene's reactivity is to do with its double bond, since it can open up and the carbons can bond to more atoms.

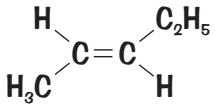
Addition Polymers

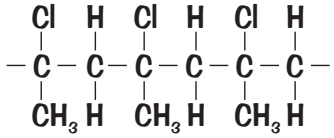
Addition polymers make up lots of different plastics. There are probably some around you right now.

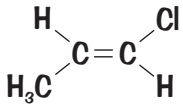
Warm-Up

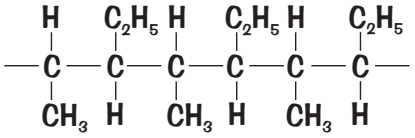
In polymerisation reactions loads of monomers are joined together to form a polymer. Polymers can be made that have many different properties, which means they can be used to make a variety of plastics. Addition polymers are made up of alkene monomers.

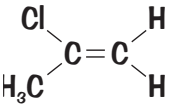
Match up each monomer on the left with the polymer it will form on the right.

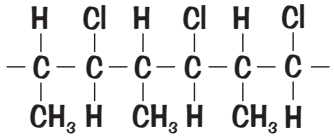












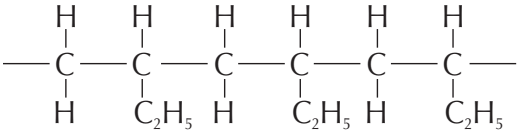
Q1 Tick the box next to the **true** statement below.

- ☐ **A** The monomer of poly(ethene) is ethene.
- ☐ **B** The polymer of poly(ethene) is ethane.
- ☐ **C** The monomer of poly(ethene) is ethane.
- ☐ **D** The polymer of poly(ethene) is ethene.

We bring you gold, frankincense... and poly-myrrh

Q2 **Figure 1** shows a section of poly(but-1-ene).

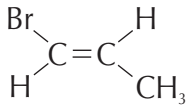
Figure 1



Draw a diagram to represent the formation of poly(but-1-ene) from its monomer.

Q3 **Figure 2** shows the structure of 1-bromoprop-1-ene.

Figure 2



a) Why is 1-bromoprop-1-ene able to take part in addition polymerisation reactions?

.....

.....

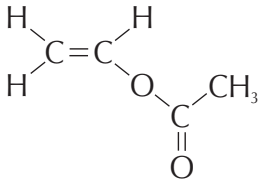
b) Draw the displayed formula of the addition polymer that forms from 1-bromoprop-1-ene monomers.

c) What is the name of the polymer that forms from 1-bromoprop-1-ene monomers?

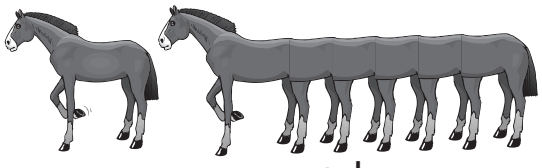
.....

Q4 Vinyl acetate polymerises to form polyvinyl acetate.
The displayed formula of vinyl acetate is shown in **Figure 3**.

Figure 3



Draw the displayed formula of the repeating unit of poly(vinyl acetate).



Polymers — they're really repetitive...

Addition polymers are produced from alkenes, because of that helpful double bond which can open up and form a chain. It also means that in an addition polymerisation reaction there are no waste products, only the polymer is formed.

Alcohols

From ales to fuels, alcohols are everywhere — so don't 'wine' about having these questions to do.

Warm-Up

Alcohols are a homologous series of useful organic compounds.
They have the general formula $C_nH_{2n+1}OH$.

Complete the table to show the number of carbon atoms in each alcohol and their formulas.

Alcohol	Number of carbon atoms	Formula
Methanol	.....	.....
Propanol	3	.....
Butanol	.....	.....

Since all alcohols contain an –OH functional group, they each take part in similar reactions.
For example, alcohols can undergo complete combustion reactions in air.

Give the balanced equation for the reaction that takes place when methanol burns completely in air.

.....

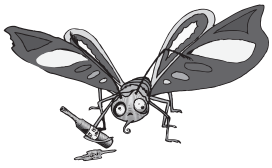
Q1 Akeel has a sample of propanol.

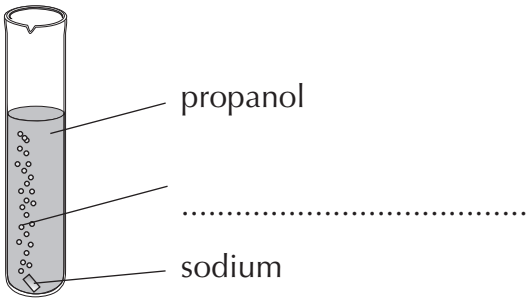
a) Akeel adds some propanol to a boiling tube of water.
Circle the correct pH of the propanol solution on the pH scale below.

pH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

b) Akeel adds some sodium to a boiling tube of pure propanol.
Figure 1 shows a diagram of the reaction taking place.
Name the gas which forms the bubbles. Write your answer on the dotted line.

Figure 1





c) Give the balanced symbol equation for the combustion of propanol.
Use only whole numbers to balance the equation.

.....

PRACTICAL

Q2 Roisin is planning to completely oxidise butanol by mixing it with concentrated sulfuric acid and an oxidising agent. Roisin will use a Bunsen burner to heat the mixture.

a) Name the organic product formed when butanol is completely oxidised.

.....

b) Roisin's teacher tells her that it would be safer to use an electric heater instead of the Bunsen burner. Explain why an electric heater is a more suitable source of heat in this experiment.

.....

.....

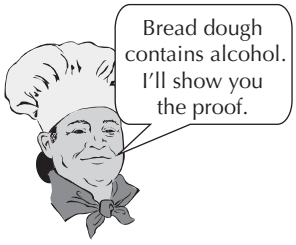
.....

Q3 Fermentation is used to make bread. Carbon dioxide released during fermentation causes the bread to rise, in a process called proofing. The more carbon dioxide that is produced, the higher the bread rises. Ethanol is also produced in the proofing process.

A dough mixture is separated into seven equal pieces, **A**-**G**. Each dough is proofed for 30 minutes at different temperatures. **Table 1** shows the change in height of each dough.

Table 1

Dough	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Temperature (°C)	25	30	32	36	38	40	42
Change in height (cm)	5	8	10	12	13	10	6



a) Describe the trend in the data in **Table 1**.

.....

.....

.....

b) Which dough, **A**-**G**, is likely to have the highest ethanol content after proofing? Explain your answer.

.....

.....

c) Fermentation happens fastest under slightly acidic conditions. Suggest how adding an alkaline ingredient to the bread dough before proofing might affect the height of the proofed dough. Explain your suggestion.

.....

.....

Alcohols are just –OH so exciting...

There are lots of other alcohols, but you only need to know about methanol, ethanol, propanol and butanol. Remember, they all have the same –OH functional group and can be used as solvents in industrial processes or can even power vehicles.

Carboxylic Acids

Carboxylic acids are quite a bit like doves — both can be recognised by their –COOH.

Warm-Up

Carboxylic acids are another homologous series.
They all have '-COOH' as a functional group.
They react with carbonates (like any other acid)
and can also react with alcohols to form esters.

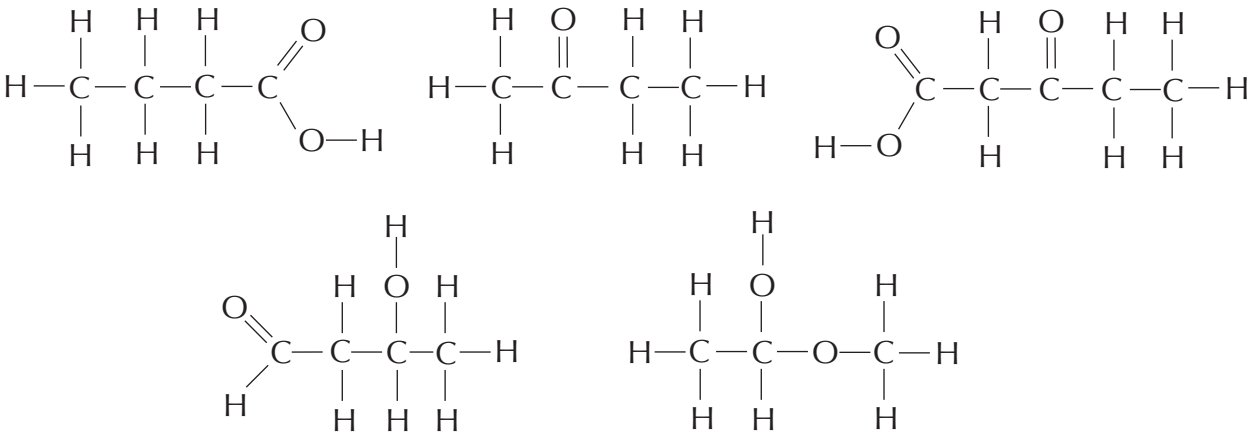
A functioning group

Draw lines to match the name of each carboxylic acid to its formula.

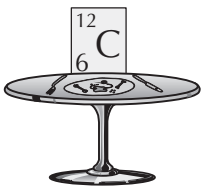
ethanoic acid	HCOOH
methanoic acid	$CH_3CH_2CH_2COOH$
propanoic acid	CH_3CH_2COOH
butanoic acid	CH_3COOH

Q1 Circle all of the carboxylic acid functional groups in **Figure 1**.

Figure 1



Q2 Carboxylic acids react with carbonates.



Identify salt **P** and compound **Q** in the equation below.

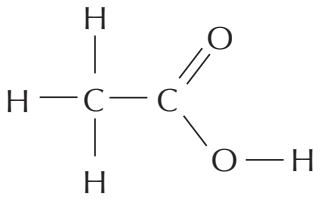
propanoic acid + calcium carbonate → **P** + water + **Q**

P: .....

Q: .....

Q3 Jessica mixes ethanol and concentrated sulfuric acid with compound **R**. A reaction takes place forming ethyl ethanoate. **Figure 2** shows the displayed formula of compound **R**.

Figure 2



a) Name compound **R**.

.....

b) Why does Jessica add concentrated sulfuric acid to the reaction mixture?

.....

c) Jessica adds compound **R** to a sample of water. What will Jessica observe?

- ☐ **A** A layer of compound **R** will form on top of the water.
- ☐ **B** Compound **R** will dissolve in the water.
- ☐ **C** Fizzing
- ☐ **D** A blue precipitate will form.

Q4 Vinegar is a dilute solution of ethanoic acid.

a) Explain why vinegar fizzes when ammonium carbonate is added.

.....

.....

b) Asha tests the pH of a sample of hydrochloric acid and of a sample of ethanoic acid. The pH of the hydrochloric acid is 0 and the pH of the ethanoic acid is 2.5. Both acids have the same concentration. Explain the difference in pH.

.....

.....

.....

.....

Carboxylic acids are such gossips — they love to ester it up...

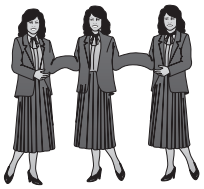
Meth, eth, prop, but... Hopefully these names have started to sink in. But if you still get a little flustered trying to remember the order, try coming up with a mnemonic to help. My personal favourite is Monkeys Eat Peanut Butter.

Condensation and Natural Polymers

It's not just addition polymers, there are condensation polymers too. Oh, what joy...

Warm-Up

Condensation polymers are formed when monomers containing different functional groups react. An example of a condensation polymer is a polyester. Condensation polymers also exist in nature and have important functions in living organisms.



Poly(Esther)

Use the words in the box below to complete the following passage about DNA.

two	double helix	branched	four

DNA is made of ..... polymer chains. Cross links form between these two chains giving DNA a ..... structure. The chains are made from ..... different monomers.

Q1 Sophie makes the following statements:

Statement 1: "Proteins and cellulose are both made up of monomers called sugars."
Statement 2: "Proteins are formed in an addition polymerisation reaction."

Sophie's statements are incorrect.

Rewrite each of Sophie's statements so that they are correct.

Statement 1: .....

.....

Statement 2: .....

.....

Q2 Plants contain DNA.

a) Name the monomer that polymerises to form DNA in plants.

.....

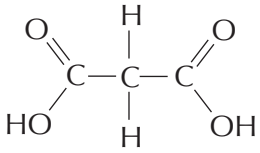
b) Describe the role of DNA in plants.

.....

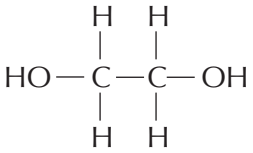
.....

Q3 Which of the following pairs of monomers cannot form a polymer by condensation polymerisation? Tick **one**.

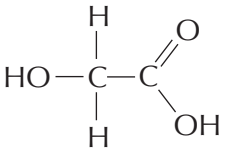
Small molecules like HCl can also be formed in condensation polymerisation reactions.

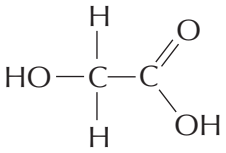


A ☐

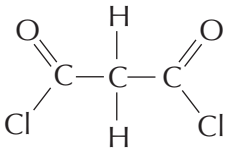


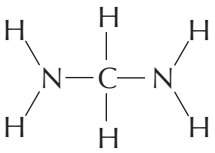
B ☐



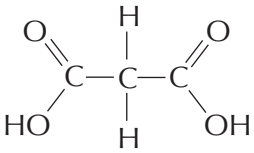


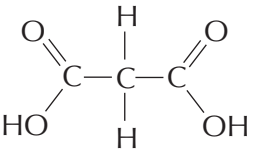
C ☐





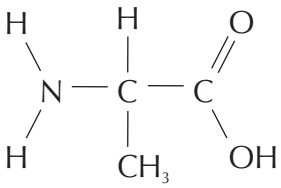
D ☐





Q4 **Figure 2** shows the displayed formula of the amino acid alanine.

Figure 1



A mean group

a) Circle alanine's **two** functional groups in **Figure 1**.

b) Alanine molecules can react via condensation polymerisation to form a polypeptide. Draw the displayed formula of this polypeptide.

c) Outline what happens when two alanine molecules react in a condensation polymerisation reaction.

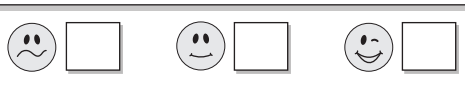
.....

.....

.....

Polymers — they're really repetitive...

The monomers used to produce a condensation polymer always need to have two functional groups. This is so that the polymer chain can keep reacting with more monomers, increasing the length of the polymer chain.



Purity and Formulations

It's time to formulate an action plan to tackle this page. Get ready for pure excitement...

Warm-Up

A chemically pure substance is something which contains a single compound or element. The purity of substances can be tested by measuring their melting or boiling points and comparing them to the known values for the pure substance.

How do impurities in a sample affect the melting point of the sample?

.....

.....

Formulations are mixtures made up of exact amounts of different components. They are made for a specific purpose.

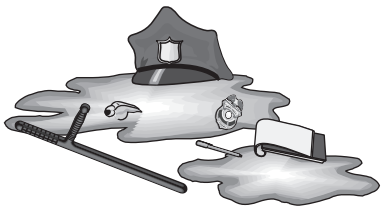
Why do formulations need precise amounts of each component?

.....

Q1 Circle each type of formulation in the list below.

shampoo	brass alloy	water	green paint
iron	tin	ammonia	carbon dioxide
steel alloy	wood	bronze alloy	cherryade

Q2 Ben has two samples of copper, **X** and **Y**. He measures the melting point of each sample. Sample **X** has a melting point of 1085 °C and sample **Y** melts over the range 910–942 °C.



a) Compare the purity of the two samples.

.....

.....

.....

b) Suggest which of the samples, **X** or **Y**, would have the highest boiling point.

.....

Q3 A lip balm company makes different lip balms using mixtures of beeswax, coconut oil and peppermint oil. The beeswax is used to give the lip balm structure, the coconut oil is used to soften the lip balm and the peppermint oil is used to add flavour.

The composition of three lip balms, **A**, **B** and **C** are given in **Table 1**.

Table 1

	Composition (g)		
Component	A	B	C
beeswax	3.5	4	3
coconut oil	3.5	3	4
peppermint oil	0.1	0.1	0.05

a) From the information given, how can you tell that these lip balms are formulations?

.....

.....

b) Suggest which lip balm, **A**, **B** or **C**, is the softest. Explain your answer.

.....

Q4 The melting ranges of different samples of glucose were measured. The results are given in **Table 2**.

Table 2

Sample	A	B	C	D
Melting range (°C)	134-143	136-143	142-144	132-142

a) i) Put the samples, **A**-**D** in order from most impure to least impure.

Most Impure .... **Least Impure**

ii) Explain your reasoning.

.....

.....

.....

.....

b) Suggest which sample, **A**-**D**, will have the lowest boiling point. Explain your answer.

.....

.....

.....

55 g of sugar, 125 g of butter and 180 g of flour — best revision formulation...

Remembering how impurities affect substances can be a little difficult. Impurities increase the boiling point, but decrease the melting point, as well as increasing the range over which melting or boiling happens.

PRACTICAL

Paper Chromatography

Chemists use paper chromatography a lot as it's a quick and easy way to find out about a mixture.

Warm-Up

Chromatography is a method used to separate different substances in a mixture.
There are different types of chromatography, including paper chromatography.
All types of chromatography involve two phases.

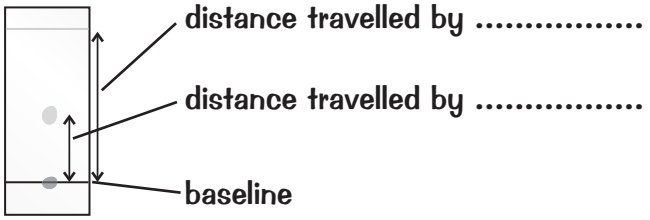
What are the two phases of chromatography?

.....

The spots of chemicals on a chromatogram can be identified by calculating their R_f values and comparing them to reference data.

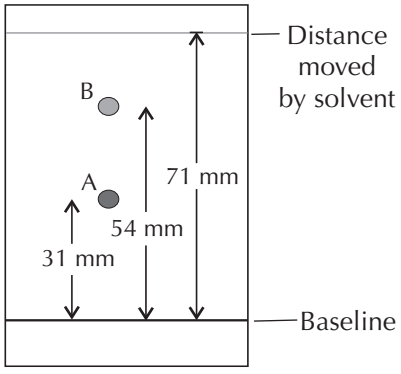
Complete the equation for calculating the R_f value of a substance and complete the labels on the diagram of the chromatogram.

$$R_f = \frac{\text{.....}}{\text{distance travelled by solvent}}$$



Q1 A food colouring was analysed using paper chromatography. The chromatogram shown in **Figure 1** was produced.

Figure 1



a) Using **Figure 1**, calculate the R_f values for dyes **A** and **B**, which are present in the food colouring.

R_f value of **A** = ...

R_f value of **B** = ...

b) Both dyes, **A** and **B**, are similarly attracted to the chromatography paper. Which dye is the most soluble in the solvent? Explain your answer.

.....

.....

.....

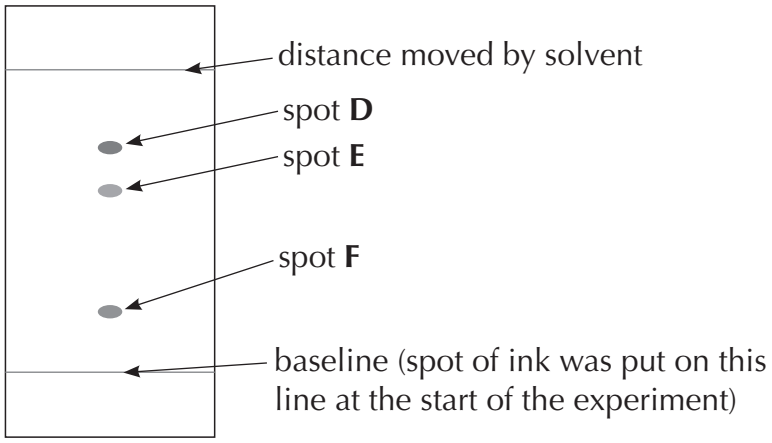
c) Is the food colouring a pure substance? Explain your answer.

.....

.....

Q2 A forensic scientist used paper chromatography to analyse the ink on a document. The chromatogram she produced is shown in **Figure 2**.

Figure 2



a) Calculate the R_f value of spot **E**. Use a ruler to help you.

R_f value of **E** = ...

b) i) The scientist knows that the ink on the document came from one of three printers. She plans to carry out chromatography experiments to separate the ink from each printer. She will then compare the chromatograms produced with the chromatogram in **Figure 2**.

Explain why the forensic scientist should use the same solvent to produce the additional chromatograms as she used for the first.

.....

.....

.....

.....

ii) Explain how her chromatograms could be used to identify which of the three printers produced the document.

.....

.....

.....

Spending all your money on pens — it's just a stationery phase...

Paper chromatography works because different substances spend different amounts of time in each of the two phases. This means that some substances travel further up the chromatography paper than others, and so have different R_f values. But remember, if you carry out the experiment again using a different solvent, the R_f values of the substances will change.

PRACTICAL

Tests for Gases

This is a small section, but there's still important stuff here. So get ready and let's go...

Warm-Up

A chemical test is a quick way to identify a gas in a lab.
However, there is no magical chemical test that will tell you what gas you've got.
Each test will only tell you whether or not a certain gas is present. If you really have no clue what the gas is, you have to run the tests one by one until you get lucky.

What gas is produced when sodium carbonate reacts with a dilute acid?

.....

What simple chemical test could you carry out to see if this gas has been produced?

.....

.....

Q1 Nithika carries out a reaction which produces a mystery gas. She collects the gas in a test tube.

a) Nithika puts a glowing splint into the test tube containing the gas. She doesn't observe anything. What does this tell you about the mystery gas?

.....

b) Next Nithika puts damp litmus paper in the gas. What gas could she be testing for? Describe the result that would indicate this gas is present.

.....

.....

c) Nithika then carries out another test. She listens out for a squeaky pop. Which gas is she testing for?

.....

d) Give an example of a safety precaution Nithika should have taken whilst carrying out these tests.

.....

.....

Required: one non-immature joke about gas...

You only need to know the tests for four gases — so there's no reason not to know them inside out and upside down. If you're having trouble remembering them all, write them out a few times — or even draw a picture for each test.

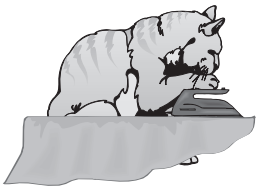
Tests for Ions

PRACTICAL

It's time for even more tests — some tests on tests to make sure you know tests for your ...exams.

Warm-Up

Negative ions (anions) such as carbonates, sulfates and halides, can be identified using chemical tests. Chemical tests can also be used to identify some metal ions (cations). Some metal ions can also be identified using flame tests, where different metal ions produce different flame colours when heated.



Describe how you would conduct a flame test on a metal compound. Include details of how you would make sure your apparatus is prepared correctly for the test.

.....

.....

.....

.....

Q1 Johnny had five samples of metal compounds. He tested each one using a flame test.

a) Draw lines to match each of Johnny's observations to the positive metal ion producing the coloured flame.

orange-red flame	Na^+
yellow flame	Cu^{2+}
crimson flame	K^+
green flame	Ca^{2+}
lilac flame	Li^+

b) Johnny's local football team is holding a fundraising event. They have ordered fireworks for a display that will explode in the team's colour, lilac. Which of the following compounds is likely to be in these fireworks? Circle the correct answer.

silver nitrate **sodium chloride** **calcium carbonate**

potassium nitrate **barium sulfate**

Q2 Clear magnesium sulfate solution and clear, colourless sodium hydroxide solution were mixed. The liquid went cloudy and white. After a while a white solid was left at the bottom and the liquid was clear again.

a) Name the white solid formed.

.....

b) Write an ionic equation, including state symbols, to show the formation of the white solid.

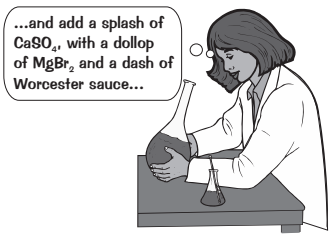
.....

Q3 Jukka tests a sample of water from his local duck pond for pollutants, first using $AgNO_3$ solution and nitric acid, and then using $BaCl_2$ solution and hydrochloric acid. A white precipitate is formed in each case.

State the **two** ions that the tests suggest could be present in the solution.

.....

Q4 Imogen is trying to identify a mystery compound.



First she adds a few drops of sodium hydroxide solution to a solution of the mystery compound.

a) i) What result would you expect Imogen to see if the mystery compound contains Fe^{2+} ions?

.....

ii) What result would you expect Imogen to see if the mystery compound contains Fe^{3+} ions?

.....

b) In fact, a blue precipitate forms. What can Imogen conclude?

.....

c) Write down an ionic equation, including state symbols, for the formation of this blue precipitate.

.....

d) Imogen suspects that the mystery compound is a sulfate. Describe a test she could carry out to see if she's right.

.....

.....

e) Imogen carries out the test for a sulfate, which produces a positive result. Write down the formula of Imogen's mystery compound.

The chemical formula for a sulfate ion is SO_4^{2-}.

.....

Q5 Select compounds from the box to match the following statements.

KCl	LiCl	$FeSO_4$	$FeCl_3$	$Al_2(SO_4)_3$
NaCl	$CuSO_4$	$CaCl_2$	$MgCl_2$	$BaCl_2$

$FeSO_4$ contains Fe^{2+} ions. $FeCl_3$ contains Fe^{3+} ions.

a) This compound forms a blue precipitate with sodium hydroxide solution.

.....

b) This compound gives a crimson flame in a flame test.

.....

c) This compound forms a white precipitate with sodium hydroxide that dissolves if excess sodium hydroxide is added.

.....

d) This compound forms a green precipitate with sodium hydroxide solution.

.....

e) This compound forms a brown precipitate with sodium hydroxide solution.

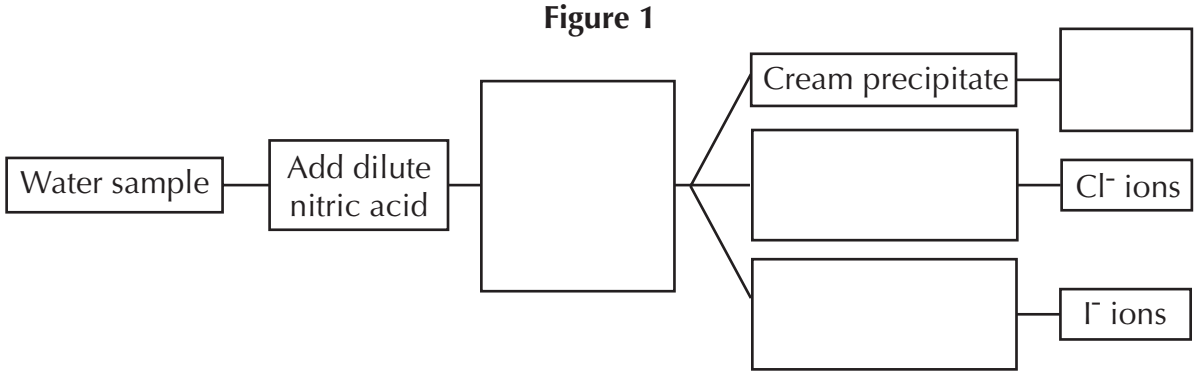
.....

f) This compound reacts with sodium hydroxide to form a white precipitate, and it also gives an orange-red flame in a flame test.

.....

Q6 Sam creates a flow chart, shown in **Figure 1**, as a key to help her identify halide anions present in a sample of water.

Figure 1



a) Finish the flow chart in **Figure 1** by completing the empty boxes.

b) Sam uses this method to identify the halide ion present in a sample of water she has. A cream precipitate forms. Give the name of this precipitate.

.....

Chemistry lessons — testing your patience...

Between the different tests and chemicals and colours, there's a lot to remember here. There are no short cuts unfortunately, you just have to do the work and learn it. Gives you a chance to get your coloured pens out though...

Flame Emission Spectroscopy

Flame emission spectroscopy — a pretty cool test with a pretty cool name.

Warm-Up

Flame emission spectroscopy is a technique that can be used to detect metal ions in a sample. It produces a line spectrum which can be analysed, using reference spectra, to provide information about the ions present.

Flame emission spectroscopy is an example of instrumental analysis — it analyses compounds using machines instead of chemical tests.

Give three advantages of using instrumental analysis to analyse substances over using chemical tests.

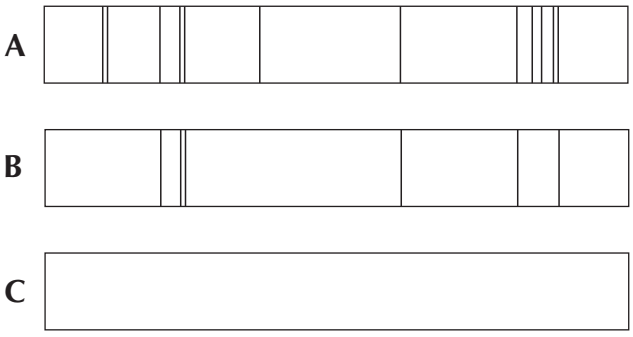
1. .....

2. .....

3. .....

Q1 **A** is a mixture of two metal ions **B** and **C**.
The flame emission spectra of **A** and **B** are given in **Figure 1**.

Figure 1



a) Given that no lines in the spectra of **B** and **C** overlap, complete **Figure 1** by drawing the flame emission spectrum of **C**.

b) As well as identifying the ions present in mixture **A**, what other information could the flame emission spectrum of mixture **A** provide about the ions?

.....

.....

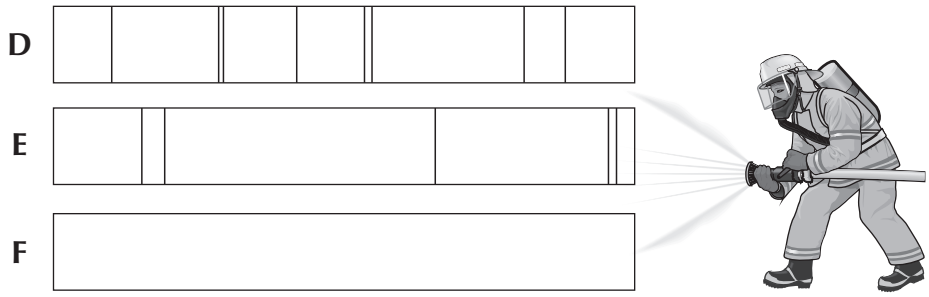
c) Flame tests can also be used to identify metal ions. Suggest why flame emission spectroscopy is likely to successfully identify the ions in **A** but a flame test will not.

.....

.....

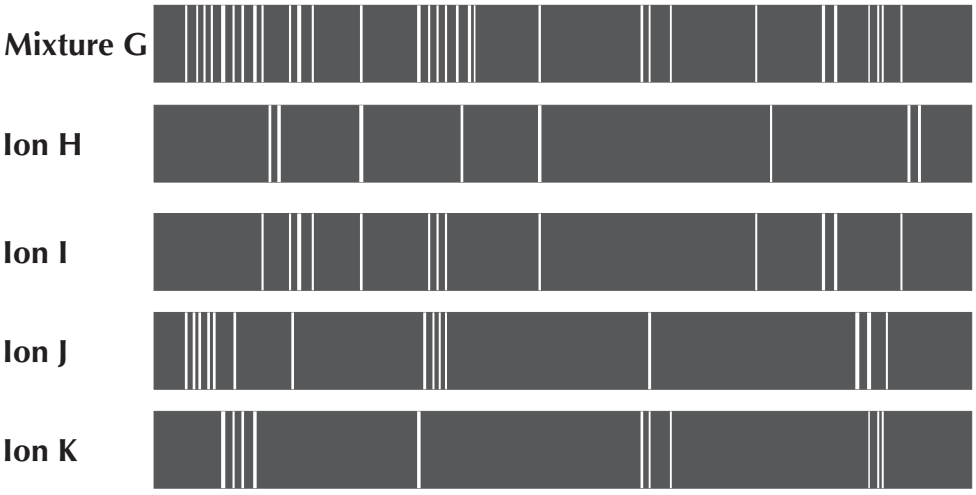
Q2 **D** and **E** are metal ions. Their line spectra are shown in **Figure 2**. **F** is a mixture of **D** and **E**. Complete **Figure 2** by drawing the line spectrum you would expect for **F**.

Figure 2



Q3 **Figure 3** shows the flame emission spectrum for a mixture of ions, **G**, and the flame emission spectra for four metal ions, **H**-**K**.

Figure 3



a) Which metal ions, **H**-**K**, are **not** present in mixture **G**?

.....

b) Does mixture **G** contain any ions not shown in **Figure 3**? Explain your answer.

.....

.....

c) Explain how a spectroscope would have been used to produce the spectrum for Mixture **G**.

.....

.....

.....

Sticking a picture straight onto the wall — frame omission...

Flame emission spectroscopy is a really handy technique for identifying metal ions in a sample and it gives a bit more information than what you'd get from your average flame test. And you still get all those pretty colours, so it's win-win.

The Evolution of the Atmosphere

Much like fashion, the atmosphere has changed over time — some changes good, some not so much.

Warm-Up

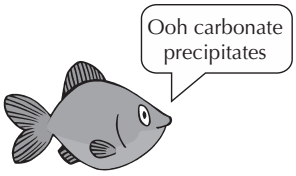
The make-up of the atmosphere has changed a lot over Earth's lifetime. There are several theories for how the atmosphere has evolved, but it's hard gathering evidence over such a long time period to support these theories.

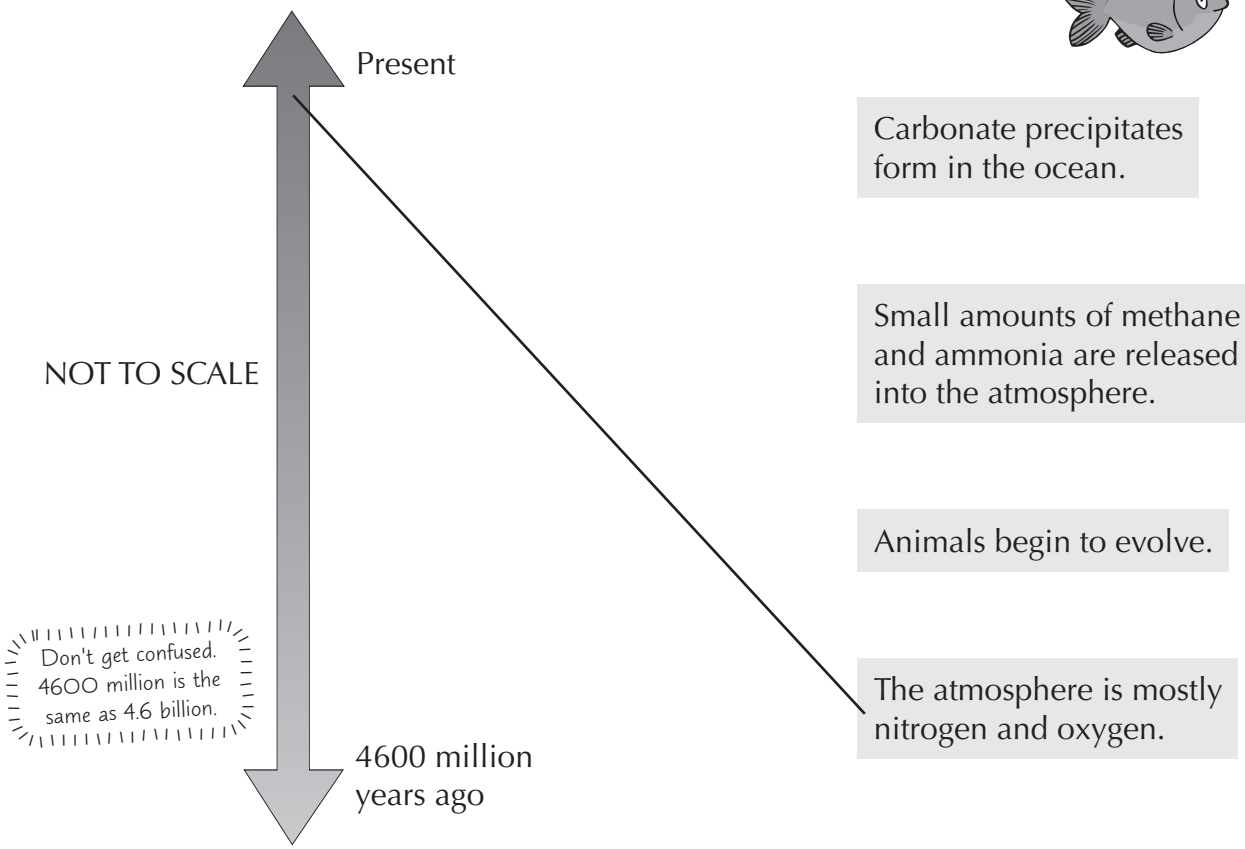
Below is a summary of one theory of how the atmosphere evolved. Use the words in the box to complete it.

carbon dioxide	oxygen	algae	volcanoes

In the first billion years of Earth's life, ... gave out lots of gases which formed the early atmosphere. At this time, ... was one of the most abundant gases in the atmosphere. Over time, this was absorbed by the oceans, as well as by ..... and green plants. These organisms produced ..... through photosynthesis. This led to today's atmosphere.

Q1 Draw lines to put the statements in the right order on the timeline. One has been done for you.

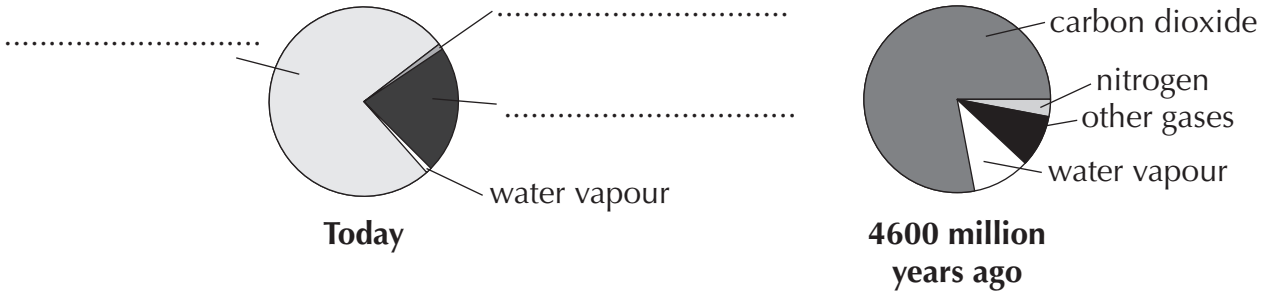




Q2 The pie charts in **Figure 1** show the composition of gases in the atmosphere during two different time periods.

An atmospheric composition

Figure 1



Today **4600 million years ago**

a) Add the labels 'nitrogen', 'oxygen' and 'other gases' to the pie chart on the left.

b) Explain the change in the proportion of water vapour in the atmosphere over this time period.

.....

.....

Q3 Explain why there will be no crude oil or coal beneath the surface of a planet that has never supported life.

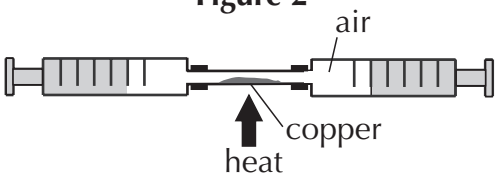
.....

.....

.....

Q4 The proportion of oxygen in the atmosphere can be found by heating an excess of copper so that it reacts with oxygen in the air to form copper oxide.

Figure 2



Think about the percentage of oxygen in the air.

There is 50 cm^3 of air in the apparatus shown in **Figure 2** before the copper is heated. Approximately, how much gas will be left in the apparatus after the copper is heated until the reaction stops?

Volume of gas remaining = ... cm^3

Oceans are trendsetters — they were water vapour before it got cool...

You should be able to recall how the atmosphere evolved into today's wonderfully life-giving sphere of, erm... gas. It's worth knowing that fossil fuels take millions of years to form and unfortunately our supply of them won't last forever.

Greenhouse Gases and Climate Change

It's not that relevant, but you'll be keen to know that I once grew a massive tomato in my greenhouse.

Warm-Up

Greenhouse gases include carbon dioxide and methane.

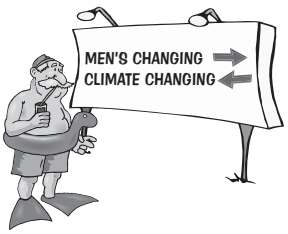
How do greenhouse gases help to support life on Earth?

.....

The levels of greenhouse gases in the atmosphere have increased due to human activities. Most scientists agree that this will lead to climate change.

Which of the following is not likely to be an effect of climate change?

- ☐ **A** Rising sea levels
- ☐ **B** Increased frequency of storms
- ☐ **C** Reduced coastal erosion
- ☐ **D** Changes in the distribution of wild species

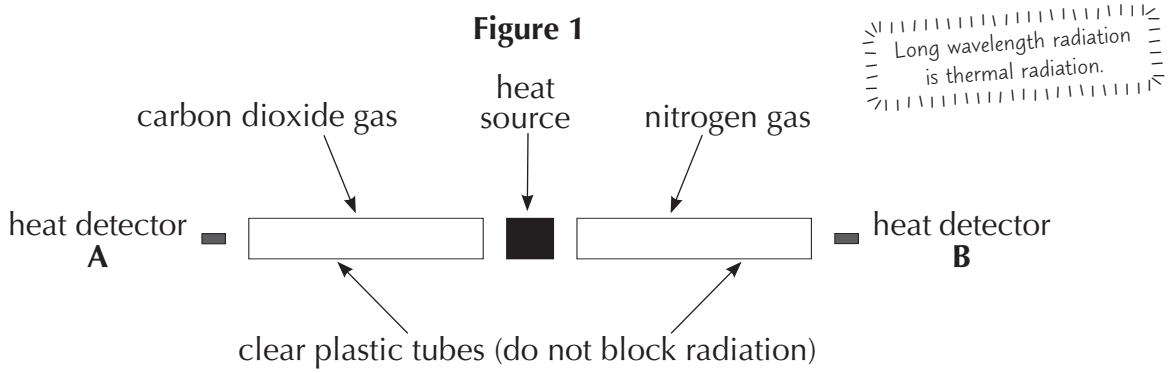


Why is it hard for scientists to avoid creating an over-simplified model of the Earth's climate?

.....

Q1 Sakchai decides to compare the effects of nitrogen and carbon dioxide on long wavelength radiation. The apparatus he uses is shown in **Figure 1**.

Figure 1



State which detector, **A** or **B**, will detect more heat from the heat source. Explain your choice.

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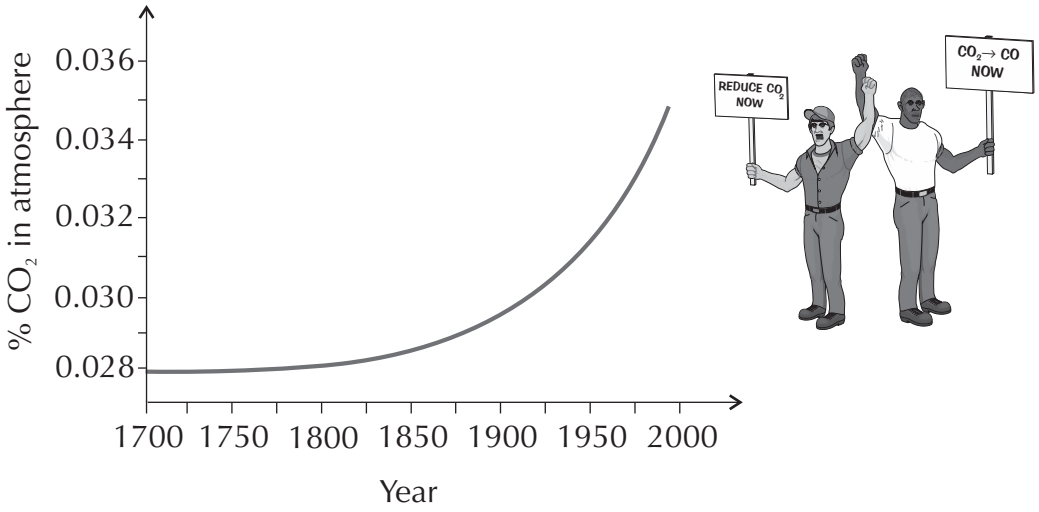
.....

Q2 Answer the questions below using the information shown in **Figure 2** and **Figure 3**.

Figure 2



a) Describe the trend shown by **Figure 2**.

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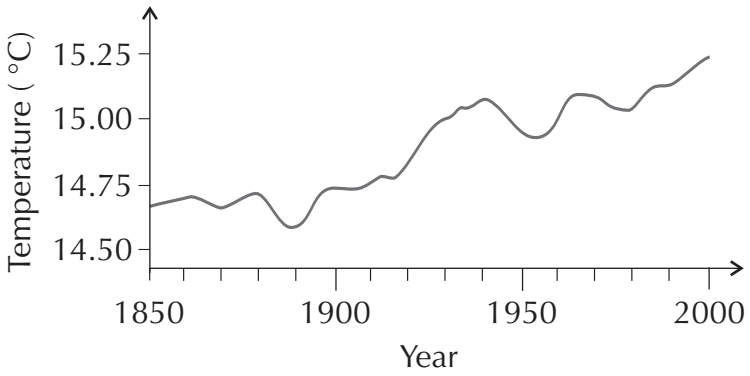
.....

b) Suggest **one** human activity that may have contributed to this trend.

.....

c) **Figure 3** shows the average global temperature between 1850 and 2000.

Figure 3



Which of the following statements represents a valid conclusion that can be drawn from **Figure 2** and **Figure 3**?

Draw your conclusions from these two graphs only.

- ☐ **A** The increase in CO_2 levels has caused a rise in global temperature.
- ☐ **B** CO_2 levels and increasing temperature are positively correlated.
- ☐ **C** Increasing CO_2 levels are causing climate change.
- ☐ **D** Increasing global temperatures are causing an increase in CO_2 levels.

Cutting greenhouse gas production — that's emission possible...

Making predictions about the climate can be tricky because there are so many variables that can affect it. Even with evidence of a correlation between a variable and climate change, you can't always be sure that one caused the other.

Carbon Footprints and Air Pollution

Keep your mind free from polluting thoughts about dinner tonight, and you'll breeze through this.

Warm-Up

A carbon footprint is a measure of the amount of carbon dioxide, methane and other greenhouse gases released by something over its whole life cycle.

Give two ways that governments can encourage people to reduce their carbon footprint.

1. .....

2. .....

When fuels are burned, they can release carbon particulates and polluting gases. These include sulfur dioxide, oxides of nitrogen and carbon monoxide.

Circle the correct options below to complete the sentences:

1. **Carbon monoxide** / **nitrogen dioxide** is a product of incomplete combustion.

2. **Carbon monoxide** / **nitrogen dioxide** can cause acid rain.

3. Global dimming is an effect caused by **carbon particulates** / **sulfur dioxide**.

Q1 **Figure 1** is an extract from Milly's diary.

Figure 1

Milly's diary — 15th Sept

8.00 am: Made a cup of tea with my kettle filled to the brim. Always good to have enough for another cuppa! Ate a lovely pineapple from Ghana.

10.00 am: Drove to the travel agent in my new 4×4 car and booked a holiday in Hawaii — leaving tonight!

11.00 am: Went shopping for a grass skirt — a must have!

11.30 am: Got home and put my new skirt on. Got a bit chilly though, so I put the heating on high. Toasty.

5.00 pm: Drove to the airport. Left all lights on — got to keep burglars away.

a) Milly's travel agent tells Milly that she thinks pineapples should be banned in the UK because their transport leads to increased carbon dioxide emissions. Give **two** reasons why people might object to the banning of pineapples in the UK.

1. .....

.....

2. .....

.....

b) Suggest **four** things that Milly could change during her day to reduce her own carbon dioxide emissions.

1. .....

2. .....

3. .....

4. .....

Q2 Explain why carbon monoxide and carbon particulates are more likely to be formed when fossil fuels are burned in engines than when they are burned in the open air.

.....

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Q3 A student burns a small sample of a fuel and collects some of the gas produced in a test tube containing a piece of damp litmus paper. The litmus paper turns red, indicating that an acid is present.

Suggest an impurity that might be present in the fuel.

.....

Q4 Air pollution can damage the environment and cause negative effects to health.

a) A higher proportion of people living near a coal-fired power station suffer from respiratory problems than people living in the open countryside. Suggest an explanation for this observation.

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b) Rain which falls near a motorway is more acidic than rain that falls in the open countryside. Explain why rain which falls near a motorway is acidic.

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Rain, rain, go away — you've corroded all me blummin' gnomes...

Reducing air pollution and cutting our carbon footprints are quite hot topics these days. Companies and governments are doing more to help the situation, so my new gnomes might not corrode quite as fast. Thank goodness.

Materials

Knowing about the properties of different materials will help you pick one that's up to the job.

Warm-Up

Ceramics, polymers and composites are examples of different types of material. These materials have particular properties which make them better suited to some jobs than others. Alloys are made by adding another element to a metal. Many alloys are used in everyday life.

Clay and glass are examples of...

... alloys. ☐ **... ceramics.** ☐ **... composites.** ☐ **... polymers.** ☐

Wood is an example of a composite material. Name one other example.

.....

Q1 **Figure 1** shows the production methods for two different types of glass, **X** and **Y**.

Figure 1

Glass X	**Glass Y**
Made by heating sodium carbonate, limestone and sand.	Made by heating sand and boron trioxide.

One of the types of glass is soda-lime glass. The other is borosilicate glass. Which type of glass, **X** or **Y**, will melt at a higher temperature?

.....

Q2 Yaseen has two rulers made from different polymers. He first tries to bend them and then he heats them. The results are shown in **Table 1**.

Table 1

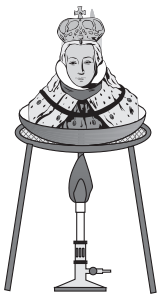
Ruler	Result on bending	Result on heating
1	Bends easily and springs back into shape.	Becomes soft and then melts. Can be remoulded.
2	Snaps in two.	Doesn't soften and eventually turns black.

a) Ruler **1** is made from a...

... thermosoftening polymer. ☐ ... thermosetting polymer. ☐

b) Why does ruler **1** melt when it's heated?

.....



Q3 **Table 2** shows the properties of three different materials.

Table 2

Material	Heat conduction	Resistance to corrosion	Strength
1	good	excellent	good
2	average	good	excellent
3	excellent	good	good

Use the information in **Table 2** to decide which material would be the most suitable for making the following objects:

a) i) Saucepan bases .....

ii) An outdoor statue .....

b) One of the materials in **Table 2** is 18 carat gold. It contains 18 parts gold to 6 parts other metals. What percentage of 18 carat gold is made from other metals?

Percentage of other metals = ... %

Q4 **Table 3** shows some data about the density and strength of three materials.

Table 3

Material	Density (g/cm^3)	Strength (MPa)
Alloy A	7.9	490
Alloy B	2.7	310
Composite C	1.8	7000

a) Which material is most likely to be an alloy of aluminium? Explain your answer.

.....

b) Composite C contains two different materials.
Suggest how these materials are arranged in composite C.

.....

..... .

c) Which of these materials would be most suitable for use as a sports car body?
Explain your answer.

.....

.....

Clay once worked for a thriving business — until it got fired...

Ceramics, composites, polymers and alloys are everywhere. Take a look around you and see if you can spot any objects made from them. Then try to imagine your life without all those objects — trust me, it is not pretty.

Corrosion

Ever found flaky orange bits on your bike after leaving it out in the rain? That's rust, my friend.

Warm-Up

Corrosion is the gradual destruction of a material as it reacts with substances in the environment. Rusting is the name given for the corrosion of iron.

Circle the correct words to complete each sentence below.

The mass of a piece of iron after it has rusted is **larger** / **smaller** than before it rusted.

The mass changes because iron atoms have bonded to **carbon dioxide** / **oxygen** molecules and **water** / **hydrogen** molecules.

Rusting can be prevented in several ways, for example, by oiling or painting the iron.

Some metals can react with substances and form a layer which protects them from further corrosion. An example of a metal that does this is aluminium.

Name the substance that is formed when aluminium corrodes.

.....

Q1 Faiza and Joe each buy an iron barbecue. Faiza stores her barbecue outside in the winter. The following summer, Faiza finds that her barbecue has started to rust.

a) Joe keeps his barbecue in the garage. Is Joe's barbecue more or less likely to rust than Faiza's? Explain your answer.

.....

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b) Faiza removes the rusty parts of her barbecue and then paints it to prevent further corrosion. Explain how painting the barbecue prevents it from rusting.

.....

.....

c) The heat produced by the barbecue damages the layer of paint on Faiza's barbecue. Joe suggests that Faiza should coat her barbecue with gold because it will prevent rusting and will also look really fancy.

Gold is less reactive than iron.

Name a method that could be used to coat Faiza's barbecue with gold.

.....

Q2 There are several methods that can be used to prevent the corrosion of metals and alloys.

a) A manufacturer wants to prevent the corrosion of an iron ship's hull by using sacrificial protection. Describe what is meant by sacrificial protection and explain how it would protect the hull from corrosion.

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b) A roofing company coats an iron roof with a layer of zinc to protect it from rusting. After a while, the zinc layer becomes scratched. Would you expect the iron roofing to begin to rust? Explain your answer.

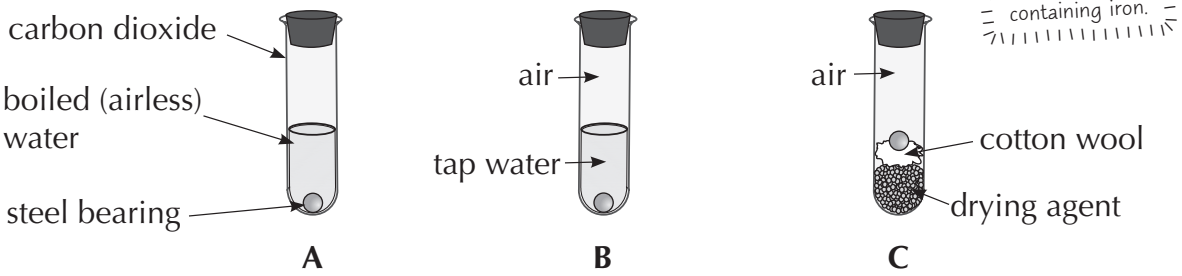
.....

.....

PRACTICAL

Q3 Krystyna is investigating rusting. She places three identical steel bearings into separate test tubes, **A**, **B** and **C**. **Figure 1** is a diagram of her experiment.

Figure 1



Steel is an alloy containing iron.

a) State the **two** things that are needed for a steel bearing to rust.

.....

b) In which test tube, **A**, **B** or **C**, will the bearing rust?

.....

c) Krystyna wraps a steel bearing with magnesium wire. She then puts it in a test tube identical to test tube **B**. Predict what will happen to the ball bearing. Explain your prediction.

Magnesium is more reactive than iron.

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Iron Man's had a really busy morning — he's rust off his feet...

Only materials containing iron will rust, but lots of other materials will corrode. While the corrosion of aluminium forms a nice protective layer, the corrosion of other metals can be pretty damaging. So best keep your bike out of the rain...

Finite and Renewable Resources

Earth's resources will run out someday — just like my inspiration for witty page introductions...

Warm-Up

Natural resources are resources which form without input from humans. They can come from the earth, sea or air. The rate at which natural resources are replenished determines whether a resource can be considered as finite or renewable.

Natural resources can be improved upon, or replaced, by man-made processes. Agriculture can also be used to enhance natural resources to meet our needs.

Complete the following table by putting the resources below in the correct columns.

food uranium rubber aluminium fresh water petrol

Finite resources	Renewable resources

Q1 Which of the following statements is true? Tick **one**.

- ☐ **A** Timber is a natural, non-renewable resource because it cannot renew itself quickly enough to be considered replaceable.
- ☐ **B** Timber is a natural, renewable resource because it can renew itself quickly enough to be considered replaceable.
- ☐ **C** Timber is a natural, renewable resource because it cannot renew itself quickly enough to be considered replaceable.
- ☐ **D** Timber is a natural, non-renewable resource because it can renew itself quickly enough to be considered replaceable.

Q2 Diesel oil is a man-made, finite resource obtained from crude oil. It is used as a fuel.

Explain why diesel oil is considered to be a finite resource.

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Q3 Leslie lives on Planet Mollim. Leslie has discovered three resources which could be used as fuels to support her planet's energy requirements. **Table 1** shows the energy density of these resources.

Table 1

Resource	Energy Density (MJ/m^3)
Nababa Fruit Skins	5.0×10^5
Angry Hair Plants	5.0×10^2
Flapadron Tears	2.7×10^7

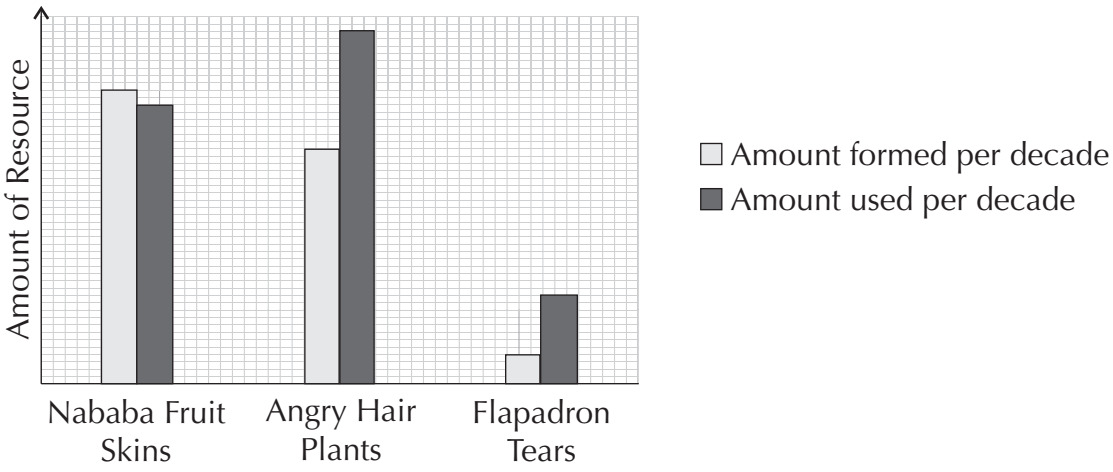
Energy density is the amount of energy released when 1 m^3 of the fuel is burnt.

a) Calculate the difference between the energy densities of Nababa Fruit Skins and Angry Hair Plants. Give your answer in standard form to 3 decimal places.

Difference in energy density = ... MJ/m^3

Leslie has predicted the amount of each resource that will be needed to provide enough energy to power Planet Mollim. **Figure 1** shows Leslie's predictions compared with the amount of each resource formed per decade.

Figure 1



b) Which fuel is most likely to be considered a renewable fuel? Explain your answer.

.....

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c) Which fuel is the most suitable as a sustainable energy source for Planet Mollim? Use the information in **Table 1** and **Figure 1** to explain your answer.

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CGP — renewing interest in science since the nineties...

It's important that you understand that some resources are renewable, and that others will run out. Lots of companies are now trying to find ways to limit their use of finite resources and develop their businesses in a more sustainable way.

Reuse and Recycling

When you've finished with this book, you could reuse it as a coaster. Or a sledge. Or a frisbee...

Warm-Up

It's important that we try to use resources in a sustainable way. This means we must take into account the needs of future generations as well as our own. One way of using resources sustainably is to reuse and recycle them. This helps to stop them from running out.

Reusing glass can help sustainability by reducing the amount of waste produced when glass is thrown away.

Give one other way in which reusing glass helps sustainability.

.....

Some forms of glass can be reused without reshaping.
Other forms of glass need to be recycled instead.

How are glass bottles recycled to make new glass products?

.....

Q1 Below is some information about aluminium, a widely used metal.

Bauxite (aluminium ore) gives 1 kg of aluminium for every 4 kg of bauxite mined.
Extracting aluminium from bauxite requires huge quantities of electricity.
Recycling aluminium uses 5% of the energy required to extract it from bauxite.

a) How much ore has to be mined to produce 1000 kg of aluminium?

.....

b) Using the information given and your own knowledge, outline **three** consequences of:

i) Mining the bauxite.

.....

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.....

ii) Not recycling the cans.

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Q2 Jet fuels can be made more sustainable by mixing a 1:1 ratio of recycled cooking oil with conventional jet fuel. **Table 1** shows some information about cooking oil and conventional jet fuels.

Table 1

	Cooking oil	Conventional jet fuel
Natural resource	Plants	Crude oil
Renewable or finite?	Renewable	Finite

Use the information in **Table 1** to explain why using a mix of conventional jet fuel and cooking oil is more sustainable than using conventional jet fuel alone.

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Q3 Nickel is a metal which is used for making batteries and can also be used as a catalyst for the hydrogenation of ethene. Nickel can be extracted from low-grade ores using bacteria.

a) Explain how bacteria can be used to extract nickel from low-grade ores.

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b) Suggest another example of an alternative extraction method that could be used to extract nickel from low-grade ores.

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c) Explain why these alternative extraction methods are so important.

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Ordered lithium diisopropylamide. Barman asked, "Why the long base?"...

Cracking jokes like the ones you'll find in this book have to be mined from the Earth's crust, you know. So to save energy and reduce the environmental costs of this book, I thought I'd recycle the wonderful pun from page 57.

Life Cycle Assessments

The total impact of the products we make and use needs to be assessed.

Warm-Up

Before a company can produce a new product, they have to carry out a life cycle assessment.

Complete the passage about life cycle assessments using words from the box below.

stage environment assess sustainable process materials protect cost

Companies have to ..... the impact their processes and products will have on the ..... and use this information to choose a ..... that does minimal harm. It also helps them to choose the best ..... for the job. They have to look at the impact of each ..... of the product's life.

Q1 Which stages of a product's life are being described below? Draw lines to match them up.

A computer being powered by electricity.

Poly(ethene) being made from ethene.

A lot of plastic bottles being thrown away.

Oil being drilled out of the ground.

Window frames being made from PVC.

Using the product.

Manufacturing the product.

Extracting the raw materials.

Manufacturing the material.

Disposing of the product.

Q2 Helen is comparing the life cycle assessment for two different CD racks. One is made from metal and the other is made from plastic.

a) Suggest which stage of the life cycle assessment would be the same for both of the racks.

.....

b) Suggest **two** environmental impacts of extracting the raw material for the metal rack.

.....

.....

Q3 Kat is a cafe owner. She wants to replace the plastic straws she gives to customers with a more environmentally friendly alternative. She carries out life cycle assessments for plastic straws and paper straws, in order to compare them. Her findings are shown in **Table 1**.

Table 1

	Plastic straw	Paper straw
Raw materials	Crude oil	Timber
Manufacturing	• Crude oil processed using fractional distillation, followed by cracking and polymerisation to produce the compounds needed for plastic. • Other oil fractions have other uses, so waste is reduced.	• Pulped timber processed, requiring a lot of energy.
Using the product	• Could be washed and reused, but typically are not.	• Can only be used once.
Product disposal	• Too small for most recycling systems, so usually sent to landfill, where they do not biodegrade. • Often end up in rivers and oceans.	• Can be recycled. • Break down in landfill within 50 days.

a) Use the information given in **Table 1** to explain why Kat may decide that paper straws are a more environmentally friendly choice.

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b) The life cycle assessment of a new biodegradable plastic straw claims that they are more environmentally friendly than traditional plastic straws because they break down in compost within three months. Kat finds out that this is only true in special industrial compost facilities.

Describe a problem with the life cycle assessment of the new straws.

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All but one of my straws were stolen. Well, that was the last straw...

It's not quite explosions and the periodic table, but chemists have a key role to play in developing materials and processes that minimise harm to the environment. Being able to interpret LCAs will help you understand the bigger picture.

Treating Water

I'd say it's you that's in for the treat with these next two pages...

Warm-Up

The water we use can come from a range of environmental sources, depending on local conditions. Waste water comes from domestic, agricultural and industrial sources. It needs to be treated before it can be returned to rivers and lakes.

Water is treated to make it potable. What is meant by potable water?

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How is potable water different to pure water?

.....

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PRACTICAL

Q1 Eva's teacher gives her three samples of water, **A**, **B** and **C**. One of the samples is sea water, one is rainwater and one is tap water. Eva needs to identify each of the three samples.

a) Eva starts by adding universal indicator to a small portion of each sample to measure the pH. Suggest why Eva did not add universal indicator to the whole of each sample.

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b) Eva distils 100 cm^3 of each sample. She uses a mass balance to measure the mass of the salt crystals left after all of the water has evaporated. She records her readings in **Table 1**.

Table 1

Sample	Mass of salt crystals (g)
A	3.57
B	0.01
C	0.00

Which of the samples, **A**, **B**, or **C**, is the sea water? Explain your answer.

.....

.....

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Q2 **Figure 1** gives some information about sources of water near to the town of Grizeton.

Figure 1

> Grizeton is located close to the coast, providing easy access to sea water. There are lakes in the surrounding region, but the warm climate means the water level drops significantly in summer. The rocks in the region are aquifers, storing large amounts of groundwater.

a) Some of the potable water supplied to Grizeton comes from treating fresh water. Explain why it is unlikely that Grizeton will obtain fresh water through the desalination of sea water.

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b) Explain whether the lakes or the aquifers would be the best source for fresh water.

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c) Grizeton also uses a sewage treatment plant to treat waste water from the town. Compare the stages of the processes used to treat fresh water and waste water.

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A teabag, milk and two sugars — that's how I treat my water...

There are loads of different stages involved in water treatment, and you need to be able to remember the lot of them (you lucky thing...). Try drawing out some flowcharts to check you know the order things happen in.

The Haber Process

Ammonia is an important little molecule and you need to know how it can be made.

Warm-Up

The Haber process is used to produce ammonia from nitrogen and hydrogen. Ammonia is used to make fertilisers.

The Barber process

Give one source of the nitrogen that is used in the reaction.

.....

Give one source of the hydrogen that is used in the reaction.

.....

The reaction between nitrogen and hydrogen which is used in the Haber process is reversible. Write the balanced symbol equation for this reaction.

.....

Q1 In industry, the Haber process is carried out at 200 atmospheres and 450 °C.

a) In comparison to the conditions used in industry, which of the following sets of conditions would result in an increase in the rate of the reaction, but a decrease in the yield of ammonia?

- ☐ **A** 800 atmospheres, 450 °C
- ☐ **B** 450 atmospheres, 200 °C
- ☐ **C** 200 atmospheres, 1000 °C
- ☐ **D** 100 atmospheres, 450 °C

b) i) How would increasing the pressure to 800 atmospheres affect the rate of the Haber process?

.....

ii) Explain the effect that carrying out the Haber process at a pressure of 800 atmospheres would have on the yield of ammonia. Refer to the reaction equation for the Haber process in your answer.

.....

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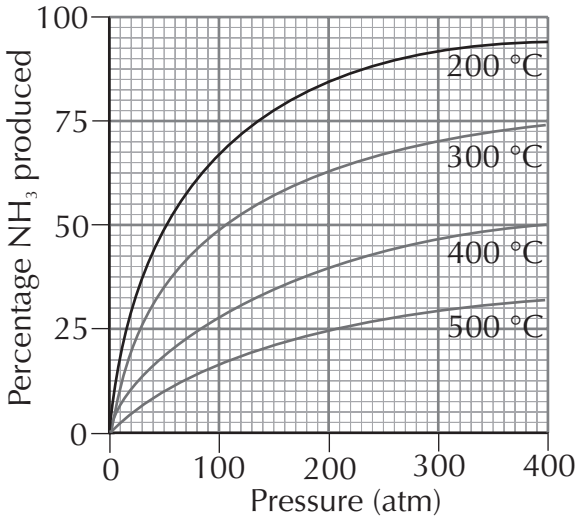
iii) Why isn't a pressure of 800 atmospheres used in industry?

.....

Q2 **Figure 1** shows how the percentage of ammonia produced during the Haber process varied under different conditions. An iron catalyst was used.

Figure 1



a) What is the percentage yield of ammonia when the process is carried out at a pressure of 270 atm and a temperature of 400 °C?

.....

b) Using **Figure 1**, explain whether the reaction to produce ammonia is exothermic or endothermic.

.....

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c) How would you expect the graphs in **Figure 1** to look if the Haber process had been carried out without using a catalyst?

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d) When the Haber process is carried out in industry, around 98% of the reagents are eventually converted to ammonia. Explain how this is possible, given the information in **Figure 1**.

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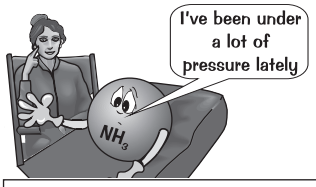

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Parking my speedboat is my kind of Haber process...

If you've found these pages tricky, look back at your notes for Topic 6 on reversible reactions and equilibria. All the same ideas are involved in this topic — they've just been applied to one specific industrial reaction.

NPK Fertilisers

But what happens to all that ammonia, I hear you cry. You're about to find out...

Warm-Up

Farmers use NPK fertilisers to make sure their plants get enough of the three main elements essential for growth and life processes. This allows the plants to grow bigger and faster, which increases crop yield.

Tick the sentences below which are true.

- ☐ **A NPK fertilisers always contain nitrogen, phosphorus and calcium.**
- ☐ **B NPK fertilisers are formulations containing various salts.**
- ☐ **C The nitrogen salts used in fertilisers are obtained directly by mining.**

Q1 Ammonium nitrate is a salt often used in fertilisers.

It is produced using the following exothermic reaction:

$$NH_3 + HNO_3 \rightarrow NH_4NO_3$$

Table 1 gives some information about the methods used to carry out this reaction in the laboratory and in industry.

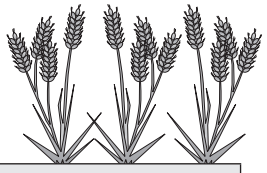

Table 1

	Laboratory	Industry
Concentrations of ammonia solution and nitric acid	Low	High
Final stage of process	Crystallisation to produce pure ammonium nitrate crystals	Evaporation of water from the reaction mixture to produce concentrated ammonium nitrate product

a) i) Explain why lower concentrations of reactants are used in the laboratory than are used in industry.

.....

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ii) Why is the final stage of the method used in industry different to that used in the laboratory?

.....

b) Give the name of a salt that could be mixed with ammonium nitrate to produce a fertiliser that is a source of both nitrogen and potassium.

.....

Q2 A 25 kg bag of NPK fertiliser is labelled 15:5:30, to show the percentages of N, P and K, respectively, in the bag.

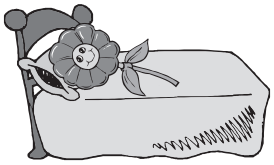
What is the total mass of nitrogen in this bag of fertiliser?
Give your answer to 2 significant figures.

mass of nitrogen = ... kg

Q3 Gary the gardener decides to investigate different fertilisers. He has four flower beds, **A**-**D**, and plants the same type of flower in each. He makes sure that the conditions of each flower bed are kept the same. **Table 2** shows what is added to each flower bed.

Table 2

Flower bed	Fertiliser
A	None
B	Phosphate rock
C	Phosphate rock reacted with nitric acid
D	Phosphate rock reacted with phosphoric acid



a) A few weeks later, Gary inspects the flowers in each bed. Gary is surprised to see that the flowers in **B** have grown the same amount as the flowers in **A**, despite adding phosphate rock which contains phosphate salts.
Explain why the flowers in **B** have not grown more than those in **A**.

.....

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b) The flowers in **C** have grown more than the flowers in **D**. Explain why this is.

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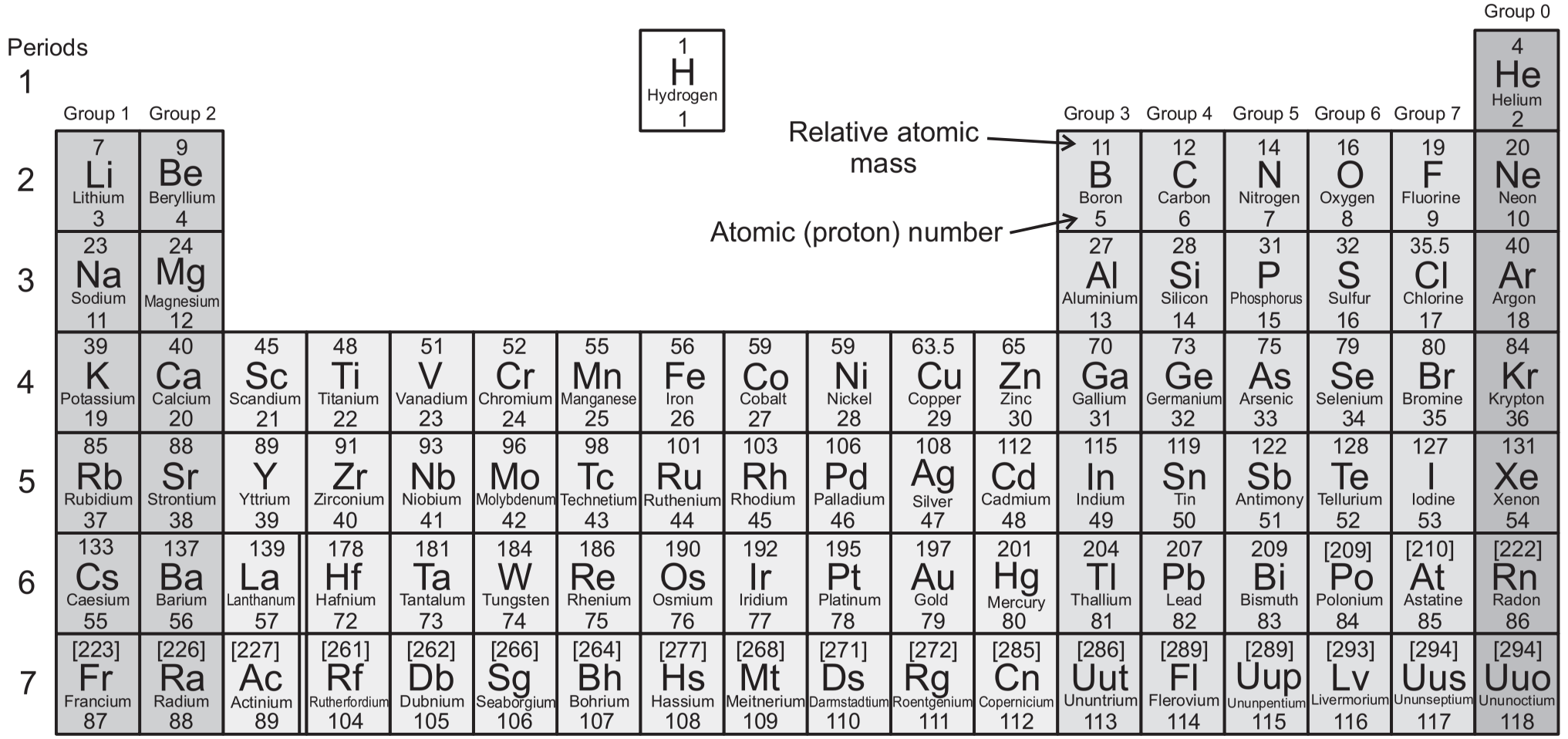
It's as easy as N P K...

You don't need to worry too much about what each of the three elements, N, P and K, do for the plants (this isn't biology after all), but you do need to make sure you remember what those elements are, and where they all come from.

The Periodic Table



The Lanthanides (atomic numbers 58-71) and the Actinides (atomic numbers 90-103) are not shown in this table.

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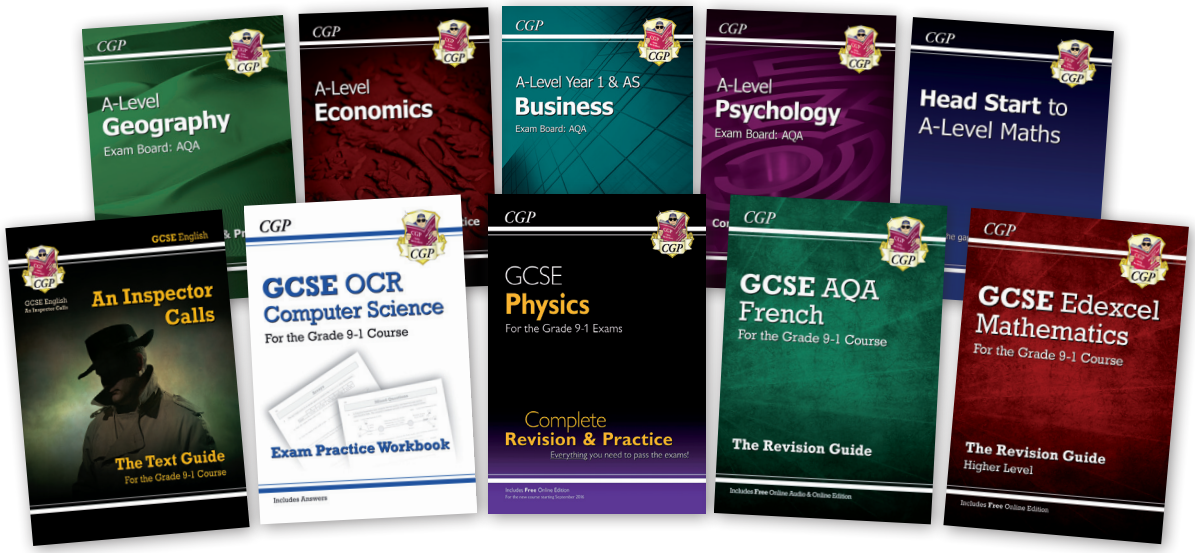

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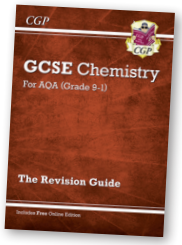

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