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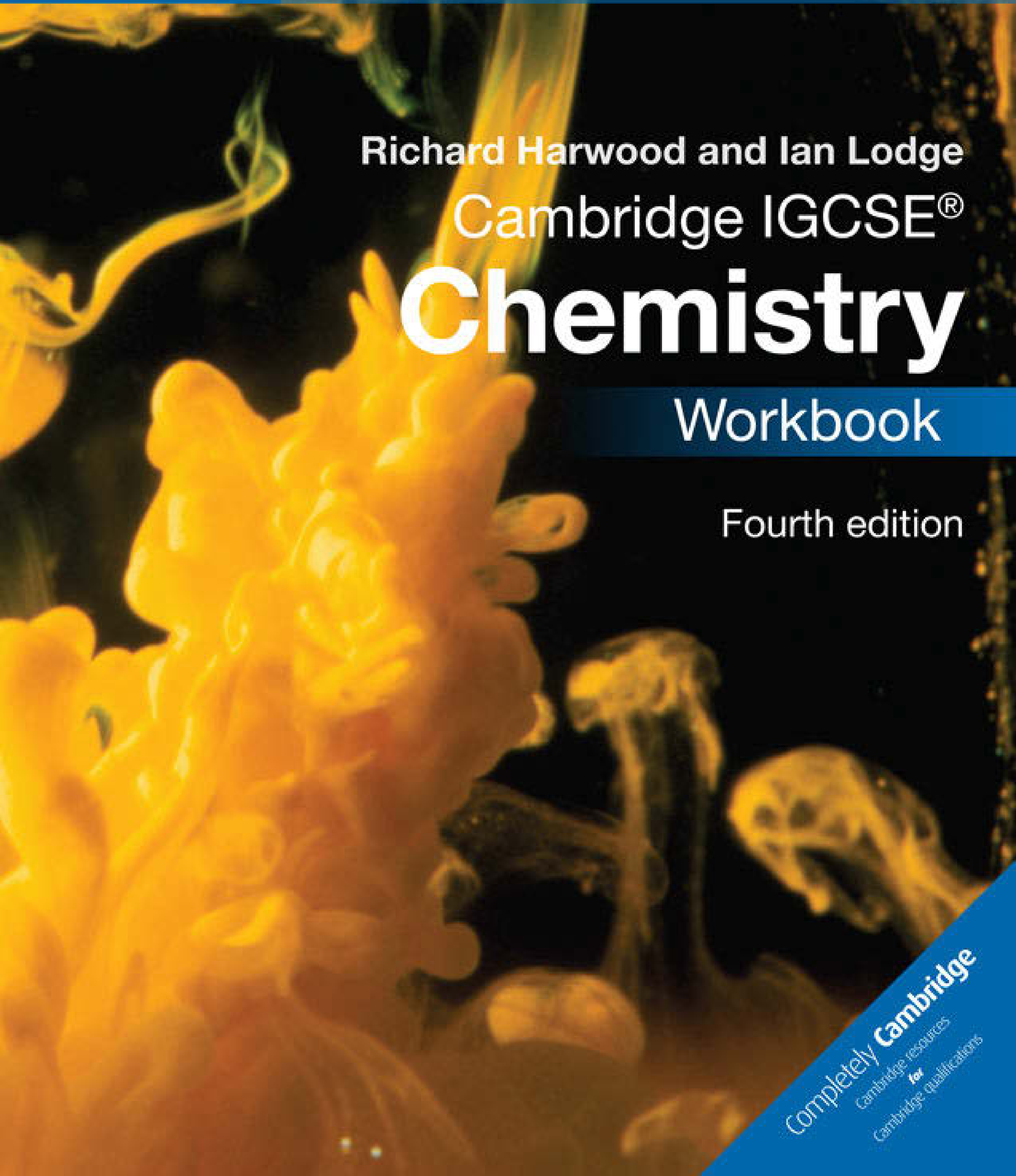
Richard Harwood and Ian Lodge

Cambridge IGCSE® Chemistry

Workbook

Fourth edition



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Introduction

This workbook contains exercises designed to help you to develop the skills you need to do well in your IGCSE Chemistry examination.

The IGCSE examination tests three different Assessment Objectives. These are:

AO1 Knowledge with understanding
AO2 Handling information and problem solving
AO3 Experimental skills and investigations

In the examination, about 50% of the marks are for objective AO1, 30% for objective AO2 and 20% for AO3.

Just learning your work and remembering it is, therefore, not enough to make sure that you get the best possible grade in the exam. Half of all the marks are for objectives AO2 and AO3. You need to be able to use what you have learnt and apply it in unfamiliar contexts (AO2) and to demonstrate experimental and data handling skills (AO3).

There are lots of exam-style questions in your coursebook which, together with the material on the accompanying CD-ROM, are aimed at helping you to develop the examination skills necessary to achieve your potential in the exams. Chapter **12** in the coursebook also deals with the experimental skills you will need to apply during your course. This workbook adds detailed exercises to help you further. There are some questions that simply involve remembering things you have been taught (AO1), but most of the exercises require you to use what you have learned to extend your knowledge to novel situations that you have not met before, or to work out, for example, what a set of data means, and indeed to suggest how an experiment might be improved: they are aimed at developing objectives AO2 and AO3. Chemistry is a subject where it is important to understand the connections between the ideas involved. So, while each exercise has a focus on a particular topic, the questions will take you to different connected areas of the subject. There are also exercises, particularly in Chapter 12, aimed at developing your skills in planning practical investigations; an important area of objective AO3.

There are a good many opportunities for you to draw graphs, read scales, interpret data and draw conclusions. These skills are heavily examined in alternative to practical written examinations and so need continuous practice to get them right. Self-assessment check lists are provided to enable you to judge your work according to criteria similar to those used by examiners. You can try marking your own work using these. This will help you to remember the important points to think about. Your teacher should also mark the work, and will discuss with you whether your own assessments are right.

The workbook follows the same chapter breakdown as the coursebook. It is not intended that you should necessarily do the exercises in the order printed, but that you should do them as needed during your course. There are questions from all sections of the syllabus and one aim has been to give a broad range of examples of how the syllabus material is used in exam questions. The workbook is aimed at helping all students that are taking the Chemistry course.

S The exercises cover both Core and Supplement material of the syllabus. The Supplement material can be identified by the Supplement symbol in the margin (as shown). This indicates that the exercise is intended for students who are studying the Supplement content of the syllabus as well as the Core.

A Some exercises contain additional information that will not be examined, but will help develop your scientific skills and broaden your knowledge. These are identified by the Additional symbol in the margin (as shown).

We trust that the range and differing approaches of the exercises will help you develop a good understanding of the course material and the skills to do really well in the exams.

The Periodic Table

Group																	
I	II											III	IV	V	VI	VII	VIII / 0
							1 **H** Hydrogen 1										2 **He** Helium 4
3 **Li** Lithium 7	4 **Be** Beryllium 9	Key	a **X** b	a = relative atomic mass **X** = atomic symbol b = proton (atomic) number								5 **B** Boron 11	6 **C** Carbon 12	7 **N** Nitrogen 14	8 **O** Oxygen 16	9 **F** Fluorine 19	10 **Ne** Neon 20
11 **Na** Sodium 23	12 **Mg** Magnesium 24											13 ***Al*** Aluminium 27	14 **Si** Silicon 28	15 **P** Phosphorus 31	16 **S** Sulfur 32	17 ***Cl*** Chlorine 35.5	18 **Ar** Argon 40
19 **K** Potassium 39	20 **Ca** Calcium 40	21 **Sc** Scandium 45	22 **Ti** Titanium 48	23 **V** Vanadium 51	24 **Cr** Chromium 52	25 **Mn** Manganese 55	26 **Fe** Iron 56	27 **Co** Cobalt 59	28 **Ni** Nickel 59	29 **Cu** Copper 64	30 **Zn** Zinc 65	31 **Ga** Gallium 70	32 **Ge** Germanium 73	33 **As** Arsenic 75	34 **Se** Selenium 79	35 **Br** Bromine 80	36 **Kr** Krypton 84
37 **Rb** Rubidium 85	38 **Sr** Strontium 88	39 **Y** Yttrium 89	40 **Zr** Zirconium 91	41 **Nb** Niobium 93	42 **Mo** Molybdenum 96	43 **Tc** Technetium –	44 **Ru** Ruthenium 101	45 **Rh** Rhodium 103	46 **Pd** Palladium 106	47 **Ag** Silver 108	48 **Cd** Cadmium 112	49 **In** Indium 115	50 **Sn** Tin 119	51 **Sb** Antimony 122	52 **Te** Tellurium 128	53 **I** Iodine 127	54 **Xe** Xenon 131
55 **Cs** Caesium 133	56 **Ba** Barium 137	57 * **La** Lanthanum 139	72 **Hf** Hafnium 179	73 **Ta** Tantalum 181	74 **W** Tungsten 184	75 **Re** Rhenium 186	76 **Os** Osmium 190	77 **Ir** Indium 192	78 **Pt** Platinum 195	79 **Au** Gold 197	80 **Hg** Mercury 201	81 ***Tl*** Thallium 204	82 **Pb** Lead 207	83 **Bi** Bismuth 209	84 **Po** Polonium 209	85 **At** Astatine 210	86 **Rn** Radon 222
87 **Fr** Francium 223	88 **Ra** Radium 226	89 † **Ac** Actinium 227	104 **Rf** Rutherfordium 261	105 **Db** Dubnium 262	106 **Sg** Seaborgium 263	107 **Bh** Bohrium 264	108 **Hs** Hassium 265	109 **Mt** Meitnerium 268	110 **Ds** Darmstadtium 281	111 **Rg** Roentgenium 273	112 **Cn** Copernicium –	113 **Uut** Ununtrium –	114 ***Fl*** Flerovium –	115 **Uup** Ununpentium –	116 **Lv** Livermorium –	117 **Uus** Ununseptium –	118 **Uuo** Ununoctium –

*58–71 Lanthanoid series	58 **Ce** Cerium 140	59 **Pr** Praseodymium 141	60 **Nd** Neodymium 144	61 **Pm** Promethium 145	62 **Sm** Samarium 150	63 **Eu** Europium 152	64 **Gd** Gadolinium 157	65 **Tb** Terbium 159	66 **Dy** Dysprosium 163	67 **Ho** Holmium 165	68 **Er** Erbium 167	69 **Tm** Thulium 169	70 **Yb** Ytterbium 173	71 **Lu** Lutetium 175
†90–103 Actinoid series	90 **Th** Thorium 232	91 **Pa** Protactinium 231	92 **U** Uranium 238	93 **Np** Neptunium 237	94 **Pu** Plutonium 244	95 **Am** Americium 243	96 **Cm** Curium 247	97 **Bk** Berkelium 247	98 **Cf** Californium 251	99 **Es** Einsteinium 252	100 **Fm** Fermium 257	101 **Md** Mendelevium 258	102 **No** Nobelium 259	103 **Lr** Lawrencium 262

1 Planet Earth

Definitions to learn

- **acid rain** rainfall with a pH usually less than 5 resulting from dissolved atmospheric pollution
- **greenhouse gas** a gas which absorbs heat (infrared radiation) and keeps the surface of the planet warm
- **photosynthesis** the photochemical reaction in the green leaves of plants that turns carbon dioxide and water into glucose and oxygen
- **respiration** the biochemical reaction in living cells that produces energy from the reaction of glucose and oxygen to produce carbon dioxide and water

Useful equations

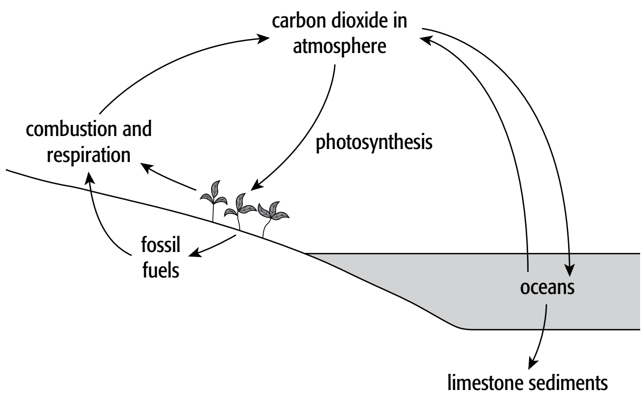
carbon dioxide + water → glucose + oxygen	$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$	photosynthesis
glucose + oxygen → carbon dioxide + water	$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$	respiration

Exercise 1.1 Global warming and the 'greenhouse effect'

This exercise will help in developing your skills at processing unfamiliar data and making deductions from novel sources.

S

The diagram shows a simplified carbon cycle.



a Describe the process of photosynthesis in simple terms.

…………………………………………………………………..

…………………………………………………………………..

…………………………………………………………………..

The '**greenhouse effect**' is caused by heat from the Sun being trapped inside the Earth's atmosphere by some of the gases which are present – their molecules absorb infrared radiation. As the amount of these 'greenhouse gases' increases, the mean (average) temperature of the Earth increases. It is estimated that, if there were no 'greenhouse effect,' the Earth's temperature would be cooler by 33 °C on average. Some of the gases which cause this effect are carbon dioxide, methane and oxides of nitrogen (NO_x).

Global warming: Since the burning of fossil fuels started to increase in the late nineteenth century, the amount of carbon dioxide in the atmosphere has increased steadily. The changes in the mean temperature of the Earth have not been quite so regular. Below are some data regarding the changes in mean temperature of the Earth and amount of carbon dioxide in the atmosphere. The first table (Table **1**) gives the changes over recent years, while the second table gives the longer-term changes (Table **2**). The mean temperature is the average over all parts of the Earth's surface over a whole year. The amount of carbon dioxide is given in ppm (parts of carbon dioxide per million parts of air).

Year	CO_2 / ppm	Mean temperature / °C
1982	340	14.08
1984	343	14.15
1986	347	14.19
1988	351	14.41
1990	354	14.48
1992	356	14.15
1994	358	14.31
1996	361	14.36
1998	366	14.70
2000	369	14.39
2002	373	14.67
2004	377	14.58
2006	381	14.63
2008	385	14.51
2010	390	14.69
2012	394	14.59

Table 1

Year	CO_2 / ppm	Mean temperature / °C
1880	291	13.92
1890	294	13.81
1900	297	13.95
1910	300	13.80
1920	303	13.82
1930	306	13.96
1940	309	14.14
1950	312	13.83
1960	317	13.99
1970	324	14.04
1980	338	14.28

Table 2

b Plot these results on the grid using the left-hand y-axis for amount of carbon dioxide and the right-hand y-axis for mean temperature. Draw two separate graphs to enable you to compare the trends. (Use graph paper if you need a larger grid.)

c What do you notice about the trend in amount of carbon dioxide?

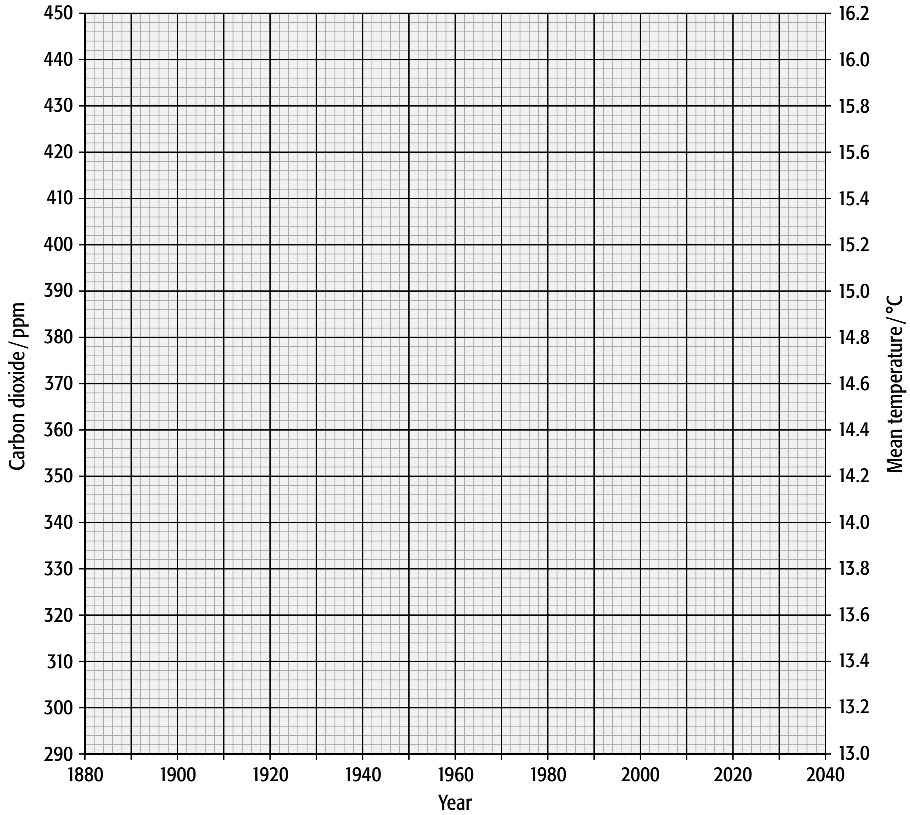
....

....

d What do you notice about the trend in mean temperature?

....

....



e Does the graph clearly show that an increase in carbon dioxide is causing an increase in temperature?

....

....

f Estimate the amount of carbon dioxide in the atmosphere and the likely mean temperature of the Earth in the years 2020 and 2040.

....

....

g Between the eleventh century and the end of the eighteenth century the amount of carbon dioxide in the atmosphere varied between 275 and 280 ppm. Why did it start to rise from the nineteenth century onwards.

....

h Other 'greenhouse gases' are present in much smaller amounts. However, they are much more effective at keeping in heat than carbon dioxide. Methane (1.7 ppm) has 21 times the effect of carbon dioxide. Nitrogen oxides (0.3 ppm) have 310 times the effect of carbon dioxide.

Name a source that releases each of these gases into the atmosphere.

Methane: ....

Nitrogen oxides: ....

Use the checklist below to give yourself a mark for your graph.
For each point, award yourself:
2 marks if you did it really well
1 mark if you made a good attempt at it, and partly succeeded
0 marks if you did not try to do it, or did not succeed.

Self-assessment checklist for graphs:

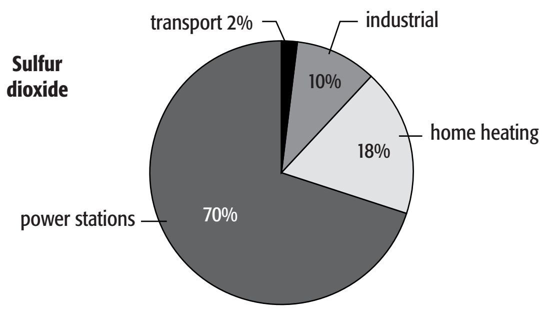
Check point	Marks awarded	
	You	Your teacher
You have plotted each point precisely and correctly for both sets of data – using the different scales on the two vertical axes.		
You have used a small, neat cross or dot for the points of one graph.		
You have used a small, but different, symbol for the points of the other graph.		
You have drawn the connecting lines through one set of points accurately – using a ruler for the lines.		
You have drawn the connecting lines through the other set of points accurately – using a different colour or broken line.		
You have ignored any anomalous results when drawing the lines.		
Total (out of 12)		

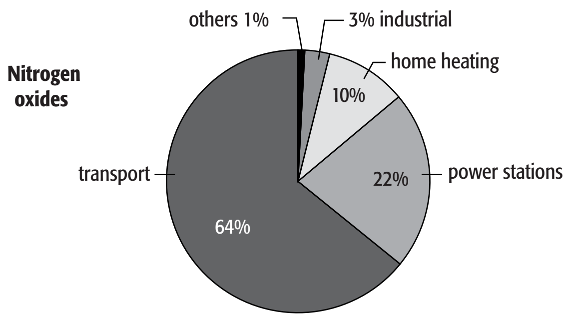
10–12 Excellent.
7–9 Good.
4–6 A good start, but you need to improve quite a bit.
2–3 Poor. Try this same graph again, using a new sheet of graph paper.
1 Very poor. Read through all the criteria again, and then try the same graph again.

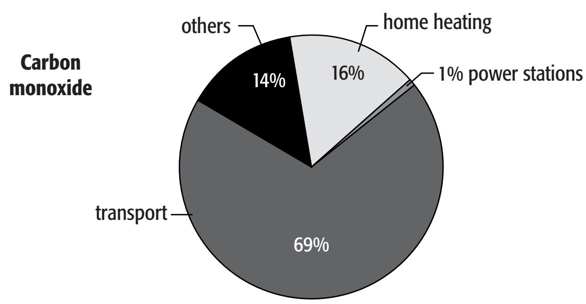
Exercise 1.2 Atmospheric pollution, industry and transport

This exercise discusses different aspects of atmospheric pollution and relates it to key aspects of human activity. It will help you in developing your skills in evaluating data and drawing conclusions from them.

The following pie charts show estimates of the sources of three major atmospheric pollutants in an industrialised country.







a What is the largest source of sulfur dioxide pollution?

....

b Name the **three** major fuels whose combustion gives rise to the levels of sulfur dioxide in the atmosphere.

....

c Units are being added to the some power stations and industrial plants to prevent the emission of sulfur dioxide. What is the name given to these units?

....

d Nitrogen oxides (NO_x) are another major pollutant of the atmosphere, particularly in large cities.

i Nitrogen monoxide is formed by the reaction of nitrogen and oxygen inside the hot engine of cars and other vehicles. Complete the following equation for the reaction producing nitrogen monoxide.

$$N_2 + O_2 \rightarrow \ldots\ldots NO$$

S

ii When leaving the car, nitrogen monoxide in the exhaust fumes reacts further with oxygen in the air to produce the brown gas which can be seen in the atmosphere over large cities. This gas is nitrogen dioxide. Balance the equation for the production of this gas.

nitrogen monoxide + oxygen ⟶ nitrogen dioxide

$$\ldots\ldots NO + O_2 \rightarrow \ldots\ldots NO_2$$

iii The operating temperature of a diesel engine is significantly higher than that of a petrol (gasoline) engine. Would you expect the level of NO_x emissions from a diesel-powered vehicle to be greater or lower than from a petrol-powered vehicle? Give the reason for your answer.

....

....

iv What attachment is fitted to modern cars to reduce the level of pollution by oxides of nitrogen?

....

e Nitrogen oxides, unburnt hydrocarbons and carbon monoxide combine together under the influence of ultraviolet light to produce photochemical smog.

i Why do you think this form of pollution is most common in large cities?

....

....

ii What other form of pollution from car exhaust fumes has now almost totally disappeared from modern cities following changes in fuel and pollution monitoring?

....

f In order to control traffic flow, London introduced a 'congestion charge' for vehicles entering the centre of the city in 2003. The table shows figures for the percentage fall in the levels of certain pollutants following the introduction of the congestion charge.

	Pollutant gas within Congestion Charge Zone	
	NO_x	**CO_2**
Overall traffic emissions change 2003 versus 2002 / %	−13.4	−16.4
Overall traffic emissions change 2004 versus 2003 / %	−5.2	−0.9
Change due to improved vehicle technology, 2003 to 2006 / %	−17.3	−3.4

i What was the measured percentage drop in the level of nitrogen oxides within the Congestion Charge Zone over the first two years following the introduction of the charge?

....

....

ii At face value there seems to be a drop in the levels of pollutants following the introduction of the congestion charge. But should we expect the fall in pollution levels to continue?

....

iii An independent study published in 2011 suggested that other factors should be taken into account, particularly when trying to study a relatively small area within a large city. One factor is hinted at in the third row of figures. What is that factor; and what other influences need to be taken into account in considering this situation?

....

....

....

....

g The use of fossil fuels in industry and transport also produces carbon dioxide. What is the reasoning behind the slogan painted on these freight containers seen waiting to be loaded on to a freight train outside a major UK station? Outline the argument behind the slogan.

....

....

....

....

....

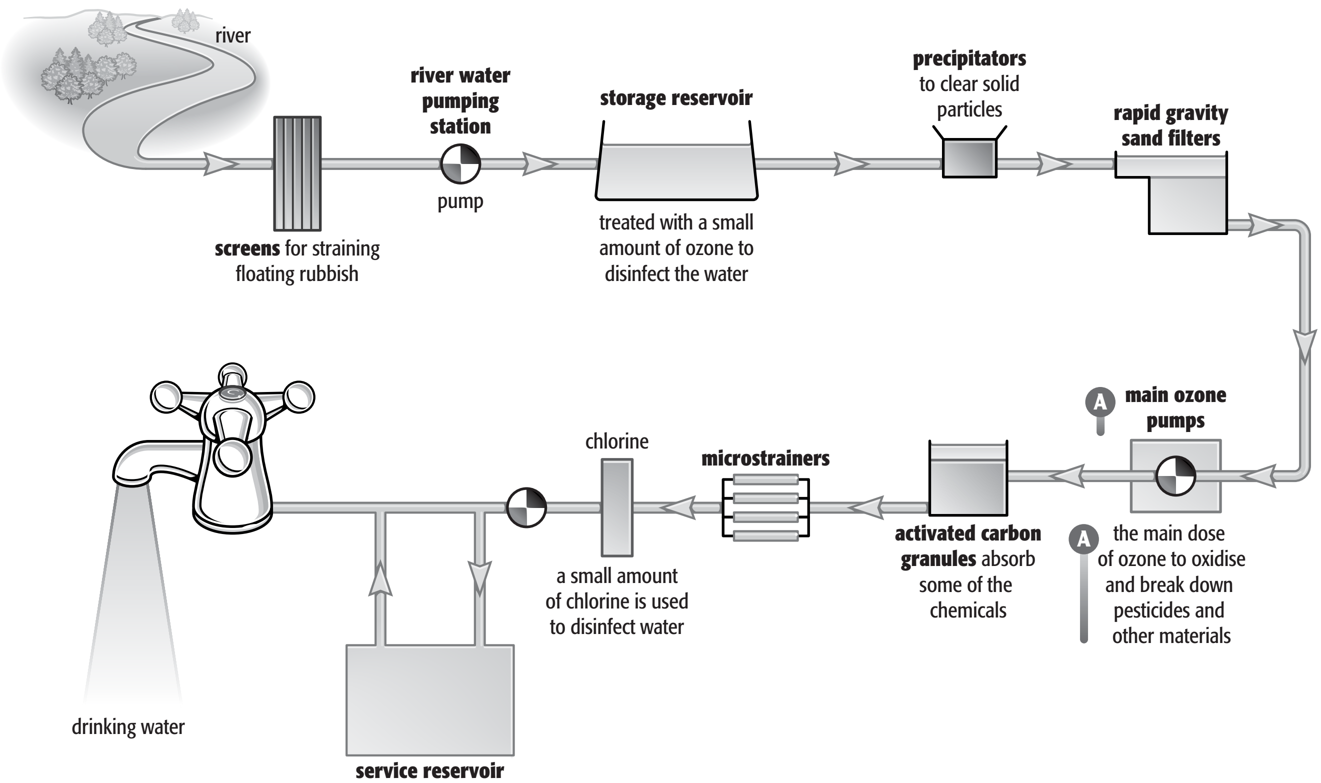
....

Exercise 1.3 Clean water is crucial

This exercise covers aspects of how we produce clean water for domestic and industrial use, focusing on stages that depend on key physical and chemical techniques.

The provision of clean drinking water and sanitation to more of the world's population is one of the key millennium goals of the United Nations. The lack of this basic provision impacts not only on the levels of disease in an area, in particular the mortality rate of children, but also on the level of education and the role of women within a community.

The diagram shows the different stages involved in a modern water plant producing water for domestic and industrial use.



a What devices are used in the early stages of processing to remove insoluble debris and material? Include comments on the size of the material removed by these methods.

....

....

....

b What is the common purpose of treating the water with chlorine and/or ozone?

....

c What other purpose does treatment with ozone achieve?

....

A **d** What type of chemical agent is ozone (O_3) behaving as in the reactions involved in part **c**?

....

e Countries that have insufficient rainfall, or where water supply is in great demand, may need to use other methods of producing clean water. Here, processes for **desalination** are used.

i What does the term **desalination** mean?

....

ii Name **two** methods that such countries use for desalination.

....

iii Give **one** disadvantage of these methods of desalination.

....

f Tap water produced by this type of treatment is clean, but it is not pure. It will contain metal and non-metal ions dissolved from the rocks that the rivers and streams have flowed over.

i Chloride ions are present in tap water. Describe a chemical test that would show the presence of chloride ions (Cl^-) in the water. Describe the test and what would be observed.

....

....

....

ii One of the chlorides often present in tap water is sodium chloride. Give the word and balanced symbol equation for the reaction taking place in the test you have described above.

sodium chloride + ... → .... + ...

....

NaCl + ... → .... + ...

S **iii** Give the ionic equation for the reaction taking place (include state symbols).

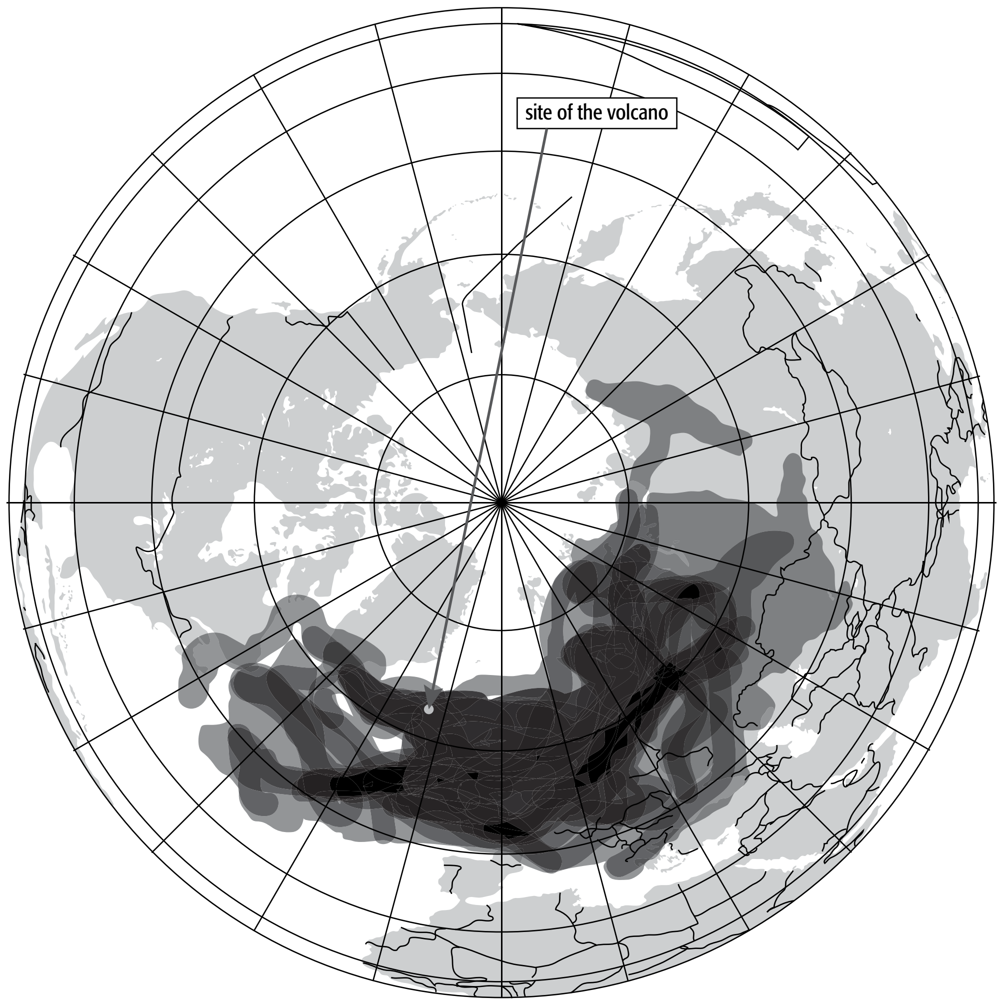
....

Exercise 1.4 Gases in the air

This exercise discusses how the composition of the Earth's atmosphere has been influenced by volcanic emissions over the duration of the life of the planet. It looks at how the composition of the atmosphere has changed and how we purify the different gases from the air.

There have been several spectacular volcanic eruptions in recent years. In 2010, clouds of ash from the relatively small eruption of the Eyjafjallajokoll volcano in Iceland caused disruption in most of European airspace throughout the month of April.

The diagram shows the spread of the volcanic ash cloud over Europe during April 2010.



Active volcanoes produce many unseen products which are thrown out into the atmosphere. The table below shows the gases released by an active Icelandic volcano.

Name of gas	Percentage of total gas released / %
sulfur dioxide	11.70
nitrogen	3.20
water vapour	35.60
hydrogen	0.39
carbon dioxide	47.40
carbon monoxide	1.71

a Which gas is present in the largest quantity in the gases released by the volcano?

....

b Explain why water is in the gas phase when it comes out of the volcano.

....

c Comment on what happens to the hydrogen released from the volcano. Why is it not kept within the Earth's atmosphere?

....

It is now recognised that the early atmosphere of the Earth was generated by release of gases from volcanoes. The composition of air has changed significantly over millions of years. The following table shows how the composition of the atmosphere has changed since the formation of the planet 4500 million years ago.

	Time in the past / million years	Approximate proportion of carbon dioxide / %	Approximate proportion of oxygen / %	Approximate proportion of gas X / %
present ↑	0	0.04	20	79
	500	1	20	78
	1000	2	19	77
	1500	5	18	75
	2000	7	10	70
	2500	10	5	60
	3000	15	1	55
	3500	21	0.5	40
	4000	40	0	30
formation	4500	90	0	10

d Using the grid below, draw graphs of how the proportions of the three gases listed in the table have changed over time from the origin of the Earth.

e Identify gas **X**, giving your reasoning.

A **f** Water vapour is released by volcanoes as a gas. What eventually happened to the water vapour in the atmosphere?

g Mark arrows on the timeline of your graph to indicate the points at which the following occurred:

i the oceans were formed
ii the first forms of bacteria (including photosynthesising algae) appeared
iii vegetation on land appeared.

S **h** Explain why the appearance of photosynthetic algae, followed by land vegetation and plants, caused a change in the level of carbon dioxide present in the air.

S **i** The gases in the atmosphere can be separated and purified by fractional distillation of liquid air. Dust-free air is cooled to around –80 °C to remove water and carbon dioxide. The air is then cooled to –200 °C at high pressure to liquefy it. The table shows the boiling points of the gases involved.

Gas	Boiling point / °C
argon	–186
helium	–269
krypton	–157
neon	–246
nitrogen	–196
oxygen	–183
xenon	–108

i Which gases will not become liquid at –200 °C?

....

ii Outline how the liquid air is separated by fractional distillation, stating clearly which gas will be the first to distil over?

....

....

....

....

iii Which **two** gases are difficult to separate by this method? Why is this?

....

....

iv Give **one** major use each for liquid nitrogen and liquid oxygen.

....

....

Exercise 1.5 Hydrogen as a fuel

This exercise introduces hydrogen as an alternative energy source and will help develop your skills at handling information regarding unfamiliar applications.

One of the first buses to use hydrogen as a fuel was operated in Erlangen, Germany, in 1996. The hydrogen was stored in thick pressurised tanks on the roof of the bus.

a Describe **two** advantages of using hydrogen as a fuel rather than gasoline (petrol).

....

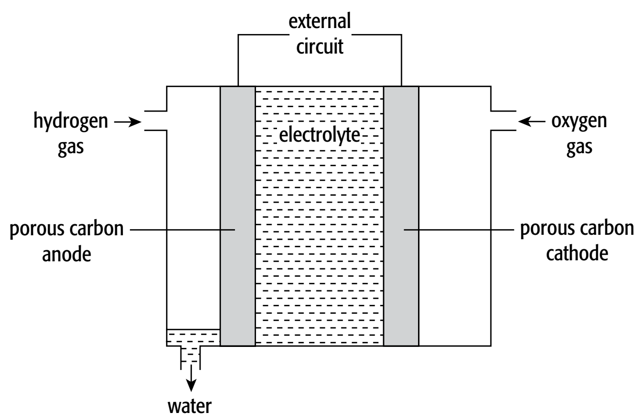
....

b Suggest **one** disadvantage of using hydrogen as a fuel.

....

S

It is possible to generate electrical energy from hydrogen using a fuel cell. The structure of a typical fuel cell is shown in the diagram.



c The reaction taking place in such a fuel cell is the combustion of hydrogen. Write the overall equation for that reaction.

....

d The equation for the reaction at the anode is

$$H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^-$$

What type of reaction is this? Explain your answer.

....

e At the cathode oxygen molecules react with water molecules to form hydroxide ions. Write an ionic equation for this reaction.

....

2 The nature of matter

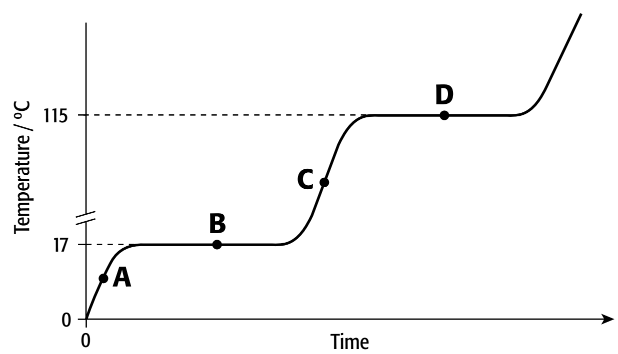
Definitions to learn

- **physical state** the three states of matter are solid, liquid and gas
- **condensation** the change of state from gas to liquid
- **melting** the change of state from solid to liquid
- **freezing** the change of state from liquid to solid at the melting point
- **boiling** the change of state from liquid to gas at the boiling point of the liquid
- **evaporation** the change of state from liquid to gas below the boiling point
- **sublimation** the change of state directly from solid to gas (or the reverse)
- **crystallisation** the formation of crystals when a saturated solution is left to cool
- **filtration** the separation of a solid from a liquid using filter paper
- **distillation** the separation of a liquid from a mixture using differences in boiling point
- **fractional distillation** the separation of a mixture of liquids using differences in boiling point
- **diffusion** the random movement of particles in a fluid (liquid or gas) leading to the complete mixing of the particles
- **chromatography** the separation of a mixture of soluble (coloured) substances using paper and a solvent
- **atom** the smallest part of an element that can take part in a chemical change
- **proton number (atomic number)** the number of protons in the nucleus of an atom of an element
- **nucleon number (mass number)** the number of protons and neutrons in the nucleus of an atom
- **electron arrangement** the organisation of electrons in their different energy levels (shells)
- **isotopes** atoms of the same element which have the same proton number but a different nucleon number

Exercise 2.1 Changing physical state

This exercise will develop your understanding of the kinetic model and the energy changes involved in changes of physical state.

The graph shows the heating curve for a pure substance. The temperature rises with time as the substance is heated.



a What physical state(s) is the substance in at points A, B, C and D?

A ……………………………… **C** ………………………………

B ……………………………… **D** ………………………………

b What is the melting point of the substance? ....

c What is its boiling point? ....

d What happens to the temperature while the substance is changing state?

....

e The substance is not water. How do we know this from the graph?

....

f Complete the passage using the words given below.

different	**diffusion**	**gas**	**spread**	**particles**
diffuse	**random**	**lattice**	**vibrate**	**temperature**

The kinetic model states that the .... in a liquid and a .... are in constant motion. In a gas, the particles are far apart from each other and their motion is said to be .... The particles in a solid are held in fixed positions in a regular .... In a solid, the particles can only .... about their fixed positions.

Liquids and gases are fluid states. When particles move in a fluid, they can collide with each other. When they collide, they bounce off each other in .... directions. If two gases or liquids are mixed, the different types of particle .... out and get mixed up. This process is called ....

S At the same .... particles that have a lower mass move faster than those with higher mass. This means that the lighter particles will spread and mix more quickly; the lighter particles are said to .... faster than the heavier particles.

g Use the data given for the substances listed below to answer the questions that follow on their physical state at a room temperature of 25 °C and atmospheric pressure.

Substance	Melting point / °C	Boiling point / °C
sodium	98	883
radon	−71	−62
ethanol	−117	78
cobalt	1492	2900
nitrogen	−210	−196
propane	−188	−42
ethanoic acid	16	118

i Which substance is a liquid over the smallest range of temperature? ....

ii Which **two** substances are gaseous at −50 °C?

.... and ....

iii Which substance has the lowest freezing point? ....

iv Which substance is liquid at 2500 °C? ....

v A sample of ethanoic acid was found to boil at 121 °C at atmospheric pressure. Use the information in the table to comment on this result.

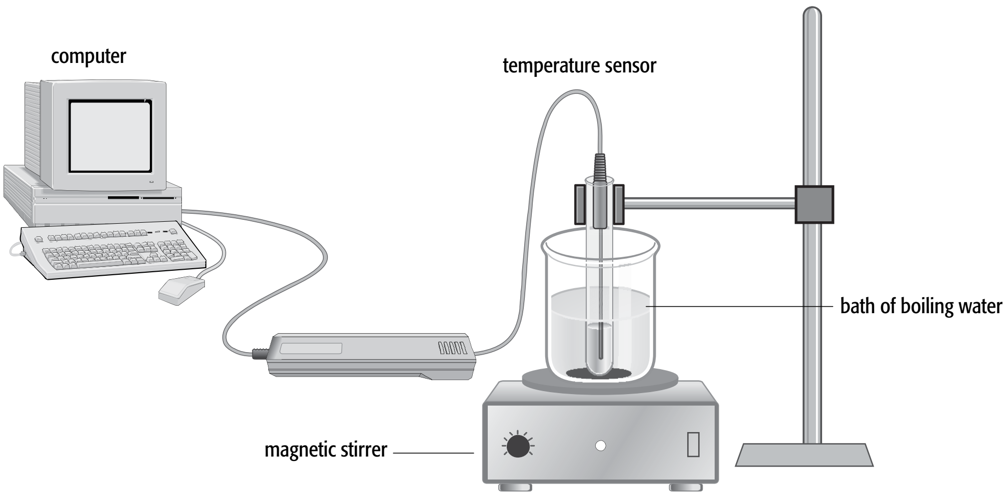
....

....

Exercise 2.2 Plotting a cooling curve

This exercise presents data obtained practically for plotting a cooling curve. It will help develop your skills in handling the data and interpreting what changes the different regions of the curve represent. Examples of sublimation are also discussed.

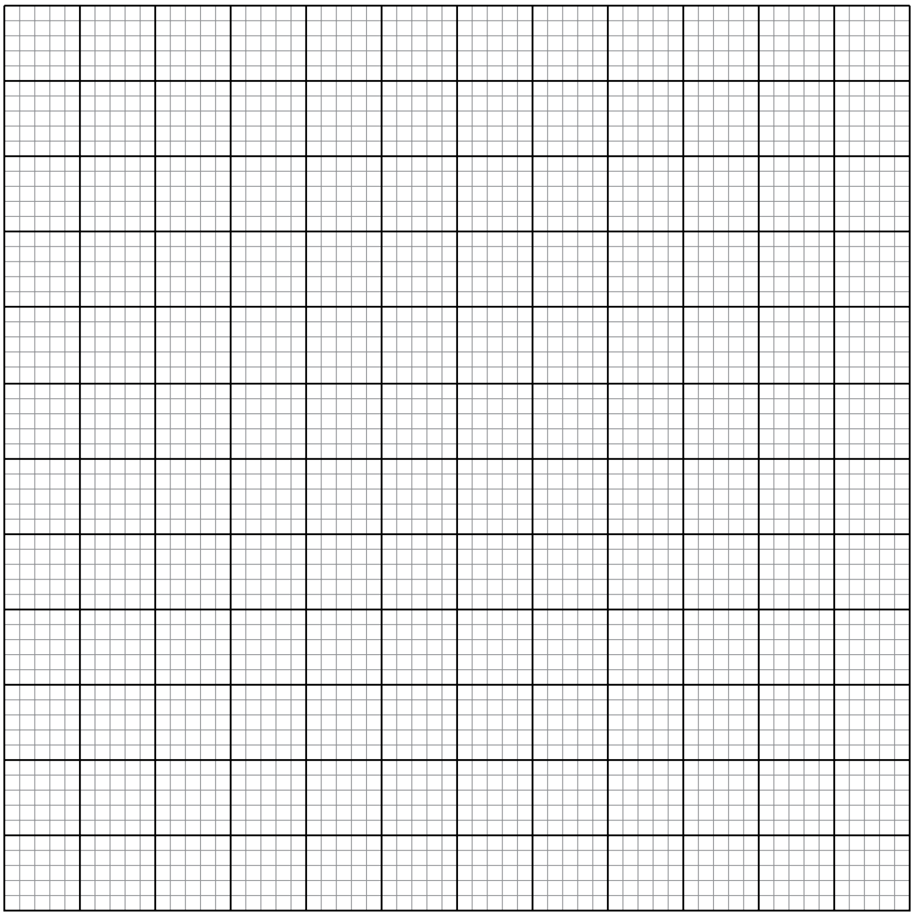
A student, carried out the following data-logging experiment as part of a project on changes of state. An organic crystalline solid was melted by placing it in a tube in a boiling water bath. A temperature sensor was placed in the liquid.



The temperature change was followed as the liquid was allowed to cool down. The data shown in the table below are taken from the computer record of the temperature change as the liquid cooled down to room temperature.

Time / min	0	0.5	1.0	1.5	2.0	2.2	2.4	2.6	2.8	3.0	3.5	4.0	4.5	5.0
Temperature / °C	96.1	89.2	85.2	82.0	80.9	80.7	80.6	80.6	80.5	80.3	78.4	74.2	64.6	47.0

a On the grid below, plot a graph of the temperature change taking place in this experiment.



b What change is taking place over the second minute of the experiment?

....

S **c** Why does the temperature remain almost constant over this period of time? Give your explanation in terms of what is happening to the organisation of the molecules of the substance.

....

....

....

....

d What change would need to be made to carry out the experiment using a compound with a melting point greater than 100 °C?

....

e A similar experiment was carried out to demonstrate the cooling curve for paraffin wax.

i In the space below, sketch the shape of the graph you would expect to produce.

ii Explain why the curve is the shape you have drawn.

....

....

f Sublimation occurs when a substance passes between the solid and gaseous states without going through the liquid phase. Both carbon dioxide and water can sublime under certain conditions of temperature and pressure.

'Dry ice' is the solid form of carbon dioxide used in commercial refrigeration. At atmospheric pressure it has a 'sublimation point' of –78.5°C.

i What difference can you see between solid carbon dioxide and water ice at atmospheric pressure?

....

....

ii If you gently shake a carbon dioxide fire extinguisher, you will feel the presence of liquid within the extinguisher. What conditions within the extinguisher mean that the CO_2 is liquid in this case?

....

....

iii Complete the following paragraph about a particular type of frost using the words listed below.

surrounding	**liquid**	**colder**	**humid**
white	**crystals**	**ice**	

Hoar frost is a powdery .... frost caused when solid .... forms from .... air. The solid surface on which it is formed must be .... than the .... air. Water vapour is deposited on a surface as fine ice .... without going through the .... phase.

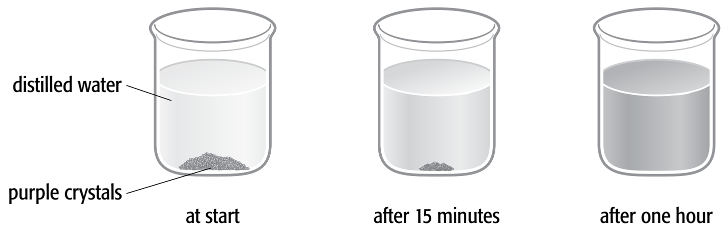
Exercise 2.3 Diffusion, solubility and separation

The processes of diffusion and dissolving in a solvent are linked. This exercise explores the basis of these processes in terms of the kinetic (particle) theory. The separation of a solvent mixture by fractional distillation is discussed.

A student placed some crystals of potassium manganate(VII) at the bottom of a beaker of distilled water. She then left the contents of the beaker to stand for one hour.

a The diagram below shows what she saw during the experiment.

After one hour, all the solid crystals had disappeared and the solution was purple throughout.



i Use the ideas of the kinetic theory to explain her observations.

....

....

....

....

....

ii If warm water at 50 °C had been used, would the observations have taken place in a longer or shorter time? Explain your answer.

....

....

....

b The process of dissolving can be used to separate and purify chemical compounds. Organic solvents such as propanone can be used to extract pigments from plants. Some grass is crushed and mixed with the propanone. The colour pigments are extracted to give a dark green solution.

i Given a pure sample of chlorophyll, describe how could you show that the green solution from the grass contained chlorophyll and other coloured pigments?

....

....

....

....

ii Draw a labelled diagram that describes the method of separating coloured pigments that you have discussed in part **i**.

Use the checklist below to give yourself a mark for your drawing.
For each point, award yourself:
2 marks if you did it really well
1 mark if you made a good attempt at it, and partly succeeded
0 marks if you did not try to do it, or did not succeed.

Self-assessment checklist for drawings

Check point	Marks awarded	
	You	Your teacher
You have made a large drawing, using the space provided.		
There are no obvious errors – liquids missing, flasks open when they should be closed, etc.		
You have drawn single lines with a sharp pencil, not many tries at the same line (and erased mistakes).		
You have used a ruler for the lines that are straight.		
Your diagram is in the right proportions.		
You have drawn label lines with a ruler, touching the item being labelled.		
You have written the labels horizontally and neatly, well away from the diagram itself.		
Total (out of 14)		

12–14 Excellent.
10–11 Good.
7–9 A good start, but you need to improve quite a bit.
5–6 Poor. Try this same drawing again, using a new sheet of paper.
1–4 Very poor. Read through all the criteria again, and then try the same drawing.

iii Explain the role of chlorophyll in the leaves of green plants.

....

....

....

....

c Propanone is a very useful solvent that mixes well with water even though it is an organic compound. A propanone:water (65%:35%) mixture used for cleaning laboratory apparatus can be separated using fractional distillation.

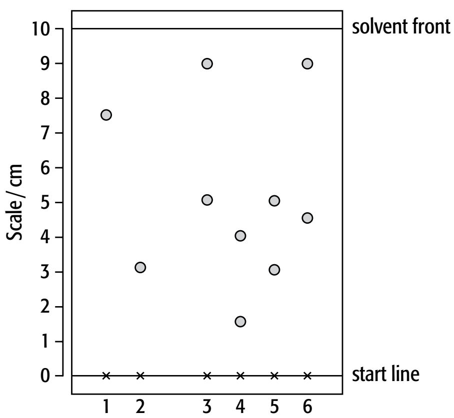
A total volume of 80 cm^3 of the mixture was distilled.

Sketch below a graph of the temperature readings against the volume of distillate collected for the distillation carried out. The thermometer is placed at the connection between the fractionating column and the condenser. The boiling point of propanone is 56 °C.

Exercise 2.4 Chromatography at the races

This exercise will help you understand aspects of chromatography by considering an unfamiliar application of the technique.

Chromatography is used by the 'Horse Racing Forensic Laboratory' to test for the presence of illegal drugs in racehorses.
A concentrated sample of urine is spotted on to chromatography paper on the start line. Alongside this, known drugs are spotted. The chromatogram is run using methanol as the solvent. When finished, the paper is read by placing it under ultraviolet light. A chromatogram of urine from four racehorses is shown below.



Spot	Description
1	caffeine
2	paracetamol
3	urine sample horse A
4	urine sample horse B
5	urine sample horse C
6	urine sample horse D

a State **two** factors which determine the distance a substance travels up the paper.

....

....

b The results show that the sample from one horse contains an illegal substance. State which horse and the drug that is present.

....

c Give a reason for the use of this drug.

....

d The results for known drugs are given as 'R_f values'.

$$R_f = \frac{\text{distance travelled by the substance}}{\text{distance travelled by the solvent}}$$

Calculate the R_f value for caffeine.

Exercise 2.5 Atomic structure

This exercise helps familiarise you with aspects of atomic structure including the organisation of electrons into energy levels (or shells), and the uses of radioactivity.

a Choose from the words below to fill in the gaps in the passage. Words may be used once, more than once or not at all.

proton	**electrons**	**nucleon**	**isotopes**	**protons**
neutrons	**nucleus**	**energy levels**		

Atoms are made up of three different particles: .... which are positively charged; .... which have no charge; and .... which are negatively charged. The negatively charged particles are arranged in different .... (shells) around the .... of the atom. The particles with a negligible mass are the .... All atoms of the same element contain the same number of .... and .... Atoms of the same element with different numbers of .... are known as ....

b This part of the exercise is concerned with electron arrangements and the structure of the Periodic Table. Complete these sentences by filling in the blanks with words or numbers.

The electrons in an atom are arranged in a series of .... around the nucleus. These shells are also called .... levels. In an atom, the shell .... to the nucleus fills first, then the next shell, and so on. There is room for:

- up to .... electrons in the first shell
- up to .... electrons in the second shell
- up to .... electrons in the third shell.

(There are 18 electrons in total when the three shells are completely full.)

The elements in the Periodic Table are organised in the same way as the electrons fill the shells. Shells fill from .... to .... across the .... of the Periodic Table.

- The first shell fills up first from .... to helium.
- The second shell fills next from lithium to ....
- Eight .... go into the third shell from sodium to argon.
- Then the fourth shell starts to fill from potassium.

c In 1986, an explosion at Chernobyl in the Ukraine released a radioactive cloud containing various radioactive isotopes. Three such isotopes are mentioned below. Use your Periodic Table to answer the following questions about them.

Element	Nucleon (mass) number
strontium	90
iodine	131
caesium	137

i How many electrons are there in one atom of strontium-90? ....

ii How many protons are there in one atom of iodine-131? ....

iii How many neutrons are there in an atom of caesium-137? ....

The prevailing winds carried fallout from Chernobyl towards Scandinavia. In Sweden, caesium-137 built up in lichen, which is the food eaten by reindeer. This gave rise to radioactive meat.

iv If radioactive caesium was reacted with chlorine, would you expect the caesium chloride produced to be radioactive? Explain your answer.

....

v State a beneficial use in industry of a radioactive isotope.

....

vi State a medical use of a radioactive isotope.

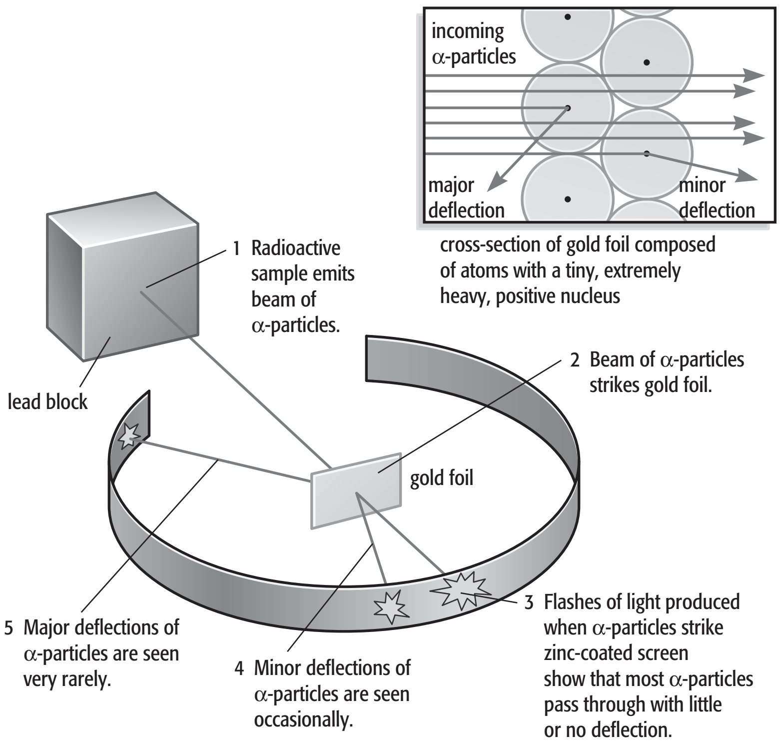
....

Exercise 2.6 Influential organisation

This exercise explores aspects of the discovery of the structure of the atom and how that structure influences the major properties of the atoms of an element.

The way in which the subatomic particles are organised within an atom gives rise to the characteristic properties of that atom. Whether an atom is radioactive, the type of bond it makes, its chemical reactivity and its position in the Periodic Table are all dependent on this organisation.

a The modern view of the structure of the atom stems from experiments carried out in Rutherford's laboratory in Manchester, UK. These experiments used α-particles (helium nuclei) fired at a sheet of gold foil from a radioactive source. Detectors analysed the direction of the particles as they passed through the foil. The design of the experiment is summarised in the following diagram.



A

i α-particles are helium nuclei. What is the composition of an α-particle and its charge?

Protons: ....

Neutrons: ....

Charge: ....