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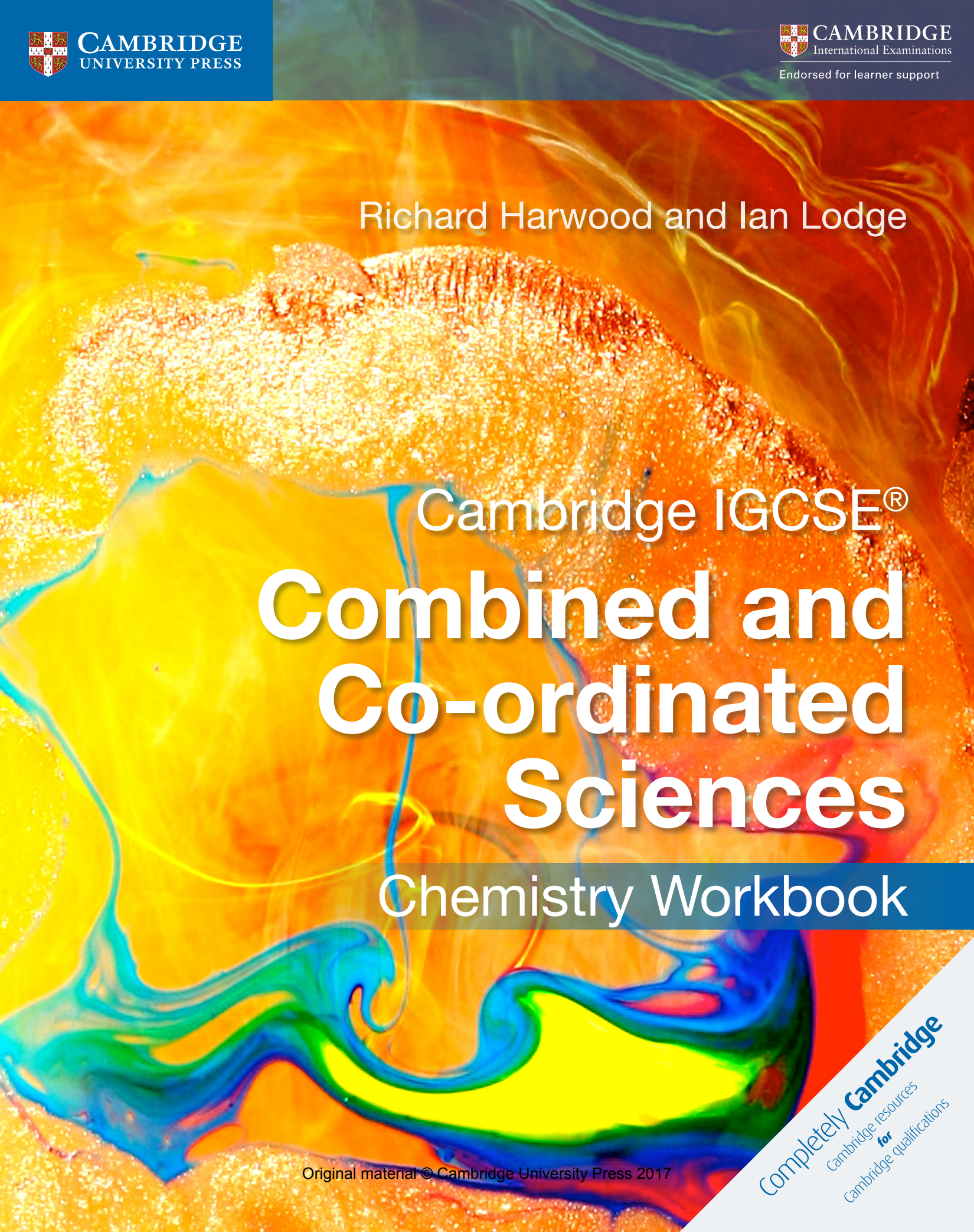
Richard Harwood and Ian Lodge

Cambridge IGCSE®
Combined and Co-ordinated Sciences
Chemistry Workbook



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Contents

Introduction

This workbook covers two syllabuses: Cambridge IGCSE Combined Science (0653) and Cambridge IGCSE Co-ordinated Sciences (0654). Before you start using this workbook, check with your teacher which syllabus you are studying and which papers you will take. You will sit either the Core paper or the Extended paper for your syllabus. If you are sitting the Extended paper, you will study the Core material and the Supplement material for your syllabus.

Once you know which paper you will be sitting, you can use the exercises in this workbook to help develop the skills you need and prepare for your examination.

The examination tests three different Assessment Objectives, or AOs for short. 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 AO1, 30% for 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 AO2 and AO3. You need to be able to use what you've learned in unfamiliar contexts (AO2) and to demonstrate your experimental skills (AO3).

There are lots of activities in your coursebook which will help you to develop your experimental skills by doing practical work. This workbook contains exercises to help you to develop AO2 and AO3 further. There are some questions that just involve remembering things you have been taught (AO1), but most of the questions require you to use what you've learned to work out, for example, what a set of data means, or to suggest how an experiment might be improved.

These exercises are not intended to be exactly like the questions you will get on your exam papers. This is because they are meant to help you to develop your skills, rather than testing you on them.

There's an introduction at the start of each exercise that tells you the purpose of it – which skills you will be working with as you answer the questions.

For some parts of the exercises, there are self-assessment checklists. You can try using these to mark your own work. 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.

There are sidebars in the margins of the book to show which material relates to each syllabus and paper. If there is no sidebar, it means that everyone will study this material.

Use this table to ensure that you study the right material for your syllabus and paper:

Cambridge IGCSE Combined Science (0653)		Cambridge IGCSE Co-ordinated Sciences (0654)	
Core	**Supplement**	**Core**	**Supplement**
You will study the material: Without a sidebar	*You will study the material:* Without a sidebar With a double grey sidebar With a double black sidebar	*You will study the material:* Without a sidebar With a single grey sidebar With a double grey sidebar	*You will study* ***everything****.* *This includes the material:* Without a sidebar With a single grey sidebar With a double grey sidebar With a single black sidebar With a double black sidebar

The Periodic Table

Key

atomic number **atomic symbol** name relative atomic mass

Group																	
I	II											III	IV	V	VI	VII	VIII
							1 **H** hydrogen 1										2 **He** helium 4
3 **Li** lithium 7	4 **Be** beryllium 9											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	57–71 lanthanoids	72 **Hf** hafnium 179	73 **Ta** tantalum 181	74 **W** tungsten 184	75 **Re** rhenium 186	76 **Os** osmium 190	77 **Ir** iridium 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 –	85 **At** astatine –	86 **Rn** radon –
87 **Fr** francium –	88 **Ra** radium –	89–103 actinoids	104 **Rf** rutherfordium –	105 **Db** dubnium –	106 **Sg** seaborgium –	107 **Bh** bohrium –	108 **Hs** hassium –	109 **Mt** meitnerium –	110 **Ds** darmstadtium –	111 **Rg** roentgenium –	112 **Cn** copernicium –		114 ***Fl*** flerovium –		116 **Lv** livermorium –		

lanthanoids	57 **La** lanthanium 139	58 **Ce** cerium 140	59 **Pr** praseodymium 141	60 **Nd** neodymium 144	61 **Pm** promethium –	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
actinoids	89 **Ac** actinium –	90 **Th** thorium 232	91 **Pa** protactinium 231	92 **U** uranium 238	93 **Np** neptunium –	94 **Pu** plutonium –	95 **Am** americium –	96 **Cm** curium –	97 **Bk** berkelium –	98 **Cf** californium –	99 **Es** einsteinium –	100 **Fm** fermium –	101 **Md** mendelevium –	102 **No** nobelium –	103 **Lr** lawrencium –

Chapter C1
Planet Earth

KEY TERMS

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

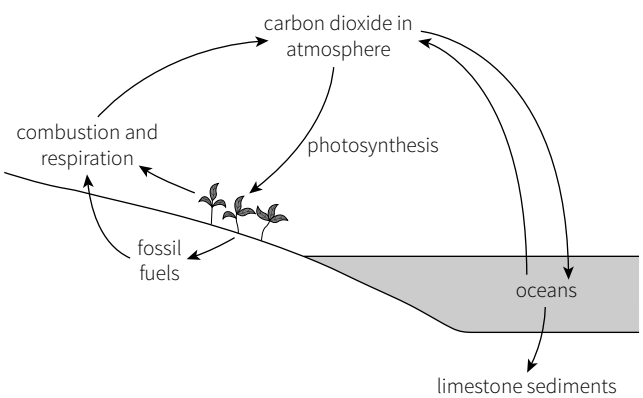
photosynthesis: the photochemical reaction in the green leaves of plants that turns carbon dioxide and water into glucose and oxygen

respiration: the biochemical reaction in living cells that produces energy from the reaction of glucose and oxygen to produce carbon dioxide and water

Exercise C1.01 Global warming and the 'greenhouse effect'

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

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. Table 1.01 gives the changes over recent years, while Table 1.02 gives the longer-term changes. 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
2014	395	14.70
2016	401	14.83

Table 1.01

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
1990	354	14.48
2000	369	14.39
2010	390	14.69

Table 1.02

b Plot these results on the grid provided 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?

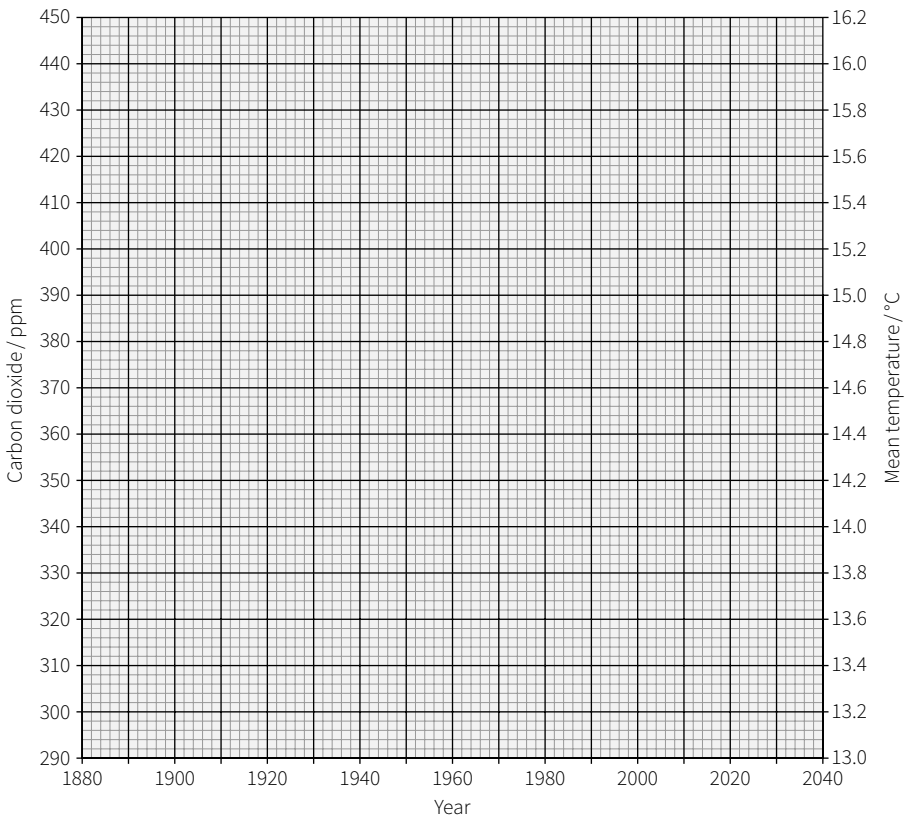
.....

.....

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.

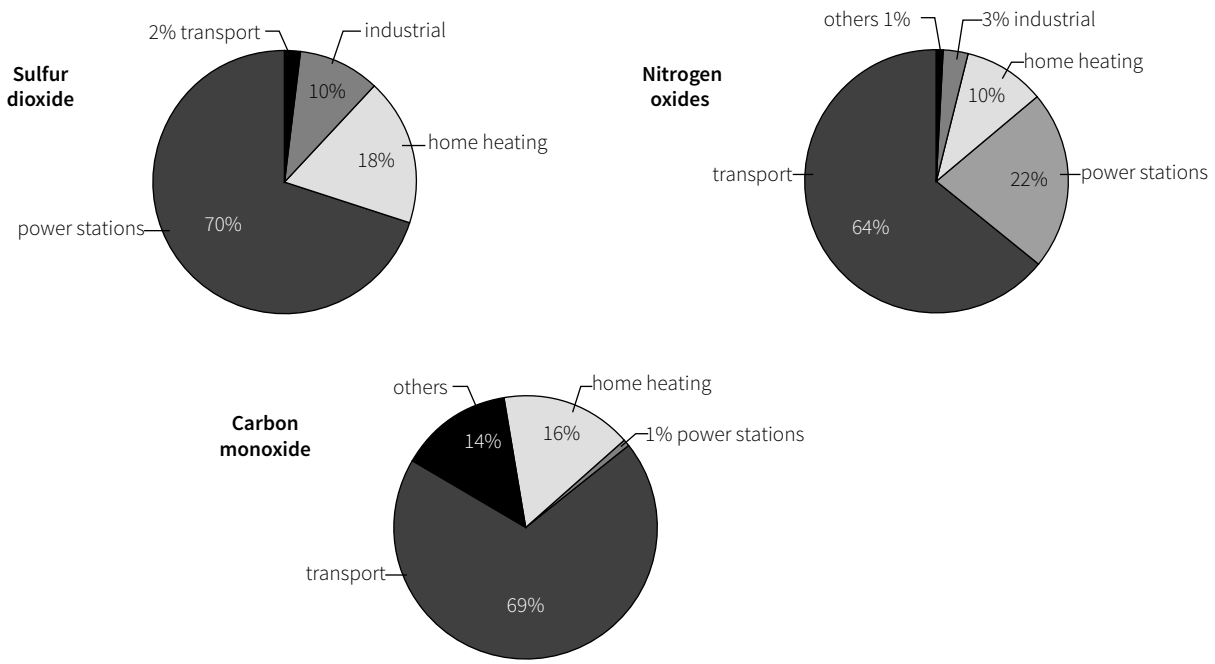
2–3 Poor. Try this same graph again, using a new sheet of graph paper.

1 Very poor. Read through all the criteria again, and then try the same graph again.

Exercise C1.02 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.

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

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

……NO + O_2 ⟶ ……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. Table 1.03 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

Table 1.03

i What was the measured percentage drop in the level of nitrogen oxides within the Congestion Charge Zone over the first 2 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?

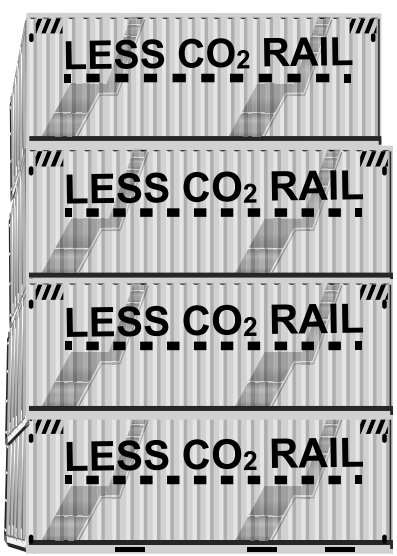
……

……

……

……

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.



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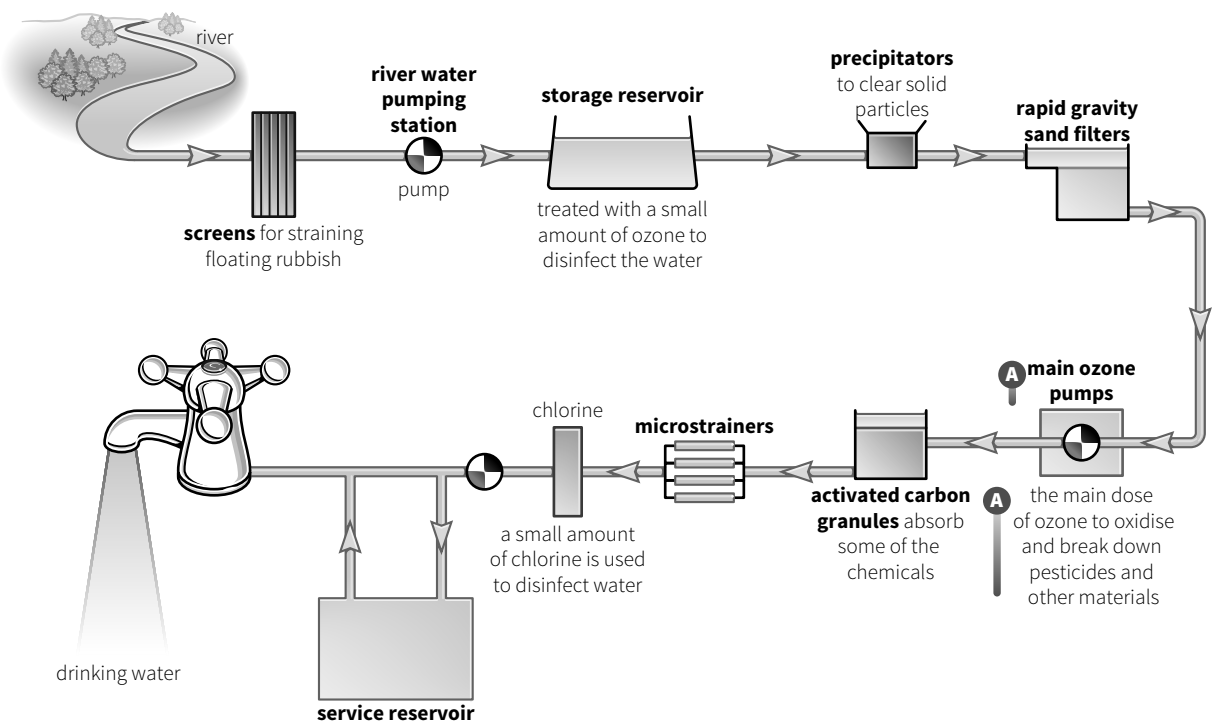
Exercise C1.03 Clean water is crucial

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?

.....

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 a water treatment plant such as shown in the diagram 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 + …….. → …….. + ……..

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

……..

Chapter C2
The nature of matter

KEY TERMS

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 C2.01 Changing physical state

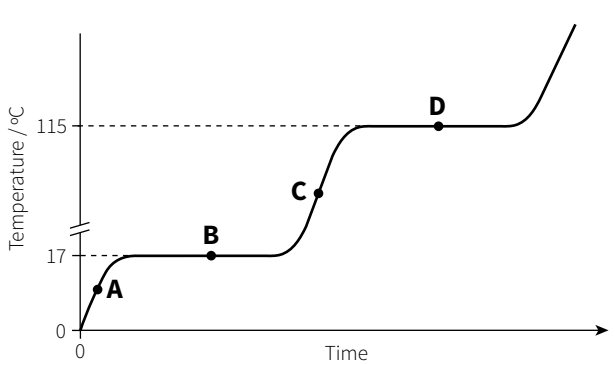
This exercise will develop your understanding of the kinetic model and the energy changes involved in changes of physical state.

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 ..... **B** .....

C ..... **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 ..... .

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 in Table 2.01 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

Table 2.01

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.

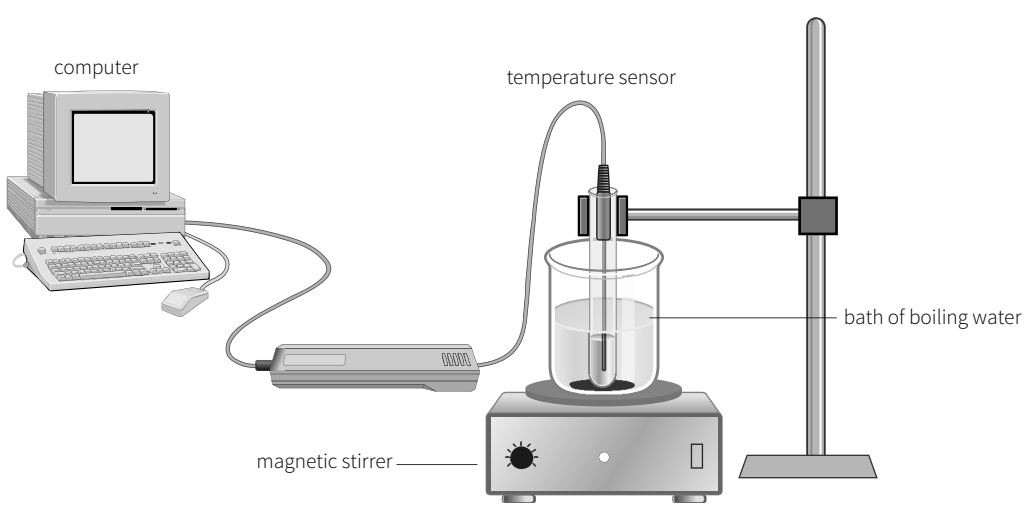
.....

.....

Exercise C2.02 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 using apparatus shown in the following diagram 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.

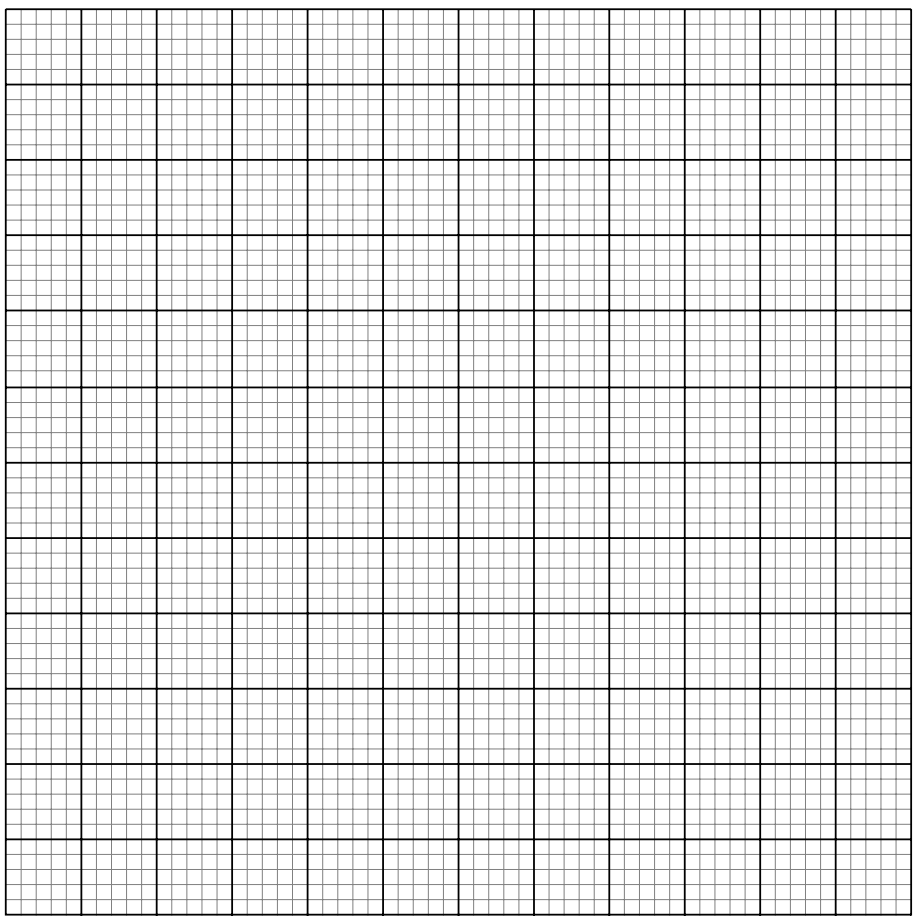


The temperature change was followed as the liquid was allowed to cool down. The data shown in Table 2.02 are taken from the computer record of the temperature change as the liquid cooled down to room temperature.

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

Table 2.02

a On the grid provided, 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?

.....

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 as seen in the diagram, 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.

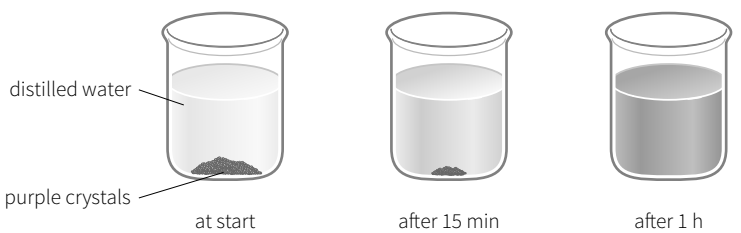
Exercise C2.03 Diffusion, solubility and separation

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 1 h.

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

After 1 h, 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.

……

……

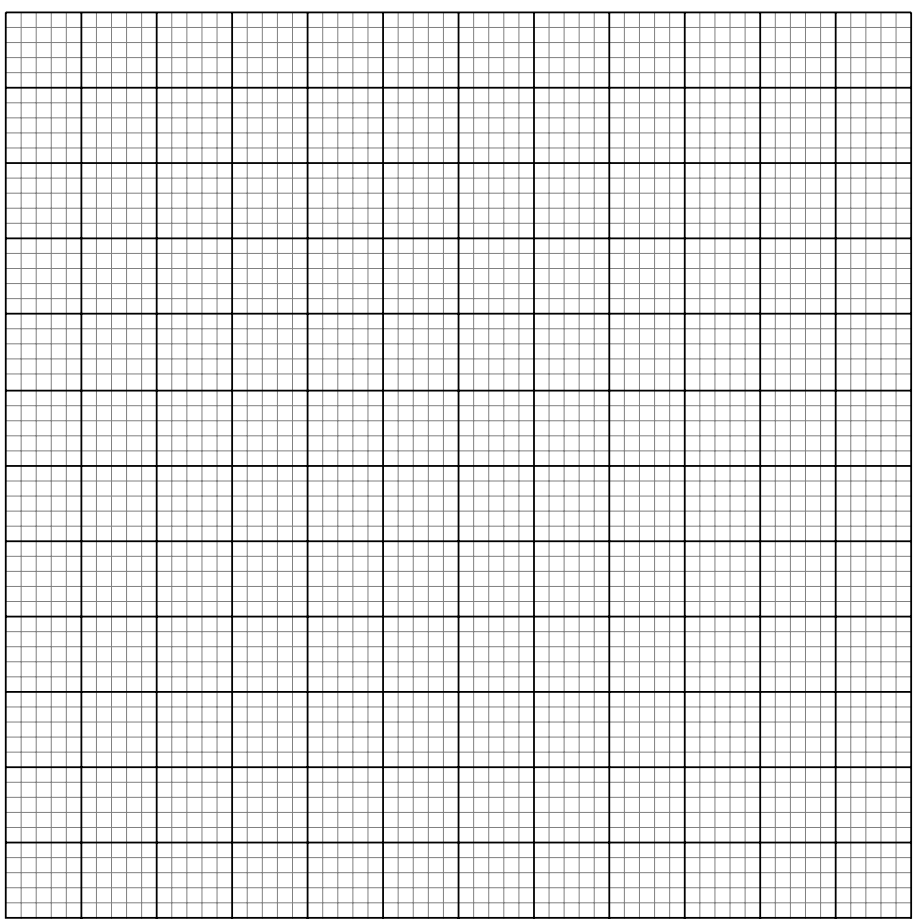
……

……

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.

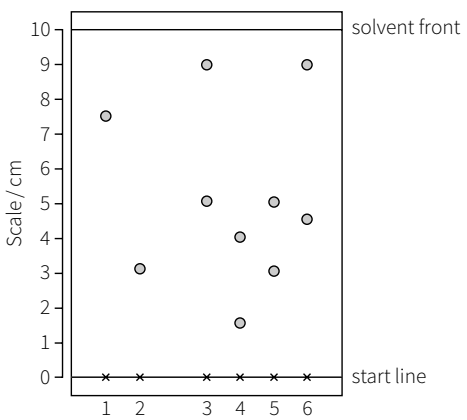


Exercise C2.04 Chromatography at the races

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 in the following diagram and details are included in Table 2.03.



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**

Table 2.03

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 C2.05 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**
neutrons	**nucleus**	**energy levels**	**protons**

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 in Table 2.04. Use your Periodic Table to answer the following questions about them.

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

Table 2.04

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? .....

Exercise C2.06 Influential organisation

This exercise explores 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 Isotopes of certain elements, such as carbon-14, can be of use in biochemical and medical research. Because they are radioactive, they can be used by scientists to track the synthesis and use of compounds important in the chemistry of cells and tissues.

i Complete Table 2.05 about the isotopes of some common elements, making deductions from the information given. For each element, the second isotope is a radioisotope used in research.

Isotope	Name of element	Proton number	Nucleon number	Number of		
				p	n	e
$^{12}_{6}C$	carbon	6	12	6	6	6
$^{14}_{6}C$						
$^{1}_{1}H$			1			
$^{3}_{1}H$	hydrogen (tritium)					
$^{31}_{15}P$		15	31			
$^{32}_{15}P$						
$^{127}_{53}I$	iodine			53		53
$^{131}_{53}I$				53		

Table 2.05

ii Researchers are able to use these radioisotopes to study the chemistry of cells because these atoms have the same chemical properties as the non-radioactive atoms. Why are the chemical properties of all isotopes of the same element identical?

.....

.....

.....

b The table below gives details of the atomic structure of five atoms, **A**, **B**, **C**, **D** and **E**. (Note that these letters are **not** their chemical symbols.)

Complete Table 2.06 to show the electron arrangement of each of the atoms.

Atom	Proton number	Electron arrangement			
		1st shell	2nd shell	3rd shell	4th shell
A	2				
B	5				
C	13				
D	15				
E	19				

Table 2.06

i How many of these atoms are of elements in the second period of the Periodic Table?

.....

ii Which two atoms belong to elements in the same group?

.....

iii How many electrons does atom **C** have which would be involved in chemical bonding?

.....

iv Draw a diagram to show the arrangement of the electrons in atom **D**.

Answers

Example answers and all questions were written by the authors.

Chapter C1 Planet Earth

Exercise C1.01 Global warming and the 'greenhouse effect'

a Photosynthesis involves the 'capture' of energy from the Sun by the green leaves of plants and the synthesis of glucose. The green pigment, chlorophyll, is essential for this process. The conversion of carbon dioxide and water into glucose is represented by the following equation:

$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$

b see diagram below

The Workbook suggests that this graph can be drawn more clearly on a larger sheet of graph paper. The data can also be usefully analysed using a computer graphing program such as Excel or Graphical Analysis – such programs allow curve fitting and extrapolation.

c There has been a steady increase in the level of carbon dioxide in the atmosphere since 1880. However, the curve has increased more sharply since the 1960s. This rate of increase has remained steady over recent decades.

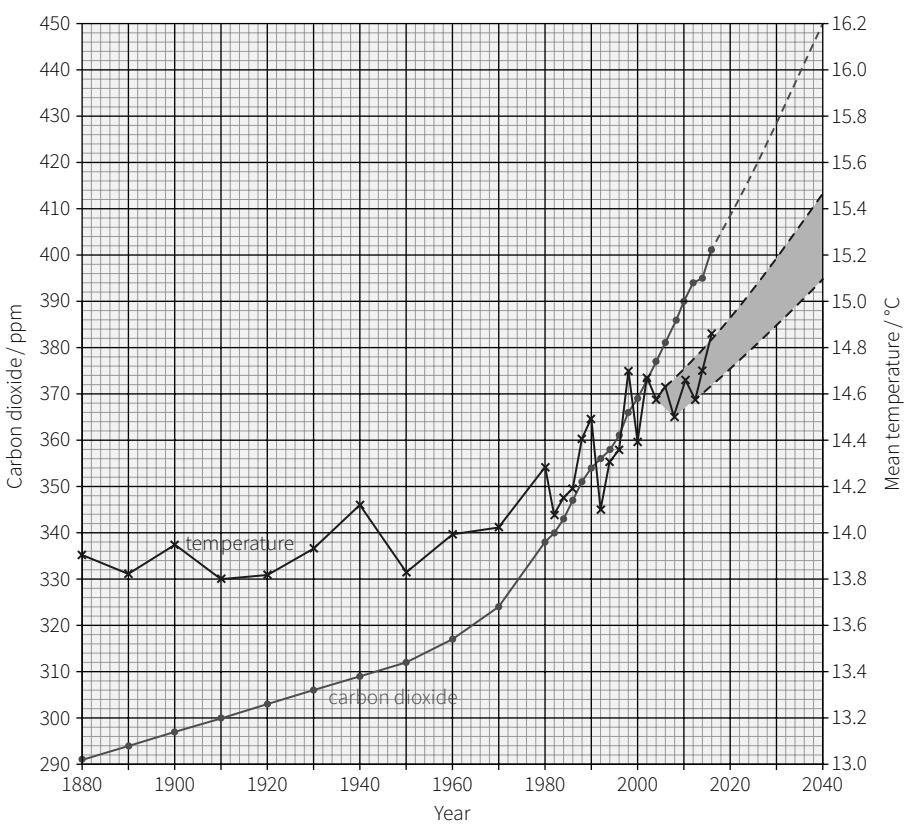
d The trend in mean temperature is more variable – showing more peaks and troughs. However, since the 1940s the broad trend is for the mean temperature to increase (this broad trend is shown by the shaded area of extrapolation on the graph below; so your extrapolation should fit anywhere within this area).

e The graphs suggest that there might be a link (correlation) between the levels of CO_2 in the atmosphere and the Earth's mean temperature as the temperature graph shows similar changes to that of the carbon dioxide levels. However, this does not prove that an increase in carbon dioxide levels causes the temperature rise.

f If the current trends were to continue then they would suggest that CO_2 levels could reach 405–410 ppm in 2020, and around 450 ppm in 2040. The mean temperature could reach around 14.9 °C in 2020 and 15.4 °C in 2040.

g The rise seems to follow the Industrial Revolution and then the increase in energy generation and transport fuelled by fossil fuels.

h methane: cattle, cultivation of rice in paddy fields
nitrogen oxides: vehicle exhaust fumes from hot engines



Exercise C1.02 Atmospheric pollution, industry and transport

a power stations

b coal, natural gas, petroleum (crude oil)

c flue gas desulfurisers (scrubbers)

d **i** $N_2 + O_2 \longrightarrow \mathbf{2}NO$

ii $\mathbf{2}NO + O_2 \longrightarrow \mathbf{2}NO_2$

iii The level of NO_x in the emissions from a diesel-engined car would be higher because the increased operating temperature would result in more reaction between nitrogen and oxygen from the air.

iv a catalytic converter (catalyser)

e **i** The levels of these polluting gases would be higher in large cities because they are mainly produced by cars and other motor vehicles, and motor traffic is highest in large cities.

ii lead – because modern cars now use lead-free petrol (gasoline)

f **i** drop for 2002 = 13.4%
level at start of 2003 = 86.6% of original value
drop for 2003 = 5,2% of 86.6 = 4.5% of original
Total drop over two years = (13.4 + 4.5)% = 17.9%

ii No, the benefits take place in the initial years following the introduction of the charge but then the reduction will level out.

iii Changes in vehicle and engine technology, including the type of fuel used, e.g. the introduction of hybrid and electric-powered cars.

The Congestion Charge Zone is not an isolated area / pollution can enter the area by being blown in by the wind / changes in human activity within the Congestion Charge Zone will affect the levels of vehicle usage in the area.

g The transport of containers by road requires a large number of vehicles – this means that they can be delivered to a large number of different destinations but with a resultant high level of emissions, including carbon dioxide.

Transport by rail means that one locomotive can move a large number of containers – the level of emissions per container is less. There may need to be some road transport at the final destination but the distances involved, and therefore the level of emissions, would be less.

Exercise C1.03 Clean water is crucial

a Screens are used to filter away floating large items of rubbish (e.g. pieces of wood, logs, debris).

b Chlorine and/or ozone disinfect the water / they kill bacteria and microorganisms.

c Ozone breaks down/oxidises pesticides and other harmful chemicals.

d It is an oxidising agent.

e **i** the removal of salt(s) from solution

ii distillation, reverse osmosis

iii They are expensive, requiring large amounts of energy and sophisticated equipment.

f **i** test: acidify the tap water with a few drops of nitric acid and then add silver nitrate solution (or lead nitrate solution)

positive result: a white precipitate (of silver chloride) is seen

ii sodium chloride + silver nitrate $\longrightarrow$ silver chloride + sodium nitrate

$NaCl + AgNO_3 \longrightarrow AgCl + NaNO_3$

iii $Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$

Chapter C2 The nature of matter

Exercise C2.01 Changing physical state

a **A** solid **B** solid and liquid (melting is in process)
C liquid **D** liquid and gas (boiling is taking place)

b 17 °C

c 115 °C

d The temperature remains constant until the change of state is complete.

e The melting point and boiling point are not those of water.

f The kinetic model states that the ***particles*** in a liquid and a ***gas*** *are* in constant motion. In a gas, the particles are far apart from each other and their motion is said to be ***random***. The particles in a solid are held in fixed positions in a regular ***lattice***. In a solid, the particles can only ***vibrate*** 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 ***different*** directions. If two gases or liquids are mixed the different types of particle ***spread*** out and get mixed up. This process is called ***diffusion***.

At the same ***temperature*** 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 ***diffuse*** faster than the heavier particles.

g **i** radon

ii radon and nitrogen

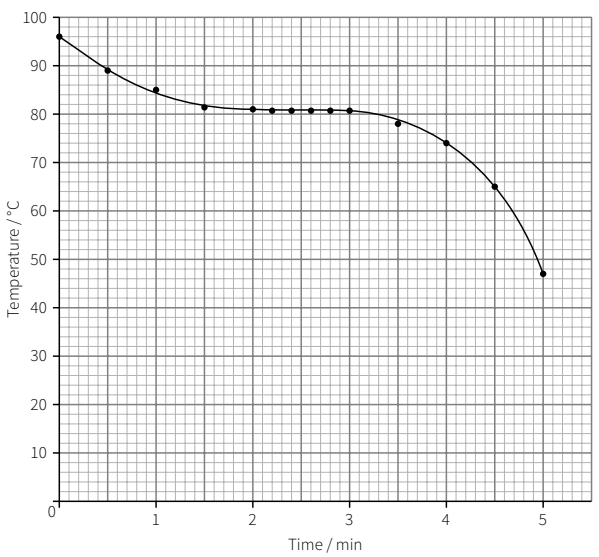
iii nitrogen

iv cobalt

v The sample of ethanoic acid is impure – the presence of impurities raises the boiling point of a substance.

Exercise C2.02 Plotting a cooling curve

a

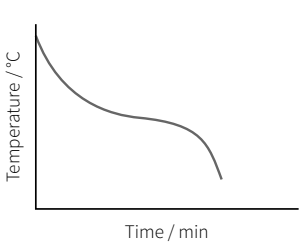


b The substance is freezing (solidifying) / turning from liquid to solid.

c The temperature stays constant because energy is being released as the substance solidifies / the molecules are giving out heat as they stop moving from place to place and become organised in a structured lattice arrangement / in the solid the molecules can only vibrate about fixed points / the heat released keeps the temperature constant until all the substance is solid.

d You would need to use an oil bath (in place of the water bath) so that the higher temperature could be reached.

e **i**



ii The curve flattens but the temperature does not stay constant while the wax solidifies. This is because wax is a mixture of substances, not a pure compound.

f **i** Water ice has a film of liquid water on its surface; solid carbon dioxide is dry (no liquid film).

ii The carbon dioxide is under pressure in the fire extinguisher.

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

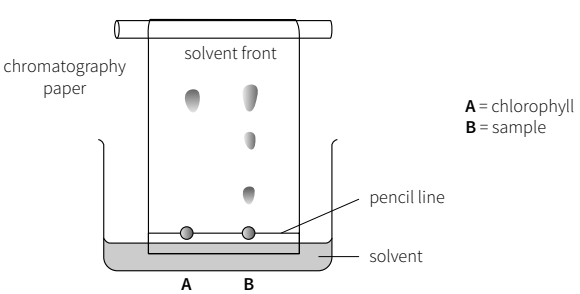
Exercise C2.03 Diffusion, solubility and separation

a **i** The purple crystals are soluble in water so the water begins to break up the crystals, and particles (ions) from the solid move into the water. This continues until all the solid dissolves. The particles then move through the liquid and spread out through the liquid until the solution is evenly coloured throughout.

ii A shorter time – if the temperature was higher, the particles would be moving faster as they would have more energy / the process of diffusion would take place more quickly.

b **i** The analysis would be done by chromatography. A piece of filter paper (chromatography paper) would be set up with a pencil line drawn across the bottom, samples of the green solution would be spotted on the line and the bottom edge of the paper then dipped carefully in a solvent (e.g. ethanol). The solvent would rise up the paper and different substances would move at different rates up the paper. One spot would be chlorophyll (green), but other (yellow) spots would be seen.

ii

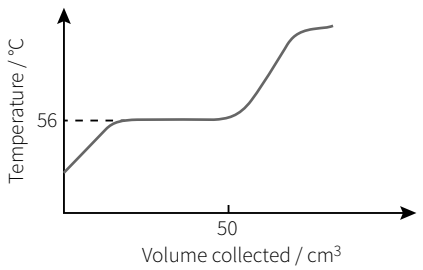


iii Photosynthesis is an endothermic process. Chlorophyll captures energy from the Sun which is then used to bring about the reaction between carbon dioxide and water to make glucose. Oxygen is a by-product of the reaction.

carbon dioxide + water ⟶ glucose + oxygen

$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$

c



Exercise C2.04 Chromatography at the races

a Two factors:

- the length of time the chromatogram is run (developed) for
- the solubility of the substance in the solvent – the more soluble the substance, the further it runs

b Horse **C**; paracetamol

c It is used as a painkiller.

d $R_f = \frac{\text{distance travelled by the substance}}{\text{distance travelled by the solvent}} = \frac{7.5}{10.0} = 0.75$

Note that you have a partial check on your answer here as the R_f value must be less than 1.

Exercise C2.05 Atomic structure

a Atoms are made up of three different particles: ***protons*** which are positively charged; ***neutrons*** which have no charge; and ***electrons*** which are negatively charged. The negatively charged particles are arranged in different ***energy levels*** (shells) around the ***nucleus*** of the atom. The particles with a negligible mass are the ***electrons***.

All atoms of the same element contain the same number of ***protons*** and ***electrons***. Atoms of the same element with different numbers of ***neutrons*** *are* known as ***isotopes***.

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

- up to ***two*** electrons in the first shell
- up to ***eight*** electrons in the second shell
- up to ***eight*** 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 ***left*** to ***right*** across the ***rows*** of the Periodic Table.

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

c **i** 38

ii 53

iii 137 − 55 = 82

Exercise C2.06 Influential organisation

a **i** see Table A2.01

ii The chemical properties of isotopes of the same element are the same because the number and arrangement of electrons in the isotopes are the same / the atoms of the isotopes all have the same number of outer electrons.

Isotope	Name of element	Proton number	Nucleon number	Number of		
				p	n	e
$^{12}_{6}C$	carbon	6	12	6	6	6
$^{14}_{6}C$	***carbon***	***6***	***14***	***6***	***8***	***6***
$^{1}_{1}H$	***hydrogen***	***1***	1	***1***	***0***	***1***
$^{3}_{1}H$	hydrogen (tritium)	***1***	***3***	***1***	***2***	***1***
$^{31}_{15}P$	***phosphorus***	15	31	***15***	***16***	***15***
$^{32}_{15}P$	***phosphorus***	***15***	***32***	***15***	***17***	***15***
$^{127}_{53}I$	iodine	***53***	***127***	53	***74***	53
$^{131}_{53}I$	***iodine***	***53***	***131***	53	***78***	***53***

Table A2.01

b see Table A2.02

Atom	Proton number	Electron arrangement			
		1st shell	2nd shell	3rd shell	4th shell
A	2	***2***			
B	5	***2***	***3***		
C	13	***2***	***8***	***3***	
D	15	***2***	***8***	***5***	
E	19	***2***	***8***	***8***	***1***

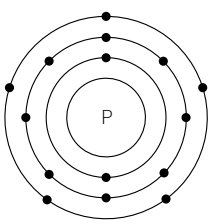
Table A2.02

i one (**B**)

ii **B** and **C**

iii three

iv



b carbon and silicon

c Group IV

d
- The halogens are ~~**metals**~~ **/ non-metals** and their vapours are **coloured /** ~~**colourless**~~.
- The halogens are **toxic /** ~~**non-toxic**~~ to humans.
- Halogen molecules are each made of ~~**one**~~ **/ two** atoms; they are ~~**monatomic**~~ **/ diatomic**.
- Halogens react with **metal /** ~~**non-metal**~~ elements to form crystalline compounds that are salts.
- The halogens get ~~**more**~~ **/ less** reactive going down the group in the Periodic Table.
- Halogens can ~~**colour**~~ **/ bleach** vegetable dyes and kill bacteria.

e

Name of element	sulfur	selenium	tellurium
density / g/cm³	2.07	***4.79***	6.24
melting point / °C	115	221	***450***
boiling point / °C	445	***685***	988
ionic radius / nm	0.184	***0.198***	***0.221***

Table A3.01

Chapter C3 Elements and compounds

Exercise C3.01 Periodic patterns in the properties of the elements

a