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Complete Chemistry for Cambridge IGCSE® Workbook

For the updated syllabus

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Oxford excellence for Cambridge IGCSE®

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Introduction

This workbook is designed to accompany the *Complete Chemistry for IGCSE* student book. It is designed to help you develop the skills you need in order to help you do well in your IGCSE Chemistry examination. The book follows the order of the chapters in *Complete Chemistry for IGCSE*. Each page of questions provides additional questions related to each double page in the student book.

The questions focus on the areas you need to know about for your exam:

- Knowledge (memory work) and understanding (applying your knowledge to answer questions about familiar or unfamiliar situations or substances).
- Handling information from data, tables, and graphs.
- Solving problems (including chemical equations and chemical calculations).
- Experimental skills and investigations.

The first 18 Units include a range of question types that you will come across in your chemistry examinations:

- Choosing words to complete sentences: you are usually given a list of words to choose from. This will help you learn and remember key facts.
- Putting statements in the correct order or selecting the correct statement from a list.
- Testing your ability to understand chemical formulae and to construct equations.
- Undertaking chemical calculations involving reacting masses, concentration, empirical and molecular formulae, and percentage yield.
- Some questions ask you to interpret data from diagrams, graphs, and tables. Others ask you to interpret the results of investigations that may be unfamiliar.
- Some pages include questions involving extended answers. These will help you organise your arguments and understand the depth of answer that is needed.

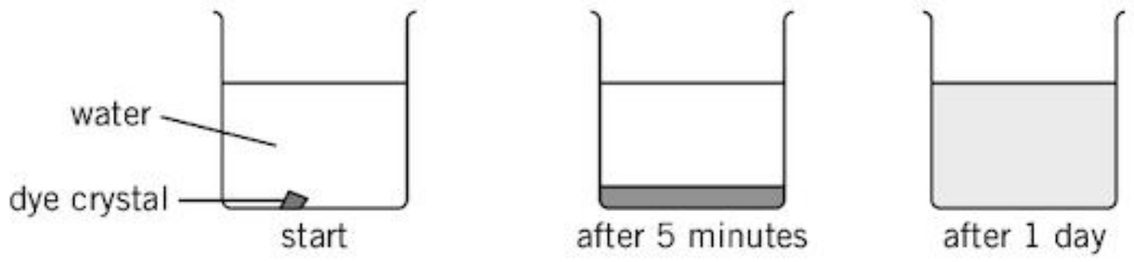
Other important features of this workbook that should help you succeed in chemistry include:

- Each unit has an extension box. The questions in these boxes are designed to challenge you. Many of them will develop your chemistry skills further. Some go beyond IGCSE and are there to stimulate your interest in chemistry. Many ask you to find relevant material from books or the internet.
- A unit on practical aspects of chemistry including apparatus, materials, and tests for ions and gases.
- A unit on mathematics for chemistry. This includes practice in writing formulae, rearranging expressions, working through calculations, and drawing graphs.
- A unit on how to analyse what a question is asking about, including the use of command words and the structure of questions. This unit also includes revision tips, which we hope will be helpful.
- A selection of IGCSE-style questions of the type that are set in the theory papers will help you to see connections between different parts of the syllabus.
- A unit on investigative practical work, which should increase your skills in devising and evaluating experiments.
- Full answers to all the questions, including the extension questions.
- A glossary to help you understand the meaning of important chemical terms.

We hope that the range of differing exercises in this workbook will help you develop your skills in and understanding of chemistry and help you succeed in this subject.

Contents

1. A student placed a crystal of a blue dye at the bottom of a beaker of water. After 5 minutes, the crystal disappeared. After 1 day, the solution was blue throughout.



a. Suggest how you could use a thin glass tube to place the crystal at the bottom of the beaker of water.

.....

..... [2]

b. State the name of the process occurring when:

i. the dye changes from a solid to a solution ..... [1]

ii. the colour spreads throughout the water. ..... [1]

c. Use ideas about moving particles to explain the results shown in the diagram.

.....

.....

..... [3]

2. **a.** Dust particles in still air appear to show Brownian motion.
Draw a diagram in the space on the right to show a dust particle undergoing Brownian motion.

[2]

Extension

b. Which are larger, dust particles or the particles of oxygen and nitrogen in the air?
Explain how you know this. [2]

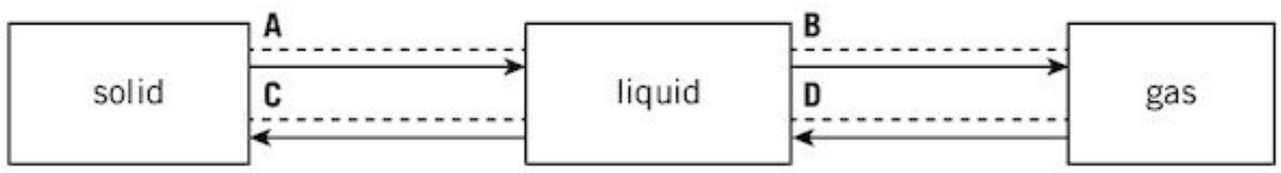
c. Use ideas of moving particles to explain why dust particles in still air show Brownian motion. [3]

1. **a.** Describe the general properties of liquids and gases in terms of **i.** their volume and **ii.** how they spread out.

liquids **i.** ..... **ii.** ..... [2]

gases **i.** ..... **ii.** ..... [2]

b. Complete the diagram by writing the names of the changes of state **A**, **B**, **C**, and **D**.



[4]

c. The table shows the melting points and boiling points of three substances.

Substance	Melting point / °C	Boiling point / °C
ethanol	–117	79
methane	–182	–164
naphthalene	81	218

i. Which substance has the lowest melting point? ..... [1]

ii. Which substance is a solid at room temperature? Explain your answer.

..... [2]

iii. Which substance is a liquid at room temperature? Explain your answer.

.....

..... [2]

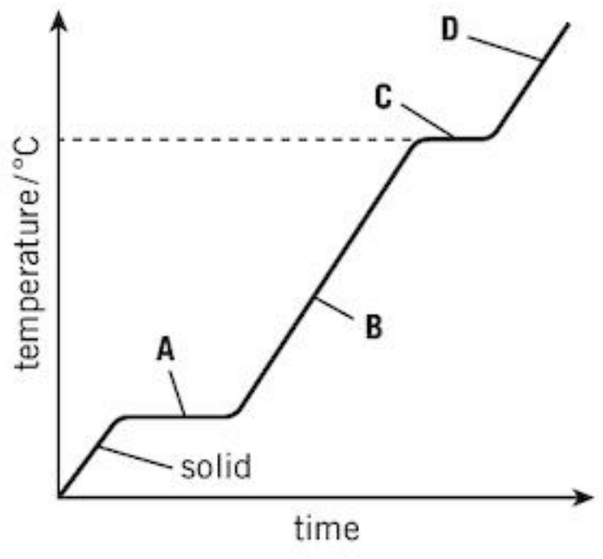
d. The diagram shows a heating curve for substance T.
What is the physical state or states of T at the following points?

A ..... [1]

B ..... [1]

C ..... [1]

D ..... [1]



Extension

e. Draw a cooling curve to show how the temperature changes when steam at 120 °C is cooled slowly to – 10 °C.
On your curve show the melting and boiling points of water. [4]

f. **i.** Iodine melts at 114 °C and boils at 184 °C.
Explain why iodine seems to sublime when you heat a crystal of iodine in a boiling tube. [2]

ii. Suggest how you could show that iodine does form a liquid at room pressure. [2]

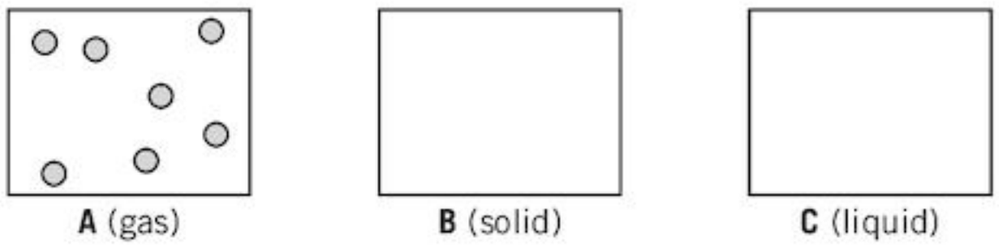
a. Use the correct words from the list to complete the sentences.

apart attraction fixed highest inside irregular lattice lowest

repulsion rotate strong surface together vibrate weak

The particles in a solid are arranged in a ..... pattern (.....). The forces of ..... between the particles are .....enough to keep them ..... and so the particles only ..... . When a liquid evaporates, the particles with the ..... energy leave the ..... of the liquid first. [8]

b. Box **A** shows the arrangement of 7 particles in a gas. Complete the boxes **B** and **C** to show the arrangement of 16 particles in a solid and 16 particles in a liquid.



[4]

c. Complete these sentences correctly by writing the words *gas, liquid,* or *solid* in the spaces provided.

The forces of attraction between the particles in a ..... are stronger than those between ..... particles but weaker than those between the particles in a ..... . Particles in a ..... only vibrate. Particles in a ..... move more slowly than those in a ..... . [6]

d. Describe the difference between boiling and evaporation.

.....

..... [2]

e. For each of the changes **i.** to **iv.** state whether energy is absorbed or released.

i. Bromine melts ..... **ii.** Water freezes .....

iii. Gaseous sulfur changes to solid sulfur .....

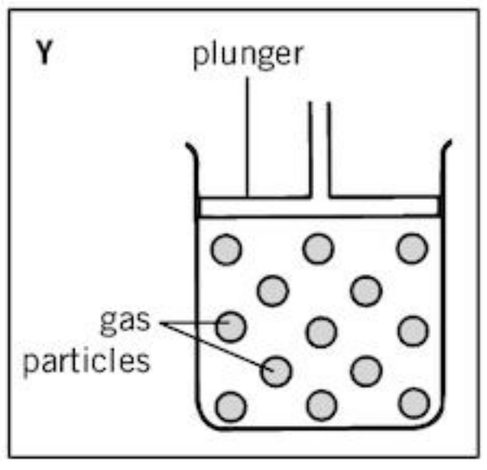
iv. Ethanol boils ..... [4]

Extension

f. Arsenic sublimes at 613 °C. Describe what happens to the particles of arsenic in terms of their arrangement, proximity (closeness), and motion when solid arsenic sublimes. [3]

g. Silicon melts at 1410 °C. Phosphorus melts at 44 °C. Explain the difference in these melting points by referring to forces between the particles and energy. [4]

1. Box **Y** shows particles of gas in a container with a plunger.



Z

a. Draw a diagram in box **Z** to show what happens when the gas is compressed. [1]

b. Use the kinetic particle theory to explain why the pressure in **Y** is less than the pressure in **Z**.

.....

..... [3]

2. The table shows how the volume of a gas changes with temperature and pressure.

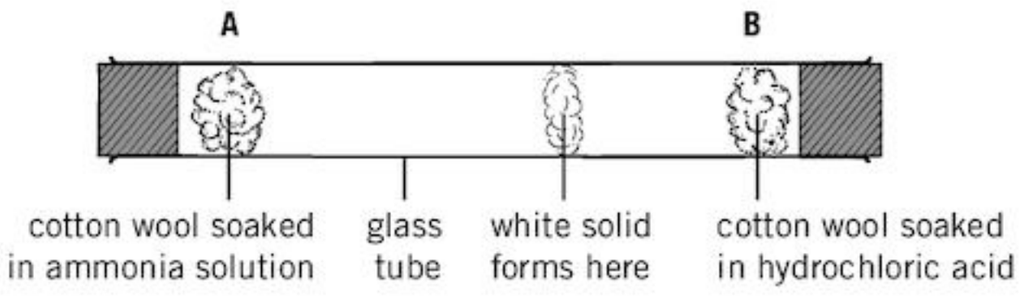
	Volume of gas at different temperatures / cm^3			
Pressure / atm	20 °C	40 °C	80 °C	160 °C
1	60	64	72	88
2	30	32	36	44
4	15	16	18	22

Describe exactly how the volume varies with pressure when the temperature is constant.

.....

..... [2]

3. A diffusion experiment is set up as shown.



a. Ammonia solution gives off ammonia gas. Hydrochloric acid gives off hydrogen chloride gas. Explain why the white solid forms and why it is closer to **B** than **A**.

.....

.....

..... [3]

Extension

b. Use books or the internet to find other gases that could replace hydrochloric acid in this experiment. [2]

c. Methylamine reacts with hydrochloric acid in a similar way to ammonia. The relative molecular mass of hydrochloric acid is 36.5. The relative molecular mass of methylamine is 31. How does the position of the white ring change when methylamine is used? Explain your answer. [3]

1. **a.** The solubilities of some compounds are shown in the table.

Compound	Solubility g / 100 cm^3 water	Compound	Solubility g / 100 cm^3 water
calcium hydroxide	0.113	potassium nitrate	37.9
calcium nitrate	102.1	silver chloride	0.0002
iron(II) hydroxide	0.00003	silver nitrate	241.3

i. What type of metal compound is very soluble in water?

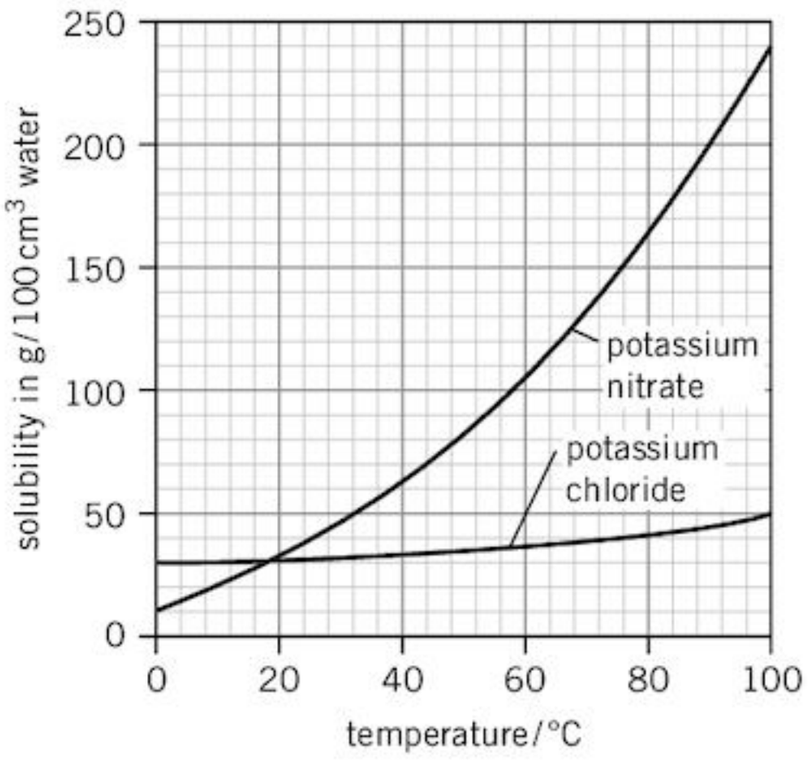
..... [1]

ii. Which compounds are insoluble in water?

..... [2]

iii. Which compound is sparingly soluble? ..... [1]

b. The graph shows the solubility of two compounds at different temperatures.



i. Deduce the solubility of potassium nitrate at 70 °C. ..... [1]

ii. Which compound is more soluble in water at 10 °C? ..... [1]

iii. Deduce the maximum mass of potassium nitrate that dissolves in 100 cm^3 of water at 60 °C.

..... [1]

iv. At what temperature is the solubility of potassium nitrate the same as that of potassium chloride?

..... [1]

Extension

v. A saturated solution of potassium nitrate in 200 g of water is cooled from 80 °C to 20 °C. What mass of solute crystallises? Show your working. [4]

vi. What is the minimum volume of water needed to dissolve 50 g of potassium nitrate at 90 °C? Show all your working. [3]

1. **a.** Which two of these substances are most likely to be pure?
Underline the correct answers.

air aspirin tablets orange juice

oxygen gas sodium chloride crystals tap water [2]

b. Why should pure substances be used to make a medical drug?

..... [1]

c. **i.** Seawater is a mixture.
What is the meaning of the term *mixture*?

..... [2]

ii. Suggest a value for the melting point of seawater. ..... [1]

2. **a.** Sulfur melts at 119 °C and boils at 445 °C.
Draw lines between the boxes on the left and the boxes on the right to complete four sentences.

	…..melts over a 4 °C temperature range.
Pure sulfur…..	…..turns to a vapour at 450 °C.
Impure sulfur…..	…..solidifies at 119 °C.
	…..has a sharp boiling point.

[2]

b. Solder is a mixture of tin and lead that is used to join metals.
The melting point of tin is 232 °C. The melting point of lead is 328 °C.
Solder melts at 183 °C.

i. Why does solder have a lower melting point than either tin or lead?

..... [2]

ii. Suggest an advantage of the low melting point of solder.

..... [1]

3. Name the separation method you could use to separate:

a. Sand from a mixture of water and sand. ..... [1]

b. Water from a solution of copper sulfate in water. ..... [1]

c. Two liquids with different boiling points. ..... [1]

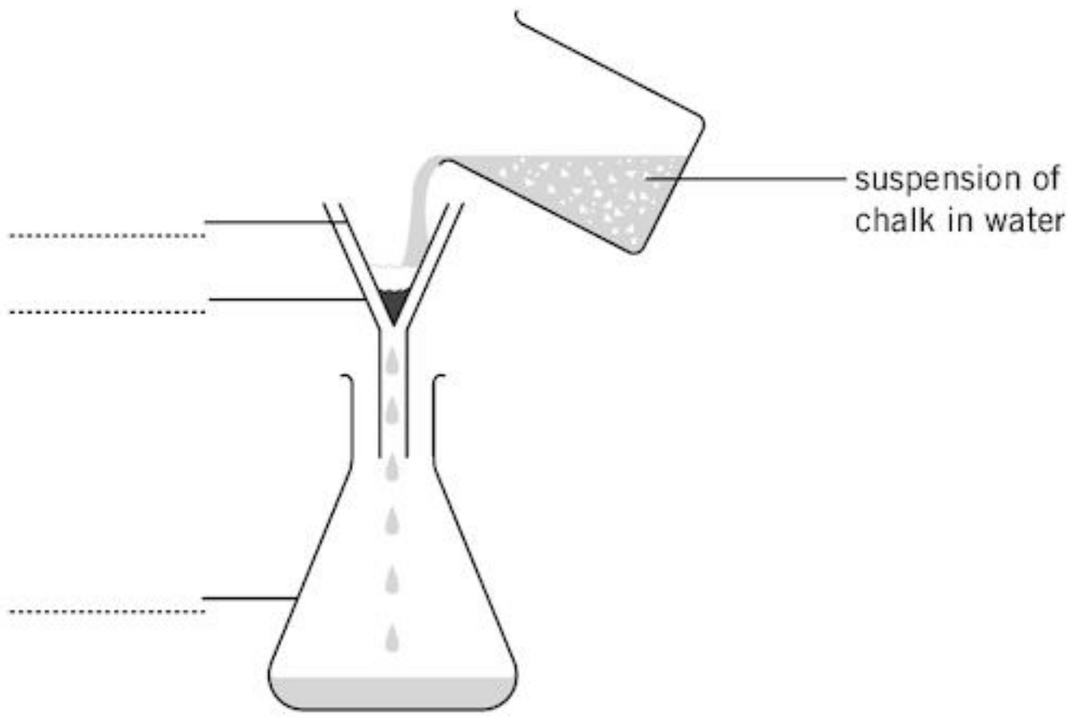
Extension

4. Use books or the internet to answer these questions:

a. Explain why salt is put on the roads in icy weather. [3]

b. Use ideas about vapour pressure to explain how impurities increase the boiling point of water. [5]

1. a. i. Complete the diagram by writing the correct labels on the dotted lines.



[3]

ii. On the diagram above label the residue and the filtrate. [2]

b. i. Put these statements about the crystallisation of zinc sulfate in the correct order.

A Filter off the crystals.

B Heat the solution to concentrate it.

C Dry the crystals with filter paper.

D Wash the crystals with a small amount of solvent.

E Leave the solution to cool and form crystals.

F By seeing if crystals form on a cold surface.

G Check that a saturated solution has formed.

Order ..... [2]

2. Calcium carbonate is insoluble in water. Sodium sulfate is soluble in water.
Describe how you could separate a mixture of powdered calcium carbonate and powdered sodium sulfate to obtain a sample of each pure solid.

.....

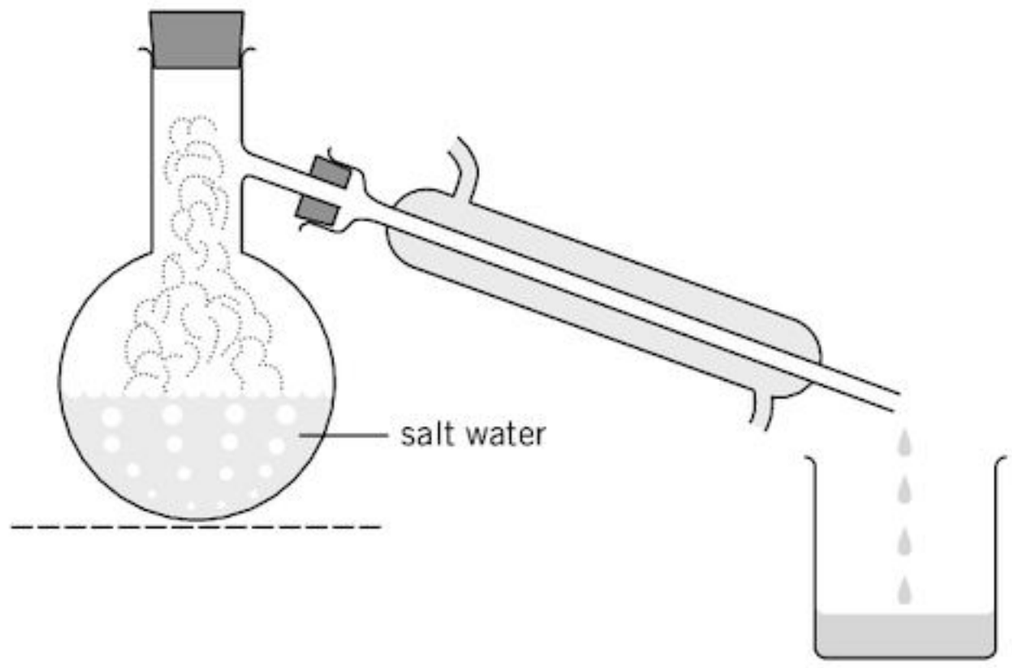
.....

..... [4]

Extension

3. Use books or the internet to describe the process of fractional crystallisation. [5]

1. a. i. Label the diagram of the distillation apparatus to show: (i) the distillation flask; (ii) the distillate; (iii) the condenser; and (iv) where cold water enters the condenser.



[4]

ii. On the diagram above, draw an arrow to show where heat is applied. [1]

b. i. Explain why this method can be used to separate salt from salty water.

..... [1]

ii. Explain why this method cannot be easily used to separate two liquids that have similar boiling points.

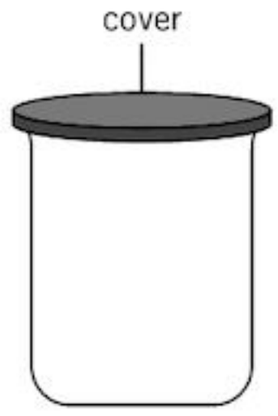
..... [1]

2. Complete the following sentences about fractional distillation of alcohols using words from the list.

boiling **condenser** **further** **higher** **liquid**
lower **receiver** **temperatures** **vaporised** **volatile**

There is a range of ..... in the distillation column, ... at the top and ..... at the bottom. When ..... the more ..... alcohols move ..... up the column than the less volatile alcohols. In the ..... the alcohol changes from vapour to ..... The alcohols are collected one by one in the ....., those with the lower ..... points condensing before those with higher ones. [10]

3. Paper chromatography can be used to separate a mixture of dyes. Complete the diagram on the right to show the apparatus set up for chromatography. Label your diagram. [3]



Extension

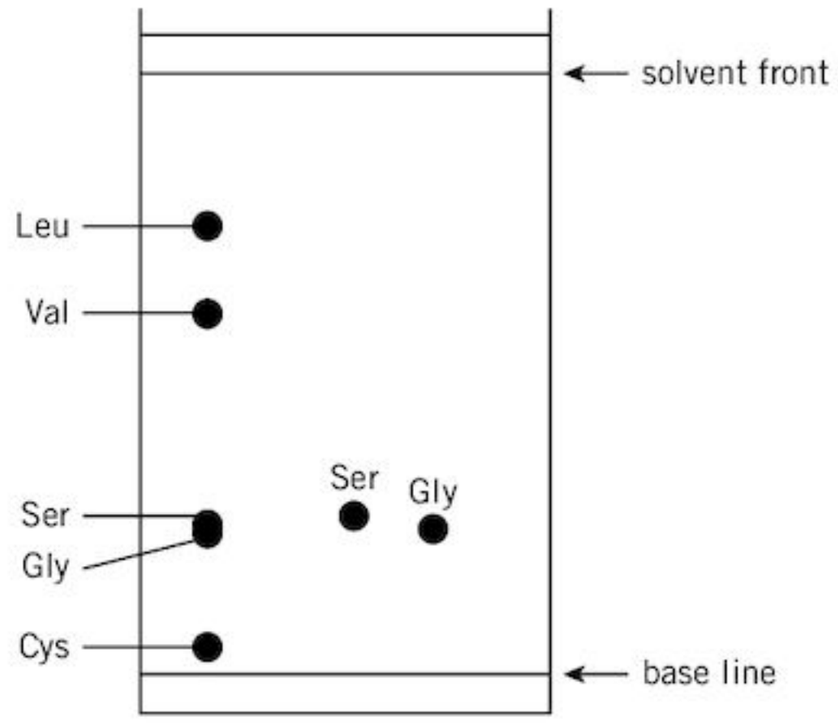
4. Use books or the internet to find out about steam distillation.

a Give two examples of the use of steam distillation. [2]

b Explain why steam distillation is used rather than simple distillation. [1]

c Describe how steam distillation is carried out. [3]

1. **a.** A paper chromatogram of some amino acids from a mixture of amino acids is shown. Two pure amino acids, Ser and Gly, were also run on the same piece of paper.



i. Why was the base line drawn in pencil and not in ink?

..... [1]

ii. How many amino acids have been completely separated? ..... [1]

iii. Which amino acids have not been separated? ..... [1]

iv. Suggest how you could you separate these amino acids.

..... [1]

v. Calculate the R_f value of Val. ..... [1]

vi. Lysine has an R_f value of 0.14. On the diagram above, draw the approximate position of Lys. Label it Lys. [1]

b. Amino acids are colourless. How can you make the spots show up?

.....

..... [2]

Extension

2. Use books or the internet to answer the following:

a. Metal ions from a coin, e.g. Ag^+, Ni^{2+}, Cu^{2+}, can be identified by paper chromatography.

Suggest how a solution of these ions can be made from the coin. [1]

b. Column chromatography can be used to check the contents of mixtures used in medical drugs. Explain briefly how column chromatography is used. [6]

1. The diagram shows part of the Periodic Table. Not all elements have been included.

							H								
Li												B	C	N	O
Na	Mg											Al			
K	Ca						Fe	Co	Ni	Cu					
Rb													Sn		

Answer these questions using **only** the elements shown in the table.

a. Give the name of one element in Group IV. ..... [1]

b. Give the name of an element in Period 5. ..... [1]

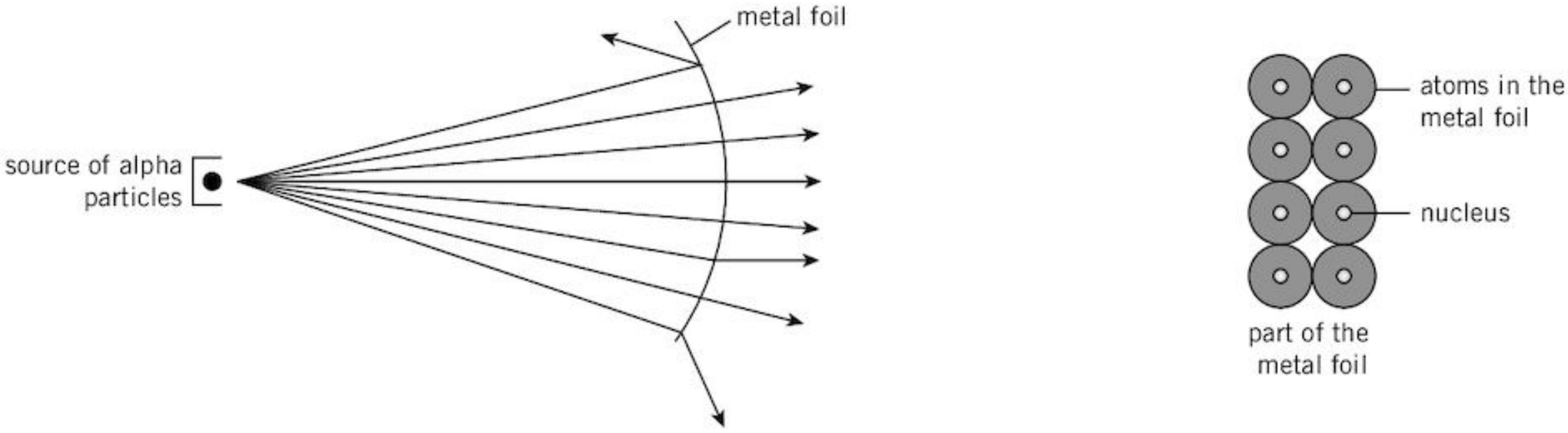
c. Give the name of a transition element. ..... [1]

d. Which element is in Period 3 and Group II? ..... [1]

e. On the Periodic Table above, shade in the boxes of the non-metallic elements. [2]

f. Which two groups of elements are not shown? ..... and ..... [2]

2. In the year 1909, scientists fired positively charged particles (alpha particles, He^{2+}) at thin metal foil. The results are shown below.



a. How does this experiment show that most of the atom is empty space?

..... [1]

b. How does this experiment show that the nucleus is very small?

..... [1]

c. Explain how this experiment shows that the nucleus has positive charges in it.

..... [2]

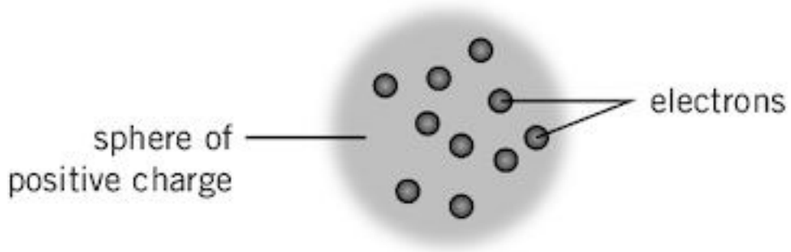
Extension

3. John Newlands was one of the first scientists to try to order elements. Use books or the internet to find out about his 'Law of Octaves'.

How does the table of elements drawn up by John Newlands differ from the modern Periodic Table? [5]

1. In 1906, J.J. Thomson suggested the model of the atom shown below.

How does this model of the atom differ from the simple model of the atom we use today?



.....

..... [3]

2. Complete these sentences about single atoms.

a. Atomic number is the number of ..... [1]

b. Nucleon number is the number of ..... [1]

c. Another name for nucleon number is ..... [1]

3. Complete this table about subatomic particles.

Subatomic particle	Relative mass	Relative charge
electron	0.00054	
	1	
proton		1+

[4]

4. The symbol of a particular carbon atom is written as ${}^{12}_{6}C$.

a. How many protons and neutrons does this C atom have?

Number of protons..... Number of neutrons..... [2]

b. Name each of these atoms and deduce the number of protons, neutrons, and electrons present.

Atom	Name of atom	Number of protons	Number of neutrons	Number of electrons
${}^{19}_{9}F$				
${}^{43}_{20}Ca$				
${}^{3}_{1}H$				
${}^{58}_{26}Fe$				

[8]

Extension

5. Write down the number of protons, neutrons, and electrons in these ions.

a. ${}^{56}_{26}Fe^{2+}$ b. ${}^{34}_{16}S^{2-}$ c. ${}^{127}_{53}I^{-}$ d. ${}^{41}_{19}K^{+}$ [8]

1. **a.** Complete the definition of isotopes using words from the list.

atoms **compound** **electrons** **element** **mass** **molecules** **neutrons** **protons**

Isotopes are ..... of the same ..... with the same number of ..... but different numbers of ..... . [4]

b. Three isotopes of hydrogen are

$^{1}_{1}H$ $^{2}_{1}H$ $^{3}_{1}H$

i. State the proton number of hydrogen. ..... [1]

ii. What is unusual about the isotope $^{1}_{1}H$? ..... [1]

iii The isotope $^{3}_{1}H$ is radioactive. What is meant by the term *radioactive*?

.....

.....

..... [3]

c. The mass of the isotope phosphorus-32 and its radioactivity was measured over a number of days. The table shows the results.

Time / days	Mass of phosphorus-32 / mg	Radioactivity / cpm
0	100	200
14	50	100
28	25	50
42	12.5	

i. Describe how the mass of phosphorus-32 changes with time.

.....

..... [2]

ii. Predict the radioactivity at 42 days. ..... [1]

2. Link the radioisotopes on the left with their uses on the right.

uranium-235	used to kill bacteria in food
cobalt-60	used to produce electrical energy
carbon-14	used to date ancient pieces of cloth

[1]

Extension

3. **a.** Complete this equation.

$^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn +$ ..... [2]

b. Describe the three main types of radioactivity. Use books or the internet to help you. [6]

1. **a.** Electrons are arranged in shells outside the nucleus.

   Give another name for these shells. ..... [1]

   b. Complete the table to show the electron distribution (electron arrangement) of the atoms shown.

Element	Number of electrons in an atom	Electron arrangement
nitrogen		
oxygen		
fluorine		
neon		
sodium		
argon		
calcium		

[8]

2. Match up the beginnings and endings.

A The Period number is .....
B The Group number is .....
C Valency is .....

D ..... related to the number of electrons that combine in a reaction.
E ..... the same as the number of outer shell electrons in an atom.
F ..... the same as the number of electron shells in an atom.

A with ..... **B** with ..... **C** with ..... [1]

3. Draw the electron distribution (electron arrangement) of these atoms. Show all the electron shells. Draw the electrons in pairs where possible.

aluminium	carbon	chlorine	helium
magnesium	neon	phosphorus	potassium

[8]

Extension

4. Give the electron distribution (electron arrangement) of the following ions:

   a. **i.** H^+ **ii.** Al^{3+} **iii.** Ca^{2+} **iv.** O^{2-} **v.** N^{3-} [5]

   b. Which of these ions have the same electron distribution? [1]

   c. Explain the importance of these ionic structures in terms of stability. [2]

1. The table gives some properties of diamond (carbon), sodium, and sulfur.

Diamond (carbon)	Sodium	Sulfur
melts above 3550 °C	melts at 98 °C	melts at 119 °C
does not conduct electricity	conducts electricity	does not conduct electricity
conducts heat quite well	conducts heat	does not conduct heat
shatters when hit	malleable	shatters when hit

a. Give one way in which diamond behaves as a typical non-metal.

..... [1]

b. Give one way in which diamond does not behave as a typical non-metal.

..... [1]

c. Give one way in which sodium behaves as a typical metal.

..... [1]

d. Give one way in which sodium does not behave as a typical metal.

..... [1]

e. Explain why sulfur is a typical non-metal.

..... [1]

2. The table shows some properties of three metals. Use each metal once to answers questions **a.**–**c.**

Metal	Density / g/cm^3	Melting point / °C	Electrical conductivity / $\Omega^{-1}m^{-1}$	Relative strength
aluminium	2.70	660	0.41	7
copper	8.92	1038	0.54	13
iron	7.86	1535	0.11	21

a. Which metal is best for making the body of an aircraft? Explain your answer.

..... [2]

b. Which metal is best for making a car body? Explain your answer.

..... [2]

c. Which metal is best for making electrical wiring? Explain your answer.

..... [2]

Extension

3. Germanium, arsenic, and silicon are metalloids. Use books or the internet to write about the position of metalloids in the Periodic Table and their properties. [6]

1. Underline the changes that are physical changes.

Burning magnesium in air | Separating iron from sulfur using a magnet

Rusting of iron | Melting zinc

Distilling plant oils from a mixture of plant oils and water [3]

2. Complete the table to show the difference between a compound and a mixture using words from the list. Some words may be used more than once.

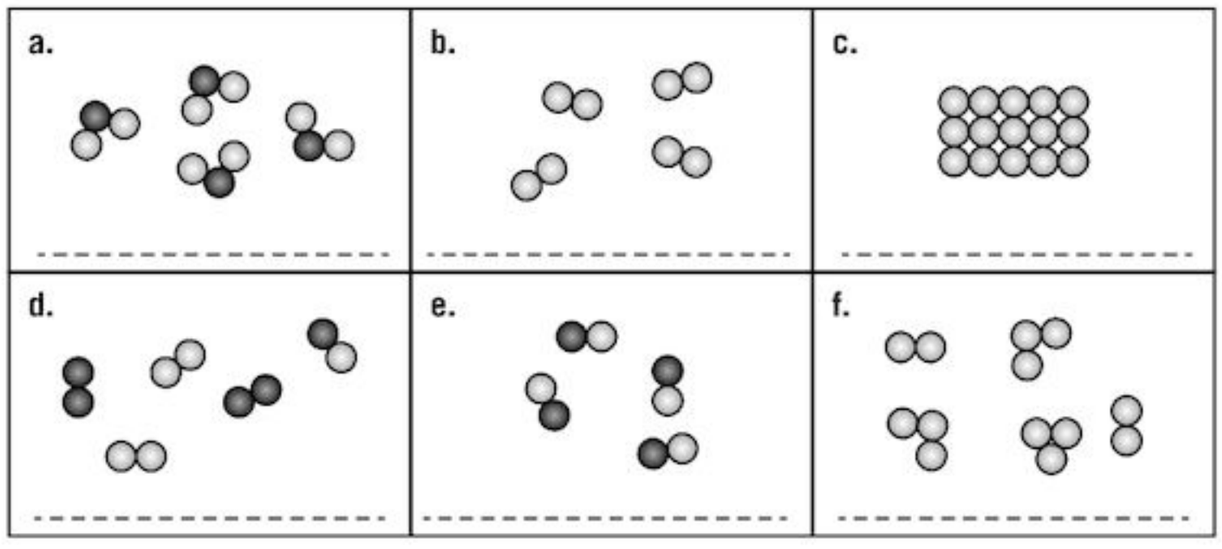
any average combined definite different elements physical present separated

Compound	Mixture
The ..... cannot be ..... by ..... means.	The substances in it can be ..... by ..... means.
The properties are ..... from those of the ..... which went to make it.	The properties are the ..... of the substances in it.
The elements are ..... in a ..... proportion by mass.	The substances can be ..... in ..... proportion by mass.

[6]

3. The diagram shows six different substances. Each circle represents an atom.

Classify these as pure elements, pure compounds, or mixtures.



[6]

4. Write chemical formulae for the following compounds.

a.

b.

c.

d.

--------- ---------- --------- --------- [4]

Extension

5. a. Use books or the internet to find out about the physical and chemical properties of zinc and sulfur. [12]

b. Suggest two methods by which you could separate sulfur from a mixture of powdered zinc and powdered sulfur. [6]

1. Read the following passage then answer the question that follows.

   Chlorine is a green gas that dissolves slightly in water to form a weakly acidic solution. Sodium is a silvery metal that reacts violently with water. When sodium reacts with chlorine, heat is given out and a white powder (sodium chloride) is formed. Sodium chloride dissolves in water and forms a solution that is not acidic.

   What information in the passage tells you that sodium chloride is a compound and not a mixture?

   .....

   .....

   ..... [3]

2. Complete these sentences about ionic compounds:

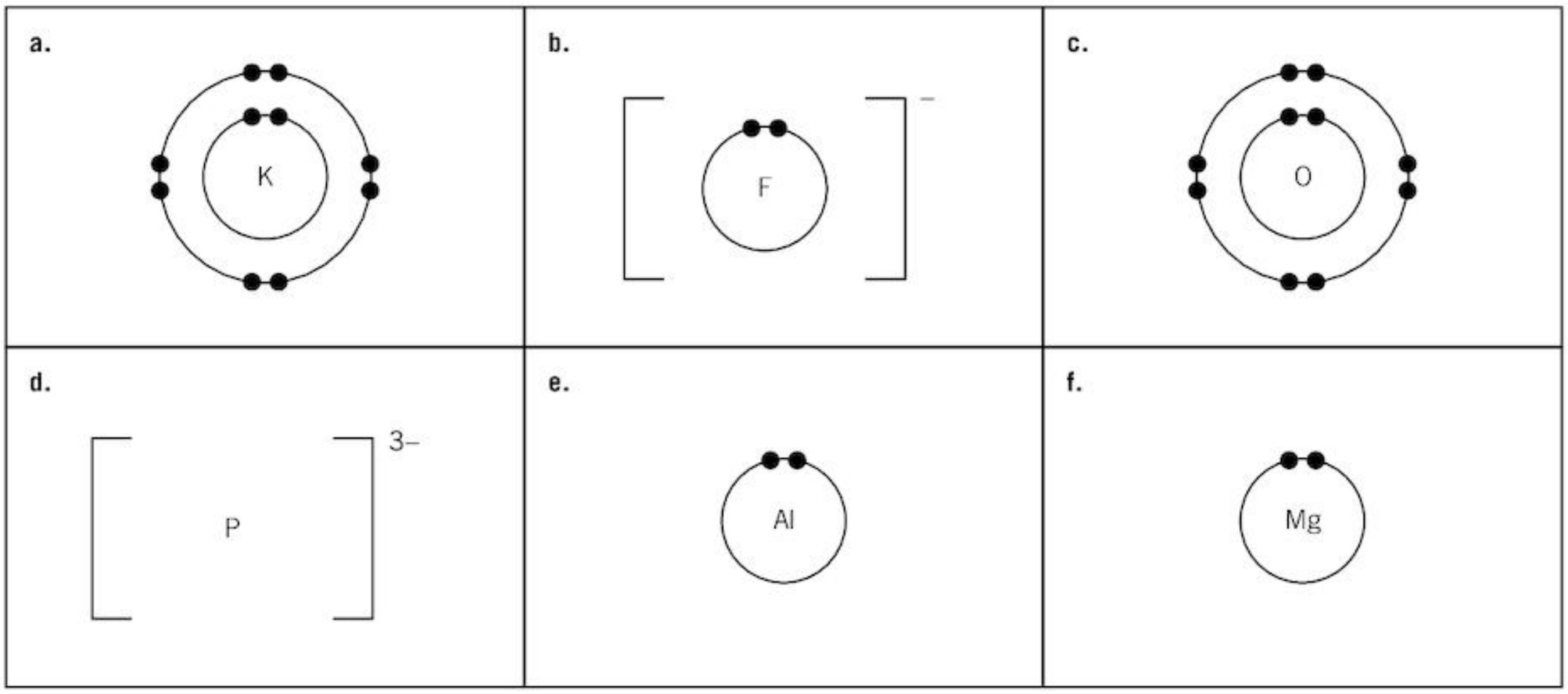
   a. An ion is a ..... particle. [1]

   b. Ions have unequal numbers of ..... and ..... . [2]

3. Put a ring around the electron arrangements that are stable ions or atoms.

   2,8 2,5 2,8,8 2,8,8,2 2 2,8,3 2,8,18,8 [4]

4. Complete the diagrams below to show the electron arrangement of the stable ions.
   Include brackets and charges.



[6]

Extension

5. **a.** Use books or formulae to find the charges on the stable ions of the following transition elements: vanadium, iron, cobalt, and copper. [2]

   b. What do you notice about the charges on these ions? [2]

1. Complete the passage about ionic structures using words from the list.

alternate **atoms** **bonds** **giant** **ions** **irregular** **lattice** **molecular** **negative** **positive** **regular** **strong** **weak**

A sodium chloride ..... is a ..... arrangement of ..... sodium ions and .....

chloride ions, which ..... with each other. The ions are held together by ..... ionic ..... .

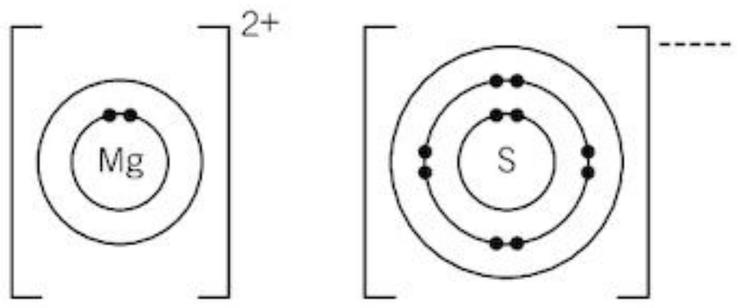
This structure is called a ..... ionic structure. [8]

2. Link the phrases on the left with the phrases on the right to make four correct sentences.

Ionic compounds are formed	..... it loses one or more electrons.
Ionic compounds have no	..... it gains one or more electrons.
When a metal atom forms an ion	..... overall charge.
When a non-metal atom forms an ion	..... by the reaction of metals with non-metals.

[2]

3. **a.** Complete the ionic structure of magnesium sulfide. Show all the electrons as dots.



[3]

b. Draw ionic diagrams for lithium chloride and magnesium fluoride in a similar way.

lithium chloride	magnesium fluoride
Li Cl	F Mg F
[3]	[4]

Extension

c. The nitride ion is N^{3-}. Draw the electron arrangement of the ions in calcium nitride. [4]

1. a. Work out the formulae of compounds **A** to **H** using the list of ions below.

Al^{3+} Br^{-} Ca^{2+} Cl^{-} Fe^{3+} H^{+} K^{+} Mg^{2+} N^{3-} Na^{+} O^{2-} S^{2-}

A magnesium bromide ..... **B** sodium oxide .....

C hydrochloric acid ..... **D** aluminium chloride .....

E potassium nitride ..... **F** calcium sulfide.....

G aluminium sulfide ..... **H** iron(III) oxide ..... [8]

b. Work out the formulae of compounds **J** to **Q**. Use the list of compound ions below to help you.

CO_3^{2-} HCO_3^{-} NH_4^{+} NO_3^{-} OH^{-} SO_4^{2-}

J magnesium nitrate ..... [1]

K potassium sulfate ..... [1]

L ammonium nitrate ..... [1]

M ammonium sulfate ..... [1]

N calcium hydroxide ..... [1]

O sodium hydrogencarbonate ..... [1]

P aluminium nitrate ..... [1]

Q lithium carbonate ..... [1]

2. Name compounds **R** to **W**. You may want to use the periodic table on page 177 to help you.

R MgI_2 ..... [1]

S $Sr(OH)_2$ ..... [1]

T $FeSO_4$ ..... [1]

U $Zn(NO_3)_2$ ..... [1]

V $(NH_4)_2CO_3$ ..... [1]

W $Ca(HCO_3)_2$ ..... [1]

Extension

3. Use the list of ions below to work out the formulae for compounds **a**. to **e**.

manganate(VII), MnO_4^{-} peroxide, O_2^{2-} phosphate, PO_4^{3-} sulfite, SO_3^{2-}

a. potassium manganate(VII) **b.** sodium peroxide **c.** calcium phosphate

d. calcium sulfite **e.** sodium phosphate [5]

1. Complete the passage about covalent bonding using words from the list.

attraction	**covalent**	**electrons**	**giving**	**ionic**	**metal**	**non-metal**
nucleus	**pair**	**repulsive**	**sharing**	**single**	**strong**	**weak**

A covalent bond is formed when ..... atoms combine. It forms because of the ..... force of ..... between the ..... of one atom and the outer ..... of the atom next to it. A single ..... bond is formed by ..... one ..... of electrons between two atoms. [8]

2. **a.** What is meant by the term *molecule*?

..... [1]

b. Put a ring around the molecules that are diatomic.

CO Cl_2 N_2 N_2O_4 O_2 O_3 P_4 S_8 [2]

3. **a** Draw diagrams to show the electron distribution (electron arrangement) in each of these diatomic molecules. Show only the outer shell electrons.

i. hydrogen	**ii.** bromine
iii. oxygen	**iv.** nitrogen

[4]

b. **i.** How many outer shell electrons are there around each atom in the molecules?

..... [1]

ii. What is the significance of this number of electrons for the hydrogen, oxygen, or nitrogen molecules?

.....

..... [2]

Extension

4. Some metals can form compounds with chlorine or hydrogen that are simple covalent molecules. Use books or the internet to find simple covalent compounds of three different metals. [3]

1. **a.** Draw dot-and-cross diagrams to show the electron distribution (electron arrangement) of each of these covalent molecules. Show only the outer shell electrons.

hydrogen bromide, HBr	water, H_2O
ammonia, NH_3	hydrogen sulfide, H_2S
methane, CH_4	phosphorus trichloride, PCl_3
carbon dioxide, CO_2	ethene, C_2H_4

[8]

b. Which of these molecules have unbonded pairs of electrons (lone pairs of electrons)?

..... [2]

Extension

2. Draw dot-and-cross diagrams to show the electron distribution (electron arrangement) of each of these covalent molecules. Show only the outer shell electrons.

a. methanol, CH_3OH **b.** ethyne, C_2H_2 **c.** hydrazine, N_2H_4 **d.** ethanol, C_2H_5OH [4]

1. The table gives some properties of some simple molecular covalent compounds and ionic compounds. Complete the table by writing either 'covalent' or 'ionic' in the last column.

Compound	Melting point / °C	Solubility in water	Electrical conductivity when molten	Covalent or ionic?
barium oxide	2852	soluble	conducts	
carbon tetrachloride	–23	insoluble	does not conduct	
potassium bromide	734	soluble	conducts	
carbon disulfide	–111	insoluble	does not conduct	
octane	–57	insoluble	does not conduct	

[2]

2. Link the properties **A** to **G** on the left with the correct reasons **1** to **7** on the right.

A Simple molecular compounds have low melting points	**1** ..... because there are no mobile ions or electrons present to conduct.
B Ionic compounds have high melting points	**2** ..... because the molecules cannot form strong enough intermolecular forces with water molecules.
C Simple molecular compounds do not conduct electricity	**3** ..... because they can form relatively strong bonds with the water molecules.
D Some simple molecular compounds do not dissolve in water	**4** ..... because the forces of attraction between the molecules are low.
E Ionic compounds conduct electricity when molten	**5** ..... because they can form relatively strong intermolecular forces with solvent molecules.
F Many ionic compounds dissolve in water	**6** ..... because the ions are free to move.
G Some molecular compounds dissolve in organic solvents	**7** ..... because there are strong forces of attraction between all the ions.

[3]

3. Put a ring around the formulae of the substances below that will dissolve in organic hydrocarbon solvents.

$Ca^{2+}O^{2-}$ CS_2 I_2 Na^+Cl^- S_8 [1]

4. Explain why ionic compounds do not conduct electricity when solid.

..... [1]

Extension

5. **a.** The simple covalent molecules CH_3OH, C_2H_5OH, and $C_6H_{12}O_6$ dissolve in water.

The simple covalent molecules CH_4, C_6H_{14}, and CH_3Cl do not dissolve in water.

What feature of the molecules seems to make them soluble in water? [1]

b. Use books or the internet to find three other examples of simple covalent molecules that are soluble in water. [3]

1. Some physical properties, **A** to **F**, are shown below.

A conducts electricity **B** does not conduct electricity **C** hard

D high melting point **E** low melting point **F** soft

Write the letters of the properties that belong to:

Diamond ..... [1]

Graphite ..... [1]

Silicon dioxide ..... [1]

2. Link the observations **A** to **E** on the left with the explanations **1** to **5** on the right.

A Giant covalent structures have a high melting point	**1** ..... because the delocalised electrons are free to move along the layers.
B Graphite conducts electricity	**2** ..... because the weak forces between the layers can easily be overcome.
C Diamond does not conduct electricity	**3** ..... because the carbon atoms are packed closer to each other on average.
D Graphite is soft	**4** ..... because it takes a lot of energy to break the large number of strong bonds.
E Diamond is denser than graphite	**5** ..... because all its electrons are involved in covalent bonding.

[2]

3. Complete these sentences by adding the correct number.

a. Each atom in diamond forms ..... covalent bonds with other atoms. [1]

b. Each atom in graphite forms ..... covalent bonds with other atoms. [1]

c. Each silicon atom in silicon dioxide forms ..... covalent bonds with oxygen atoms,

but each oxygen atom forms ..... covalent bonds with silicon atoms. [2]

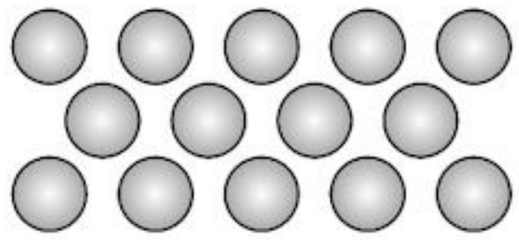
Extension

4. There are two forms of the compound boron nitride, BN. One of these forms is similar to graphite.

a. In this form of boron nitride, the atoms alternate. Draw the structure of this form of boron nitride. [3]

b. Explain why this form of boron nitride can be used as a lubricant. [2]

1. **a.** Complete the diagram below to show the structure of a metal. Label your diagram.



[4]

b. Use the information in your diagram to explain:

i. why metals conduct electricity.

..... [2]

ii. why metals are ductile.

.....

.....

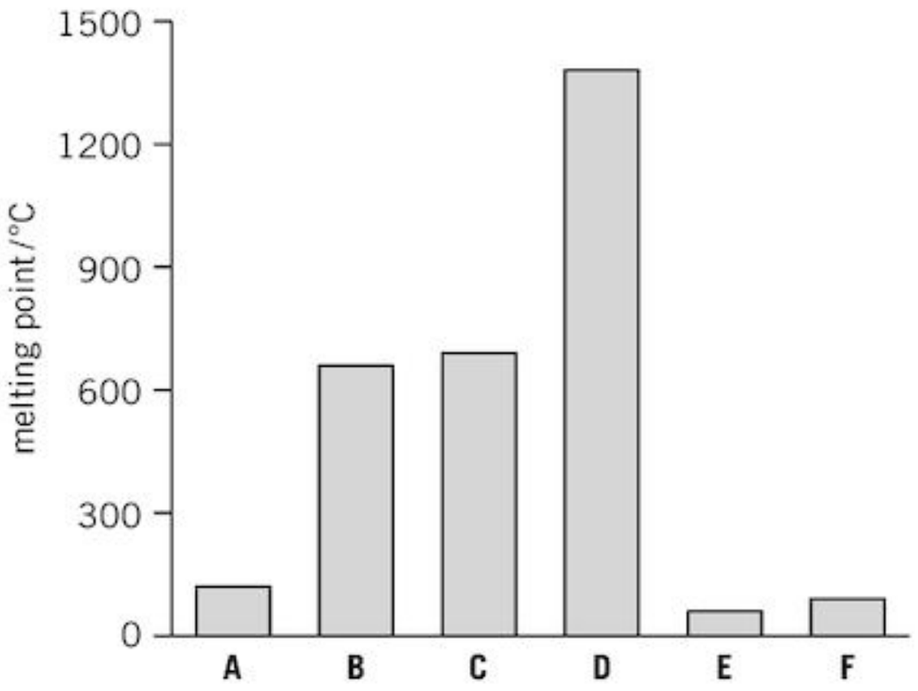
..... [3]

iii. why metals such as nickel have high melting points.

.....

..... [2]

2. The bar chart shows the melting point of six successive elements **A** to **F** in the Periodic Table.



a. One of these elements is a giant covalent structure.
Which one? ..... [1]

b. Which elements are metals? Give a reason for your answer.

.....

..... [2]

c. Which elements are non-metals? Give a reason for your answer.

.....

..... [2]

Extension

3. Bronze is a mixture of copper and tin. Tin atoms are larger than copper atoms. Use your knowledge of the structure of metals to explain why bronze is less malleable than either copper or tin alone. [2]

1. Complete these sentences about the formulae of compounds using words from the list.

atoms **bonded** **hydrogen** **ionic** **molecular** **nitrogen** **ratio**

The formula for giant covalent and ..... compounds is the ..... of ..... or ions in the compound. The formula of a simple molecule shows exactly how many atoms are ..... together in each molecule. For example, ammonia has one ..... and three ..... atoms so its ..... formula is NH_3. [7]

2. **a.** Complete the table to show the valencies of the atoms shown.

			H								
Li						B	C	N	O	F	Ne
Na	Mg					Al			S	Cl	
K	Ca		transition elements		Zn					Br	

[10]

b. Which atoms in the table lose electrons when they form ions?

..... [1]

c. Which atoms in the table gain electrons when they form ions?

..... [1]

d. Name two atoms in the table that share electrons when they form compounds.

..... [1]

e. Write the formulae of the following compounds by balancing the valencies.

i. A compound of H and S .....

ii. A compound of B and O .....

iii. A compound of C and S .....

iv. A compound of C and Br .....

v. A compound of Ca and N .....

vi. A compound of Al and O .....

vii. The simplest compound of C and H ..... [7]

Extension

3. Work out the valencies of the elements in these compounds:

a. O in hydrogen peroxide, H_2O_2

b. Fe in Fe_2O_3

c. C in carbon monoxide, CO

d. Cu in Cu_2O

e. Pb in $PbCl_4$

f. H in magnesium hydride, MgH_2 [6]

1. Write chemical equations for these 'model' reactions.

   a. O = O and H – H / H – H gives H – O – H / H – O – H

   ..... [2]

   b. C and C + O = O gives C≡O and C≡O

   ..... [2]

2. Complete these examples to show the stages in writing equations.

   a.

	H_2	+	Cl_2	→	HCl		
atoms per molecule	..... × H	+	..... × Cl		..... × H ..... × Cl		[1]
balance	H_2	+	Cl_2	→	.....HCl		[1]

   b.

	Mg	+	O_2	→	MgO		
atoms per molecule	..... × Mg	+	..... × O		..... × Mg ..... × O		[1]
balance	O ..... Mg	+	..... O	→	..... MgO		[1]
balance	Mg ..... Mg	+	O_2	→	..... MgO		[1]

3. Balance these equations:

   a. $K + Br_2 \rightarrow KBr$

   ..... [1]

   b. $Al + O_2 \rightarrow Al_2O_3$

   ..... [1]

   c. $Na + O_2 \rightarrow Na_2O$

   ..... [1]

   d. $N_2 + H_2 \rightarrow NH_3$

   ..... [1]

   e. $Rb + H_2O \rightarrow RbOH + H_2$

   ..... [1]

Extension

f. $I_2O_5 + CO \rightarrow I_2 + CO_2$ [1]

g. $MgO + HNO_3 \rightarrow Mg(NO_3)_2 + H_2O$ [1]

h. $Ca(OH)_2 + HCl \rightarrow CaCl_2 + H_2O$ [1]

i. $PbO + NH_3 \rightarrow Pb + N_2 + H_2O$ [1]

1. Complete these sentences about relative masses of particles using words from the list.

A_r **atoms** **average** **carbon-12** **formula** **molecular** **M_r** **sum** **twelve**

Relative atomic mass (symbol .....) is the ..... mass of naturally occurring ..... of an element on a scale where the ..... atom has a mass of exactly ..... units. The relative ..... mass (symbol .....) is the ..... of the relative atomic masses of the atoms in a molecule. For ionic substances we use the term relative ..... mass. [9]

2. **a.** Complete the table to calculate the relative molecular mass or relative formula mass of the compounds shown.

Compound	Number of each atom	A_r of atom	M_r calculation
phosphorus trichloride PCl_3	P = Cl =	P = 31 Cl = 35.5	1 × 31 3 × ..... _____ M_r =
magnesium hydroxide $Mg(OH)_2$		Mg = 24 O = 16 H = 1	_____ M_r =
ethanol C_2H_5OH		C = 12 O = 16 H = 1	_____ M_r =
ammonium sulfate $(NH_4)_2SO_4$		N = 14 H = 1 S = 32 O = 16	_____ M_r =
glucose $C_6H_{12}O_6$		C = 12 H = 1 O = 16	_____ M_r =

[10]

b. Use the Periodic Table to help you calculate the relative molecular / formula mass of these compounds.

i. $Al_2(SO_4)_3$ ..... [1]

ii. $Co(NO_3)_2$ ..... [1]

iii. $Cr(CO)_6$ ..... [1]

Extension

c. Calculate the relative formula mass of these compounds.

i. $Sr(NO_3)_2.4H_2O$ **ii.** $Fe(ClO_4)_2.6H_2O$ **iii.** $Ba(BrO_3)_2$ **iv.** $Mn(NO_3)_2.6H_2O$ [4]

1. Complete the following by using values of M_r to calculate the masses of reactants and products.

a. i. $2H_2 + O_2 \rightarrow 2H_2O$

2 × ..... + 1 × ..... → 2 × ..... [1]

..... g + ... g → ..... g [1]

ii. $2Al + 3Cl_2 \rightarrow 2AlCl_3$

2 × ..... + 3 × ..... → 2 × ..... [1]

..... g + ... g → ..... g [1]

b. Use simple proportion to do these calculations about the reacting masses.

When 48 g of magnesium is burnt completely in oxygen, 80 g of magnesium oxide is formed.

$2Mg + O_2 \rightarrow 2MgO$

48 g 80 g

i. Complete the calculation to show the mass of magnesium oxide formed when 12 g of Mg is burnt.

$\frac{\text{.....}}{\text{.....}} \times 80 =$ ..... g [2]

ii. What mass of magnesium is needed to form 8 g of magnesium oxide?

..... [1]

iii. What mass of magnesium oxide is formed when 168 g of magnesium is burnt?

..... [1]

2. a. Complete the calculation to show the percentage by mass of carbon in ethane, C_2H_6.

$\frac{2 \times \text{.....}}{(\text{....} \times 12) + (\text{....} \times 1)} \times 100 =$ ..... % [2]

b. Calculate the percentage by mass of nitrogen in ammonia, NH_3. Show your working.

..... % [2]

c. Calculate the percentage by mass of calcium in calcium carbonate, $CaCO_3$. Show your working.

..... % [2]

Extension

d. Calculate the percentage by mass of sodium in sodium phosphate, Na_3PO_4. Show your working.

..... % [2]

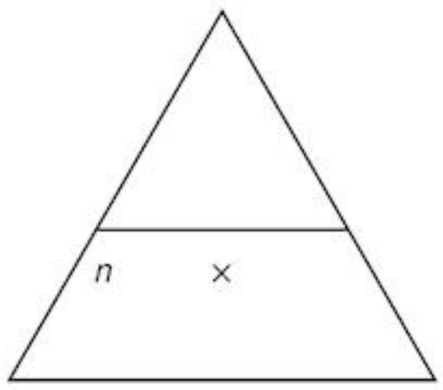
1. Complete the table to show the molar mass of the elements and compounds. The first two have been partly completed.

A_r values: Ba = 137, C = 12, Cl = 35.5, H = 1, K = 39, Mg = 24, N = 14, O = 16, P = 31

Element / compound	Formula	Number of atoms	Molar mass / g
iodine	I_2	2I	2 × 127 = ...
propane	C_3H_8	3C, 8H	(3 × 12) + (.... × .....) = ...
magnesium oxide	MgO	1Mg, 1O	= .....
....	$BaCO_3$	.....	= .....
....	KNO_3	.....	= .....
phosphorus(V) chloride	PCl_5	.....	= .....

[11]

2. **a.** Complete the calculation triangle to show the relationship between mass (m), number of moles (n), and molar mass (M).



[1]

b. Complete the table using the A_r values below.
C = 12, Ca = 40, H = 1, O = 16, P = 31, S = 32

Element or compound	Formula mass, M_r	Mass taken / g	Number of moles
O_2	32	4	
NaCl		11.7	
$CaSO_4$		27.2	
P_2O_5			0.4
CO_2			0.1
P_4		86.8	
CH_4			24.0

[13]

Extension

3. **a.** Calculate the mass of 0.4 mol of $Cu(NO_3)_2.6H_2O$. A_r of Cu = 64. [2]

b. How many moles of $Cu(ClO_4)_2$ are there in 7.86 g of $Cu(ClO_4)_2$? [2]

c. How many chloride ions are there in 0.25 mol $MgCl_2$?

(Avogadro constant = 6.02×10^{23} mol^{-1}) [2]

1. Complete these equations to show the reacting masses.

a. i. $2Mg + O_2 \rightarrow 2MgO$

$2 \times ..... + 1 \times ..... \rightarrow 2 \times .....$ [1]

$..... g + ... g \rightarrow ..... g$ [1]

ii. $4PH_3 \rightarrow P_4 + 6H_2$

$4 \times ..... \rightarrow 1 \times ..... + 6 \times .....$ [1]

$..... g \rightarrow ..... g + ... g$ [1]

iii. $CS_2 + 3Cl_2 \rightarrow CCl_4 + S_2Cl_2$

$1 \times ..... + 3 \times ..... \rightarrow 1 \times ..... + 1 \times .....$ [1]

$..... g + ... g \rightarrow ..... g + ... g$ [1]

b. Use the number of moles shown in the equation below to answer the questions that follow.

$I_2O_5 + 5CO \rightarrow I_2 + 5CO_2$

M_r values	334	28	254	44

i. How many moles of CO react with 1 mole of I_2O_5? ..... [1]

ii. How many moles of CO_2 are formed from 1 mole of CO? ..... [1]

iii. How many moles of I_2 are formed using 10 moles of CO? ..... [1]

iv. What mass of CO_2 is formed using 20.04 g of I_2O_5 and excess CO?

..... [3]

v. What mass of I_2 is formed using 21 g of CO and excess I_2O_5?

..... [3]

2. 168 g of iron reacts with excess oxygen to form 232 g of an oxide of iron.

iron + oxygen → iron oxide

a. Calculate the mass of oxygen in the iron oxide. ..... [1]

b. Calculate the moles of oxygen in the oxide. ..... [1]

c. Calculate the moles of iron in the iron oxide. ..... [1]

d. Calculate the ratio of the iron to oxygen to give the formula of this oxide of iron.

ratio ..... formula ..... [2]

Extension

3. Use the equation in **1. a. iii.** to calculate the mass of CCl_4 formed from 2 moles of Cl_2 in the presence of excess CS_2. [2]

1. Complete these relationships:

   a. 1 dm^3 = ... cm^3. [1]

   b. One mole of gas at r.t.p. occupies ..... dm^3. [1]

   c. Volume of gas at r.t.p. in dm^3 = ... × ..... [1]

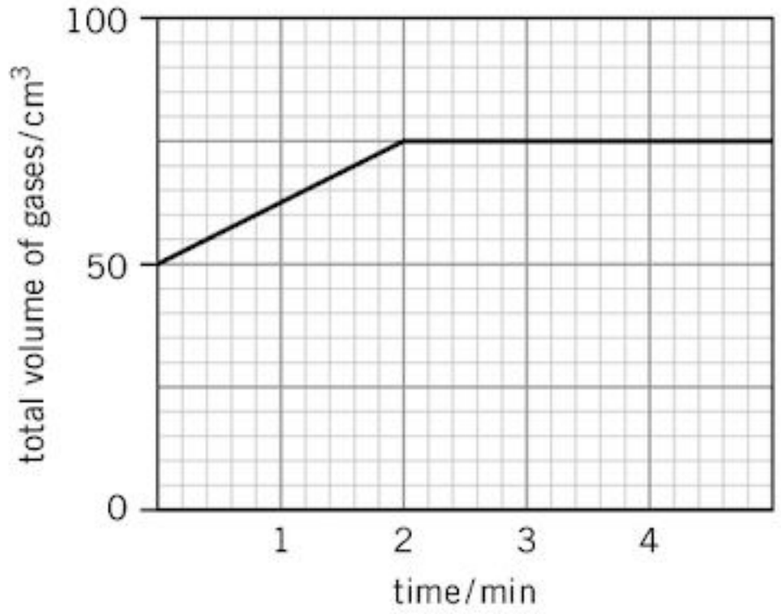
   d. Moles of gas at r.t.p. = $\frac{\text{.....}}{\text{.....}}$ [1]

2. Complete the table to show the mass, moles, or volume of different gases.

Gas	M_r of gas	Mass of gas / g	Moles of gas / mol	Volume of gas / dm^3
ammonia	17	8.5		
oxygen	32			480
carbon dioxide	44	3.08		
hydrogen chloride		292	8	
ethane	30			3

[10]

3. Nitrogen(I) oxide, N_2O, decomposes when heated to form two other gases. The graph shows how the volume of gas (corrected to r.t.p.) changes during the decomposition.



   a. Deduce the volume of nitrogen(I) oxide at the start of the experiment. ..... [1]

   b. Deduce the volume of gases present at the end of the experiment. ..... [1]

   c. Deduce the ratio volume of gas at start : volume of gases at the end. ..... [1]

   d. Use this ratio to complete the balanced equation for this reaction.

   ..... $N_2O(g) \rightarrow$ ..... $N_2(g) + O_2(g)$ [1]

Extension

4. Propane burns in excess oxygen to form carbon dioxide and water.

   $$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

   Calculate the volume of $CO_2(g)$ formed when 8.8 g of propane are completely burnt. [3]

1. Complete these relationships for a solute in solution.

   a. concentration in mol/dm^3 = $\frac{\text{amount of solute in .....}}{\text{..... in .....}}$ [3]

   b. amount of solute (moles) = [1]

   c. volume of solution (dm^3) = [1]

2. **a.** Change these values into cm^3.

   i. 0.2 dm^3 ..... [1]

   ii. 0.04 dm^3 ..... [1]

   iii. 3.5 dm^3 ..... [1]

   iv. 0.008 dm^3 ..... [1]

   b. Change these values into dm^3.

   i. 25 cm^3 ..... [1]

   ii. 750 cm^3 ..... [1]

   iii. 4 000 cm^3 ..... [1]

   iv. 156 cm^3 ..... [1]

3. Complete the table to show the moles and mass of solute and the concentrations.

Solute	M_r of solute	Mass of solute / g	Volume of solution cm^3 or dm^3	Concentration of solution / mol/dm^3
sodium hydroxide	40	8	250 cm^3	
silver nitrate	170		200 cm^3	0.5
copper(II) sulfate	160	40		0.125
potassium sulfate	174	3.48	750 cm^3	
ammonium chloride	53.5		5.0 dm^3	0.8
sulfuric acid	98	4.9		2.0

[6]

Extension

4. The solubility of copper(II) fluoride, CuF_2, in water is 4.54×10^{-1} mol/dm^3.
   15 g of copper(II) fluoride was added to 200 cm^3 of water and stirred until no more dissolved. Calculate the mass of copper(II) fluoride remaining.
   A_r values: Cu = 64, F = 19 [4]

1. Complete the following calculations to find the empirical formulae.

   a. A compound of lead and chlorine contains 20.7 g of lead and 14.2 g of chlorine.
   A_r values: Pb = 207, Cl = 35.5

   moles of Pb = ... mol moles of Cl = ... mol [1]

Divide by lowest number of moles	Pb	.....	Cl	.....
		.....		..... [1]
Result of division =		.....	=	.....

   Simplest ratio ..... So empirical formula is ..... [2]

   b. A compound of carbon and hydrogen contains 85.7% of carbon and 14.3 % of hydrogen by mass.
   A_r values: C = 12, H = 1

   mole % of C = ... mol mole % of H = ... mol [1]

Divide by lowest number of moles	C	.....	H	.....
		.....		..... [1]
Result of division =		.....	=	.....

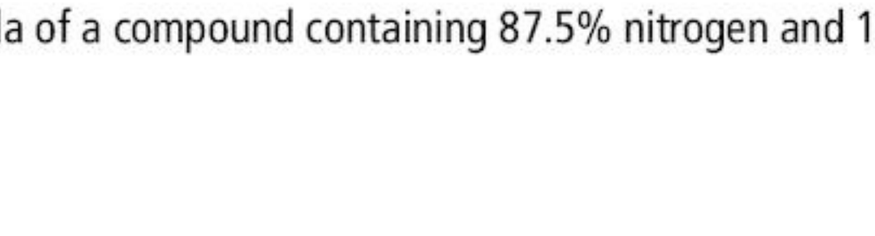
   Simplest ratio ..... So empirical formula is ..... [2]

   c. Deduce the empirical formula of a compound containing 87.5% nitrogen and 12.5 % hydrogen.
   A_r values: H = 1, N = 14

   Empirical formula ..... [3]

Extension

2. Aluminium burns in a stream of chlorine to form aluminium chloride.



   a. Suggest how you could use this apparatus to find the empirical formula of aluminium chloride. [8]

   b. What safety precautions are needed when carrying out this experiment? [3]

1. Complete these sentences about empirical and molecular formulae using words from the list.

atoms compound empirical ionic molecular molecules simplest

The molecular formula of a ..... shows the number of ..... of each type in one molecule.

The empirical formula shows the ..... ratio of atoms that combine. The formula of

an ..... compound is the same as its ..... formula. [5]

2. Write the empirical formula of the following compounds whose molecular formula has been given.

a. Hydrogen peroxide, H_2O_2. Empirical formula ..... [1]

b. Cyclohexane, C_6H_{12}. Empirical formula ..... [1]

c. Dinitrogen tetroxide, N_2O_4. Empirical formula ..... [1]

d. Antimony(III) oxide, Sb_4O_6. Empirical formula ..... [1]

e. Butane, C_4H_{10}. Empirical formula ..... [1]

f. Phosphorus(V) oxide, P_4O_{10}. Empirical formula ..... [1]

g. Sodium sulfate, Na_2SO_4. Empirical formula ..... [1]

3. Complete the table to deduce the empirical formula mass and molecular formulae of compounds **A** to **D**.

A_r values: C = 12, Cl = 35.5, H = 1, O = 16, P = 31, S = 32

Empirical formula	Empirical formula mass / g	Relative molecular mass, M_r / g	Molecular formula
A P_2O_3		220	
B SCl		135	
C CH_2O		60	
D CCl_2		332	

[8]

Extension

4. 360 g of a compound, made up of carbon, hydrogen, and oxygen only, contains 144 g carbon and 24 g hydrogen.
The compound has a relative molecular mass of 180.
Deduce the empirical and molecular formulae of this compound. [5]

6.7 Finding percentage yield and percentage purity

1. 18 g of limestone reacted with excess dilute hydrochloric acid. 3840 cm^3 of carbon dioxide were formed at r.t.p. Work through the calculation to find the percentage purity of this sample of limestone, which is impure calcium carbonate, $CaCO_3$. Give your answer to two significant figures. A_r values: C = 12, Ca = 40, O = 16

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

a. Molar mass of calcium carbonate = ... g/mol [1]

b. Volume of CO_2 in dm^3 = ... dm^3 [1]

c. Moles of CO_2 = $\frac{\text{.....}}{\text{.....}}$ = ... mol [1]

d. Moles of $CaCO_3$ in limestone sample = ... mol [1]

e. Mass of $CaCO_3$ in limestone sample = ... g [1]

f. Percentage purity = $\frac{\text{.....}}{\text{.....}}$ × ..... = ...% [1]

2. Methyl benzoate can be prepared by reacting methanol with benzoic acid.

$$\underset{\text{methanol}}{CH_3OH} + \underset{\text{benzoic acid}}{C_6H_5CO_2H} \rightarrow \underset{\text{methyl benzoate}}{C_6H_5CO_2CH_3} + H_2O$$

When 24.4 g of benzoic acid is reacted with excess methanol, 25.84 g of methyl benzoate is produced. Work through the calculation to find the percentage yield of methyl benzoate. A_r values: C = 12, H = 1, O = 16

a. Molar mass of benzoic acid = ... g/mol [1]

b. Moles of benzoic acid = ... mol [1]

c. Moles of methyl benzoate expected (if 100 % yield) = ... mol [1]

d. Molar mass of methyl benzoate = ... g/mol [1]

e. Mass of methyl benzoate expected (if 100 % yield) = ... g [1]

f. Percentage yield $\frac{\text{.....}}{\text{.....}}$ × ..... = ...% [1]

Extension

3. A student reacts 5.4 g of aluminium with excess oxygen.

$$4Al + 3O_2 \rightarrow 2Al_2O_3$$

The mass of aluminium oxide produced is 8.67 g. Calculate the percentage yield.
A_r values: Al = 27, O = 16 [4]

7.1 Oxidation and reduction

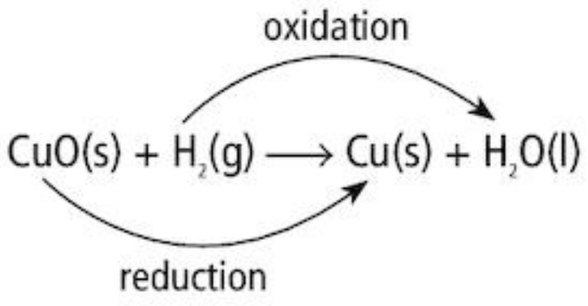
1. Complete these sentences about oxidation and reduction using words from the list.

gain heat loss oxidation reactants redox reduction

Reactions that involve both oxidation and ..... are called ..... reactions. Oxidation is the ..... of oxygen, and reduction is the ..... of oxygen. Combustion involves the ..... of a substance, during which ..... is given out and one or more of the ..... is a gas. [7]

2. Draw arrows to show which of the elements or compounds have undergone oxidation and which have undergone reduction. An example is given below.

Example:



a. $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ [2]

b. $PbO(s) + H_2(g) \rightarrow Pb(s) + H_2O(l)$ [2]

c. $Fe_2O_3(s) + 3C(s) \rightarrow 2Fe(s) + 3CO(g)$ [2]

d. $C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$ [2]

e. $ZnO(s) + C(s) \rightarrow CO(g) + Zn(s)$ [2]

f. $3Fe(s) + 4H_2O(g) \rightarrow Fe_3O_4(s) + 4H_2(g)$ [2]

Extension

3. Which substances in these equations undergo oxidation and which undergo reduction?

a. $CH_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$ [2]

b. $CS_2 + 2H_2 \rightarrow 2H_2S + C$ (Hint: oxygen and sulfur are in the same Group) [2]

1. Complete these half-equations. Balance the charges by adding electrons.
State whether oxidation or reduction has taken place.

a. $Ca \rightarrow Ca^{2+}$ + ... Oxidation or reduction? ..... [2]

b. Cl_2 + ... → ..... Cl^- Oxidation or reduction? ..... [2]

c. Al^{3+} + ... → ..... Oxidation or reduction? ..... [2]

d. $Fe^{2+} \rightarrow Fe^{3+}$ + ... Oxidation or reduction? ..... [2]

e. O_2 + ... → ..... O^{2-} Oxidation or reduction? ..... [2]

f. $Pb^{4+} + 2e^- \rightarrow$ ..... Oxidation or reduction? ..... [2]

g. ..... Br^- → ..... + ... Oxidation or reduction? ..... [2]

2. Write down the formulae of the ions present in each of these compounds.

a. NaOH ..... and ..... [1]

b. $MgCl_2$ ..... and ..... [1]

c. $Ba(NO_3)_2$ ..... and ..... [1]

d. $CuSO_4$ ..... and ..... [1]

e. Al_2O_3 ..... and ..... [1]

f. $Fe(OH)_2$ ..... and ..... [1]

3. Write ionic equations for these reactions. In each case, cancel the spectator ions.
Where a solid or liquid is formed do not separate into ions. The first one has been partly done for you.

a. $CuCl_2(aq) + 2NaOH(aq) \rightarrow Cu(OH)_2(s) + 2NaCl(aq)$

ions ..... + ... $2Na^+ + 2OH^-$ $2Na^+ + 2$..... [2]

cancel ..... + ... $2Na^+ + 2OH^-$ $2Na^+ + 2$..... [1]

equation $Cu^{2+}(aq)$ + ...(aq) → .....(s) [1]

b. $BaCl_2(aq) + MgSO_4(aq) \rightarrow BaSO_4(s) + MgCl_2(aq)$

ions ..... + ... + ... + ... [2]

cancel ..... + ... + ... + ... [1]

equation ..... [1]

Extension

4. Write ionic equations for these reactions.

a. $Pb(NO_3)_2(aq) + 2KCl(aq) \rightarrow PbCl_2(s) + 2KNO_3(aq)$ [2]

b. $Cl_2(aq) + 2KI(aq) \rightarrow I_2(aq) + 2KCl(aq)$ [2]

1. Complete these sentences about oxidation states using words from the list.

atoms compound electrons number shared zero

Oxidation state (oxidation .....) tells us how many ..... each atom of an element has gained, lost, or ..... when forming a ..... . The oxidation state of ..... of an uncombined element is ..... . [6]

2. Use the oxidation states (oxidation numbers) in the list to deduce the oxidation states of the atoms or ions which are underlined.

Group I ions and hydrogen in most simple compounds: +1
Group II ions in compounds: +2
Most Group III atoms or ions in compounds: +3
Oxygen atoms or ions in compounds: –2 (except in peroxides where it is –1)
Group VII atoms or ions in compounds not containing oxygen: –1

a. $\underline{Fe}O$ ..... [1] **b.** $\underline{Mn}O_2$ ..... [1] **c.** $Na_2\underline{S}$ ..... [1]

d. $\underline{Fe}Cl_3$ ..... [1] **e.** $H_2\underline{O}_2$ ..... [1] **f.** $\underline{Ge}Cl_4$ ..... [1]

g. $\underline{B}_2O_3$ ..... [1] **h.** $\underline{Cu}_2O$ ..... [1] **i.** $\underline{S}O_3$ ..... [1]

3. Write the oxidation states (oxidation numbers) in the spaces underneath the underlined elements and suggest whether the underlined atoms or ions have undergone oxidation or reduction in each of the following equations.

a. $4\underline{Fe} + 3O_2 \rightarrow 2\underline{Fe}_2O_3$

.... Oxidation or reduction? ..... [2]

b. $\underline{C} + O_2 \rightarrow \underline{C}O_2$

.... Oxidation or reduction? ..... [2]

c. $\underline{Pb}O + H_2 \rightarrow \underline{Pb} + H_2O$

.... Oxidation or reduction? ..... [2]

d. $\underline{Cl}_2 + 2KBr \rightarrow Br_2 + 2K\underline{Cl}$

.... Oxidation or reduction? ..... [2]

e. $2\underline{P} + 3Cl_2 \rightarrow 2\underline{P}Cl_3$

.... Oxidation or reduction? ..... [2]

Extension

4. Deduce the oxidation states of the underlined atoms.

a. $K\underline{Mn}O_4$ **b.** $Mg\underline{S}O_4$ **c.** $\underline{N}O_2^-$ **d.** $\underline{S}O_3^{2-}$ **e.** $\underline{P}_2O_5$

1. The phrases below are about oxidising and reducing agents.
Link the beginnings **A** to **D** on the left with the endings **1** to **4** on the right.

A An oxidising agent	**1** ..... increases during a redox reaction.
B The oxidation state of an oxidising agent	**2** ..... is oxidised during a redox reaction.
C A reducing agent	**3** ..... is reduced during a redox reaction.
D The oxidation state of a reducing agent	**4** ..... decreases during a redox reaction.

[2]

2. The boxes show phrases describing the use of potassium manganate(VII) and potassium iodide in redox reactions.
Make these phrases into two sentences describing the use of these two reagents.

..... an oxidising agent.....	..... to brown.....
..... in the presence of a reducing agent.	..... that turns from colourless.....
..... in the presence of an oxidising agent.	..... that turns from purple.....
..... to colourless.....	..... a reducing agent.....

Acidified potassium manganate(VII) is .....

.....

..... [2]

Acidified potassium iodide is .....

.....

..... [2]

3. Identify the oxidising and reducing agents in these equations.
Underline the reducing agent and put a ring around the oxidising agent.

a. $2Mg + O_2 \rightarrow 2MgO$ [1]

b. $PbO + H_2 \rightarrow Pb + H_2O$ [1]

c. $2I^- + Cl_2 \rightarrow I_2 + 2Cl^-$ [1]

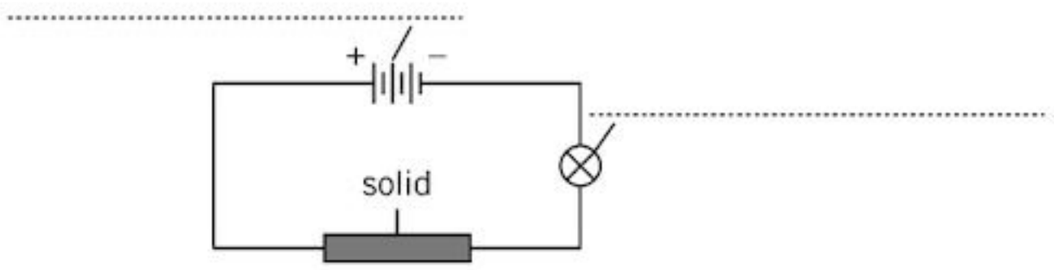
d. $H_2O_2 + 2I^- \rightarrow I_2 + 2H_2O$ [1]

Extension

e. $3CuO + 2NH_3 \rightarrow 3Cu + N_2 + 3H_2O$ [1]

f. $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$ [1]

1. a. i. Label the diagram to show the apparatus used to show whether or not a solid conducts electricity. [2]



ii. On the diagram above put an arrow to show the direction of flow of the electrons. [1]

2. Define the terms:

Electrolyte ..... [1]

Electrolysis .....

..... [2]

Insulator ..... [1]

3. Link the phrases **A** to **D** on the left with the phrases **1** to **4** on the right.

A Molten sodium chloride conducts electricity.....	**1** ..... because there are free electrons that move when a voltage is applied.
B Metals conduct electricity.....	**2** ..... because the ions are not free to move.
C Sulfur does not conduct electricity.....	**3** ..... because the ions are free to move.
D Solid sodium chloride does not conduct electricity.....	**4** ..... because none of the electrons is free to move.

[2]

4. Aluminium with a steel core is used in high-voltage power cables.

a. Give two properties of aluminium that are related to this use.

..... [2]

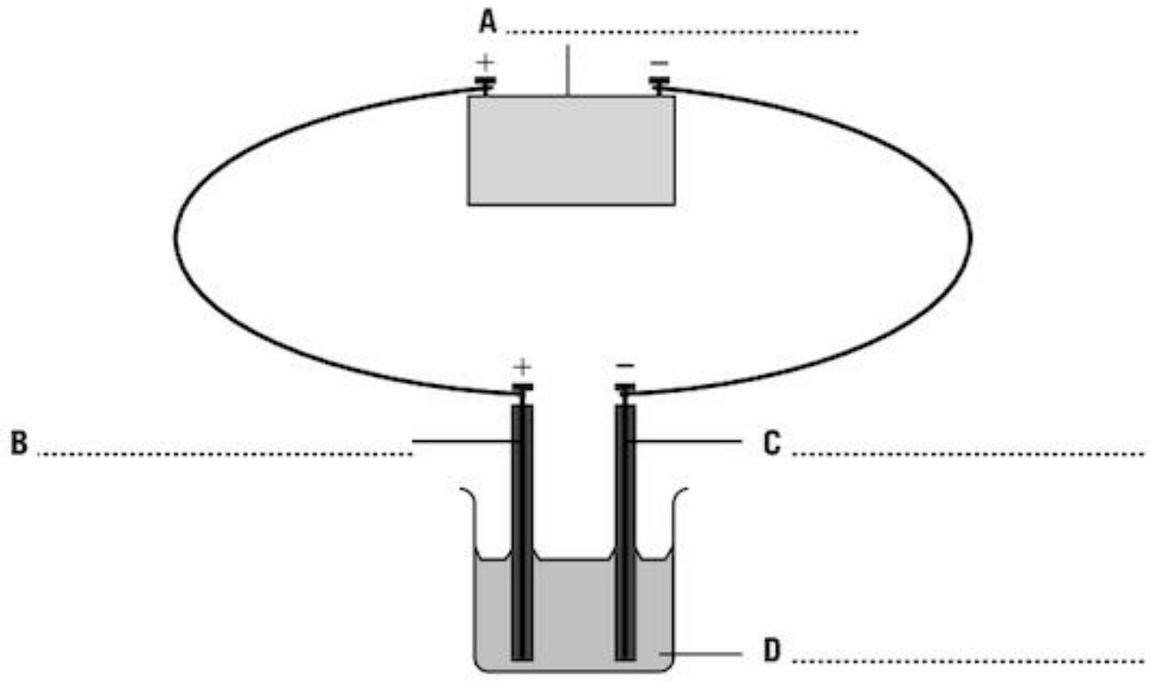
b. Give two properties of steel that are related to this use.

..... [2]

Extension

5. Use books or the internet to find some substances that have delocalised electrons and to explain why the presence of delocalised electrons is not always associated with electrical conduction. [4]

1. Complete the diagram of an electrolysis cell by labelling the power supply, the anode, the cathode, and the electrolyte, and show the direction of electron flow in the external circuit. [5]



2. Complete these sentences about metal reactivity in aqueous solution using words from the list.

hydrogen **ions** **less** **more** **silver** **sodium** **water**

Reactive elements such as ..... are ..... likely to form ions than ..... reactive elements such as ..... If a metal is more reactive than ....., its ..... stay in solution during electrolysis and hydrogen arising from hydrogen ions in ..... bubbles off. [7]

3. Complete the table to show the electrode products and observations at the anode when various substances are electrolysed using graphite electrodes.

Electrolyte	Cathode (–) product	Anode (+) product	Observations at the anode
concentrated KCl(aq)			
ZnBr(l)			
dilute H_2SO_4(aq)			
dilute NaCl(aq)			
concentrated HCl(aq)			
dilute $AgNO_3$(aq)			

[18]

Extension

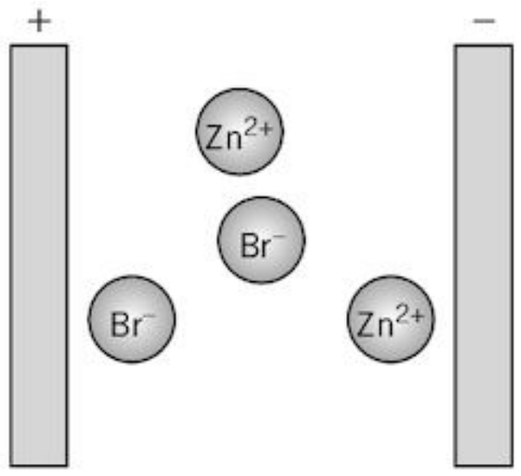
4. What substances are formed at the anode and cathode when the following solutions are electrolysed? Give reasons for your answers.

   a. Concentrated aqueous sodium bromide. [4]

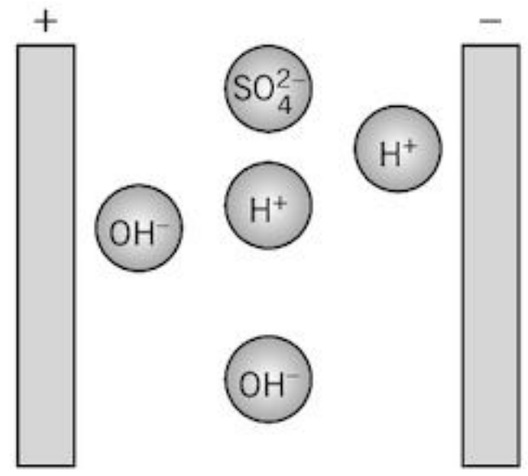
   b. Moderately concentrated aqueous sodium chloride. [4]

1. Complete these diagrams to show:
   - the movement of ions during electrolysis (show this by drawing straight arrows)
   - what happens to the ions in terms of electron loss or gain to or from the electrodes (show this by curly arrows).

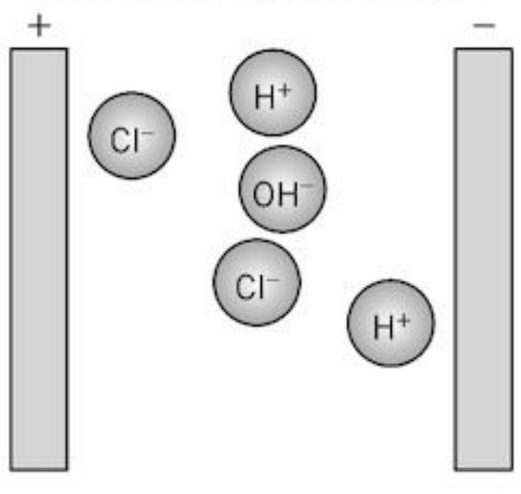
a. molten zinc bromide



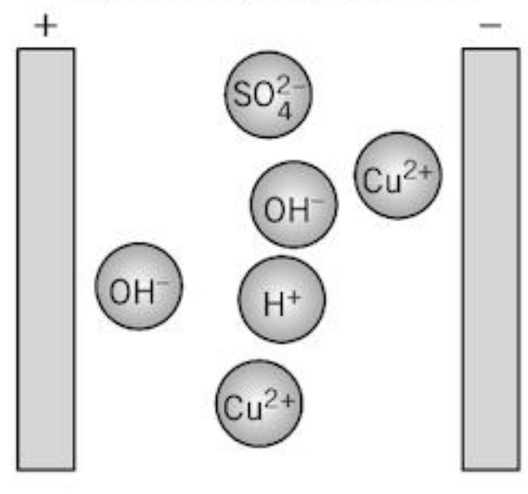
b. dilute sulfuric acid



c. concentrated hydrochloric acid



d. aqueous copper(II) sulfate



[8]

2. **a.** Complete these sentences using words from the list.

anode cathode gain lose negative positive

i. When ..... ions ..... electrons, reduction occurs. [2]

ii. When ..... ions ..... electrons, oxidation occurs. [2]

iii. Reduction takes place at the ..... and oxidation at the ..... [1]

b. Complete these half-equations for the reaction at the electrodes.

i. Zn^{2+} + ... → Zn [1]

ii. ..... Cl^- → ..... + ... [2]

iii. ..... H^+ + ... → ..... [2]

iv. Al^{3+} + ... → ..... [1]

Extension

3. Write half-equations for these reactions at a graphite electrode.

a. The conversion of hydroxide ions to oxygen and water. [2]

b. The conversion of oxide ions to oxygen molecules. [2]

1. **a.** Brine is electrolysed using titanium anodes and nickel cathodes.

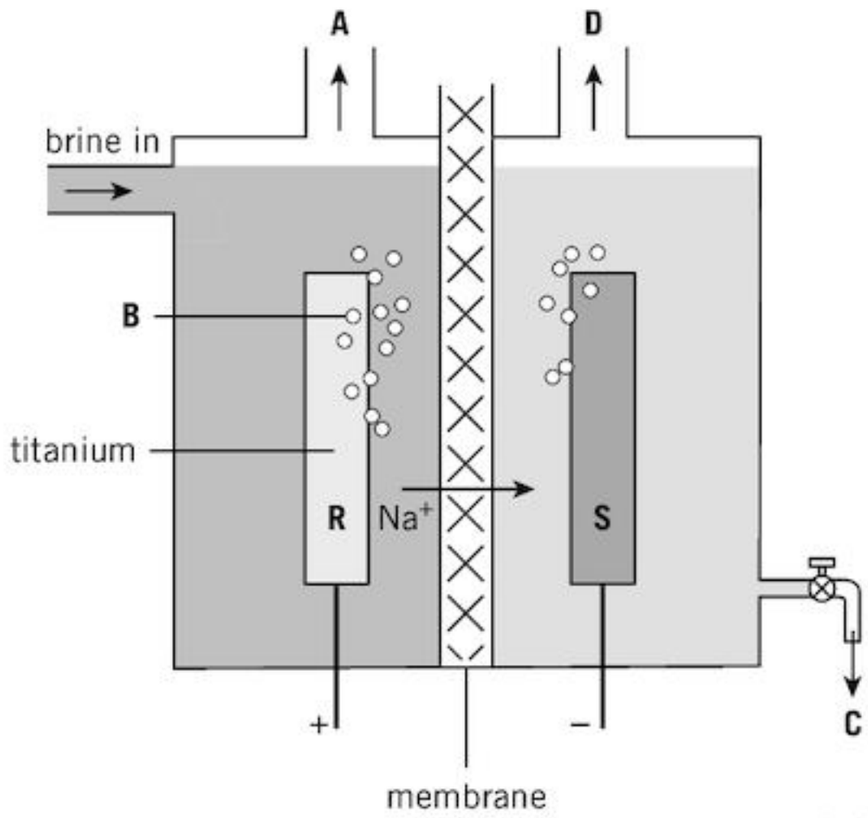
i. What is brine? ..... [1]

ii. Complete the overall equation for the reaction during this electrolysis. Include state symbols.

2 .....(.....) + $2H_2O$(.....) →

2NaOH(.....) + ...(g) + H_2(.....) [2]

b. The diagram shows a cell used for electrolysing brine.



i. Give the names of the gases collected at

A ..... **D** ..... [2]

ii. Which letter in the diagram represents the anode? ..... [1]

iii. Explain why oxygen is not given off at the anode.

.....

..... [2]

iv. Explain why sodium is not given off at the cathode.

.....

..... [2]

v. What substance is removed at **C**? ..... [1]

vi. Explain why this substance is formed.

.....

.....

..... [3]

Extension

2. Write half-equations for the reactions occurring at the anode and the cathode in this electrolysis cell. [4]

1. Copper(II) sulfate can be electrolysed using graphite electrodes or copper electrodes. Complete the table to show what happens at each electrode and to the electrolyte.

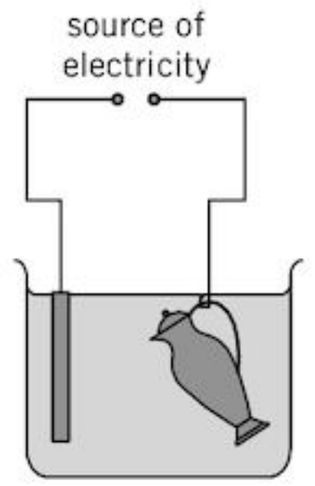
What happens….	using graphite electrodes	using copper electrodes
to the mass of the electrodes?	anode: cathode:	anode: cathode:
to the appearance of the electrodes during electrolysis?	anode: cathode:	anode: cathode:
to the electrolyte? (Give any observations.)		

[10]

2. A nickel jug can be electroplated with silver. Look at the diagram on the right and then answer the questions.

a. On the diagram label the anode **A**, the cathode **C**, and the electrolyte **E**. [2]

b. Describe and explain what happens to the cathode as the electroplating proceeds.



.....

.....

.....

.....

.....

..... [4]

Extension

3. Write ionic equations for the reactions at:

a. the anode when aqueous copper(II) sulfate is electrolysed using graphite electrodes. [2]

b. the cathode when an object is electroplated with nickel. (You will have to find out the usual charge on nickel ions to answer this question.) [2]

1. Describe these changes as either exothermic or endothermic.

   a. The decomposition of copper(II) carbonate by heating. ..... [1]

   b. Burning paraffin. ..... [1]

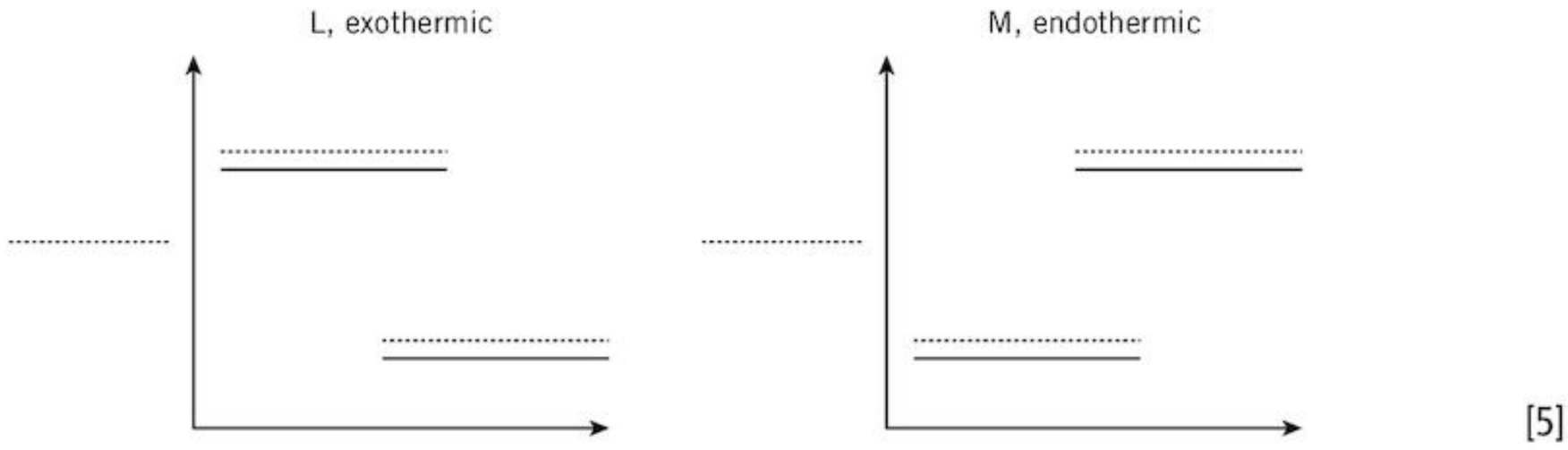
   c. Your tongue gets cold when you put sherbet on it. ..... [1]

   d. Respiration in the cells of the body provides energy. ..... [1]

   e. The temperature of the solution rises when concentrated hydrochloric acid is diluted.

   ..... [1]

2. **a.** Complete these energy level diagrams for an exothermic and an endothermic reaction. Include an arrow in each diagram in the correct position.



[5]

   b. Explain why energy level diagram **L** represents an exothermic reaction.

   .....

   ..... [2]

3. Calcium carbonate can be converted to calcium oxide and carbon dioxide.

   $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ Energy change, $\Delta H = +178$ kJ/mol

   What type of energy change is taking place during this reaction and how does the information above show this?

   Type of energy change. ..... [1]

   How you know from the information. .....

   ..... [1]

Extension

4. Propane burns in excess oxygen.

   $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$ Energy change = –2219 kJ/mol propane

   a. Calculate the energy change when 8.8 g of propane are burnt. [2]

   b. Calculate the energy change when 4.8 dm^3 of carbon dioxide is produced. [3]

1. Order these phrases to describe the relationship between bond breaking and bond making in exothermic and endothermic reactions. Then write them out in the correct order in the spaces below. Most phrases may be used more than once.

..... in forming new bonds	..... than the energy absorbed .....
..... is greater	..... in the reactants.
..... in breaking the bonds	..... the energy released .....
..... in the products	..... is less .....

In an exothermic reaction .....

.....

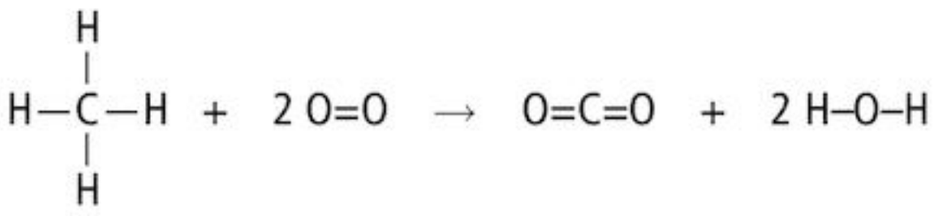
..... [1]

In an endothermic reaction .....

.....

..... [1]

2. Complete the table to calculate the energy change when 1 mole of methane reacts with excess oxygen to form carbon dioxide and water.



Bond energies in kJ/mol: C–H 413, O=O 498, C=O 805, O–H 464

Bonds broken (endothermic +) / kJ	Bonds formed (exothermic –) / kJ
4 × (C–H) = 4 × 413 = ... × (O=O) = ... = ...	
Total	

Overall energy change = (+ .....) + (– .....) = ... kJ [5]

Extension

3. Calculate the energy change of the reaction using the bond energies above and H–H = 436 kJ/mol.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$ [5]

4. The bond energy of the C=O bond in CO_2 is 805 kJ/mol. The bond energy of the C=O bond in propanone, CH_3COCH_3, is 749 kJ/mol. Suggest why they are different. [2]

1. Methane burns in excess air to form carbon dioxide and water.

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ Energy change = –818 kJ/mol methane

Draw a labelled energy level diagram for this reaction.

[3]

2. The table shows the temperature changes produced by burning the fuels **A**, **B**, **C**, and **D** underneath a copper can filled with 100 cm^3 of water.

Fuel	Amount burnt / g	Initial temperature of water / °C	Final temperature of water / °C	Density / g/cm^3
A	2.0	20	25	0.90
B	1.0	18	21	0.55
C	4.0	21	29	0.87
D	3.5	15	24	1.10

a. Which fuel gave the greatest temperature rise in the experiment? ..... [1]

b. Which fuel produced the most energy per gram? ..... [1]

c. **i.** Which fuel would be the cheapest to transport by the lorryload? Give a reason for your answer.

..... [2]

ii. Apart from your answer to part **c. i.** give one other factor that would influence how expensive it is to transport a fuel.

..... [1]

d. Complete these sentences about burning fossil fuels using words from the list.
Some words may be used more than once.

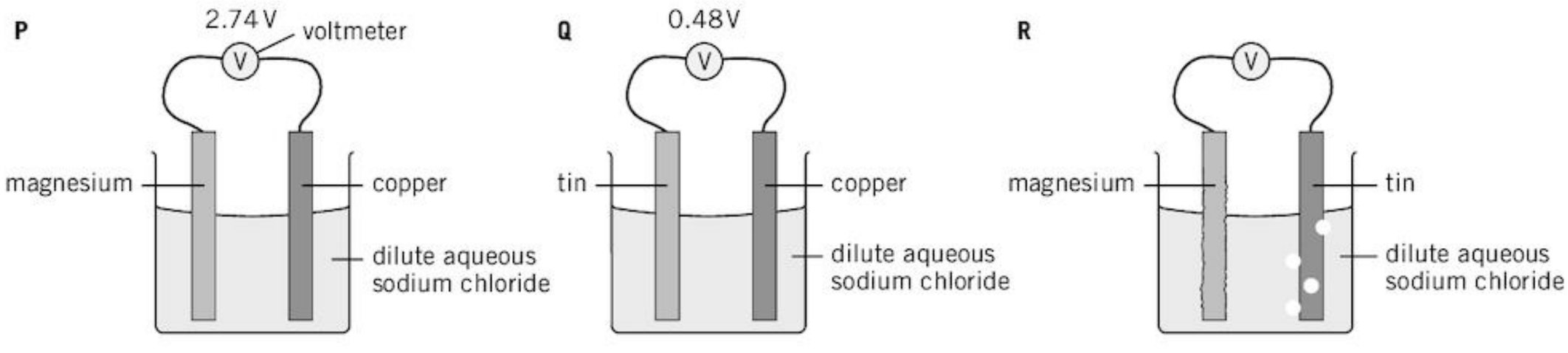
acid coal carbon dioxide global sulfur

When fossil fuels such as ..... burn, they produce ...., which contributes to ..... warming. Burning coal in power stations also produces ...., which causes ..... rain. [4]

Extension

3. Use books or the internet to find out how the energy produced when uranium-235 decays is used to generate electricity. [5]

1. The diagram shows three electrochemical cells.



a. Copy and complete these sentences about electrochemical cells using words from the list.

copper gain ions electrons hydrogen more negative positive wires

Magnesium is ..... reactive than copper. It forms ..... more readily than copper. So in cell **P** magnesium loses electrons. Magnesium becomes the ..... pole of the cell. The ..... flow along the ..... to the ..... strip. At the ..... pole of the cell, ... ions from the solution ..... electrons and hydrogen gas is formed. [9]

b. The voltage produced in an electrochemical cell is a measure of the reactivity of the two metals.

i. Look at cells **P** and **Q**. Which metal, magnesium or tin, is more reactive? Explain your answer.

..... [2]

ii. Deduce the voltage of cell **R**. ..... [1]

c. Part of the reactivity series is shown below:

lithium magnesium zinc iron tin copper silver

most reactive ⟶ least reactive

i. Which metal could replace magnesium in cell **P** to get a higher voltage?

..... [1]

ii. Which metal could replace copper in cell **Q** to get a higher voltage?

..... [1]

iii. Which reactive metal could replace magnesium in cell **R** to obtain a lower voltage?

..... [1]

Extension

2. Use books or the internet to help you write the two half-equations for the reaction in a fuel cell with an acidic electrolyte. [4]

1. Hydrated and anhydrous cobalt(II) chloride can be converted to one another.

$$\underset{\text{pink hydrated}}{CoCl_2.6H_2O} \rightleftharpoons \underset{\text{blue anhydrous}}{CoCl_2} + 6H_2O \qquad \Delta H \text{ is } +$$

   a. What is the meaning of the symbol $\rightleftharpoons$? ..... [1]

   b. What would you observe when water is added to anhydrous cobalt(II) chloride?

   ..... [1]

   c. How could you change pink cobalt(II) chloride to blue cobalt(II) chloride?

   ..... [1]

   d. Explain how you know that the reaction blue cobalt(II) chloride to pink cobalt(II) chloride is exothermic.

   .....

   ..... [2]

2. Complete these sentences:

   a. In a ..... system, no substances can escape from the reaction mixture. [1]

   b. At equilibrium the ..... of the ..... reaction is equal to the ..... of the ..... reaction. [2]

3. When a mixture of hydrogen and iodine is heated, an equilibrium mixture with hydrogen iodide is formed.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

   In the box on the right, draw the molecules in this equilibrium mixture that contains more product than reactants.

   Use • to represent a molecule of I_2

   Use ○ to represent a molecule of H_2

   Use □ to represent a molecule of HI [3]

Extension

4. **a.** For the reaction shown in question **3**, draw a sketch graph to show how the concentration of HI changes with time, starting with a mixture of only H_2 and I_2. [3]

   b. On the same sketch graph draw a line to show how the concentration of HI changes with time, starting with pure HI. [3]

1. Sulfur dioxide reacts with oxygen to form an equilibrium mixture with sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \text{Energy released}$$

Complete the following sentences about this reaction.

a. When oxygen is removed the position of equilibrium shifts to the ..... [1]

b. If the temperature is increased the position of equilibrium shifts so that the concentration of $2SO_3(g)$ ..... [1]

c. Decreasing the pressure shifts the position of equilibrium to the ..... because there are ..... moles of gas molecules in the equation on the ..... [3]

d. Adding a catalyst ..... [1]

2. In which direction does the position of equilibrium shift when the pressure on each of these reactions is increased?

a. $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ ..... [1]

b. $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$ ..... [1]

c. $4HCl(g) + O_2(g) \rightleftharpoons 2H_2O(g) + 2Cl_2(g)$ ..... [1]

d. $2HCl(g) \rightleftharpoons H_2(g) + Cl_2(g)$ ..... [1]

3. When bismuth trichloride, $BiCl_3$, is added to water the following reaction occurs.

$$\underset{\text{colourless solution}}{BiCl_3(aq)} + H_2O(l) \rightleftharpoons \underset{\text{white precipitate}}{BiClO(s)} + 2HCl(aq)$$

a. What would you see when concentrated HCl is added to the mixture?

..... [1]

b. What would you see when a large volume of water was added to the reaction mixture?

..... [1]

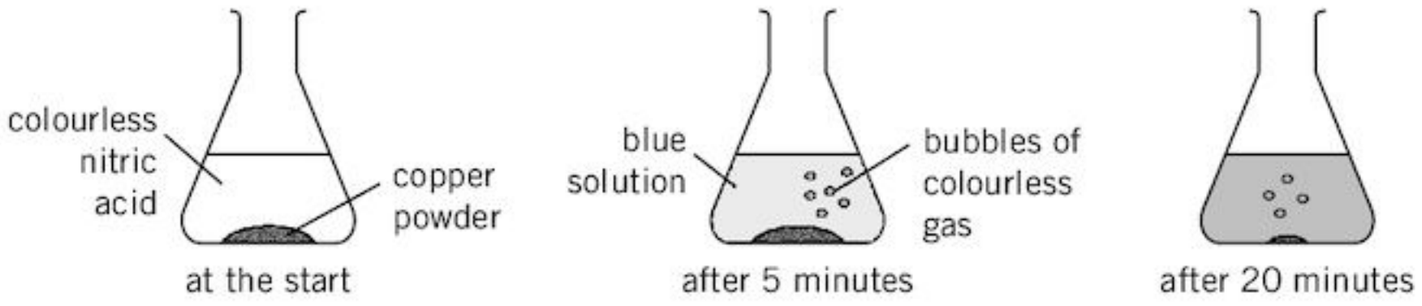
c. Explain why increasing pressure has no effect on this reaction.

..... [1]

Extension

4. Use books or the internet to find out the best conditions for the synthesis of sulfur trioxide (question **1**). Why are these conditions used? [8]

1. The diagrams show the reaction of 50% nitric acid with copper.



a. What three pieces of information from the diagram show that a chemical reaction is occurring?

.....

..... [3]

b. Suggest three different ways by which you could measure the rate of this reaction.

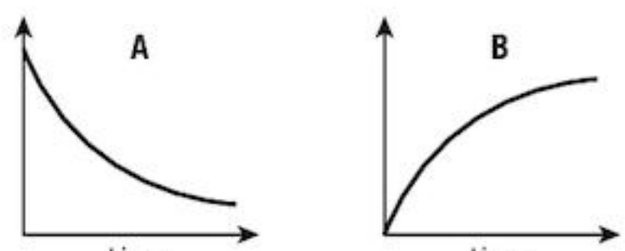
1 .....

2 .....

3 ..... [3]

c. Results from measurement of rate can be plotted on a graph.

Link each way that you chose in part **b**. to either graph **A** or graph **B** on the right.



Method 1 .....

Method 2 .....

Method 3 ..... [3]

d. **i.** Convert these rates to cm^3 gas/minute

Q 0.03 dm^3/min ..... [1]

R 0.3 cm^3/s ..... [1]

S 1.5 dm^3/hour ..... [1]

ii. Which of the rates **Q**, **R**, or **S** is the slowest? ..... [1]

Extension

2. Convert these values into moles per second.

a. 120 cm^3 of CO_2 gas released in 2 minutes. [3]

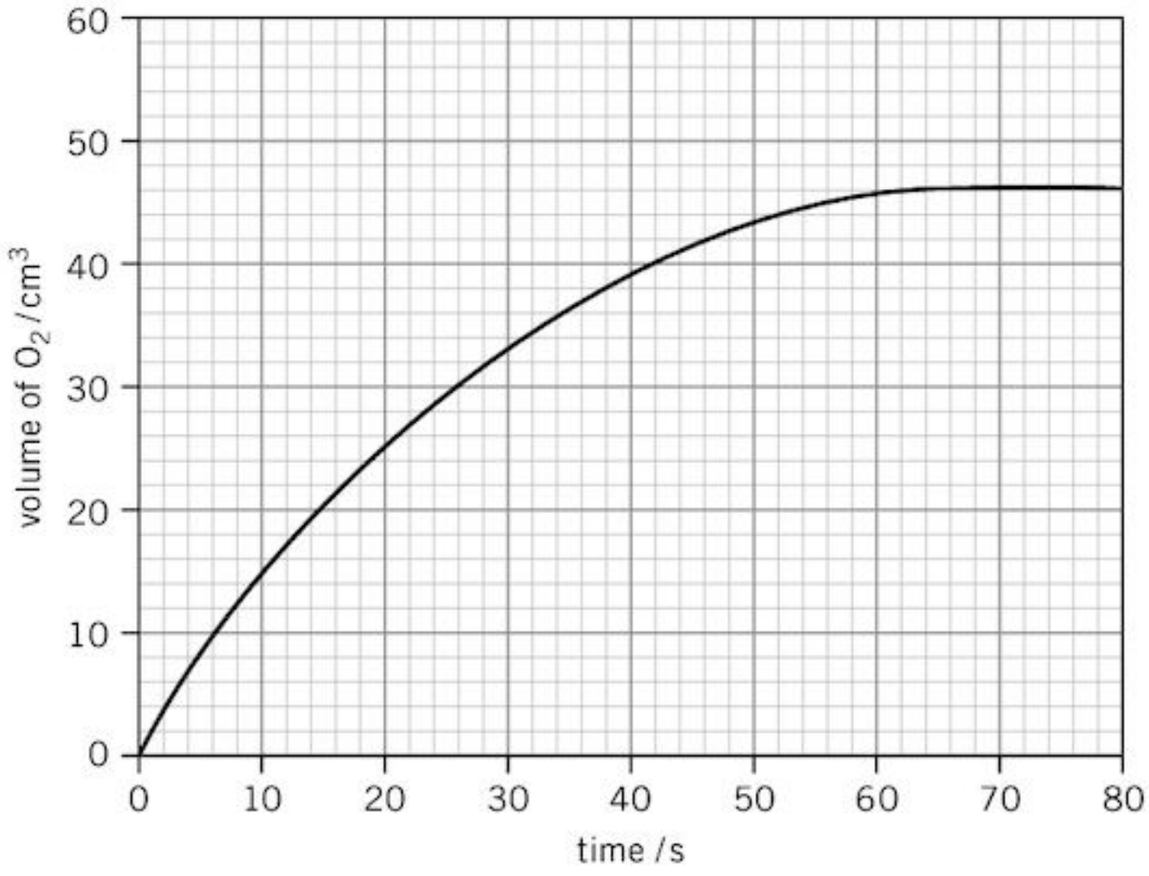
b. 9.2 g NO_2 released in 20 minutes. [3]

1. The decomposition of hydrogen peroxide is speeded up by catalysts.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

A student investigated how the rate of reaction changes when two different catalysts are used.

The results using catalyst **A** are shown below.



a. At what time is the reaction just complete? ..... [1]

b. What volume of gas has been released when the reaction is just complete?

..... [1]

c. What volume of gas has been produced in the first 30 seconds of the reaction?

..... [1]

d. Calculate the average rate of reaction in the first 30 seconds of the reaction. Draw lines on the graph to show how you did this.

..... [2]

e. The reaction was repeated using catalyst **B**. The results are shown in the table.

Time / s	0	4	10	20	30	40	50	60	70	80
Volume / cm^3	0	16	27	38	43	45	46	46	46	46

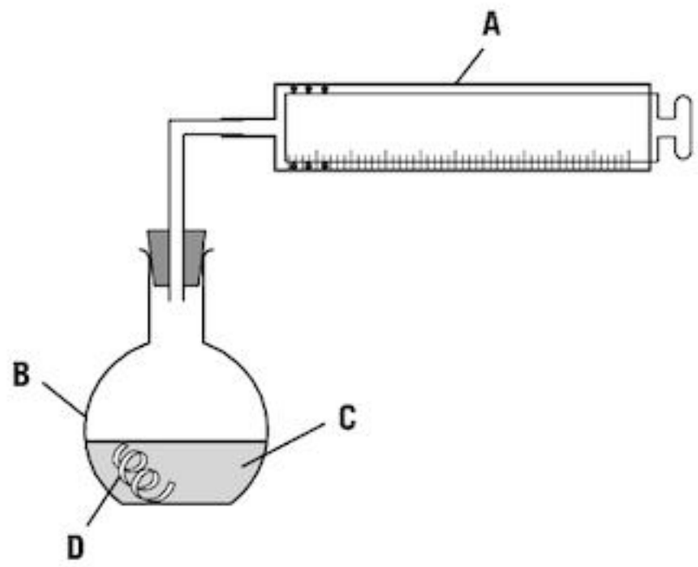
Plot a graph of these results on the same grid as for catalyst **A** above. Draw the best-fit curve through the points.

[2]

Extension

2. Measurement of change in gas volume or mass with time can be used to calculate rate of reaction. Use books or the internet to find out about other methods of following the course of a reaction and why they work. [6]

1. Magnesium reacts with dilute hydrochloric acid. The volume of hydrogen gas released can be measured using the apparatus shown below.



   a. Name the pieces of apparatus and chemicals **A**, **B**, **C**, and **D**.

      A ..... [1]

      B ..... [1]

      C ..... [1]

      D ..... [1]

   b. The apparatus was used to find how the rate of the reaction was changed with different concentrations of hydrochloric acid.

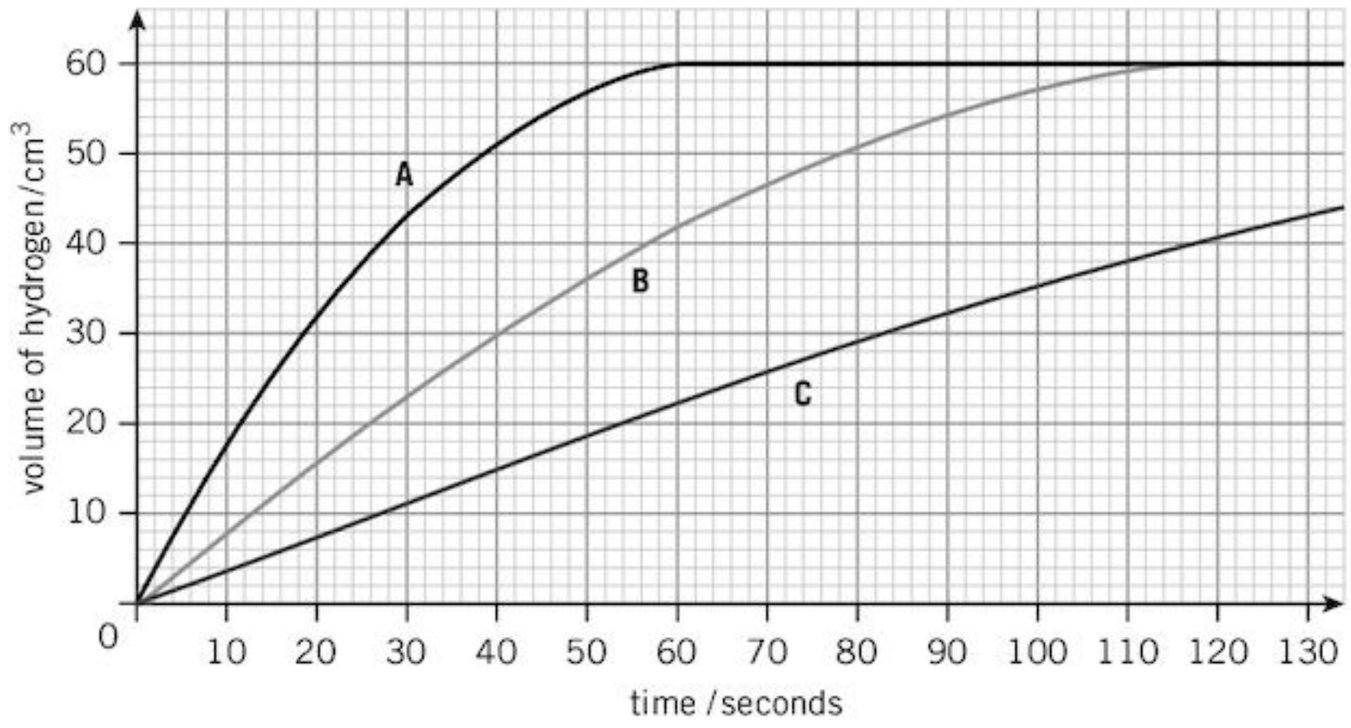
      State three factors that should be kept constant to make this a fair test.

      1 .....

      2 .....

      3 ..... [3]

   c. The graph below shows the results.



      i. Which line represented the most concentrated hydrochloric acid? ..... [1]

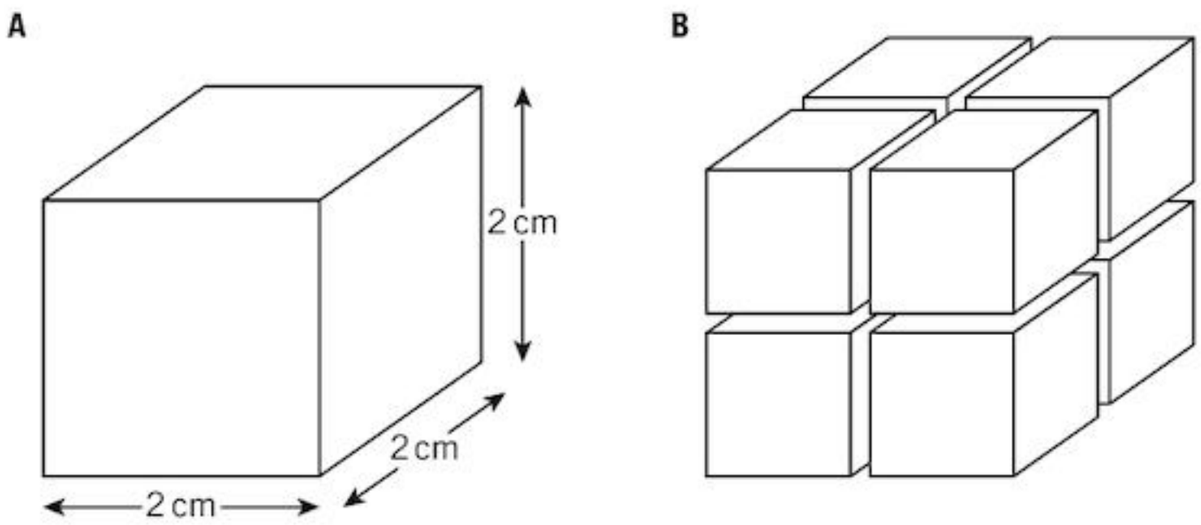
      ii. Calculate the average rate of reaction over the first 60 seconds for line **B**.

      ..... [1]

Extension

iii. Draw tangents to the graph (line **A**) at 20 seconds and at 40 seconds and find the gradient (slope) by drawing triangles (see page 128 for details of how to do this). Deduce the rates of reaction at these times by calculating the value of each gradient (slope). Show your working. [4]

1. Look at the cube of marble (calcium carbonate) labelled **A** in the diagram.



a. **i.** Calculate the surface area of cube **A** (see page 124 if you are not sure how to do this).

..... [1]

ii. Now imagine that this cube is cut into 8 separate cubes (**B** in the diagram above).

Calculate the total surface area of these 8 cubes. Show your working.

.....

..... [2]

iii. Which set of cubes **A** or **B** has the greater number of calcium and carbonate ions exposed for reaction with hydrochloric acid?

..... [1]

b. 4 g of large marble chips were reacted with 20 cm^3 of 0.5 mol/dm^3 hydrochloric acid.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

The experiment was repeated with 4 g of medium-sized marble chips then with 4 g of small marble chips. All other conditions remained the same.

On the axes below draw a sketch graph to show how the volume of carbon dioxide released changes with time using large, **L**, medium, **M**, and small, **S**, marble chips. Label your lines **L**, **M**, and **S**.

[2]

Extension

2. **a.** Calculate the total surface area of cubes of marble of side 1 cm^3 that have been split into separate cubes each of side: **i.** 0.1 cm **ii.** 0.001 cm. [6]

b. Explain why there is a danger of explosions in sawmills, where wood is cut up. [4]

1. Complete these sentences about the collision theory of rates of reaction using words from the list.

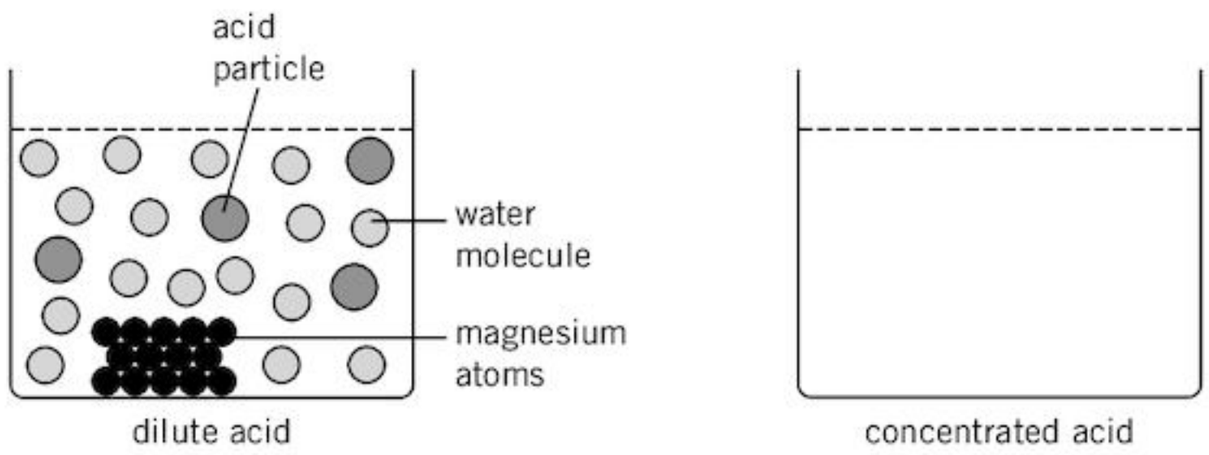
bonds collide energy faster frequency increases rate successful

In order to react, particles must ..... with each other. The collisions must have enough ..... to break ..... to allow a reaction to happen. Increasing the concentration of a reactant ..... the ..... of collisions and so increases the ..... of reaction. Increasing temperature makes particles move ..... and increases the energy of the particles so that there are more ..... collisions. [8]

2. Use the particle diagrams below to answer the following questions about the reaction.

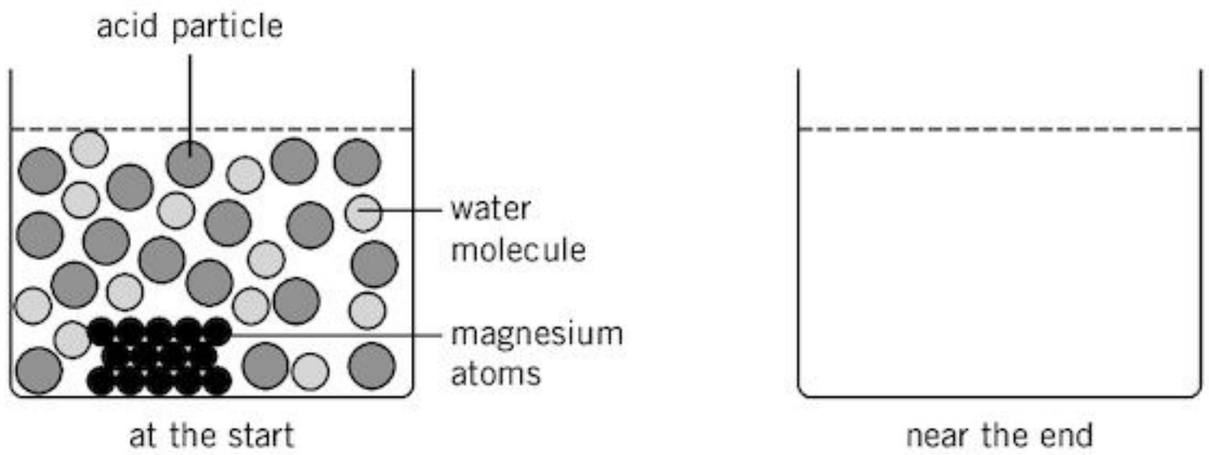
$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

a. Complete the diagram on the right to show the particles of acid and water in a concentrated solution of acid.



[3]

b. Complete the diagram on the right to show the relative number of acid, magnesium, and water particles when the reaction is nearly complete.



[3]

3. Use the collision theory to explain why 1 g of magnesium powder reacts more rapidly than 1 g of magnesium ribbon with 1 mol/dm^3 hydrochloric acid.

.....

.....

..... [3]

Extension

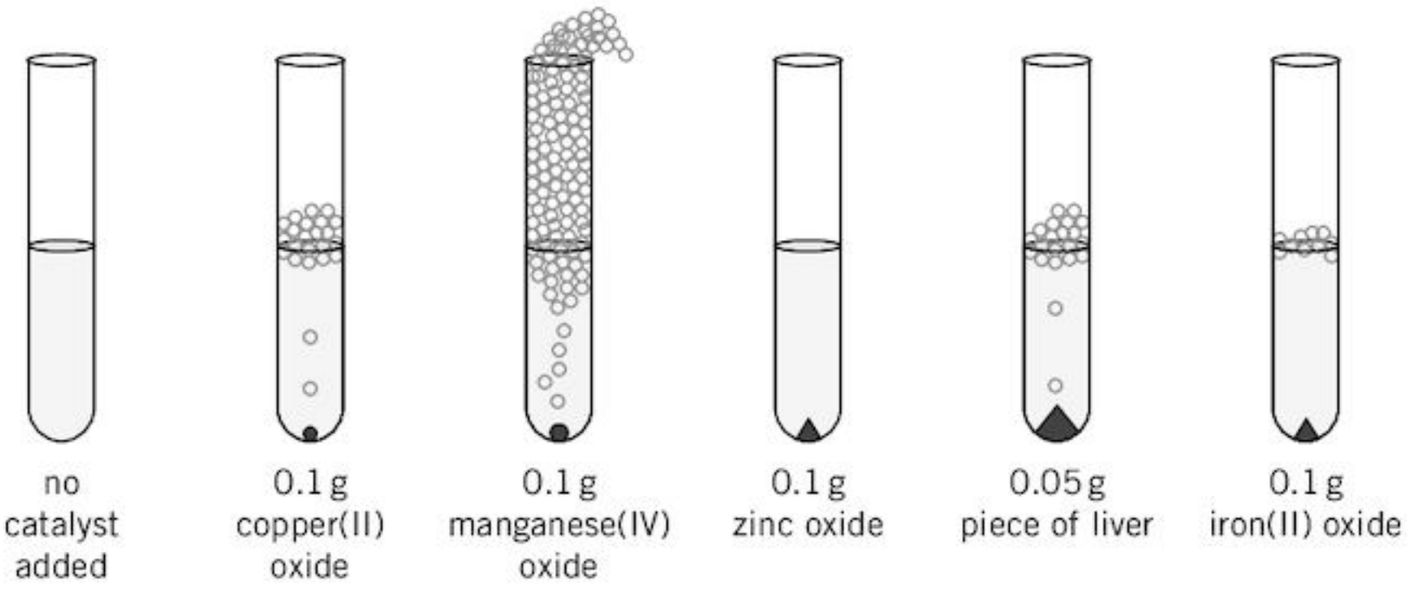
4. Use books or the internet to find out about activation energy and why increasing the temperature increases the rate of reaction. [4]

1. Catalysts speed up the decomposition of hydrogen peroxide.

$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$

A simple way of finding out how effective a catalyst is in this reaction is to add two drops of washing-up liquid to the solution under test and measure the height of the foam produced.

The result of adding different substances to the same concentration of hydrogen peroxide is shown in the diagram.



a. Suggest why a foam was formed without shaking the tubes.

.....

..... [2]

b. Which substance is the best catalyst for the reaction? ..... [1]

c. Use the information in the diagram to explain why the piece of liver is a better catalyst than copper(II) oxide.

.....

..... [2]

d. i. Liver contains biological catalysts. What is the general name given to a biological catalyst?

..... [1]

ii. What could you do to the piece of liver to make it a more efficient catalyst in this reaction? Explain your answer.

.....

..... [2]

e. Suggest a more accurate method for comparing the rates of this catalysed reaction.

.....

..... [3]

Extension

2. Use books or the internet to help you construct an energy profile diagram for an uncatalysed reaction and the same reaction using a catalyst. [5]

1. **a.** Complete these sentences about photochemical reactions using words from the list.

carbon **chlorophylls** **leaves** **light** **only** **pigments** **water**

Chemical reactions that ..... occur in the presence of .....

are called photochemical reactions. Photosynthesis is a photochemical reaction that

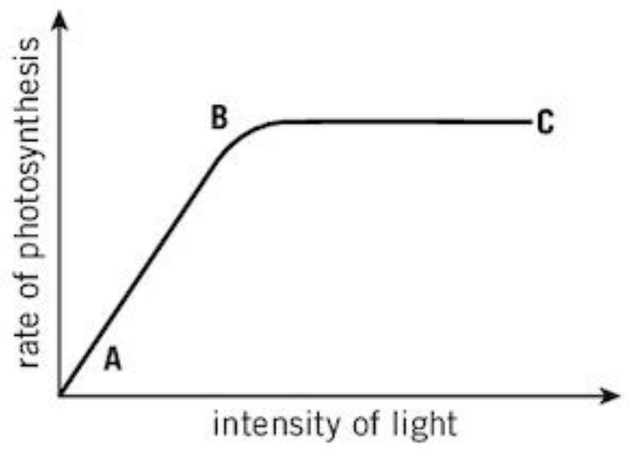
uses ..... in plant ..... called ..... to catalyse

the conversion of .....dioxide and ..... to glucose and oxygen. [7]

b. Complete the chemical equation for photosynthesis.

..... + ... → $C_6H_{12}O_6$ + $6O_2$ [2]

2. The graph shows how the rate of photosynthesis is affected by the brightness (intensity) of light.



a. Describe how rate of photosynthesis varies with light intensity from **A** to **B**.

..... [1]

b. Suggest why the graph is horizontal between **B** and **C**.

..... [1]

3. The equation shows the photochemical reaction taking place when a black and white film is exposed to light.

$2AgBr \rightarrow 2Ag + Br_2$

Complete the two half-equations for this reaction and state whether oxidation or reduction is taking place.

.....Ag^+ + ... → 2Ag Oxidation or reduction? .....

$2Br^-$ → ..... + ... Oxidation or reduction? ..... [3]

Extension

4. Use books or the internet to find out how chlorine reacts with methane in a photochemical reaction. [5]

1. **a.** Link the colours of these indicators to the following pH values.

pH 3 **pH 7** **pH 11**

i. Litmus is blue at pH ..... [1]

ii. Methyl orange is red at pH ..... [1]

iii. Universal indicator is green at pH ..... [1]

iv. Litmus is red at pH ..... [1]

v. Methyl orange is yellow at pH ..... [1]

b. Link the phrases **A** to **E** on the left with the pH values **1** to **5** on the right.

A highly acidic	**1** pH 6
B neutral	**2** pH 8
C highly alkaline	**3** pH 1
D weakly acidic	**4** pH 14
E weakly alkaline	**5** pH 7

[3]

2. **a.** Name these acids and alkalis by choosing the correct formula from the list.

$Ca(OH)_2$ CH_3COOH H_2CO_3 HNO_3 H_3PO_4 H_2SO_4 NaOH NH_3

i. ammonia ..... [1]

ii. ethanoic acid ..... [1]

iii. carbonic acid ..... [1]

iv. sulfuric acid ..... [1]

v. calcium hydroxide ..... [1]

vi. phosphoric acid ..... [1]

vii. nitric acid ..... [1]

viii. sodium hydroxide ..... [1]

b. What group of atoms is found in all alkaline solutions?

..... [1]

3. **a.** Many acids and alkalis are corrosive. What does the word *corrosive* mean?

..... [1]

Extension

b. Use the internet to find out the hazards associated with concentrated and dilute sodium hydroxide, hydrochloric acid, sulfuric acid, and ammonia. [8]

1. Complete these sentences about strong and weak acids using words from the list.

all **anions** **equilibrium** **hydrogen** **ionised** **molecules** **water** **partially**

Aqueous solutions of acids contain ..... ions. In strong acids ..... the acid .....

are dissociated (.....) to form hydrogen ions and ..... When weak acids are dissolved in

..... they become ..... dissociated. We can write this as an .....

e.g. $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$. [8]

2. Use the information in the table to answer parts **a.** and **b.**

Acid 0.1 mol/dm^3 solution	Relative electrical conductivity	pH	Rate of reaction
ethanoic, CH_3COOH	0.5		
hydrochloric, HCl	25		
methanoic, HCOOH	2	2.4	
sulfuric, H_2SO_4	40		

[7]

a. Hydrogen ions conduct electricity better than other ions. The greater the concentration of hydrogen ions, the better is the electrical conductivity.

Complete the third column of the table using the following pH values: pH 0.7, pH 1.0, pH 2.9. [3]

b. The rate of reaction of magnesium with different acids depends on the hydrogen ion concentration in the acid. Suggest whether the reaction of magnesium with each of these acids is fast or slow. Write your answers in the fourth column. [4]

3. Are 0.1 mol/dm^3 solutions of each of the acids or alkalis **A**, **B**, **C**, and **D** weak or strong? Write 'weak' or 'strong' in the spaces provided.

A pH 13 ..... [1]

B pH 4 ..... [1]

C pH 9 ..... [1]

D pH 1..... [1]

4. Ammonia reacts with water: $NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

How does this equation show that aqueous ammonia is an alkali?

..... [1]

Extension

5. Use the internet to find the solubilities of the hydroxides of barium, calcium, and magnesium. Suggest why there is a trend in the pH values of saturated solutions of these hydroxides. [4]

1. Complete these word equations for the general reactions of acids.

   a. acid + metal → ..... + ... [2]

   b. acid + metal oxide → ..... + ... [2]

   c. acid + metal carbonate → ..... + ... + ... [3]

   d. acid + metal hydroxide → ..... + ... [2]

2. Complete these word equations.

   a. sodium hydroxide + nitric acid → ..... [1]

   b. zinc oxide + hydrochloric acid → ..... [1]

   c. iron + sulfuric acid → ..... [1]

   d. sulfuric acid + lead carbonate → ..... [1]

   e. barium hydroxide + nitric acid → ..... [1]

   f. hydrochloric acid + tin oxide → ..... [1]

3. Complete the balanced chemical equations for these reactions.

   a. $Zn + H_2SO_4 \rightarrow$ ..... [1]

   b. $MgO + \ldots\ldots HNO_3 \rightarrow$ ..... [2]

   c. $CuCO_3 + \ldots\ldots HCl \rightarrow$ ..... [2]

   d. $\ldots\ldots NaOH + H_2SO_4 \rightarrow$ ..... [2]

   e. $Na_2CO_3 + \ldots\ldots HCl \rightarrow$ ..... [2]

   f. $Ca + \ldots\ldots HCl \rightarrow$ ..... [2]

   g. $Ca(OH)_2 + \ldots\ldots HNO_3 \rightarrow$ ..... [2]

4. What is the general name given to reactions **b.**, **c.**, **d.**, **e.**, and **g.** in question **3**?

   ..... [1]

5. Complete the equation below for the reaction of an alkali with an ammonium salt.

   $Ca(OH)_2 + \ldots\ldots NH_4Cl \rightarrow CaCl_2 + \ldots\ldots H_2O + \ldots\ldots$ [2]

Extension

6. Farmers add ammonium sulfate to the soil to increase the growth of crop plants.
   Explain why adding calcium hydroxide to the soil at the same time as ammonium sulfate is not a good idea. [3]

1. Complete these simple definitions of an acid and a base.

   a. An acid reacts with a ..... to form a ..... and ..... [3]

   b. A base reacts with an ..... to form a ..... and ..... [3]

2. A more general definition of an acid is a proton donor.

   a. What is a proton?

   ..... [1]

   b. Explain why a hydrogen ion can be described as a proton.

   .....

   ..... [2]

   c. Define a base using the word 'proton'.

   ..... [1]

3. The equation below shows the ions present in the reactants and products of a neutralisation reaction.

   $H^+(aq) + NO_3^-(aq) + Na^+(aq) + OH^-(aq) \rightarrow NO_3^-(aq) + Na^+(aq) + H_2O(l)$

   a. Cancel out the spectator ions in this equation. [1]

   b. Write the ionic equation for this reaction.

   ..... [1]

   c. Explain, in terms of ions, why this is a neutralisation reaction.

   ..... [1]

4. Identify which are the acids and which are the bases in these equations in terms of the transfer of protons. The first one has been done for you.

   proton donated

   a. $2HCl + MgO \rightarrow MgCl_2 + H_2O$

   b. $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ [1]

   c. $H_2S + H_2O \rightleftharpoons HS^- + H_3O^+$ [1]

Extension

5. Identify which are the acids and which are the bases in these equations.

   a. $HCOOH + HClO_2 \rightleftharpoons HCOOH_2^+ + ClO_2^-$ [2]

   b. $NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3$ [2]

1. Complete these sentences about oxides using words from the list.

acidic **alkaline** **alkalis** **basic** **left** **Periodic** **right** **water**

Oxides of many metals on the ..... of the ..... Table react with acids. These are called ..... oxides. Some of these oxides react with ..... to form ..... solutions. Oxides of many non-metals on the ..... of the Periodic Table react with ..... These are called acidic oxides. Many of these oxides react with water to form ..... solutions. [8]

2. Complete these equations to show the reactions of some oxides with either acids or bases.

a. $MgO + ...HCl \rightarrow ..... + ...$ [2]

b. $SO_2 + ...NaOH \rightarrow Na_2SO_3 + ...$ [2]

c. $CuO + H_2SO_4 \rightarrow ..... + ...$ [1]

d. $CO_2 + ... NaOH \rightarrow Na_2CO_3 + ...$ [2]

e. $ZnO + ...HNO_3 \rightarrow ..... + ...$ [2]

f. $CaO + H_2SO_4 \rightarrow ..... + ...$ [1]

3. Complete these equations to show the reactions of some oxides with water to form acids or alkalis.

a. $SO_2 + H_2O \rightarrow .....$ [1]

b. $CO_2 + H_2O \rightarrow .....$ [1]

c. $CaO + H_2O \rightarrow .....$ [1]

d. $P_4O_6 + ...H_2O \rightarrow ..... H_3PO_3$ [2]

e. $Na_2O + H_2O \rightarrow .....$ [2]

4. Some oxides react with both acids and alkalis. What is the term used to describe these oxides?

..... [1]

Extension

5. Complete the equations for these reactions of zinc and aluminium oxides.

a. $..... + ...KOH \rightarrow K_2ZnO_2 + ...$ [2]

b. $Al_2O_3 + ... HCl \rightarrow ..... + ...$ [2]

c. $Al_2O_3 + ... \rightarrow 2NaAlO_2 + ...$ [2]

1. Zinc sulfate can be made by first warming sulfuric acid with excess zinc.

   How is a solution of zinc sulfate obtained from the reaction mixture?

   ..... [1]

2. Crystals of copper(II) sulfate can be made by warming excess copper(II) carbonate with sulfuric acid. Put the following stages in the correct order.

   A Allow the solution to cool and deposit crystals.

   B Pour the filtrate into an evaporating basin.

   C Wash and dry the crystals.

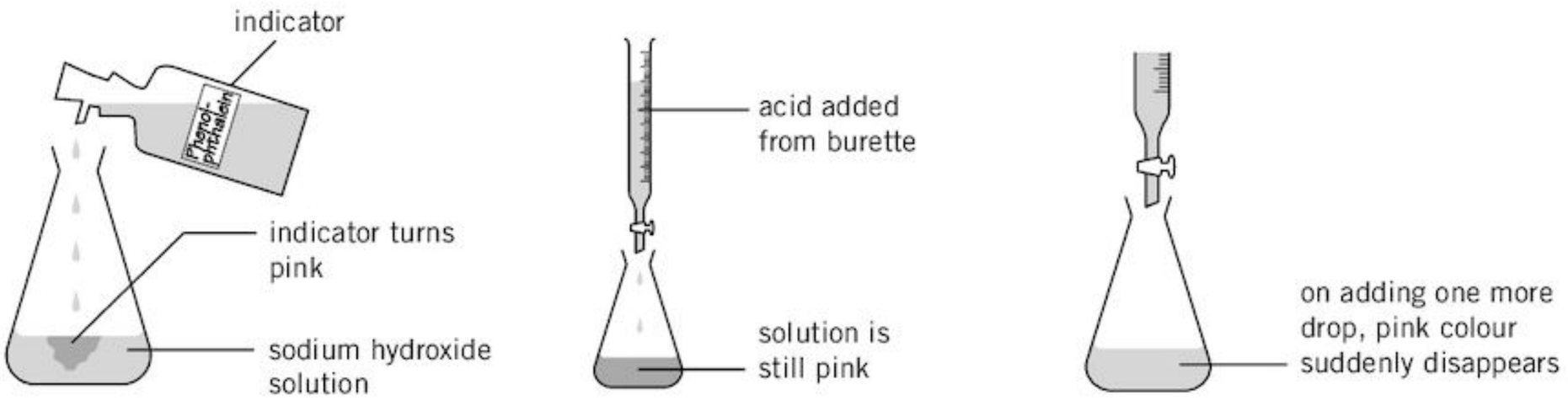
   D Filter the mixture to remove excess copper(II) carbonate.

   E Warm the filtrate until the solution is very concentrated.

   F Filter off the crystals.

   The order is ..... [2]

3. The diagram shows the first three stages in making a soluble salt (sodium chloride) by neutralising an alkali (sodium hydroxide) with an acid (hydrochloric acid).



   Describe the next three stages of the procedure to get colourless crystals of sodium chloride.

   .....

   .....

   ..... [3]

Extension

4. Use books or the internet to help you answer these questions.

   a. Why should you not heat copper(II) nitrate strongly when drying the crystals? [2]

   b. Why should you not use the titration method when preparing crystals of zinc sulfate? [2]

1. Complete these sentences about solubility using words from the list.

ammonium **carbonates** **compounds** **hydroxides** **nitrates** **precipitate** **solutions**

Salts such as ....., sodium salts, and ..... salts are soluble in water.

Many ..... and ..... are insoluble, except those from Group I. An insoluble substance formed when two ..... of soluble ..... are mixed is called a ..... . [7]

2. Crystals of lead iodide can be made from solutions of lead nitrate and potassium iodide. Put the following stages in the correct order.

A Filter the mixture.

B Make up aqueous solutions of lead nitrate and potassium iodide.

C Dry the residue of lead iodide in a warm oven.

D Rinse the residue on the filter paper with distilled water.

E Mix the solutions. A yellow precipitate forms.

The order is ..... [2]

3. **a.** The equation below shows the ions present in the reactants and products of a precipitation reaction.

$Ag^+(aq) + NO_3^-(aq) + K^+(aq) + Br^-(aq) \rightarrow AgBr(s) + NO_3^-(aq) + K^+(aq)$

i. Cancel out the spectator ions in this equation. [1]

ii. Write the ionic equation for this reaction.

..... [1]

b. Write ionic equations for these precipitation reactions.

i. $BaCl_2(aq) + K_2SO_4(aq) \rightarrow BaSO_4(s) + 2KCl(aq)$

..... [2]

ii. $Pb(NO_3)_2(aq) + 2KCl(aq) \rightarrow PbCl_2(s) + 2KNO_3(aq)$

..... [3]

Extension

Write ionic equations for these precipitation reactions.

iii. The reaction between iron(III) chloride and barium hydroxide. [3]

iv. The reaction between sodium carbonate and magnesium iodide. [2]

1. Describe how you would prepare 250 cm^3 of a standard solution of concentration 1.0 mol/dm^3 sodium hydroxide.

.....

.....

.....

..... [4]

2. The table below shows the results of a titration experiment. The titration was repeated several times.

	Rough titre	2nd titre	3rd titre	4th titre	5th titre
final burette reading / cm^3	33.00	33.30	32.10	32.90	34.65
initial burette reading / cm^3	0.05	1.20	0.10	0.05	02.50
titre / cm^3					

a. Complete the last row in the table. [2]

b. Which titres would you take to average? Explain why.

.....

..... [2]

3. Work through this calculation to find the concentration of a solution of sodium hydroxide when 25.0 cm^3 of a solution of sodium hydroxide is exactly neutralised by 12.2 cm^3 of sulfuric acid of concentration 0.100 mol/dm^3.

a. moles of acid = ... $\times \frac{\text{.....}}{1000}$ = ... mol H_2SO_4 [1]

b. The equation for the reaction is: $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

i. How many moles of NaOH react with 1 mole of H_2SO_4? ..... [1]

ii. How many moles of NaOH are needed to react with the amount (in mol) of H_2SO_4 you calculated in part **a**?

..... [1]

c. Calculate the concentration of NaOH in the sodium hydroxide solution. [2]

Extension

4. 25.0 cm^3 of a 0.05 mol/dm^3 solution of barium hydroxide, $Ba(OH)_2$, was titrated with hydrochloric acid. It took 15.5 cm^3 of hydrochloric acid to neutralise the barium hydroxide. Calculate the concentration of the hydrochloric acid. [4]

1. **a.** A 'cell' of the Periodic Table is shown below.

48
Cd
112

i. What does 48 represent? ..... [1]

ii. What does 112 represent? ..... [1]

b. Complete these sentences about the Periodic Table.

i. The elements in the Periodic Table are arranged in order of increasing

..... [1]

ii. The groups are numbered ..... to ..... [1]

iii. The period number tells you the number of ..... in an atom. [1]

iv. The outer shell electrons in an atom are called ..... [1]

2. Explain why Group VIII elements are unreactive.

.....

..... [2]

3. Describe the position of metals and non-metals in the Periodic Table both across a period and down a group.

.....

.....

.....

..... [4]

4. Both hydrogen and Group I elements have one electron in their outer shell.

Why is hydrogen not placed in Group I in the Periodic Table?

.....

..... [2]

Extension

5. Use books or the internet to describe:

a. How the structure of the Group V elements changes down the group along with their nature as metals or non-metals. [4]

b. How the type of oxides formed by Group V elements changes down the group. [4]

1. The table shows some properties of some Group I metals.

Group I metal	Density / g/cm^3	Melting point / °C	Metallic radius / nm	Observations when the metal reacts with water
lithium	0.53	181	0.157	Moves over the surface very slowly Fizzes gently Does not melt or go into a ball Does not burst into flame
sodium	0.97	98	0.191	.....
potassium	0.86		0.235	Moves over surface very rapidly Fizzes very rapidly Melts and goes into a ball then bursts into flame Slight 'pop' when reaction near the end
rubidium	1.53	39		.....

a. Complete the table by writing in the following:

i. The observations in the last column for sodium and rubidium. [6]

ii. Your prediction for the melting point of potassium and the metallic radius of rubidium. [2]

b. Caesium is below rubidium in the Periodic Table. Predict a value for the density of caesium.

..... [1]

2. Explain what happens in terms of electron transfer when sodium reacts with chlorine.

.....

.....

..... [4]

Extension

3. Use books or the internet to find out why it is easier to remove the outer electron from a potassium atom than it is to remove the outer electron from a sodium atom. [5]

1. The table shows some properties of fluorine, chlorine, bromine, and iodine.

Halogen	Melting point / °C	Boiling point / °C	State at –40 °C	Depth of colour	Atomic radius / nm
fluorine	–220	–88			
chlorine	–101	–35			
bromine	–7	59			
iodine	114	184			

a. What is the trend in the melting points of the halogens?

..... [1]

b. Use the values of the melting and boiling points in the table to deduce the state of the halogens at –40 °C. Write your answers in the table. [4]

c. Draw an arrow in the 5th column to show the trend in the depth of colour (light → dark). [1]

d. Draw an arrow in the 6th column to show the trend in atomic radius (smaller → larger). [1]

2. **a.** Complete these sentences about the displacement reactions of halogens using words from the list.

bromine **chlorine** **colourless** **halide** **halogen** **less** **more** **orange**

When aqueous ..... is added to a ..... solution of potassium bromide, the solution turns ..... because ..... has been displaced.

This is because a ..... reactive ..... displaces a ..... reactive halogen from an aqueous solution of its ..... . [8]

b. What would you observe when an aqueous solution of bromine is added to an aqueous solution of potassium iodide? Explain these observations.

.....

.....

..... [4]

Extension

3. Write ionic equations for the following:

a. The reaction of aqueous chlorine with aqueous magnesium iodide. [2]

b. The reaction of aqueous bromine with aqueous potassium astatide, KAt. [2]

12.4 Group VIII: the noble gases

1. Link the Group VIII gases **A** to **D** on the left with their uses **1** to **4** on the right.

A argon	**1** Produces a red glow for advertising signs.
B helium	**2** Used in car headlamps and for lasers.
C neon	**3** Filling balloons and airships.
D krypton	**4** To provide an inert atmosphere in welding.

[2]

2. The density of air and some noble gases at r.t.p. in g/dm^3 are given below.

Air: 1.20 Ar 1.78 He 0.18 Kr 3.74 Ne 0.90

Which gases could you use to fill balloons that float upwards in air?

..... [1]

3. **a.** Use ideas about electron arrangement to suggest why the Group VIII elements are monatomic and not diatomic.

.....

..... [2]

b. If we fire high-speed electrons at an atom, they can knock an electron out of an atom. The energy required to do this is called the first ionisation energy.

Complete this equation representing the first ionisation energy of argon.

$Ar \rightarrow Ar^+ + ...$ [1]

Extension

c. The graph on the right shows the first ionisation energies of some elements in order of increasing atomic number.

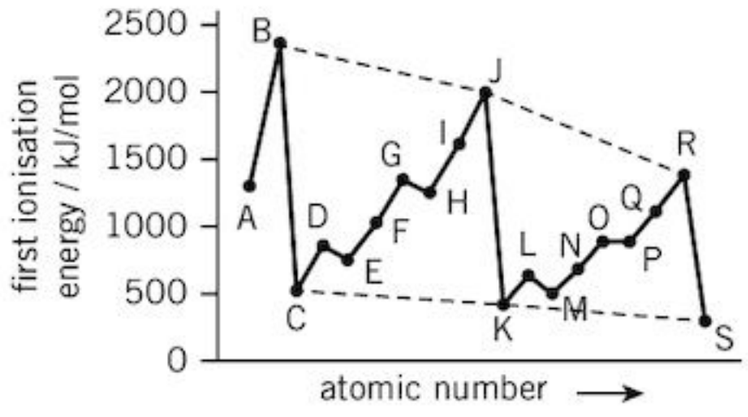
Which letters are likely to represent Group VIII elements? Explain why.

.....

.....

.....

..... [2]



1. The boxes below show some properties of a non-transition element and of a transition element. The boxes are muddled up. (M = metal)

A Melting point 1890 °C	**B** Forms a chloride of formula MCl_2 only
C Forms chlorides that are pink and green	**D** Density 3.51 g/cm^3
E Forms chlorides of type MCl_2, MCl_3, and MCl_4	**F** Forms a colourless chloride
G A compound of M is a good catalyst	**H** Melting point 725 °C
I Density 5.96 g/cm^3	**J** Compounds of M show no catalytic activity

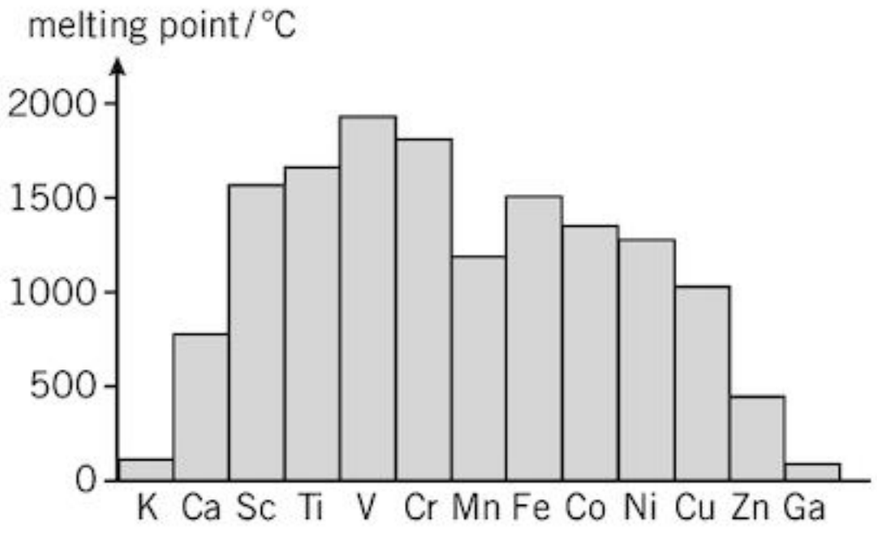
a. Which letters represent the properties of a transition element?

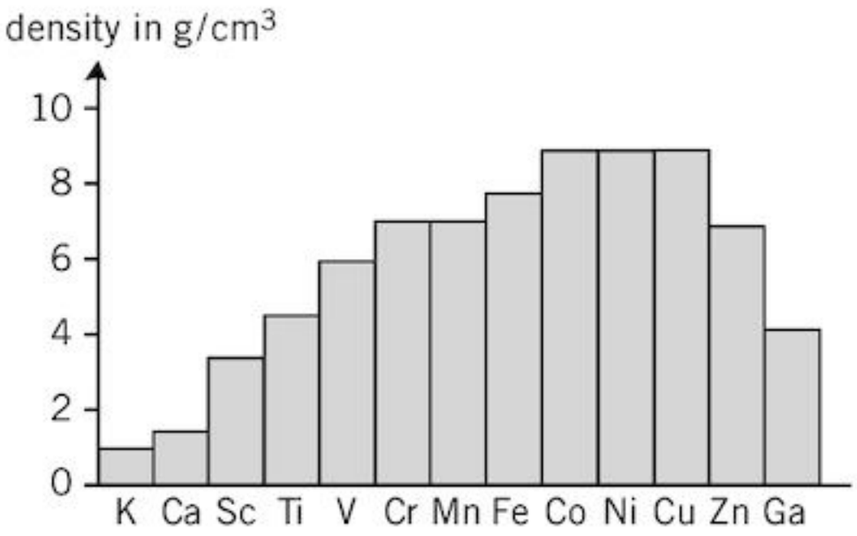
..... [3]

b. Give two other typical properties of transition elements that are not mentioned above.

..... [2]

2. The bar charts show the melting point and densities of some metals in Period 4.





a. What information in the bar charts suggests that calcium is not a transition element?

..... [2]

b. What is the pattern in the density of the metals across Period 4?

..... [2]

Extension

3. Zinc is in the central block of the Periodic Table. Use text books and the internet to find out about the properties of zinc that suggest that it is not a transition element. [4]

1. The table shows some information about some of the elements in Period 3.

Element	Na	Mg	Al	Si	P	S	Cl
Electronic structure	2,8,1						
Melting point / °C	98	649	660	1410	590	119	–101
Formula of typical compounds	$NaCl$ Na_2O	$MgCl_2$ MgO	$AlCl_3$	$SiCl_4$ SiH_4	PCl_3 PH_3	H_2S	HCl
Valency in compounds	1	2	3	4	3	2	1

a. Complete the 2nd line of the table to show the electronic structures. [1]

b. Complete the 4th line of the table to show the formulae of the three typical oxides. [3]

c. **i.** Describe how the melting points of the elements change across the period.

..... [2]

ii. What type of structures are Na, Mg, and Al?

..... [1]

iii. Explain in terms of structure and bonding why Si has the highest melting point in this period.

.....

..... [2]

iv. Explain in terms of structure and bonding why the melting points of P, S, and Cl are relatively low.

.....

..... [2]

2. Phosphorus forms another chloride with the formula PCl_5.

a. Deduce the valency of the phosphorus in this compound. ..... [1]

b. Deduce the formula of the oxide of phosphorus that has the same valency as the phosphorus in PCl_5.

..... [1]

Extension

3. Explain why the reactivity of the metals decreases from sodium to aluminium. [3]

1. Typical metallic properties of transition elements are high melting points and high density. Other metals have properties that are not typical of most metals. Link the properties **A** to **E** on the left with the metals **1** to **5** on the right.

A A metal that is liquid at room temperature.	**1** Iron
B A very unreactive metal.	**2** Potassium
C A metal that is solid at room temperature and has a low melting point.	**3** Nickel
D A metal that rusts.	**4** Gold
E A metal, other than iron, that is magnetic.	**5** Mercury

[3]

2. Complete the equation for density:

$$\text{density (in g/cm}^3\text{)} = \frac{\text{..... (in .....)}}{\text{..... (in .....)}}$$

[2]

3. **a.** Complete these sentences about the chemical properties of reactive metals.

i. They react with dilute hydrochloric acid to form a ..... and ..... [1]

ii. They react with chlorine to form metal ..... [1]

b. Write balanced equations for the following:

i. The reaction of aluminium with oxygen.

..... [2]

ii The reaction of magnesium with hydrochloric acid.

..... [2]

Extension

4. A 2 cm × 2 cm × 2 cm cube of magnesium reacts completely with hydrochloric acid. 13.92 dm^3 of hydrogen is produced. Calculate the density of magnesium. A_r Mg = 24 [4]

1. **a.** Complete these equations for the reactions of metals with water or steam.

i. ..... Na(s) + ... $H_2O(l)$ → ..... + ... [3]

ii. ..... Fe(s) + ... → ..... $Fe_3O_4(s)$ + ... [3]

b. Complete these sentences about the reaction of metals with water.

The products formed by metals that react with ..... water are a metal

..... and ..... The hydroxides are alkaline and so turn ..... litmus

..... The products formed by metals that react only with steam are a metal

..... and ..... Copper does not react with water because it is

..... reactive than ..... and cannot take the ..... away from the

hydrogen in the water. [10]

2. Some observations for the reaction of metals with water are given in the table.

Metal	Observations
barium	
calcium	gives off bubbles rapidly with cold water, disappears quite quickly
lead	
magnesium	gives a few bubbles with hot water, disappears slowly
zinc	reacts when heated to red-heat with steam

a. Put calcium, magnesium, and zinc in order of their reactivity. Put the least reactive first.

..... [1]

b. Barium is more reactive than calcium and lead is less reactive than zinc.
Write the observations for barium and lead in the table above. [3]

3. Put these metals in order of their reactivity with hydrochloric acid using the information below.

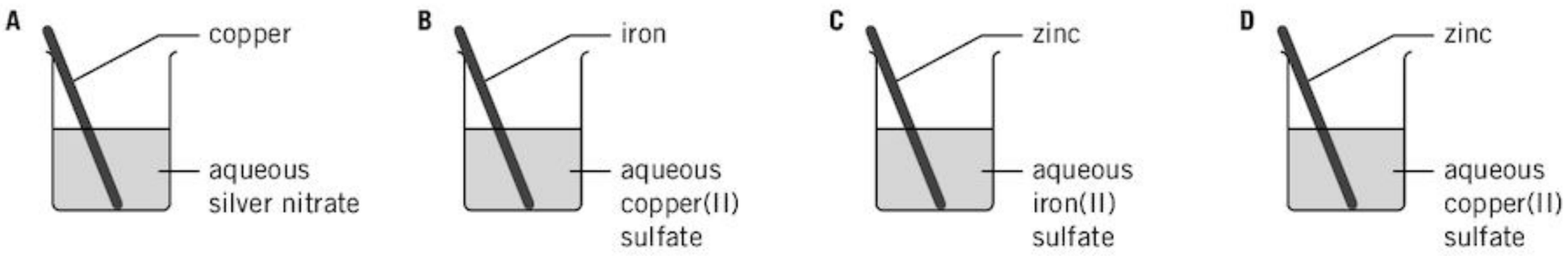
Metal	Concentration of HCl(aq) in mol/dm^3	Observations
iron	0.5	slow bubbling
lead	6.0	slow bubbling
lithium	0.5	rapid stream of bubbles
magnesium	0.5	steady stream of bubbles

least reactive ..... most reactive [1]

Extension

4. Write an ionic equation for the reaction of magnesium with hydrochloric acid.
Split this equation into two half-equations, one showing oxidation and the other reduction. [4]

1. The diagram shows different metals placed in solutions of metal salts. In each case a reaction occurs.



Some of the results are shown in the table.

Experiment	Colour at the start		Colour after 20 minutes	
A	metal	brown	metal	silver-grey surface
	solution	colourless	solution	blue
B	metal	silvery grey	metal	.....
	solution		solution	
C	metal	grey	metal	.....
	solution	light green	solution	colourless
D	metal		metal	
	solution		solution	

a. Complete the table to show the colour changes. [8]

b. Use the results to arrange the metals in order of their reactivity.

least reactive ..... most reactive [1]

c. Explain why there would be no colour change when a copper rod is placed in aqueous zinc sulfate.

..... [1]

2. Identify the reducing agent and the oxidising agent in each of these equations.

a. $Fe(s) + CuO(s) \rightarrow FeO(s) + Cu(s)$

reducing agent ..... oxidising agent ..... [1]

b. $Fe_2O_3(s) + 3Mg(s) \rightarrow 2Fe(s) + 3MgO(s)$

reducing agent ..... oxidising agent ..... [1]

Extension

3. Split these equations into two ionic half-equations and identify the reducing agent.

a. $Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$ [3]

b. $Mg(s) + Pb(NO_3)_2(aq) \rightarrow Pb(s) + Mg(NO_3)_2(aq)$ [3]

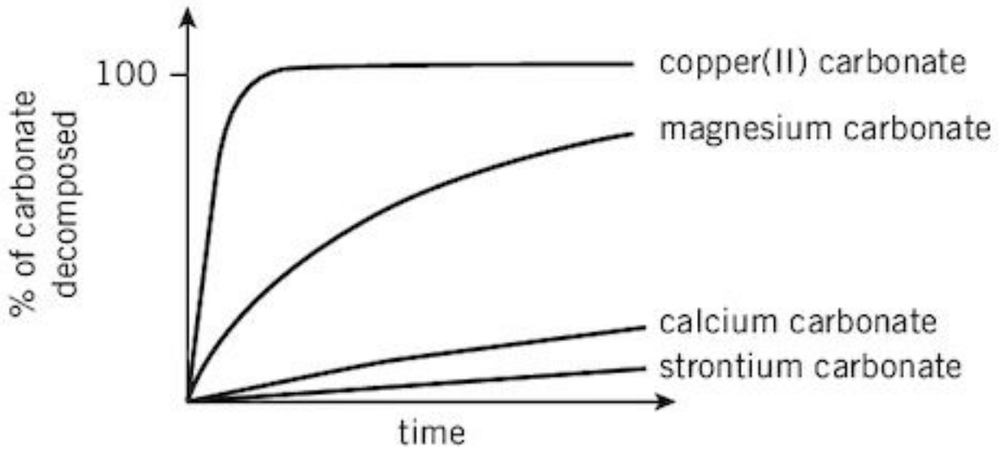
1. Complete these sentences about the reactivity series using words from the list.

electrons **exothermic** **less** **more** **positive** **reduce**

A ..... reactive metal will ..... the oxide of a ..... reactive metal. This reaction is .....

The more reactive metal loses ..... and forms ..... ions more easily. [6]

2. The graph below shows how the percentage decomposition of four carbonates with heat changes with time.



a. Put these carbonates in order of increasing rate of thermal decomposition.

..... [1]

b. Link the compounds **A** to **E** with the thermal decomposition products **1** to **5**.

A sodium nitrate	**1** oxide + water
B copper(II) nitrate	**2** nitrite + oxygen
C zinc hydroxide	**3** oxide + carbon dioxide
D magnesium carbonate	**4** does not decompose
E sodium hydroxide	**5** oxide + nitrogen dioxide + oxygen

[3]

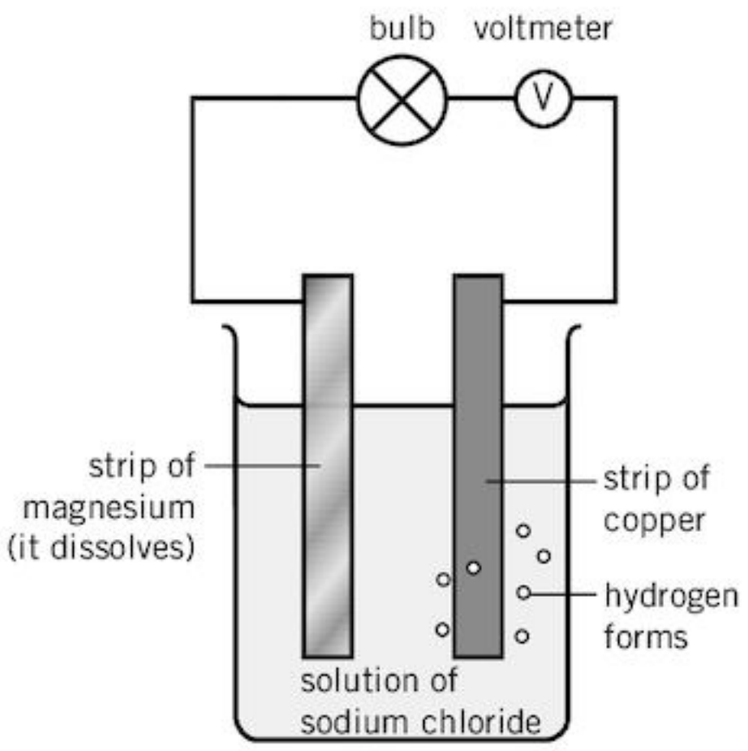
Extension

3. Write balanced equations, including state symbols, for:

   i. the thermal decomposition of magnesium nitrate

   ii. the thermal decomposition of potassium nitrate. [6]

1. The diagram shows a simple electrochemical cell.



a. Write a half-equation for the reaction at the left-hand electrode.

..... [1]

b. Which is the positive pole of the cell? Explain why.

.....

..... [3]

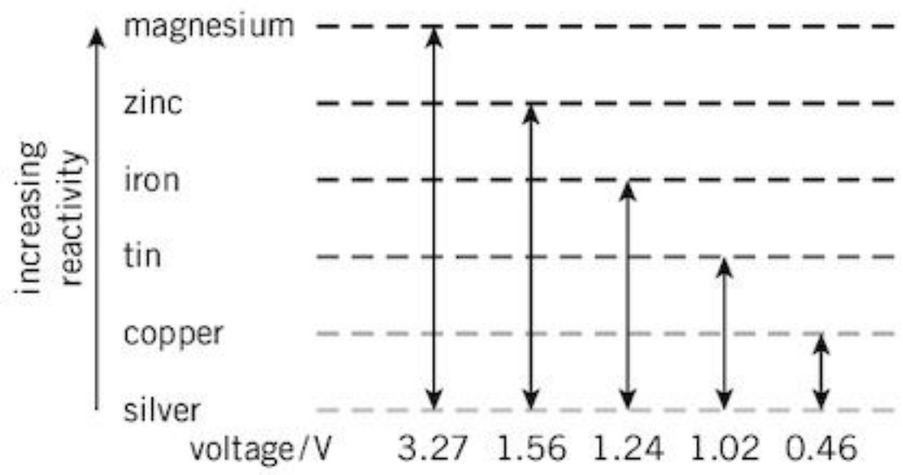
c. On the diagram above put arrows to show the direction in which electrons flow round the circuit. [1]

2. The diagram on the right shows the voltages of some simple cells.

Calculate the value of the voltages of electrochemical cells with these electrodes:

a. iron and copper .....V [1]

b. zinc and iron .....V [1]



Extension

3. Blocks of zinc can be placed on ships' hulls to prevent rusting. Explain, using ideas about electron transfer, why zinc protects the hull from rusting. [4]

1. Read this paragraph about copper mining and then answer the questions that follow.

An opencast copper mine processes copper ore, which contains 15% copper. There is also 0.5% cobalt and 0.0001% gold that can be extracted. 69 tonnes of graded rock produces 16 tonnes of copper ore, which can be treated to produce pure copper. The rock waste is dumped next to a nearby river. The processing also produces lead and cadmium, which are poisonous.

a. What is the percentage of copper in the graded rock?

..... [1]

b. The mine produces huge amounts of waste rock. Explain why.

..... [1]

c. When the price of copper drops, it may not be worth extracting the copper. Despite this, the mining still continues. Suggest why.

..... [1]

d. What environmental problems may arise from the dumping of waste rock and processing copper?

.....

.....

..... [3]

e. What advantages may a mine bring to the local area?

.....

..... [2]

f. What disadvantages may a mine bring to the local area?

.....

.....

..... [2]

Extension

2. The price, relative abundance in the Earth's crust, and relative reactivity (1 is most reactive) of several metals are shown in the table.

Metal	Aluminium	Copper	Iron	Silver	Tin	Zinc
reactivity	1	5	3	6	4	2
abundance / %	8	0.06	5	0.000007	0.0002	0.007
relative price	4	12	1	340	39	3.7

Compare the abundance with the reactivity of the metals and with the prices. How well do the lists match? Suggest reasons for any differences. [4]

1. The table shows the order of some metals in the reactivity series. It also shows the position of carbon.

Metal	Reactivity	Extracted by	Energy needed to extract the metal	Cost of extraction
lithium calcium cerium aluminium				
carbon				
zinc lead copper silver gold				

a. Draw an arrow in the second column of the table to show the reactivity of the metals (least reactive → most reactive). [1]

b. Complete the third column of the table to show which metals are extracted by heating their oxides with carbon and which are extracted by electrolysis. [2]

c. **i.** In the fourth and fifth columns draw arrows to show the amount of energy needed to extract the metal (less energy → more energy) and the cost of extraction (lower cost → higher cost). [2]

ii. Explain why there might be exceptions in the order in part **c. i.**

..... [1]

d. Which elements in the table can be found 'native' (not combined in compounds)?

..... [1]

e. Which elements could be extracted by reaction of their oxides with hydrogen?

..... [1]

2. Manganese is extracted by reduction of manganese oxide with hot aluminium.

Write a word equation for this reaction.

..... [1]

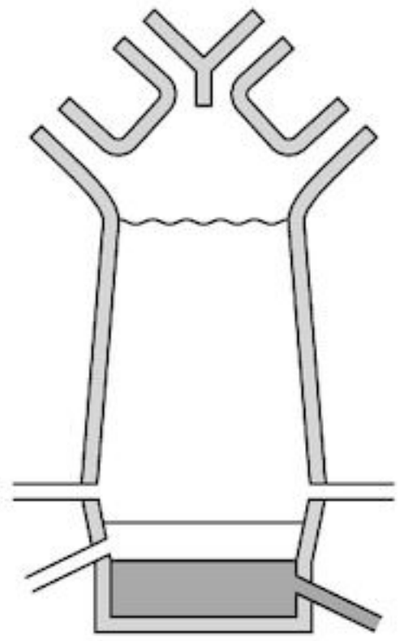
Extension

3. Write balanced equations for the following:

a. The reduction of chromium(III) oxide to chromium using aluminium. [2]

b. The reduction of iron(III) oxide with carbon monoxide to form iron. [2]

1. The diagram below shows a blast furnace for the extraction of iron.



On the diagram draw arrows and the following letters to show:

A → where air is blown into the furnace

B → where the iron ore is added to the furnace

C → where the molten iron is removed

D → where the slag is removed

E → where waste gases exit the furnace [5]

2. Iron(III) oxide is reduced in the furnace by carbon monoxide.

What are the two stages in the formation of this carbon monoxide?

.....

..... [2]

3. The following phrases are about the purpose of the limestone added to the furnace but they are muddled up. Put these phrases in the correct order and then write them out in the correct order in the space below.

At the high temperatures in the furnace	..... silicon dioxide (sand)	..... which is an impurity in the ore.
The calcium oxide reacts with	..... and floats on top of the molten iron.	..... to form calcium oxide.
..... the limestone undergoes thermal decomposition	..... which runs down the furnace	The calcium silicate formed is a slag .....

.....

.....

.....

..... [3]

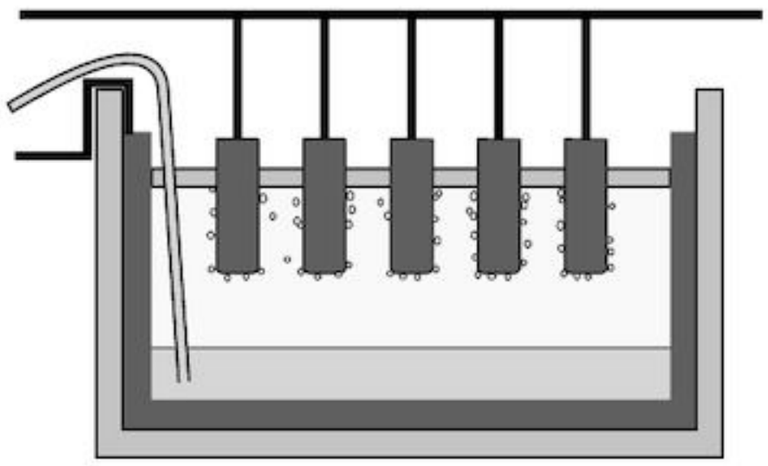
4. Complete this equation for the reduction of iron oxide to iron.

$Fe_2O_3(s)$ + ... CO → ..... + ... [2]

Extension

5. Use books or the internet to find out three ways to make pure iron. [3]

1. The diagram shows an electrolysis cell used to extract aluminium from aluminium oxide.



On the diagram above, label the electrolyte as **E**, the cathode as **C**, the anode as **A**, and the molten aluminium as **M**. [4]

2. Complete these sentences about the electrolyte using words from the list. Not all the words are used.

calcite cryolite dissolved energy evaporated high

low melts pressure temperature 950 1500

Aluminium oxide ..... at a very high temperature. It would require too much

..... to keep the aluminium oxide molten at this ..... So the aluminium

oxide is ..... in molten ..... and calcium fluoride. This lowers the

operating temperature to about ..... °C. The temperature is kept relatively

..... by keeping the percentage of aluminium oxide in the mixture at 5%. [7]

3. **a.** Complete these equations for the reactions at the anode and cathode.

i. Al^{3+} + ... → ..... [2]

ii. ..... O^{2-} → ..... + ... [2]

b. Construct the overall equation for this electrolysis.

..... [2]

4. Explain why the carbon anodes have to be renewed from time to time.

.....

..... [2]

Extension

5. The actual reaction at the cathode may involve two moles of Al_2O_3 splitting into an Al^{3+} ion and one other ion. The other ion then decomposes into Al_2O_3 and oxygen.

Write equations for these reactions. [4]

1. Complete the table about the uses and properties of different metals and alloys.

Metal or alloy	Use	Properties that makes it suitable for the use
aluminium	drinks can	1. ..... [1] 2. ..... [1]
aluminium alloy (90.25% Al, 6% Zn, and 3.75% Mg/Cu)	aircraft body	1. ..... [1] 2. ..... [1]
brass (70% Cu, 30% Zn)	door handles	1. ..... [1] 2. ..... [1]
bronze (95% Cu, 5% Sn)	one use ..... [1]	1. ..... [1] 2. resistant to corrosion
cobalt alloy (65% Co, 30% Cr, 5% Mo)	two uses 1. ..... [1] 2. ..... [1]	1. remains hard at high temperatures 2. does not change shape easily
copper	1. electrical wiring 2. saucepan base	1. ..... [1] 2. ..... [1]
'silver coinage metal' (75%Cu, 25% Ni)	coins	1. ..... [1] 2. ..... [1]

Extension

2. Commercial aluminium is 99.5% aluminium with a little iron and silicon. This is preferred for engineering use instead of pure aluminium. Use your knowledge of the structure of metals to explain why. [3]

1. Complete the phrases **A** to **F** about steel-making using phrases **1** to **6**.

A Calcium oxide is added	**1** ..... is poured into a basic oxygen converter.
B A jet of oxygen	**2** ..... which floats on the iron and is removed.
C The molten iron from the blast furnace	**3** ..... are solid acidic oxides.
D This gives a slag	**4** ..... the acidic oxides of silicon and phosphorus.
E The calcium oxide reacts with	**5** ..... because it is a basic oxide.
F The oxides of phosphorus and silicon	**6** ..... oxidises the impurities C, Si, P, and S to their oxides.

[3]

2. Now put the pairs of phrases in the correct order to describe the correct sequence during steel-making, i.e. letter–number, letter–number, letter–number, etc.

..... [2]

3. Complete the table about the uses and properties of different steels.

Steel	Use	Properties which makes it suitable for the use
mild steel (99.7 Fe, 0.3% C)	two uses **1.** ..... [1] **2.** ..... [1]	one property ..... [1]
stainless steel (70% Fe, 20% Cr, 10% Ni)	two uses **1.** ..... [1] **2.** ..... [1]	one property ..... [1]
tungsten steel (95% Fe, 5% W)	drill bits	two properties **1.** ..... [1] **2.** ..... [1]

Extension

4. Complete the equations for these two reactions in the basic oxygen converter.

a. P_4O_{10} + ... $CaO \rightarrow$ ..... $Ca_3(PO_{....})_2$ [2]

b. Fe_2O_3 + ... $CO \rightarrow$ ..... Fe + ... [2]

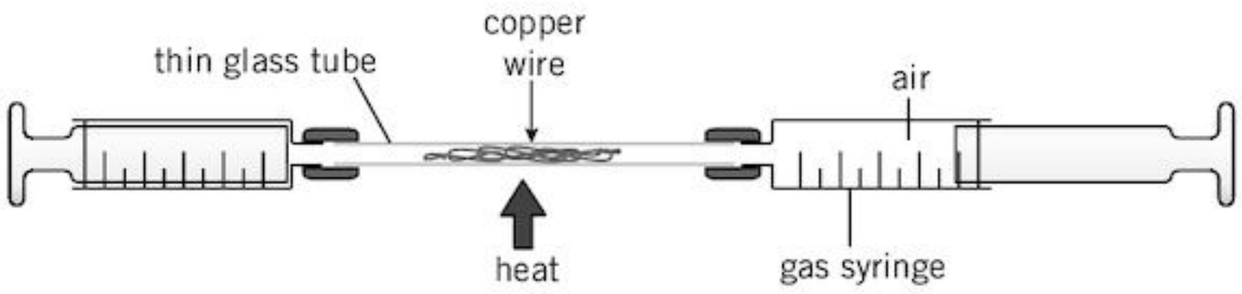
1. The table shows the percentage of some of the gases in dry air in 1985 and 2015.

Gas	% by volume in 1985	% by volume in 2015
nitrogen	78.082	78.081
oxygen	20.950	20.946
carbon dioxide	0.034	0.0397
neon	0.0018	0.0018
helium	0.000524	0.000524
methane	0.00014	0.000179

Which two gases have shown the largest percentage change relative to their original amount since 1985?

..... [1]

2. The apparatus shown was used to deduce the % of oxygen in the air.



80 cm^3 of air was drawn into the right-hand syringe. The air was then passed over the heated copper until there was no further decrease in volume. The final volume of air was measured immediately in the right-hand syringe and was 62.9 cm^3.

a. What volume of oxygen had reacted? ..... [1]

b. Calculate the % of oxygen in this sample of air. Show your working.

% O_2 in the air = ...% [1]

c. How does this volume compare with the volume in the table? Give a reason for the difference based on your knowledge of the behaviour of gases.

.....

.....

..... [3]

Extension

3. Oxygen is involved in combustion reactions. Oxides are formed as products. Write a balanced equation for the complete combustion of ethane, C_2H_6. [2]

1. The table shows the boiling points of some of the gases in air.

Gas	CO_2	Xe	Kr	O_2	Ar	N_2	Ne	He
Boiling point / °C	–32	–108	–153	–183	–186	–196	–246	–269

a. Which gases are not noble gases? ..... [1]

b. Which is the most reactive of these gases? ..... [1]

c. What is the relationship between the boiling point of the noble gases and their relative atomic mass?

..... [1]

d. What method is used to separate these gases and what physical property does this depend on?

..... [2]

2. Carbon dioxide is first removed by bubbling the air through concentrated aqueous sodium hydroxide.

a. What type of oxide is carbon dioxide? Put a ring around the correct answer.

acidic **amphoteric** **basic** **neutral** [1]

b. What type of chemical reaction occurs when carbon dioxide is absorbed by aqueous sodium hydroxide?

..... [1]

3. A mixture of liquefied air contains largely nitrogen and oxygen.

Explain why nitrogen boils off first when the temperature of liquefied air is raised.

..... [1]

4. Explain why oxygen is used in each of the following:

a. Steelworks .....

..... [2]

b. Cutting metals ..... [1]

c. Hospitals ..... [1]

Extension

5. Carbon dioxide reacts with hydroxide ions to form carbonate ions and water. In the presence of excess carbon dioxide and water the carbonate ions react further to form hydrogencarbonate ions, HCO_3^-.
Write ionic equations for these two reactions. [4]

1. **a.** Complete these sentences about the sources of carbon monoxide and sulfur dioxide in the atmosphere using words from the list below. Not all the words are used.

burn carbon excess fossil gaseous limited oxygen sulfur

Carbon monoxide is formed when ..... compounds ..... in a ..... supply of air.

Sulfur dioxide is formed when ..... fuels containing ..... burn in air. [5]

b. Name a natural source in the atmosphere of **i.** nitrogen oxides **ii.** sulfur dioxide.

i. ..... **ii.** ..... [2]

2. Give one harmful effect of:

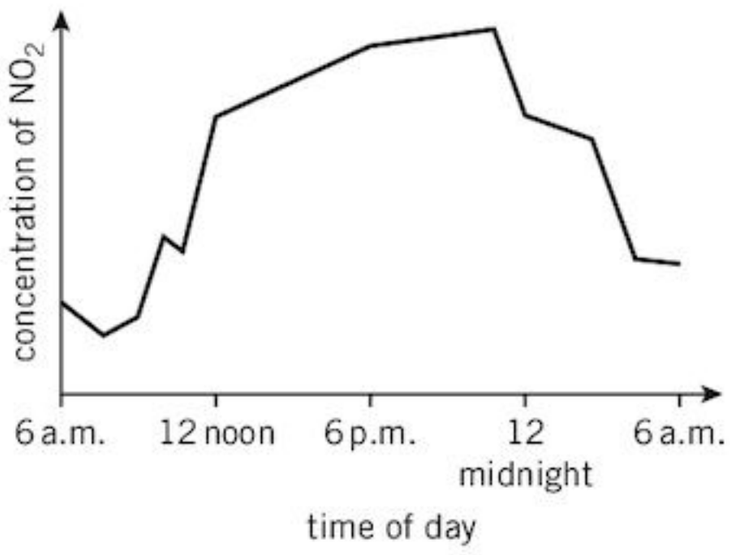
a. An aqueous solution of sulfur dioxide on buildings made of limestone.

..... [1]

b. Nitrogen dioxide on humans. ..... [1]

c. Carbon monoxide on humans. ..... [1]

3. The graph below shows the concentration of nitrogen dioxide in the air in the streets of a large city throughout a particular day.



Describe and explain the shape of this graph.

.....

.....

..... [4]

4. Explain the function of a catalytic converter attached to a car exhaust.

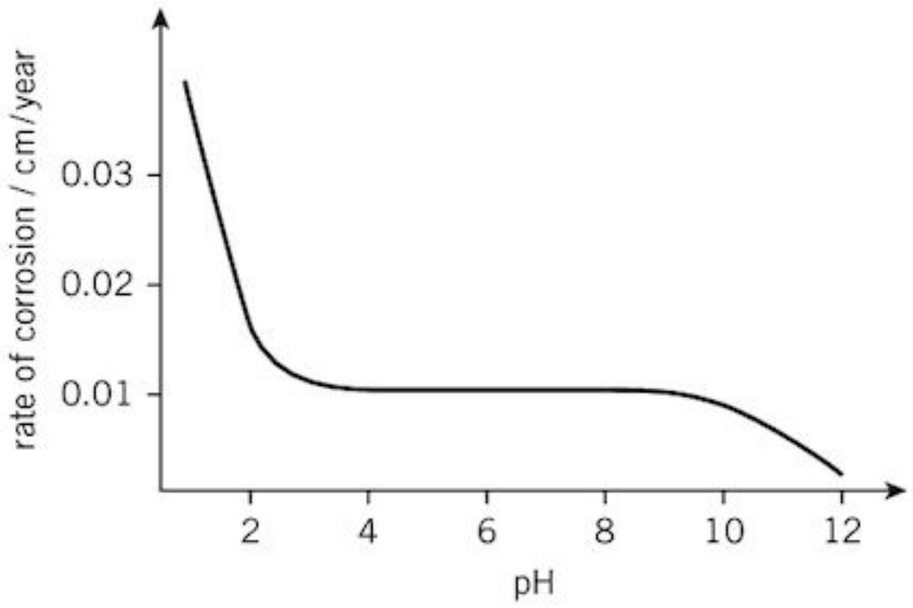
.....

..... [3]

Extension

5. Write balanced equations for the reaction of **i.** NO_2 and **ii.** NO with carbon monoxide in a catalytic converter. [4]

1. The graph shows the rate of corrosion of iron at different pH values in aerated water.



a. Describe how the corrosion of iron varies with pH.

.....

..... [3]

b. At neutral pH values, as corrosion uses up H^+ ions, OH^- ions are left in solution. These first react with iron(II) ions to form iron(II) hydroxide ('green rust').

Complete the ionic equation for this reaction. Include state symbols.

$Fe^{2+}(aq)$ + ... → ..... [3]

c. At more alkaline pH values 'green rust' is converted to 'red rust' (hydrated iron(III) oxide).

i. Give the name of the oxidising agent in this reaction. ..... [1]

ii. 'Green rust' is converted to 'red rust' more rapidly at more alkaline pH values. What information from the graph suggests that 'red rust' protects the iron from corrosion better than 'green rust'?

..... [1]

2. Suggest reasons for the following:

a. The iron in a ship's hull rusts more quickly than the same sort of iron on a bridge far from the sea.

.....

..... [2]

b. An iron object in the desert rusts very slowly.

..... [1]

c. Painting an iron object stops it from rusting.

.....

..... [2]

Extension

3. Blocks of magnesium can be placed on ships' hulls to prevent rusting. Explain using ideas about electron transfer why magnesium protects the hull from rusting. [4]

1. The table shows the concentration in mg/dm^3 of some ions present in water from three different sources.

Ion	Seawater	Rainwater	River water
Na^+	10 000	9	11
Ca^{2+}	900	2	1
K^+	1 000	1	4
SiO_3^{2-}	500	0.5	7
Cl^-	17 000	16	12
HCO_3^-	7 00	3	2
NO_3^-	trace	0.01	3

a. What is the commonest compound obtained when seawater is evaporated?

..... [1]

b. Which positive ion in seawater in the table is present at the lowest concentration?

..... [1]

c. What are the major differences between rainwater and river water in terms of the concentration of the ions present?

.....

.....

..... [3]

d. Drinking water can be made from seawater by desalination. What is meant by the term desalination?

..... [1]

e. Which ion in river water is most likely to be a harmful pollutant and what is the most likely source of this ion?

..... [2]

f. What organisms present in river water might make it unfit to drink?

..... [1]

g. River water is treated so that it is fit to drink.

What is the purpose of these stages in the purification?

Filtration ..... [1]

Chlorination ..... [1]

Extension

2. Use books or the internet to find out why some samples of water are described as 'hard' and how sodium carbonate is used to treat hard water. [4]

1. **a.** Hydrogen reacts with oxygen to form water.

	$2H_2(g)$	+	$O_2(g)$	→	$2H_2O(l)$
oxidation state	0		0		+1 –2

Explain why this is a redox reaction in terms of changes in oxidation state.

.....

..... [3]

b. Hydrogen reduces hot copper(II) oxide to copper. Write a symbol equation for this reaction. Include state symbols.

..... [2]

c. Describe how you could prepare hydrogen in the laboratory using a named metal.

.....

.....

..... [3]

2. Ammonia can be made in the laboratory by heating an ammonium salt with calcium hydroxide.

$$2NH_4Cl(s) + Ca(OH)_2(s) \rightarrow CaCl_2(s) + 2H_2O(l) + 2NH_3(g)$$

a. Name two salts shown in this equation.

..... [2]

b. Name two bases shown in this equation.

..... [2]

c. Name two simple molecules shown in this equation.

..... [2]

d. Suggest why the ammonia gas is collected by downward displacement of air.

..... [1]

e. How could you test for the ammonia released in this reaction?

Test .....

Result ..... [2]

Extension

3. **a.** Write an ionic equation for the reaction shown in question **2**. [2]

b. Explain which is the acid and which is the base in terms of proton transfer. [2]

1. Ammonia is manufactured by the Haber process. Complete these sentences about this process using words from the list.

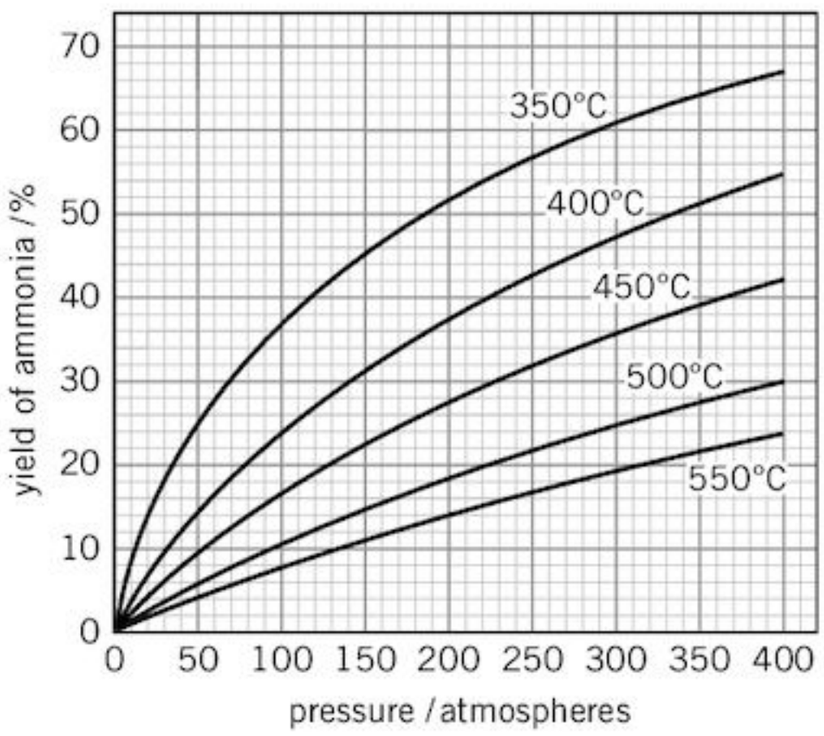
compressed **converter** **hydrogen** **iron** **natural** **oxygen** **steam**

The hydrogen is made by reacting ..... gas with ..... . The nitrogen comes from the air after ..... has been removed by reaction with ..... . The nitrogen and hydrogen are ..... and pumped into a ..... , where they react at 450 °C in the presence of a catalyst of ..... [7]

2. Complete the equation for the synthesis of ammonia.

$N_2(g)$ + ... (g) $\rightleftharpoons$ ..... (g) [2]

3. The graph below shows the effect of temperature and pressure on the percentage yield of ammonia.



a. Describe the effect of pressure on the percentage yield.

..... [1]

b. How does the data in the graph show that the reaction is exothermic?

..... [1]

c. What is the percentage yield of ammonia at 200 atmospheres and 350 °C?

..... [1]

d. State one advantage and one disadvantage of using a low temperature in the reaction.

.....

..... [2]

Extension

4. Draw and label an energy level diagram for ammonia synthesis showing the overall energy change and the activation energy of the catalysed and uncatalysed reaction. [5]

1. Complete these sentences about fertilisers using words from the list.

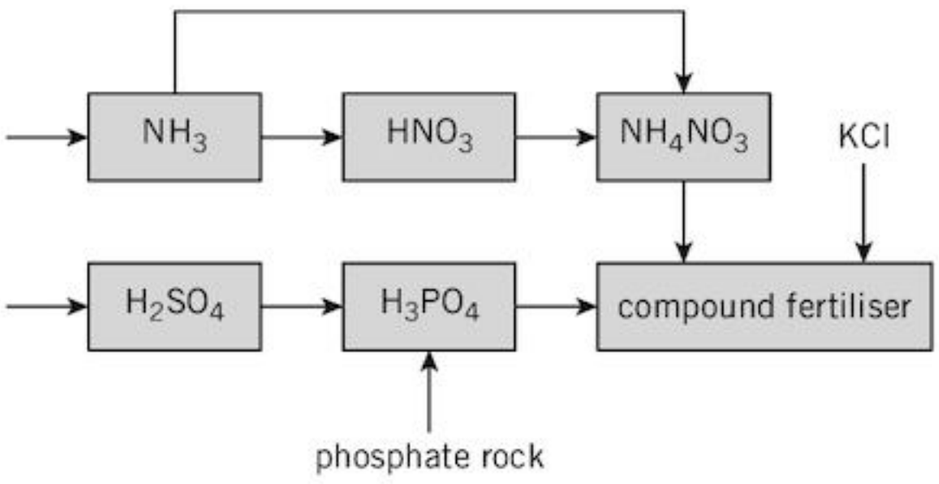
fertilisers **nitrates** **nutrients** **phosphates** **phosphorus** **proteins** **salts**

For healthy growth crop plants need three major elements, nitrogen, ..., and potassium.

Plants take up these elements in the form of nitrates, ..., and potassium .....

The ..... are needed to make ..... for growth. Farmers add ..... to the soil to add back the ..... that plants have absorbed for growth. [7]

2. A flow chart for making fertilisers is shown below.



a. Name the compounds in the diagram:

NH_3 ..... HNO_3 .....

NH_4NO_3 ..... H_2SO_4 .....

H_3PO_4 ..... KCl ..... [6]

b. Write a word equation for the reaction between NH_3 and HNO_3.

..... [1]

c. Name a suitable acid and base for making these fertilisers.

i. Ammonium sulfate ..... [2]

ii. Potassium chloride ..... [2]

iii. Sodium phosphate ..... [2]

d. Name the three raw materials used to make NH_3.

..... [3]

Extension

3. Use books or the internet to write about the process of eutrophication, which happens as a result of nitrate and phosphate fertilisers getting into rivers. [5]

1. Petroleum contains unwanted sulfur compounds.

   a. Why is it important that these sulfur compounds do not remain in fuels obtained from the fractional distillation of petroleum?

   .....

   ..... [2]

   b. The sulfur compounds are converted to hydrogen sulfide by reduction with hydrogen using a catalyst. What is the purpose of the catalyst?

   ..... [1]

   c. The hydrogen sulfide is then separated from other gases by reacting it with an organic solvent. Suggest why the solvent is able to separate hydrogen sulfide from the other gases.

   ..... [1]

   d. Hydrogen sulfide is obtained from the solution by heating. It is then oxidised by oxygen to form sulfur and water. Complete the equation for this reaction.

   ..... $H_2S(g)$ + ... → ..... S(s) + ... [2]

2. **a.** What is the most important use of sulfur?

   ..... [1]

   b. Give two uses of sulfur dioxide other than the one you wrote in part **a**.

   .....

   ..... [2]

3. Sulfur dioxide is oxidised to sulfur trioxide in the atmosphere.

   a. How is acid rain formed from sulfur trioxide?

   ..... [1]

   b. Describe and explain the effect of acid rain on a building made of limestone.

   .....

   ..... [3]

   c. Describe one effect of acid rain on plants.

   ..... [1]

Extension

4. Sulfites are used as food preservatives. Use books or the internet to find out how sulfites react with acids and write an ionic equation for this reaction. [3]

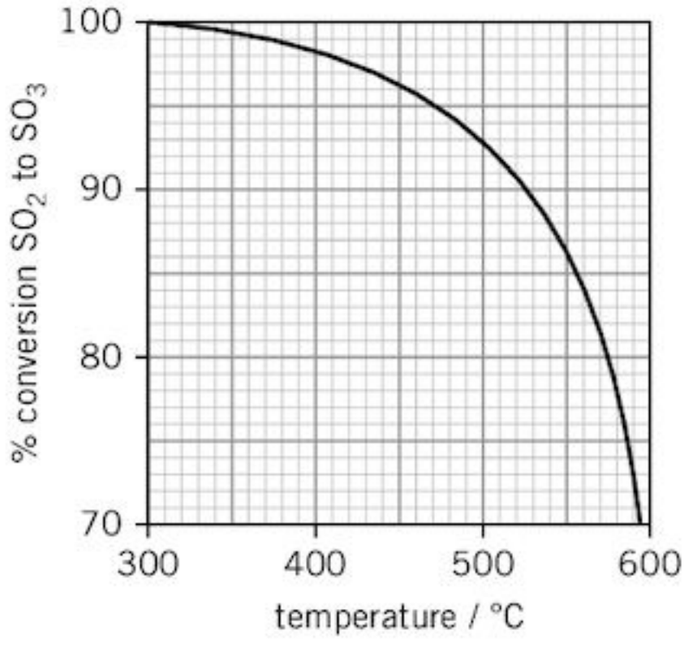
1. In the Contact process, sulfur dioxide is converted to sulfur trioxide in the presence of vanadium(V) oxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

a. What is the purpose of the vanadium(V) oxide?

..... [1]

b. The graph below shows the percentage conversion of SO_2 to SO_3 at different temperatures.
The pressure was just above atmospheric pressure.



i. Describe in detail the effect of temperature on the percentage conversion of SO_2 to SO_3.

.....

..... [2]

ii. Deduce the percentage conversion of SO_2 to SO_3 at 500 °C.

..... [1]

iii. How does the data in the graph show that the reaction is exothermic?

..... [1]

c. **i.** Predict the effect of increasing the pressure on this reaction. Explain your answer.

.....

..... [2]

ii. Explain why the reaction does not need to be carried out at high pressure.

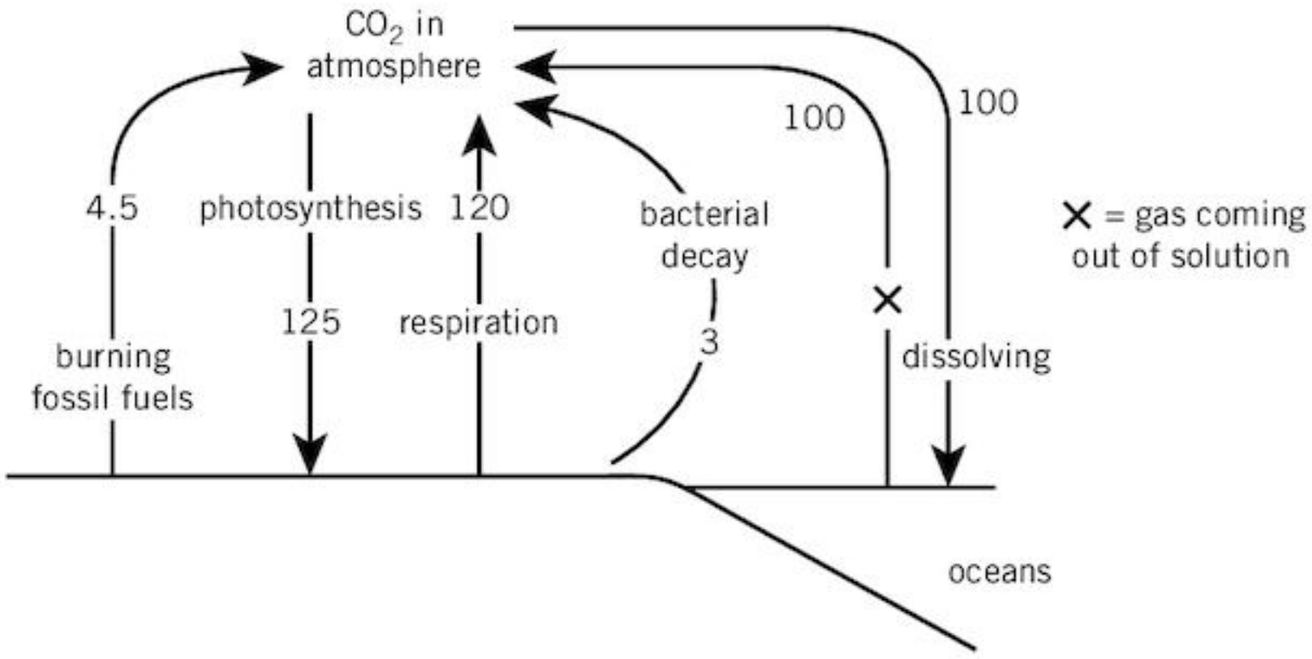
..... [1]

Extension

2. **a.** Construct a balanced equation for the reaction of concentrated sulfuric acid with carbon to form sulfur dioxide, carbon dioxide, and water. [2]

   b. Construct a balanced equation for the oxidation of hydrogen sulfide by concentrated sulfuric acid to form sulfur dioxide, sulfur, and water. [2]

1. The diagram shows the carbon cycle. The numbers are the relative amounts of carbon transferred per year.



a. What are the two main processes releasing carbon dioxide into the atmosphere?

..... [1]

b. What are the two main processes removing carbon dioxide from the atmosphere?

..... [1]

c. Comment on the balance between these processes.

.....

..... [2]

d. Gases dissolve better in cold water than hot water.

If the oceans get warmer, explain the effect this might have on the carbon cycle.

.....

..... [2]

e. Describe two other factors that might upset the balance of the carbon cycle.

.....

..... [2]

2. Write the word equation for photosynthesis and give the essential conditions.

Equation ..... [1]

Conditions ..... [2]

Extension

3. Use books or the internet to explain how the calcium carbonate shells of sea creatures are formed using dissolved carbon dioxide as a source. [4]

1. a. Link the carbon compounds **A** to **E** on the left with their descriptions **1** to **5** on the right.

A Carbonate	**1** Colourless, poisonous gas that is lighter than air.
B Carbon dioxide	**2** Colourless, slightly acidic gas that is heavier than air.
C Carbon monoxide	**3** Gas lighter than air that has a relative molecular mass of 16.
D Hydrogencarbonate	**4** A double charged anion found in chalk.
E Methane	**5** An ion with a single negative charge formed when CO_2 dissolves in water.

[3]

2. a. Finish these symbol equations for the **complete** combustion of methane and propane.

i. CH_4 + ...O_2 → ..... + ... [2]

ii. C_3H_8 + ... → ..... + ... [2]

b. Write symbol equations for the incomplete combustion of methane and propane to form carbon monoxide and water.

i. ..... [2]

ii. ..... [2]

c. What other substance may be formed when propane undergoes incomplete combustion?

..... [1]

3. When citric acid reacts with sodium hydrogencarbonate, the temperature falls and a citrate is formed.

i. Write a word equation for this reaction.

..... [1]

ii. What type of energy change is occurring?

..... [1]

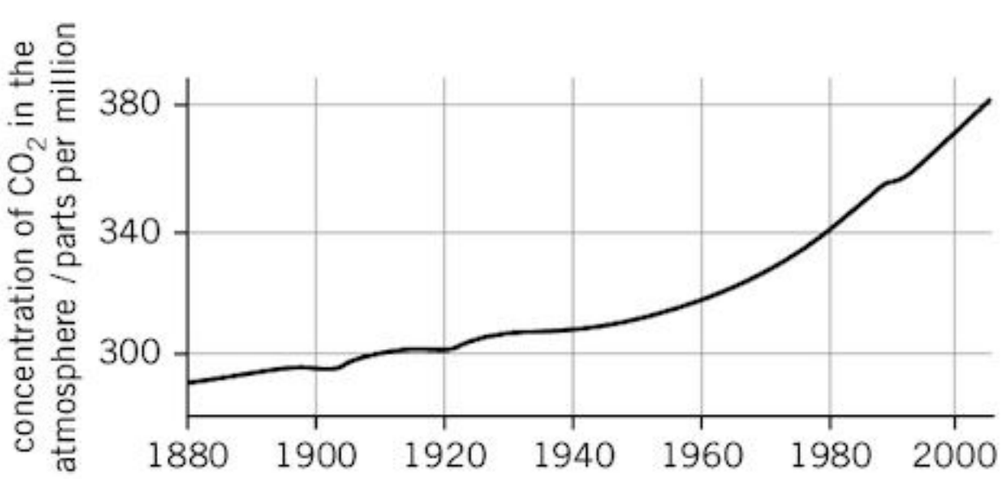
4. Calcium carbonate decomposes when heated. Write a symbol equation for this reaction.

..... [1]

Extension

5. Construct equations for the **complete** combustion of ethanol, C_2H_5OH, and the **complete** combustion of glucose, $C_6H_{12}O_6$. [4]

1. The graphs show the concentration of carbon dioxide in the atmosphere and the estimated global mean temperature over a period of 120 years.



a. Carbon dioxide is a greenhouse gas. What is the meaning of the term *greenhouse gas*?

..... [2]

b. How does the information from the graphs support the idea that carbon dioxide is a greenhouse gas?

.....

..... [2]

c. What evidence is there from these graphs that global warming might not be related to the concentration of carbon dioxide in the atmosphere?

.....

..... [2]

d. i. Give the name of the second most abundant greenhouse gas in the atmosphere.

..... [2]

ii. Give two sources of this gas.

..... [2]

2. The absorption of energy by greenhouse gases may lead to global warming.

Give three effects of global warming.

.....

.....

..... [3]

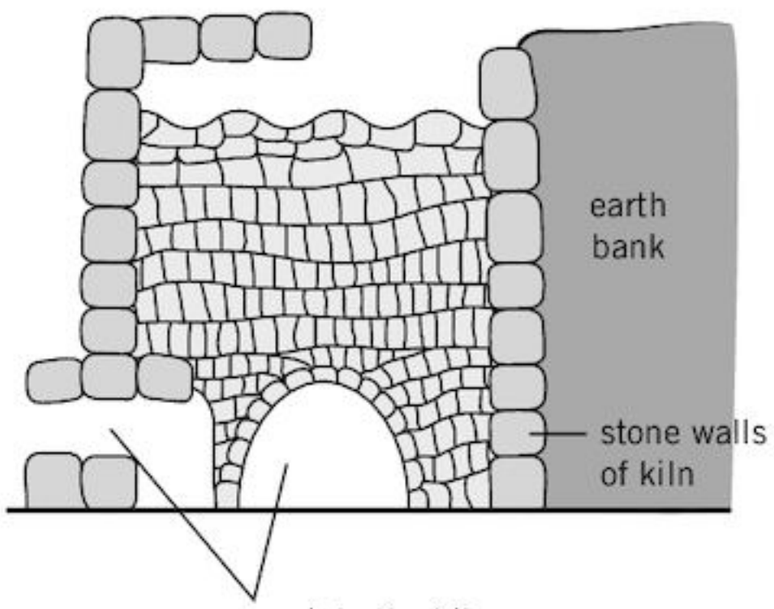
Extension

3. One suggestion for 'capturing' the carbon dioxide given off by industry is to use the reaction:

$$K_2CO_3(aq) + H_2O(l) + CO_2(g) \rightleftharpoons 2KHCO_3(aq)$$

Suggest how this might work to remove carbon dioxide and store the carbon so that it does not escape into the atmosphere. [4]

1. The diagram shows an old-fashioned kiln for making calcium oxide from calcium carbonate.



a. Put the following labels on the diagram:

T to show where the limestone is tipped into the kiln.

F to show where the fuel (coal) is being burnt. [2]

b. How does air get into the kiln and why is it needed?

.....

..... [3]

c. The walls of the kiln are made of granite. Granite is mainly a mixture of silicon dioxide and aluminium oxide. Why are the walls made of granite and not of limestone?

.....

..... [2]

d. The equation shows the thermal decomposition of calcium carbonate:

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

Explain why the backward reaction is unlikely to occur in the lime kiln.

.....

..... [3]

2. Flue gas desulfurisation is a process that removes sulfur dioxide from waste gases in power stations. Explain how this process works.

.....

.....

..... [4]

Extension

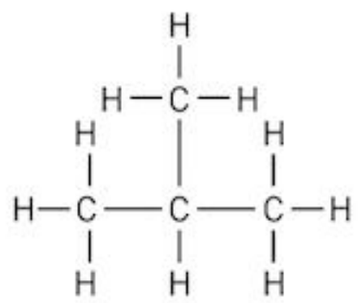
3. When you bubble carbon dioxide through limewater, the limewater first goes cloudy (milky) and then the cloudiness disappears. Use books or the internet to help you explain these observations. [4]

1. Petroleum is a fossil fuel. Name two other fossil fuels.

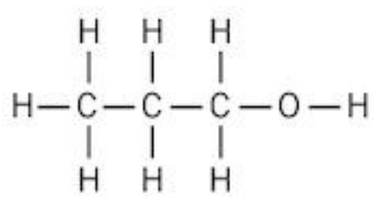
..... [2]

2. The full structural formulae (displayed formulae) of some organic compounds are shown below.

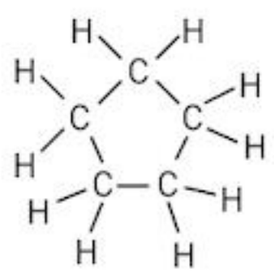
A



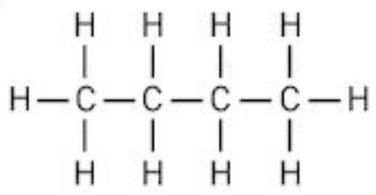
B



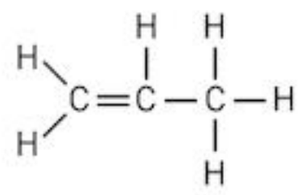
C



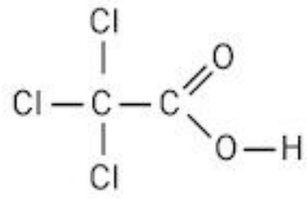
D



E



F



a. Which of these compounds are hydrocarbons? Explain why.

.....

..... [2]

b. Which of these compounds are most likely to be found in petroleum?

..... [1]

c. **i.** Which one of these compounds is a branched-chain compound? ..... [1]

ii. Which one of these compounds is a ring compound? ..... [1]

d. The molecular formula of compound **A** is C_4H_{10}.

Deduce the molecular formulae of compounds **B** to **F**.

B ..... **C** .....

D ..... **E** .....

F ..... [5]

3. Petrol can be made from coal using the following route:

A coal	→	**B** decomposition using heat and hydrogen	→	**C** refining based on boiling point	→	**D** petrol

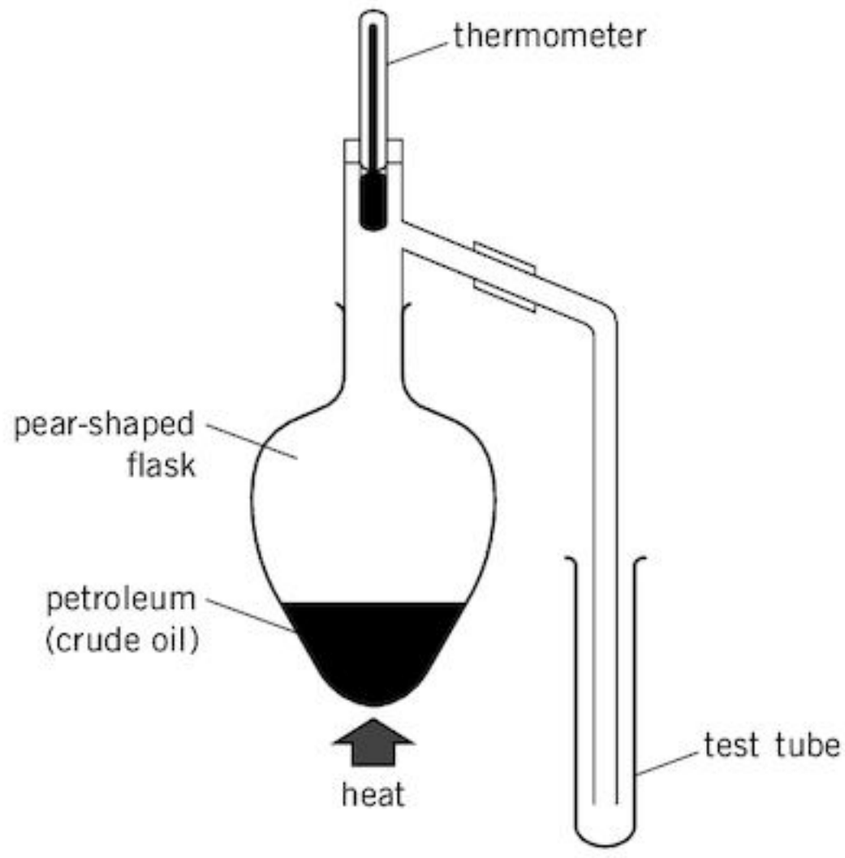
a. Which stage, **A**, **B**, **C**, or **D**, involves distillation? ..... [1]

b. Which stage involves reduction? ..... [1]

Extension

4. Petroleum contains a number of aromatic hydrocarbons. Use books or the internet to describe the main features of aromatic hydrocarbons. Give the name of two aromatic hydrocarbons. [4]

1. The diagram shows a simple experiment to separate petroleum fractions.



Describe how you could use this apparatus to separate the hydrocarbon fractions.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [4]

2. The table shows some properties of the different petroleum fractions.

Fraction	Boiling point range / °C	Size of molecules	Volatility	Ease of flow	Ease of burning
1	up to 100				
2	100–150				
3	150–200				
4	200–300				

a. In the third column draw an arrow to show how the size of the molecules varies with the boiling point range (low → high). [1]

b. **i.** Some compounds are volatile. What is the meaning of the term volatile?

..... [1]

ii. In the fourth column draw an arrow to show how the volatility of the compounds varies with the boiling point range (low → high). [1]

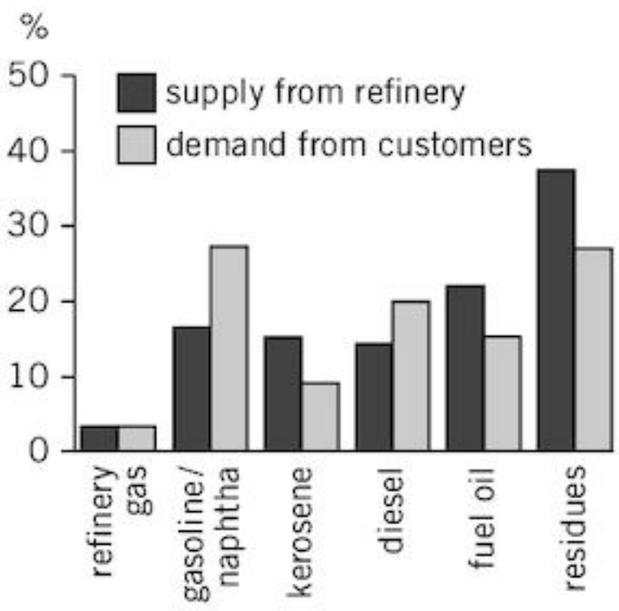
c. In the fifth column draw an arrow to show how the viscosity ('syrupiness') of the compounds varies with the boiling point range (flows easily → flows less easily). [1]

d. In the sixth column draw an arrow to show how the ease of burning of the compounds varies with the boiling point range (difficult → easy). [1]

Extension

3. Use ideas of molecular size and intermolecular forces to explain how fractional distillation separates a mixture of compounds into different fractions. [5]

1. The bar chart shows the supply and demand for different petroleum fractions.



a. Which of the fractions shown has molecules with the longest chains?

..... [1]

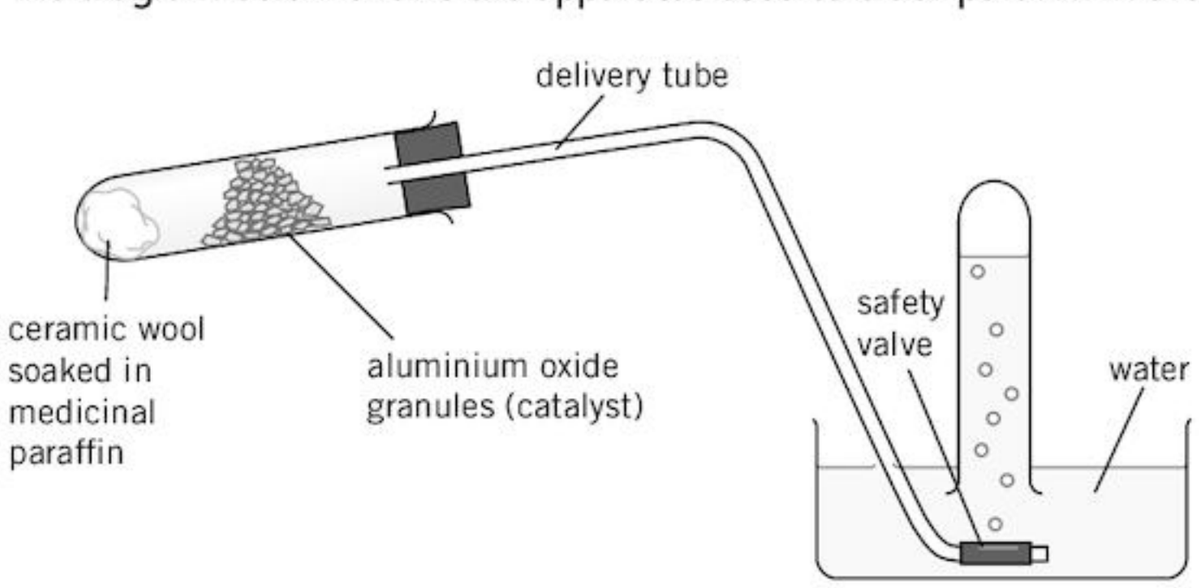
b. **i.** For which fractions is the demand much greater than the supply?

..... [1]

ii. For which fractions is the supply much greater than the demand?

..... [1]

2. The diagram below shows the apparatus used to crack paraffin in the laboratory.



a. Put the letter **P** on the diagram to show where the gaseous product is collected. [1]

b. On the diagram, draw two arrows to show where the apparatus should be heated. [2]

3. Complete these equations for cracking.

a. $C_{10}H_{22} \rightarrow C_4H_{10} +$ ..... [1]

b. $C_{14}H_{30} \rightarrow C_3H_8 + C_4H_8 +$ ..... [1]

Extension

4. Explain why it is less likely that oil companies will crack fractions containing hydrocarbons with the formulae C_8H_{18} and $C_{33}H_{68}$ than other fractions. [4]

1. **a.** What is meant by the term **homologous series**?

.....

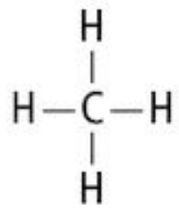
..... [2]

b. To which homologous series do these compounds belong?

Propene ..... Butanol .....

Hexane ..... Propanoic acid ..... [4]

2. Complete the table to show the formulae and structures.

Name of compound	Molecular formula	Simplified structural formula	Full structural formula
methane			
propane	C_3H_8	$CH_3CH_2CH_3$	
propanol		$CH_3CH_2CH_2OH$	
ethanoic acid			
butene		$CH_3CH{=}CHCH_3$	

[10]

Extension

3. Write general formulae for the alkenes, alcohols, and the homologous series which includes $CH_3CH_2NH_2$ and $CH_3CH_2CH_2CH_2NH_2$. [3]

1. Complete these sentences about alkanes.

   a. Alkanes are ..... because they only have hydrogen and carbon atoms in their structure. [1]

   b. All the bonds in alkanes are .... bonds. [2]

   c. Alkanes do not decolourise aqueous bromine. This shows that they are ..... hydrocarbons. [1]

   d. Alkanes are generally unreactive except for ..... and reaction with ..... [2]

2. Name the alkanes with unbranched chains of:

   a. Five carbon atoms ..... [1]

   b. Four carbon atoms ..... [1]

   c. Eight carbon atoms ..... [1]

3. How do the boiling points of the alkanes change with relative molecular mass?

   ..... [1]

4. Complete these equations for the typical reactions of alkanes.

   a. C_5H_{12} + ... O_2 → ..... CO_2 + ... H_2O [2]

   b. CH_4 + Cl_2 → ..... + HCl [1]

5. Which two words describe the reaction in **4. b.**? Put rings around the correct answers.

   addition cracking neutralisation photochemical polymerisation substitution [2]

6. **a.** Draw two isomers of the hydrocarbon with the formula C_5H_{12}. [2]

Extension

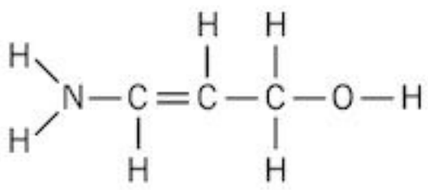
b. Draw all the isomers of the hydrocarbon with the formula C_6H_{14}. [3]

1. The table gives some information about the alkenes. Complete the table in the spaces provided.

Name of alkene	Molecular formula	Boiling point / °C
ethene	.....	–102
.....	C_3H_6	.....
.....	.....	–7
pentene	.....	30

[6]

2. The structure of compound **T** is shown below.

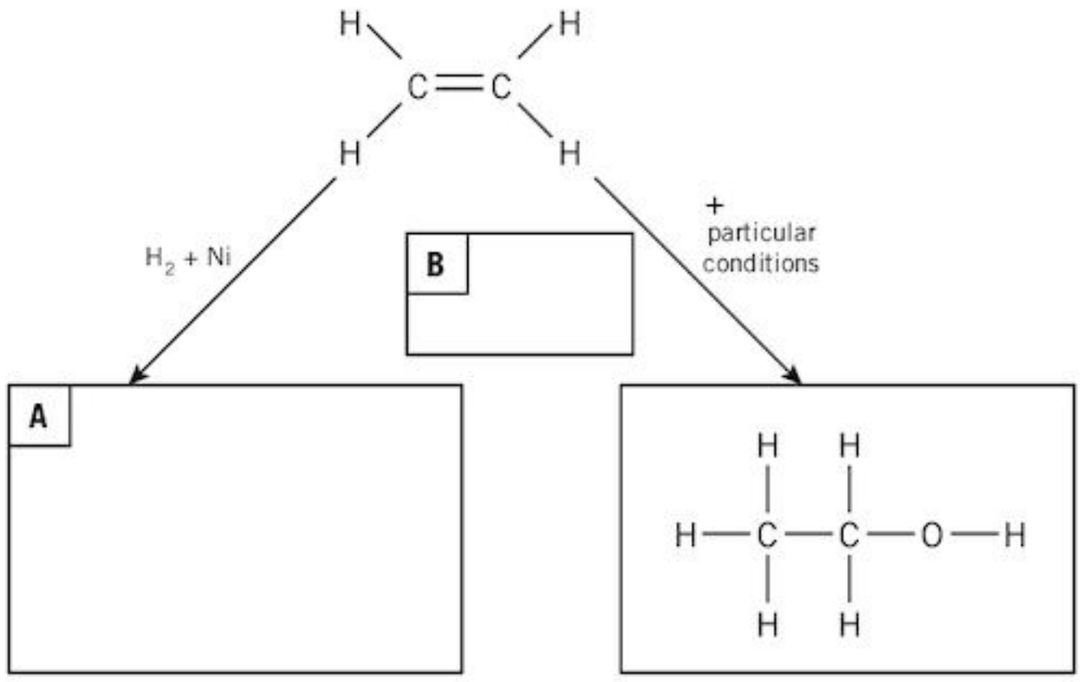


a. On the structure of **T** above draw a ring around the functional group which makes this compound unsaturated. [1]

b. An excess of compound **T** is added to a few drops of aqueous bromine in a test tube. Predict the colour change of the mixture in the test tube.

From ..... to ..... [2]

3. **a.** Complete the boxes in the diagram below to show the structure of **A** and formula of the additional reagent **B** including the state symbol. [2]



b. State the particular reaction conditions to form C_2H_5OH.

..... [3]

Extension

4. Draw three isomers of the compound with the molecular formula C_4H_8. [3]

1. **a.** Ethanol can be manufactured by fermentation or by hydration of ethene.

Complete the table about these reactions.

	Fermentation	Hydration of ethene
reagents needed		
temperature / °C		
pressure		
catalyst		

[8]

b. Give two disadvantages of producing ethanol by fermentation.

.....

..... [2]

c. Give two advantages of producing ethanol by fermentation.

.....

..... [2]

d. Give two advantages of producing ethanol by hydration of ethene.

.....

..... [2]

2. **a.** Complete the equation for the complete combustion of butanol.

C_4H_9OH + ... O_2 → ..... CO_2 + ... H_2O [2]

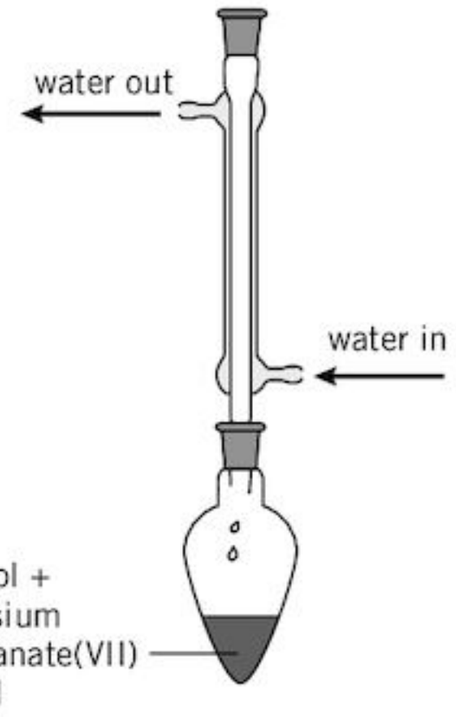
b. Draw and label a diagram of the apparatus you could use to compare the energy released by burning different alcohols. [5]

Extension

3. Calculate the mass of water formed when 9.2 g of ethanol burns in excess air. (A_r values H = 1, C = 12, O = 16)

C_2H_5OH + $3O_2$ → $2CO_2$ + $3H_2O$ [4]

1. The diagram shows the apparatus used to convert ethanol to ethanoic acid.



   a. On the diagram, draw an arrow to show where heat is applied. [1]

   b. What type of reagent is the potassium manganate(VII)?

   ..... [1]

   c. What colour change would you expect to see if the potassium manganate(VII) was not in excess?

   from .....

   to ..... [2]

   d. Why is the condenser in the upright position?

   .....

   .....

   ..... [2]

2. Ethanoic acid ionises in water.

   $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$

   a. How does this equation show that ethanoic acid is a weak acid?

   .....

   ..... [2]

   b. Explain why water is acting as a base in this reaction.

   ..... [2]

3. Complete these equations for some reactions of ethanoic acid.

   a. ..... CH_3COOH + ... Na → ..... + ... [3]

   b. ..... CH_3COOH + Mg → ..... + ... [3]

   c. CH_3COOH + NaOH → ..... + ... [2]

   d. ..... + ... → CH_3COOCH_3 + ... [3]

Extension

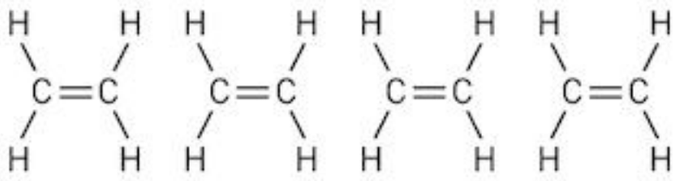
4. Write formulae for the esters **a.** ethyl butanoate and **b.** propyl methanoate. [2]

1. Complete the following sentences about polymers using words from the list.

addition bonds ethene join molecules monomers other polymerisation

A polymer is a substance that has very large ..... formed when lots of small molecules called ..... join together. This process is called ..... . When poly(ethene) is formed, one of the C=C ..... of ..... is broken and the monomers ..... together in a chain. A reaction in which two or more molecules join and no ..... molecule is formed is called an ..... reaction. [8]

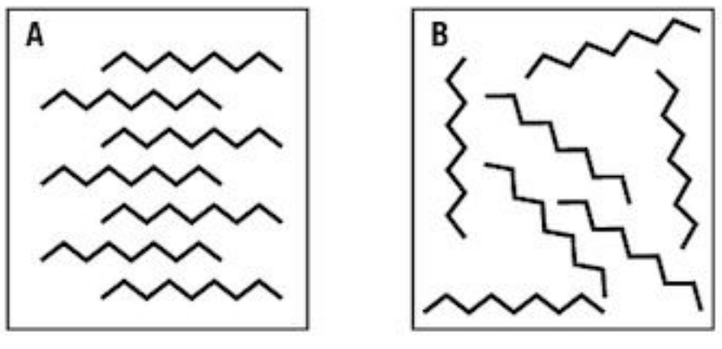
2. In the box below draw a section of the polymer chain formed by the addition of four units of ethene monomers.



↓

[2]

3. The diagram below shows two types of poly(ethene). The zig-zag lines are the chains of the polymers.



Which polymer, **A** or **B**, has the lower density? Explain your answer.

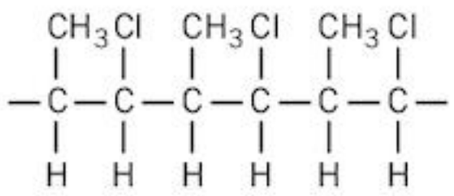
.....

..... [2]

Extension

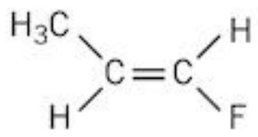
4. 56 kg of ethene was converted to poly(ethene). Each chain of poly(ethene) contains an average of 20 000 carbon atoms. Calculate the approximate number of moles of poly(ethene) formed. (A_r values H = 1, C = 12) [4]

1. The diagram shows an addition polymer.



a. Draw brackets round the repeat unit of this polymer. [1]

b. The structure of a monomer is shown below.

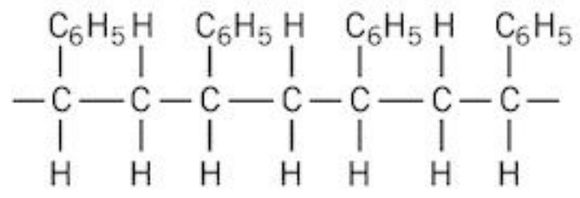


Draw a section of the polymer chain formed from this monomer. Show three repeat units. [3]

c. Draw the structure of the polymer formed from but-2-ene, $CH_3–CH=CH–CH_3$, as one repeat unit of this polymer with brackets and *n*. [3]

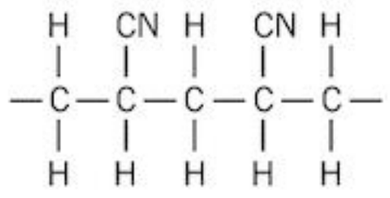
2. Draw the monomers of polymers **A** and **B**.

A



Monomer A

B



Monomer B

[4]

Extension

3. Write the equation for the formation of the polymer of ethyl ethenoate, $CH_2=CH(OOCCH_3)$. Show one unit of the polymer with brackets and *n*. Hint: you first have to work out the full structure of the ethyl ethenoate molecule. [3]

18.3 Condensation polymerisation

1. Complete these sentences about condensation polymerisation using words from the list.

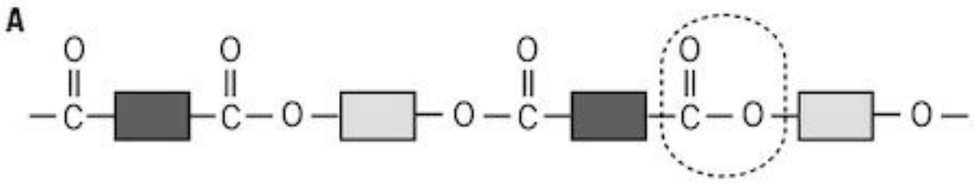
chloride **eliminated** **functional** **small** **water**

In condensation polymerisation, molecules with different ..... groups react together.

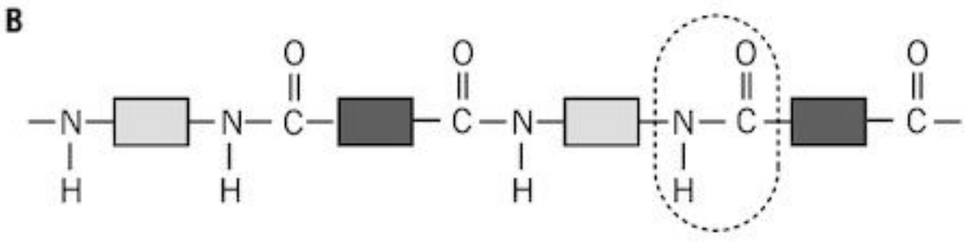
A ..... molecule such as ..... or hydrogen ..... is ..... [5]

2. The diagram shows two polymers, **A** and **B**.

A



B

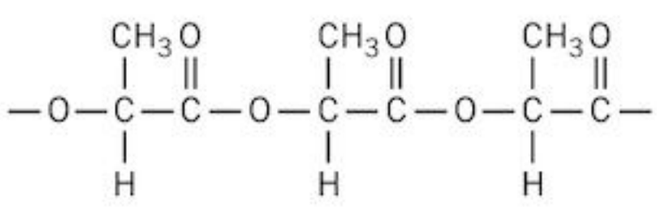


a. On each of the diagrams above put brackets to show one repeat unit. [2]

b. Give the name of the linking group in

i. Polymer **A** ..... **ii.** Polymer **B** ..... [2]

3. The structure of poly(lactic acid) is shown below.



a. Give the names of the two functional groups that react to form this polymer.

..... and ..... [2]

b. Draw the structure of the single monomer that is used to form this polymer. [2]

Extension

4. Deduce the structure of one repeat unit of the polymer formed from these two monomers: $HOOC–(CH_2)_3–COOH$ and $H_2N–(CH_2)_6–NH_2$.

1. a. Link the properties of plastics **A** to **E** on the left with the best uses **1** to **5** on the right.

A Most plastics don't conduct electricity	**1** ..... so they can be used for food containers.
B Plastics do not react with acids	**2** ..... so they can be used as insulators.
C Plastics have a low density	**3** ..... so they can be used to make bags.
D Plastics are flexible	**4** ..... so they can be used to make climbing ropes.
E Many plastics are strong	**5** ..... so they can be used to make storage boxes.

[3]

b. Give one use for each of these polymers:

i. Nylon ..... [1]

ii. Poly(ethene) ..... [1]

2. Suggest which properties of plastics are suitable for:

a. A drink bottle .....

..... [3]

b. A fishing line .....

..... [3]

3. The strength of a plastic depends on the strength of the intermolecular forces between the chains and how tangled (muddled up) the chains become.

The graph shows how the strength of a plastic depends on the length of the polymer chains.

Suggest reasons for the shape of this graph.

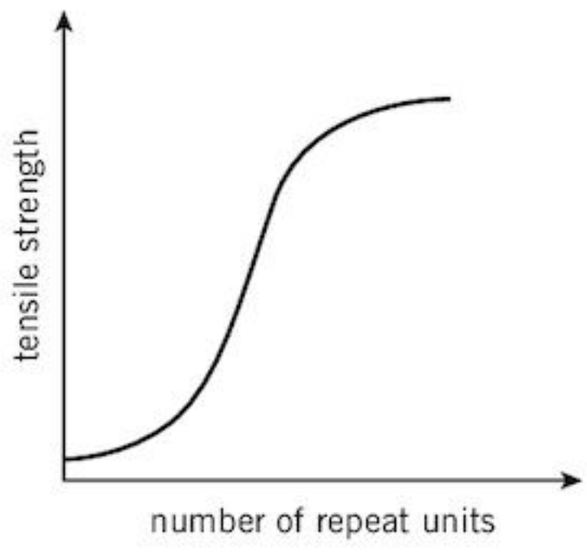
.....

.....

.....

.....

..... [2]



Extension

4. Use books or the internet to find out the difference between thermoplastics and thermosetting plastics in terms of structure and uses. [6]

1. Many plastics are non-biodegradable.

   What is meant by the term non-biodegradable?

   .....

   ..... [2]

2. We can get rid of waste plastics by recycling, through landfill sites, or by burning them.

   a. Give two advantages of recycling plastics.

   .....

   ..... [2]

   b. State two problems with recycling plastics.

   .....

   ..... [2]

   c. Give two advantages of putting plastics in landfill sites.

   .....

   ..... [2]

   d. Give one advantage of burning plastics.

   .....

   ..... [1]

3. a. Suggest pollution problems other than global warming that might arise when the following plastics are burnt.

      i. A plastic with the structure $-CH_2-CHCl-CH_2-CHCl-$

      ..... [1]

      ii. A synthetic rubber containing sulfur atoms.

      ..... [1]

   b. i. What substances are formed when poly(ethene) is burnt in excess air?

      ..... and ..... [1]

      ii. Polyethene usually burns with a black-edged flame. Explain why.

      .....

      ..... [2]

Extension

4. Use books or the internet to find out why plasticisers are added to plastics, how they work, and what problems might be associated with them. [5]

18.6 The macromolecules in food (1)

1. Complete these sentences about macromolecules in food using words from the list.

catalysed **enzymes** **monomers** **polymerised** **starch** **sugar** **water**

Plants make a ..... called glucose from carbon dioxide and ..... by photosynthesis.

In plant cells glucose ..... are ..... to make ..... and cellulose.

This polymerisation is ..... by proteins called ..... . [7]

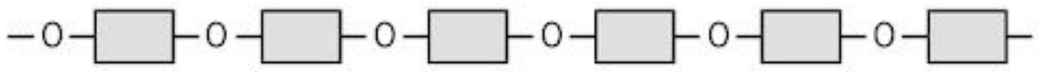
2. **a.** The structure below represents a molecule of glucose.

Glucose is a monosaccharide.

Draw block diagram structures of a disaccharide and a trisaccharide in the space below.

Disaccharide Trisaccharide [2]

b. The diagram below shows part of a starch molecule.



i. How many repeat units are shown? ..... [1]

ii. What type of polymerisation has taken place when starch is formed from glucose?

..... [1]

3. The diagram shows a block diagram of fructose.

Draw a diagram to show part of the polymer of fructose. Show four repeat units. [3]

Extension

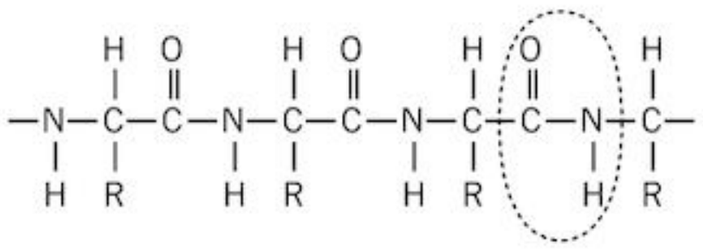
4. Glucose is a good reducing agent. Describe its reducing action with Fehling's solution and with ammoniacal silver nitrate. Use books or the internet to help you. [4]

1. Complete these sentences about amino acids and proteins using words from the list.

amine condensation nitrogen oxygen sulfur twenty

All amino acids contain carbon, hydrogen, ..., and ..... Two simple amino acids found in proteins contain ..... as well. Proteins are ..... polymers formed by the reaction of carboxylic acid and ..... groups from amino acids. Most proteins are formed by the polymerisation of about ..... types of amino acids. [6]

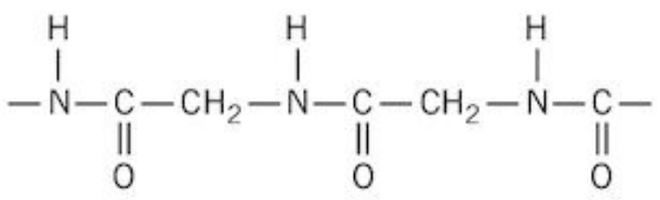
2. The diagram below shows part of a protein.



a. On the diagram above, put brackets to show one repeat unit. [1]

b. Give the name of the linking group. ..... [1]

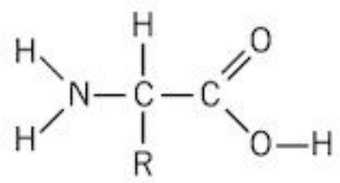
3. The structure of part of poly(glycine) is shown below.



Deduce the structure of the monomer which is used to form this polymer. [2]

Extension

4. The general structure of an amino acid is shown on the right. Draw a diagram to show the two possible compounds obtained when the amino acid cysteine reacts with the amino acid alanine. The R group of cysteine is $-CH_2SH$. The R group of alanine is $-CH_3$. [3]



1. Hydrolysis reactions occur naturally in the body using enzymes.

   a. What is an enzyme?

   ..... [2]

   b. What is the meaning of the term hydrolysis?

   ..... [2]

   c. Complete the word equations for these two examples of hydrolysis.

   i. protein + ... → .... [1]

   ii. starch + ... → ..... [1]

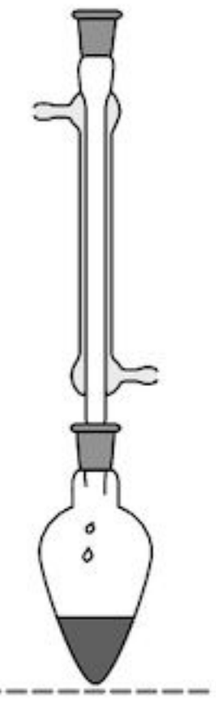
   d. Hydrolysis of proteins and carbohydrates can also be carried out in the laboratory.

   Complete the table to compare hydrolysis in the body with hydrolysis in the laboratory.

	Hydrolysis in the body	Hydrolysis in the laboratory
temperature		
pressure		
catalyst		
reaction fast or slow?		

[8]

2. The diagram shows the apparatus used for hydrolysing proteins.



   a. Put arrows on the diagram to show where water enters the condenser and where it goes out. [1]

   b. Why is the condenser in the vertical position?

   .....

   .....

   ..... [2]

Extension

3. Fats are an essential part of our diet. What are fats chemically and how can they be converted to soaps in the laboratory? Use books or the internet to help you. [5]

19.1 Chemistry: a practical subject

When planning an experiment, you have to think about what things you can change (the variables) and what things you can measure.

- The variable that you choose the values for is the *independent variable*, e.g. 10 s, 20 s, 30 s, and so on.
- The variable that you measure at each of these values is the *dependent variable,* e.g. 15 cm^3 gas at 10 s, 28 cm^3 gas at 20 s, and so on.
- All the other values, which have to be kept constant to make the experiment a fair test, are the *control variables*.

Identify the three types of variable in each of these experiments.

1. The effect of temperature on the rate of reaction of hydrochloric acid with calcium carbonate by measuring the volume of carbon dioxide released at 10 s intervals.

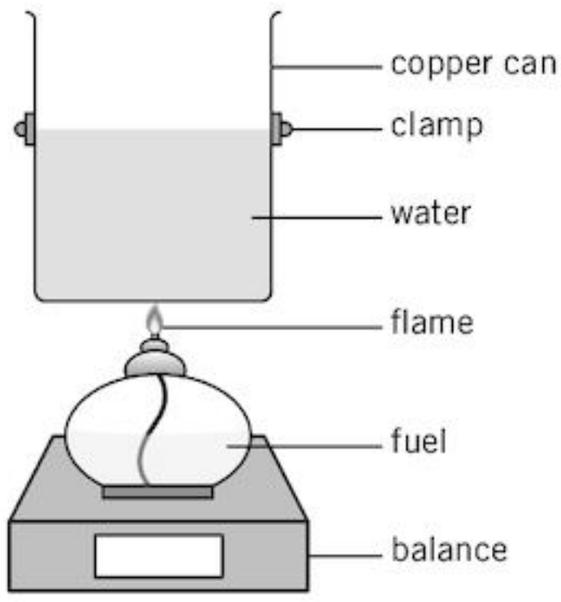
   a. Independent variable: ..... [1]

   b. Dependent variable: ..... [1]

   c. Control variables: .....

   ..... [2]

2. The energy released by burning different fuels was compared by measuring the temperature rise of the water in the copper can when 1 g of fuel was burnt.



   a. Independent variable: ..... [1]

   b. Dependent variable: ..... [1]

   c. Control variables: .....

   ..... [2]

Extension

3. During the electrolysis of aqueous copper(II) sulfate using copper electrodes, copper is removed from the anode. The amount removed depends on the electric current and the time.

$$\text{mass removed} = \text{constant} \times \text{current (amps)} \times \text{time (seconds)}$$

A student wanted to find out how the electric current and time affected the mass of copper removed. Identify the independent variable, the dependent variable, and the control variables. [4]

19.2 Example of an experiment

Many salts increase in solubility as the temperature increases. Plan an experiment to see if this is true using the salt potassium chloride as an example. This exercise guides you through the stages in this experiment.

1. Planning:

   a. What apparatus do you need?

   .....

   ..... [5]

   b. What are the independent and dependent variables?

   .....

   ..... [2]

   c. What will you keep constant?

   .....

   ..... [2]

2. Carrying out:

   Describe how you will carry out the experiment. Give possible volumes and masses of the substances used.

   .....

   .....

   .....

   .....

   ..... [5]

3. Evaluation:

   a. Explain why it might be difficult to control the temperature.

   .....

   ..... [2]

   b. Suggest improvements that you could make to the experiment.

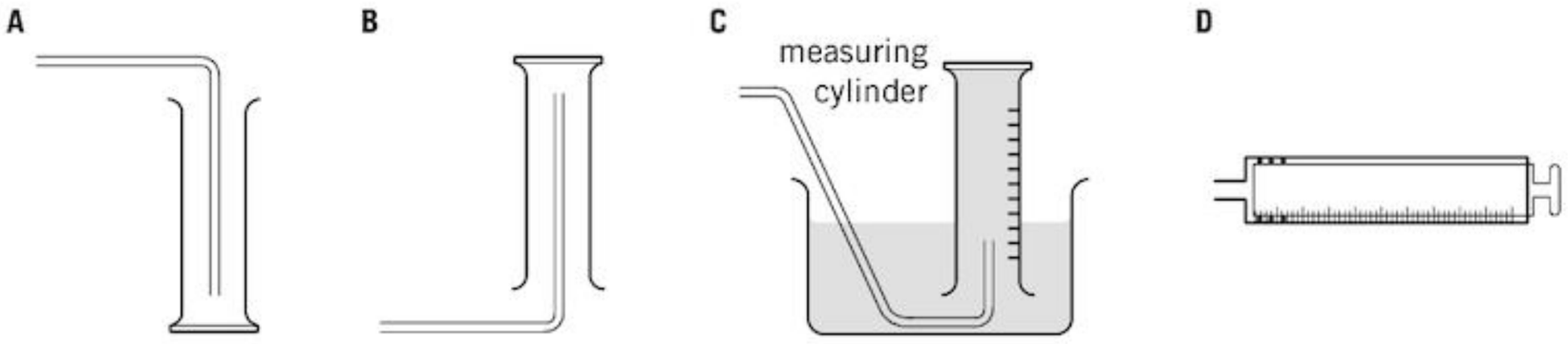
   .....

   ..... [2]

Extension

4. Suggest why scientists publish their results in scientific journals. [3]

1. The diagram shows four ways of collecting gases in the laboratory.



Which method of gas collection, **A**, **B**, **C**, or **D**, is used for the following?

a. Measuring the volume of a gas that is sparingly soluble in water ..... [1]

b. Collecting a gas that is lighter than air ..... [1]

c. Measuring the volume of a gas accurately ..... [1]

d. Collecting a gas that is heavier than air ..... [1]

2. Which method of gas collection, **A**, **B**, **C**, or **D**, involves the following?

a. Upward displacement of air ..... [1]

b. Collection in a gas syringe ..... [1]

3. Link the gases **A** to **F** on the left with the best test results **1** to **6** on the right.

A Ammonia	**1** Relights a glowing splint.
B Carbon dioxide	**2** Turns damp red litmus paper blue.
C Chlorine	**3** Turns acidified aqueous potassium manganate(VII) colourless.
D Hydrogen	**4** Turns limewater milky.
E Oxygen	**5** Bleaches damp litmus paper.
F Sulfur dioxide	**6** 'Pops' with a lighted splint.

[3]

Extension

4. Are these gases soluble in water, insoluble in water, or slightly soluble in water?

a. carbon dioxide **b.** sulfur dioxide **c.** carbon monoxide **d.** oxygen **e.** hydrogen bromide
f. hydrogen sulfide **g.** hydrogen [7]

19.4 Testing for cations

1. Complete the table showing what happens when the following aqueous ions react with aqueous sodium hydroxide and aqueous ammonia.

Aqueous ion	Reaction with sodium hydroxide	Reaction with aqueous ammonia
$Al^{3+}(aq)$	At first .... In excess	At first .... In excess ....
$Cr^{3+}(aq)$	At first .... In excess	At first .... In excess ....
$Cu^{2+}(aq)$	At first .... In excess	At first .... In excess ....
$Fe^{3+}(aq)$	At first .... In excess	At first .... In excess ....

[16]

2. Aqueous zinc ions and calcium ions both give a white precipitate on addition of a small amount of aqueous sodium hydroxide. Describe how you could distinguish between these two ions.

.....

..... [2]

3. What colour do these ions give to a non-luminous (blue) Bunsen flame?

a. lithium ..... **b.** potassium ..... [2]

Extension

4. Write ionic equations for these reactions. Include state symbols.

a. The reaction of aqueous iron(II) sulfate with aqueous sodium hydroxide. [3]

b. The reaction of aqueous aluminium chloride with excess aqueous sodium hydroxide. [3]

19.5 Testing for anions

1. Link the anions **A** to **E** on the left with the best test results **1** to **5** on the right.

A Aqueous bromide ions	**1** Ammonia produced when heated with sodium hydroxide and aluminium foil.
B Carbonate ions	**2** White precipitate formed on addition of aqueous nitric acid and barium nitrate.
C Aqueous nitrate ions	**3** SO_2 produced when warmed with dilute hydrochloric acid.
D Sulfite ions	**4** Effervescence of carbon dioxide on the addition of an acid.
E Aqueous sulfate ions	**5** Cream precipitate on addition of aqueous nitric acid and silver nitrate.

[3]

2. **a.** Write a symbol equation for the reaction of aqueous silver nitrate with aqueous sodium chloride. Include state symbols.

..... [2]

b. Convert this equation into an ionic equation.

..... [2]

3. Compound **A** was warmed with aluminium and sodium hydroxide. A gas was given off which turned damp red litmus blue.

When compound **B** was electrolysed, a gas was released at the anode which bleached damp litmus paper. **B** also gave a yellow colour in the flame test.

When an aqueous solution of **A** was added to an aqueous solution of **B**, a white precipitate was formed.

Identify compounds **A** and **B**. Explain your answers.

.....

.....

.....

.....

..... [4]

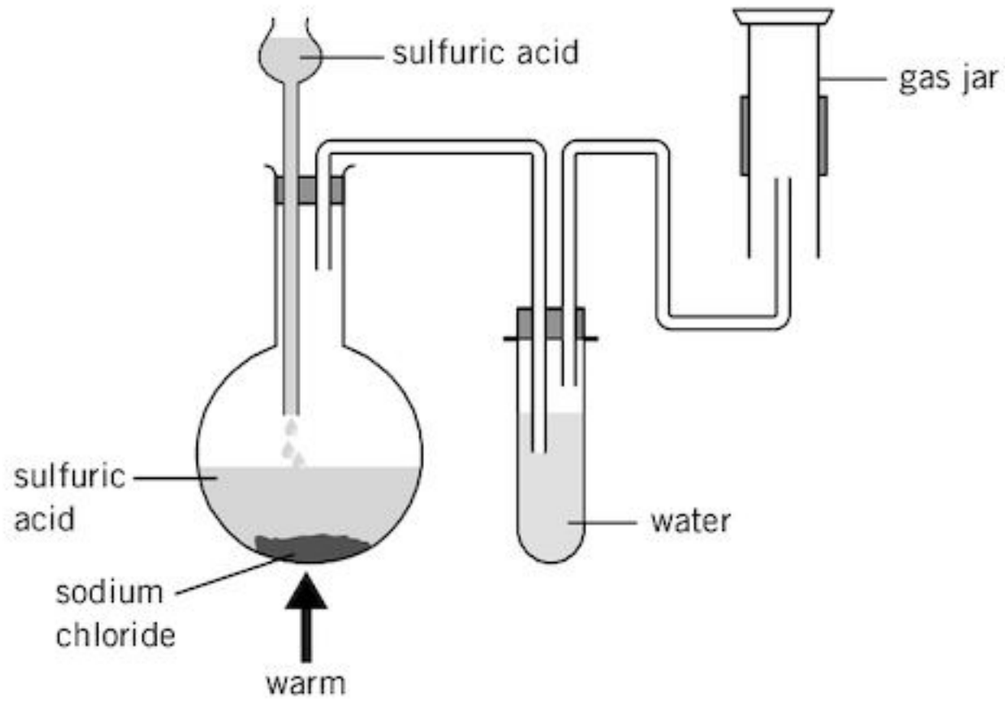
Extension

4. Write ionic equations, including state symbols, for these reactions.

a. The reaction of aqueous barium chloride with aqueous potassium sulfate. [2]

b. The reaction of sulfite ions with hydrogen ions. [3]

1. The apparatus below was used to prepare hydrogen chloride gas. Identify and explain three errors.



.....

.....

.....

.....

..... [6]

2. Crystals of zinc sulfate can be prepared by adding pieces of zinc to warm dilute sulfuric acid until the zinc is in excess.

   a. Explain why the zinc was added a little at a time.

   .....

   ..... [2]

   b. On the right, draw a labelled diagram of the apparatus used to separate excess zinc from a solution of zinc sulfate and zinc. [3]

   c. Describe how you could make crystals of zinc sulfate from a solution of zinc sulfate.

   .....

   .....

   ..... [2]

Extension

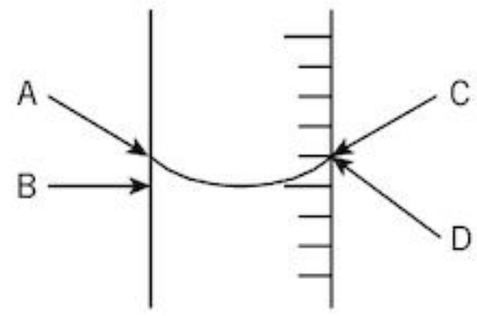
3. Use books or the internet to find out how sulfur dioxide could be prepared in a school laboratory. [5]

1. Accurate results are close to the true value. State two things that will help you get accurate results.

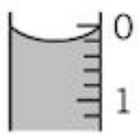
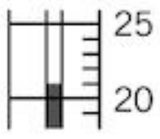
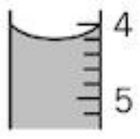
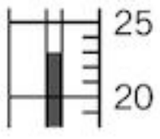
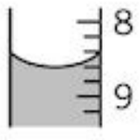
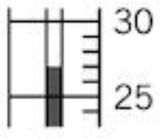
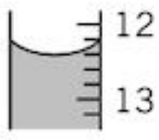
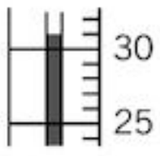
.....

..... [2]

2. The diagram on the right shows part of a burette. Where should you position your eye (direction **A**, **B**, **C**, or **D**) to get a precise reading? Ring the correct answer.



3. A student added aqueous 2.0 mol/dm³ hydrochloric acid from a burette to 20 cm³ of a solution of sodium hydroxide in a flask. After each addition of acid, the temperature of the mixture in the flask was measured. Complete the table below by taking the thermometer and burette readings.

Burette diagram	Total volume of acid added / cm³	Thermometer diagram	Maximum temperature / °C
			
			
			
			

[4]

Extension

4. Use books or the internet to find out the difference between accuracy and precision. [2]

1. A flask containing 0.25 mol/dm^3 hydrochloric acid was placed on a digital balance and excess calcium carbonate was added. The balance was immediately set to zero and the readings of decrease in mass were taken every 10 seconds.

   The total decrease in mass at each 10-second interval is given below.

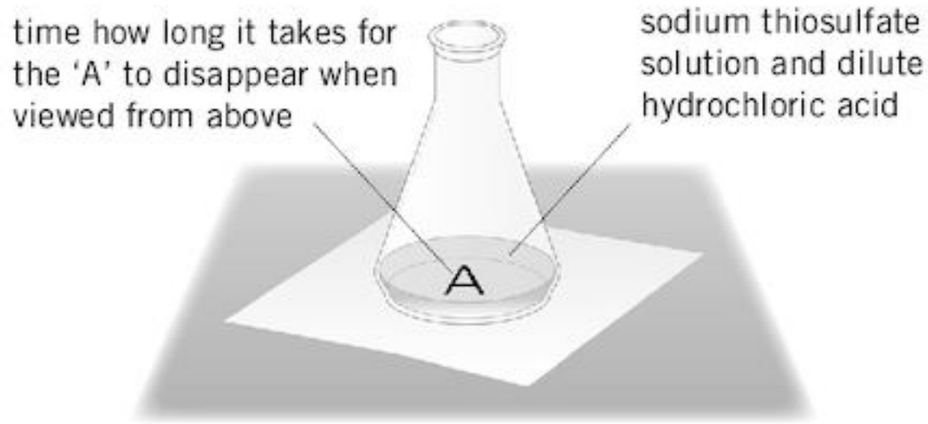
   start 0.0 g, 0.50 g, 0.89 g, 1.24 g, 1.44 g, 1.56 g, 1.68 g, 1.79 g, 1.82 g, 1.82 g

   The results from a repeat experiment are:

   start 0.0 g, 0.72 g, 1.04 g, 1.24 g, 1.44 g, 1.52 g, 1.62 g, 1.74 g, 1.78 g, 1.78 g

   Draw a suitable table to display these results and obtain an average value of the change in mass loss. [4]

2. The apparatus shown below can be used to show how reaction rate changes with temperature for the reaction between sodium thiosulfate and hydrochloric acid.



   As the reaction proceeds a precipitate of sulfur is made, which gradually makes the letter 'A' disappear.

   The rate is proportional to $\frac{1}{\text{time taken for the letter 'A' to disappear}}$.

   Draw the headings of a suitable table to enable you to record the results of the experiment at different temperatures. [2]

Extension

3. Calculate the maximum volume of carbon dioxide formed in question **1.** when the reaction was complete. [3]

1. • A number in front of a formula unit multiplies all the way through.

   • The number can refer to atoms or ions or moles of atoms or moles of ions.

   So 2NaCl contains two sodium ions and two chloride ions, and 5CO contains five carbon atoms and five oxygen atoms.

   • A small subscript number after an atom or ion refers only to that atom or ion.

   So $CaCl_2$ contains one calcium ion and two chloride ions, and in Al_2O_3 there are two aluminium ions and three oxygen ions.

   In $3SO_3$ there are three sulfur atoms and $3 \times 3 = 9$ oxygen atoms.

   How many atoms of each element are there in the formulae shown?

   a. Na_2O ..... **b.** Mg_3N_2 .....

   c. $5PCl_3$ ..... **d.** $2Al_2O_3$ .....

   e. $4H_2SO_4$ .....

   f. $3Li_2CO_3$ ..... [6]

2. Using brackets:

   • Brackets keep particular groups of atoms together, for example (NO_3) for nitrates, (OH) for hydroxides.

   • You must not change the numbers within the brackets.

   • A subscript after a bracket multiplies all through the atoms inside the brackets.

   So $Mg(NO_3)_2$ contains one magnesium ion and two nitrate (NO_3^-) ions.

   In $2NO_3^-$ ions there are 2 N atoms and $2 \times 3 = 6$ O atoms.

   And in $4Mg(NO_3)_2$ there are 4 Mg ions, $4 \times 2 = 8$ N atoms and $4 \times 3 \times 2 = 24$ O atoms.

   How many atoms of each element are there in the formulae shown?

   a. $Sn(SO_4)_2$ .....

   b. $(NH_4)_2SO_4$ .....

   c. $Ni(ClO_4)_2$ .....

   d. $2Ba(IO_3)_2$ ..... [4]

3. Water of crystallisation is added on separately.
   e.g. $CuSO_4.5H_2O$ contains (1 Cu, 1 S, 4 O) + (5×2 H, 5×1 O)

   How many atoms of each element are there in $CoCl_2.6H_2O$?

   ..... [1]

4. You need to work out the number of atoms correctly in order to calculate the relative formula masses of compounds.

   Calculate the relative formula mass of $Cr_2(SO_4)_3$.

   ..... [1]

20.2 Rearranging expressions

Learn to rearrange expressions from first principles rather than having to rely on a 'triangle' to help you.

- The idea is that whatever you do to one side of the equation, you do to the other.

  Example: $\text{moles} = \frac{\text{mass}}{M_r}$

- To make mass the subject: multiply both sides by M_r (to cancel M_r on the right)

  $\text{moles} \times M_r = \frac{\text{mass}}{\cancel{M_r}} \times \cancel{M_r}$ So moles $\times M_r$ = mass

- To make M_r the subject: divide both sides by *mass* (to cancel mass on the right)

  $\frac{\text{moles}}{\text{mass}} = \frac{\cancel{\text{mass}}}{M_r \times \cancel{\text{mass}}}$ then turn both sides upside down: $M_r = \frac{\text{mass}}{\text{moles}}$

Now try rearranging these expressions:

1. $\%\ \text{yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$

   a. Make actual yield the subject: [1]

   b. Make theoretical yield the subject: [1]

2. concentration (in mol/dm^3) $= \frac{\text{moles}}{\text{volume (in dm}^3\text{)}}$.

   a. Make moles the subject: [1]

   b. Make volume (in dm^3) the subject: [1]

3. Write the formula for density making mass the subject. [1]

4. Energy = mass × specific heat capacity × temperature rise

   Make mass the subject of the expression. [1]

1. Sometimes, when you do calculations, the number will come out as, for example, 2.5 04 on your calculator. The 04 is called the index or power to the base 10. Numbers like this on your calculator are examples of standard form. We write this 2.5×10^4.

   $1 \times 10^1 = 10$

   $1 \times 10^2 = 10 \times 10 = 100$

   $1 \times 10^3 = 10 \times 10 \times 10 = 1000$

   $2.5 \times 10^3 = 2.5 \times 10 \times 10 \times 10 = 2500$

   a. Write 1 000 000 in standard form. ..... [1]

   b. Write 7×10^4 in non-standard form. ..... [1]

   c. Write 3300 in standard form. ..... [1]

2. Very small numbers can also be written in standard form.

   $1 \times 10^{-1} = 0.1$ or $\frac{1}{10}$

   $1 \times 10^{-2} = 0.01$ or $\frac{1}{100}$

   $1 \times 10^{-3} = 0.001$ or $\frac{1}{1000}$

   $2.5 \times 10^{-3} = 2.5 \times 0.001 = 0.0025$

   a. Write 0.00001 in standard form. ..... [1]

   b. Write 5×10^{-3} in non-standard form. ..... [1]

   c. Write 0.0035 in standard form. ..... [1]

3. When you multiply numbers in standard form, you simply add the indices (superscripts).

   Example 1: $(2.4 \times 10^3) \times (2 \times 10^2) = 2.4 \times 2 \times 10^{3+2} = 4.8 \times 10^5$

   Example 2: $(5.0 \times 10^{-2}) \times (1.5 \times 10^4) = 5.0 \times 1.5 \times 10^{-2+4} = 7.5 \times 10^2$

   a. What is the product of $(4.0 \times 10^{-3}) \times (3.5 \times 10^2)$? ..... [1]

   b. What is the product of $(2.4 \times 10^{-2}) \times (1.5 \times 10^{-3})$? ..... [1]

4. When you divide numbers in standard form, you simply subtract the indices.

   Example: $\frac{2.4 \times 10^5}{1.2 \times 10^2} = \frac{2.4}{1.2} \times 10^{5-2} = 2.0 \times 10^3$

   What is the result of $(4.0 \times 10^{-3}) \div (3.5 \times 10^2)$? ..... [1]

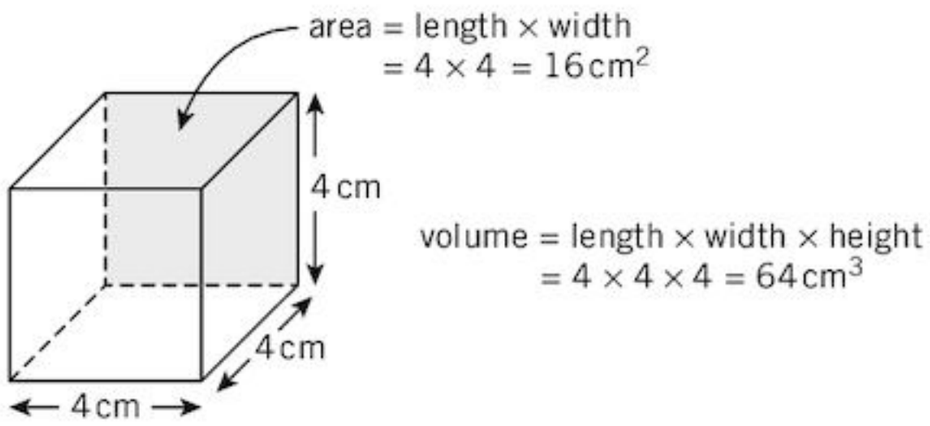
5. Percentages.

   In chemistry the result of a smaller number divided by a larger number is multiplied by 100 to get the percentage.

   What is the percentage yield if the actual yield of a product in a reaction is 4.5 g and the theoretical yield is 5.5 g?

   $$\% \text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100 = \frac{4.5}{5.5} \times 100 = 82\%$$

1. The diagram shows how to calculate the area of one side of a cube and the volume of a cube.



- The area of a rectangle = length × width. If the length and width are in cm, then the area is in cm^2.
- The volume of a regular figure such as a cube is length × width × height. If the dimensions are in cm, then the volume is in cm^3.

Look at the diagram of the cube above.

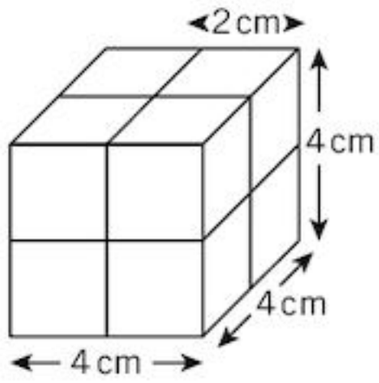
a. i. How many sides does the cube have? ..... [1]

ii. What is the area of one side? ..... [1]

iii. What is the total surface area of the cube? ..... [1]

b. i. Look at the diagram of the cube on the right.
How many smaller cubes has it been cut up into?

..... [1]



ii. What is the surface area of each of the smaller cubes?

..... [1]

iii. What is the total surface area of all the cubes?

..... [1]

iv. How does this help explain why the same mass of smaller particles reacts faster with acid than larger particles?

.....

..... [2]

2. A decimetre (dm) is one-tenth of a metre.

a. i. How many cm are there in 1 metre? ..... [1]

ii. How many cm are there in 1 decimetre? ..... [1]

b. Explain why there are 1000 cm^3 in 1 dm^3.

.....

..... [2]

1. When doing chemical calculations, it is important that we give the answer to the correct number of significant figures and round figures correctly.

   Significant figures:

   236.38 has 5 significant figures

   32.4 has 3 significant figures

   0.0067 has 2 significant figures (zeros before a number **are not** significant figures)

   0.0300 has 3 significant figures (zeros after a number after a decimal point **are** significant figures)

   Rounding:

   2.3<u>6</u>6 rounded to two significant figures is 2.4

   2.5<u>5</u>7 rounded to two significant figures is 2.6

   2.3<u>4</u>6 rounded to two significant figures is 2.3

   You can see that when rounding if the next figure along is 5 or above, then the figure to be rounded goes up by 1.

   a. Round these values to 3 significant figures:

   i. 4.357 ..... **ii.** 0.08732 .....

   iii. 137.2 ..... **iv.** 0.005498 ..... [4]

   b. Round these values to 2 significant figures:

   i. 436 ..... **ii.** 3.447 .....

   iii. 56.79 ..... **iv.** 0.00545 ..... [4]

2. When performing a calculation in several stages **do not round between the steps**. You should only round at the end. You should round to the same number of significant figures as the data in the question.

   To see the effect of rounding in the middle of a calculation, work through this example.

   When 1 mole of pentane is burned in excess air 5 moles of carbon dioxide are formed. Calculate the volume of carbon dioxide when 6.67 g of pentane burn.

Calculation	Answer when keeping the figures in your calculator	Value when rounding
moles pentane = $\frac{6.67}{72.0}$	.....	round to 1 significant figure .....
multiply by 5 (because 5 moles of carbon dioxide are formed from 1 mole of pentane)	.....	round to 1 significant figure .....
multiply by 24 to get dm^3 of carbon dioxide	Answer to 3 significant figures	Answer to 3 significant figures .....

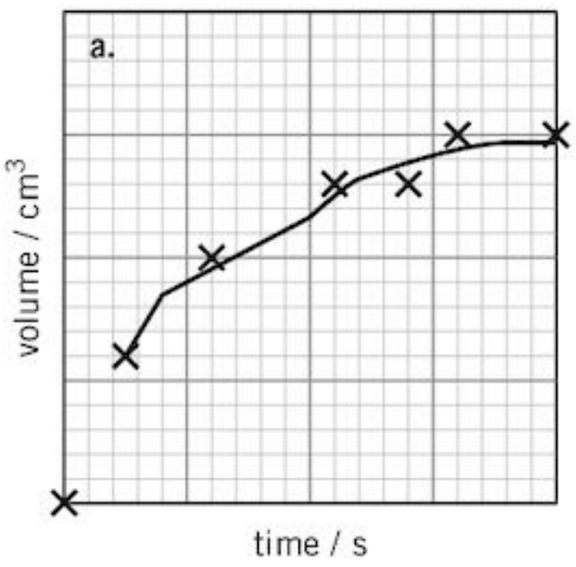
[6]

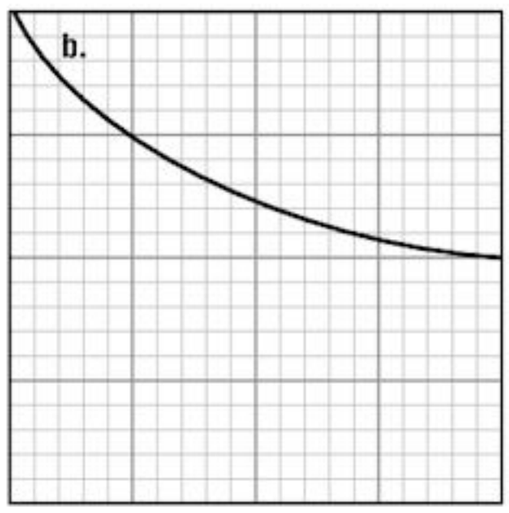
20.6 Drawing graphs (1)

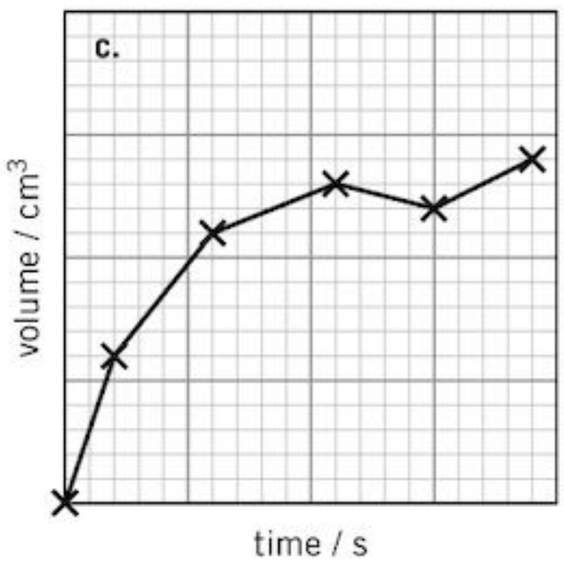
1. When drawing graphs remember:

   - The axes should be fully labelled and include units.
   - Use as much of the graph paper as possible.
   - Use an × to plot the points rather than + or ·, which cannot be so easily seen.
   - If it looks as though the line will form a curve, do not use a ruler to join the points to each other.
   - Draw the line of best fit (with equal numbers of points each side of the line if necessary).
   - Ignore any points which do not fit in with the general trend of the line (anomalous points).

What is wrong with each of these graphs?







a. .....

.....

..... [3]

b. .....

.....

..... [3]

c. .....

..... [2]

2. Extrapolation and interpolation:

   The graph on the right shows how to extrapolate and interpolate values.

   Always make sure that you draw lines as shown to the values that are asked for.

   Deduce the volume of gas released in the first:

   a. 2.4 minutes. ..... [1]

   b. 5 minutes ..... [1]

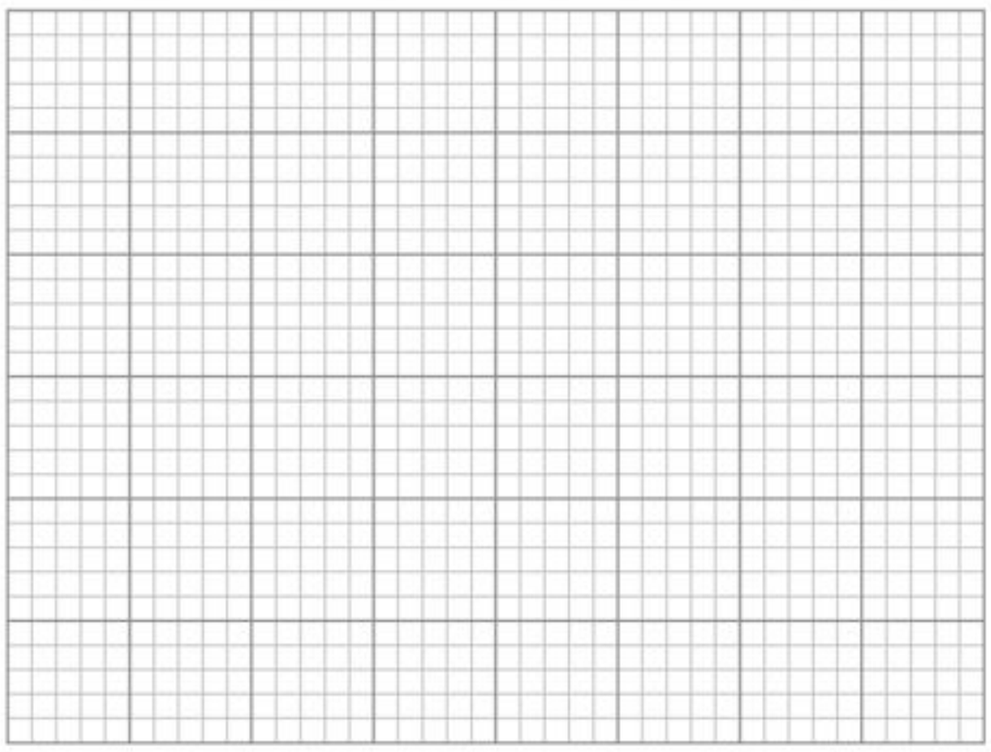
1. The table shows how the electrical conductivity of a solution changes as an acid is added to an alkali.

Volume of acid / cm^3	0	2	3	4	5	6	7	8
Conductivity / $ohms^{-1}m^{-1}$	2.8	1.8	1.3	0.8	0.7	1.0	1.2	1.5

a. On the grid below plot the points using the data in the table. [3]

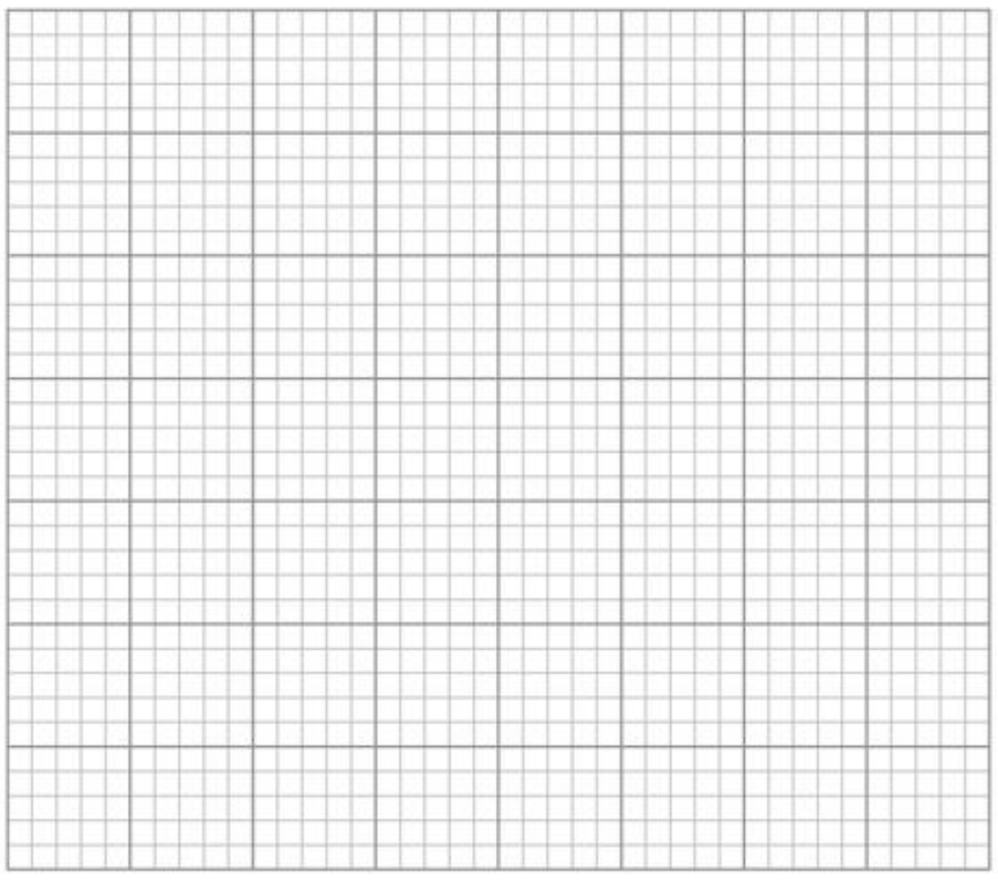
b. Draw two straight lines to connect these data points that intersect. Label this intersection point P. [2]

c. Deduce the volume of acid added at point P. ..... [1]



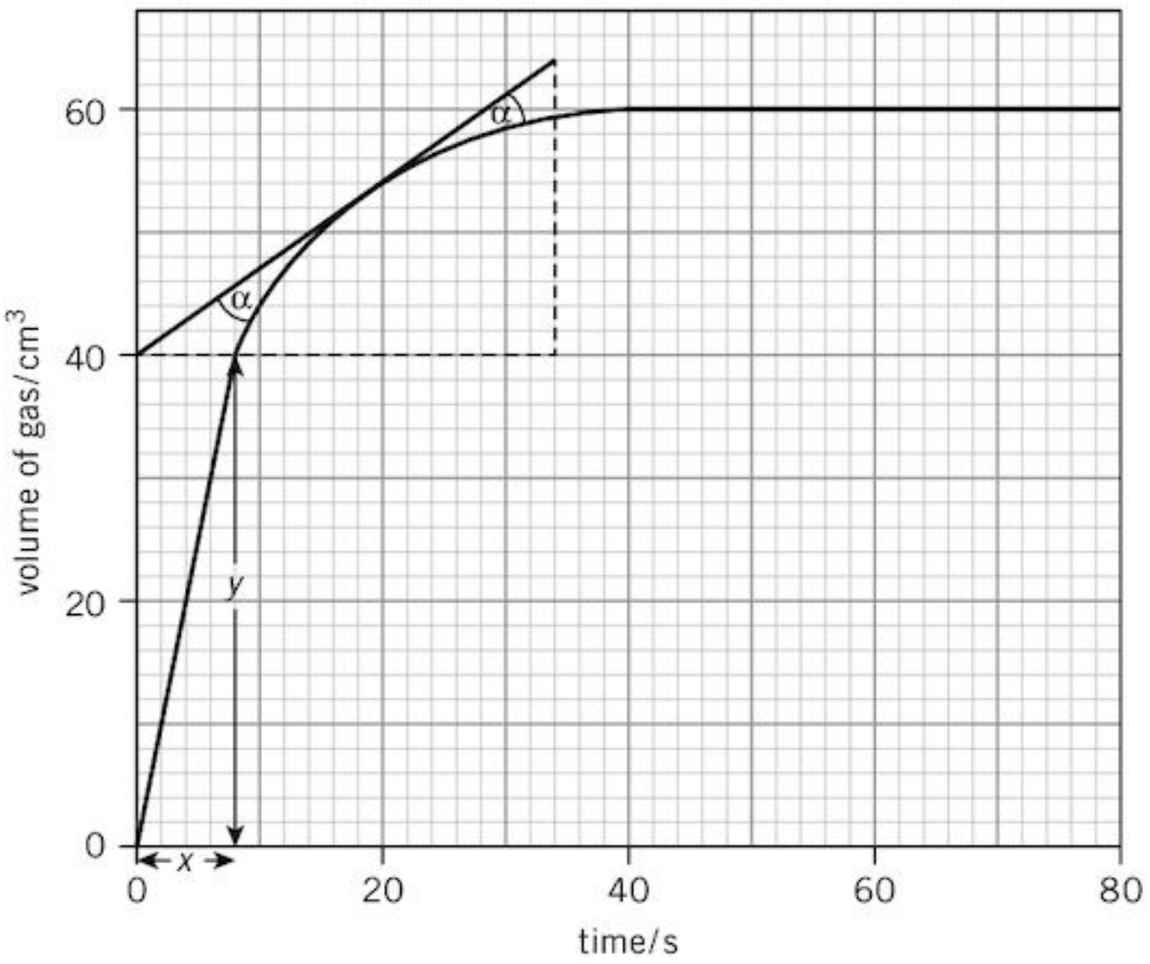
2. The table shows how the volume of gas changes when magnesium reacts with hydrochloric acid.
Plot a graph of these results on the grid below. [4]

Time / s	0	10	20	30	40	50	60	70
Volume of gas / cm^3	0	24	39	47	52	54	55	56



20.8 Drawing graphs (3)

1. Look at the graph below.



- We can find the initial rate of reaction from a graph by taking the rise, *y*, over the run, *x*, of the gradient (slope). This is 40 cm^3 ÷ 8 s. So the rate is 5 cm^3 / s.

- We can find the rate at any other point by drawing a tangent to the curve (see the graph above). Note that the angles α should be equal.

In this case the gradient is $\frac{64 - 40}{34 - 0} = 0.71\ cm^3/s$

a. The table shows how the mass of a product in a reaction increases with time.

Time / s	0	20	40	60	80	100	120	140
Mass / g	0	0.08	0.16	0.24	0.30	0.34	0.37	0.40

Plot a graph using these results.

[4]

b. Calculate the initial rate of reaction over the first 40 seconds.

..... [2]

c. Why would the rate calculated over the first 100 seconds be an average rate?

..... [1]

21.1 Using command words

Command words tell us what sort of thing we need to write in response to a question. Here is a list of the command words used in chemistry and how to respond to them.

Calculate: You need to work out a problem using numbers.

- The problem may be in several stages.
- Look out for the number of marks: this often shows you the number of stages needed in the calculation.
- Always show your working.

Example: Calculate the mass of 11 dm^3 of carbon dioxide. The answer involves: **i.** finding the moles of carbon dioxide using the relationship that 1 mol of a gas occupies 24 dm^3, then **ii.** multiplying moles by the molar mass of carbon dioxide.

Define: You need to be able to write down the main points about a term.

- The only way to do this is by memorising key terms.

Example: Define oxidation in terms of electron transfer. Answer: Oxidation is loss of electrons.

Deduce: You have to work out something from the information given in the question.

Example: Sodium sulfate is Na_2SO_4. Deduce the formula of the sulfate ion. Answer: SO_4^{2-}

Describe: You have to write about a sequence of events, draw a diagram, or state what happens.

- If you are asked to describe observations, remember to state what you see, hear, smell, or feel. You do not need to give the names of the substances.

Example 1: Describe how to obtain sodium chloride crystals from a solution of sodium chloride. Answer: Warm to the crystallisation point then filter off the crystals.

Example 2: Describe your observations when you add acid to an aqueous solution of sodium carbonate. Answer: Bubbles are seen. NOTE: The answer 'carbon dioxide is given off' is not correct.

Example 3: Describe the apparatus used for paper chromatography. In answering this, the best way is to include a labelled diagram.

Determine: The answer can't be found directly, but could be obtained from a graph or by calculation.

Example: Determine the volume of gas released after 20 seconds.

Explain: You have to use a particular theory to describe why something happens.

Example: Explain why the volume of a gas increases with temperature. Answer: The particles of gas move faster and get further away from each other (use of kinetic particle theory).

Measure: Taking a value directly using suitable measuring instruments.

Example: Measure the temperature of the solution to the nearest °C.

More command words

Predict: You have to make connections between various items of data.

- You often have to extrapolate or interpolate data when answering these questions.

Example: Predict the melting point of potassium (when given the melting points of other Group I elements). The answer involves looking at the melting points of the elements either side of potassium and choosing a suitable value in between these.

State/Give: Only a short answer is needed.

Example: State/Give the electronic structure of sodium. Answer: 2, 8, 1.

Suggest: You have to use your general chemical knowledge to write about a situation that is unfamiliar to you. You may need to:

- Think of substances similar to the one that is being asked about.
- Think of general ideas of structure, bonding, electrolysis, redox, rate, or equilibrium to answer the question.

Example: The structure of one type of boron nitride is similar to graphite. Suggest why boron nitride is slippery. (You have to think about the properties of graphite that make it slippery, then repeat these for boron nitride.) Answer: There are weak forces between the layers, so the layers can slide over each other.

What is meant by: A definition is usually needed.

- The only way to do this is by memorising relevant key terms.

What is meant by the term *isotopes*? Answer: Isotopes are atoms with the same number of protons but different numbers of neutrons.

NOTE: Command words are often combined, e.g.:

State the meaning of the term combustion.

Describe and explain the effect of increasing the temperature on the position of this equilibrium.

Question structure

- It is useful to look at the wording in past papers to get a feeling for the language used.
- Look not only for the command words, but also for the smaller words that instruct you what to do.
- Look at the number of marks given for the question. This often gives you an indication of how many different points you need to include in your answer. For simple questions, however, you may need to write two points to get one mark.
- Underline the key words.

Example 1: Describe and explain two methods by which you can determine the rate of this reaction.

Example 2: What observations would you make when aqueous bromine is added to compound X? Suggest the molecular formula for the product.

There is no one correct way of revising. You should find the best way of revising for yourself.

- Don't just read through books or notes and hope that you will remember things.
- Don't leave revision to the last moment. It is best to revise material throughout the year.
- Revision should be active (see below).

Here is a list of things to help you find the best way for you to revise:

- Find the best time of day to revise. Some people revise better in the evening, others in the morning.
- Find a time when you will not be disturbed.
- Find the best conditions needed for you to revise. Some people prefer to revise in absolute silence; others find it useful to have some music in the background.
- Revise regularly. You may find it useful to revise a topic about a week after you have finished it, to make sure that you have really understood it.
- Find the best length of time for each revision session. You may find that several short periods of revision, for example three spells of 20 minutes with breaks in between, are more productive than one longer period of revision.
- Don't imagine that you are revising usefully unless you test yourself from time to time to prove that you are remembering material.
- Make sure that you pay more attention to topics that you find difficult. Don't ignore them!
- Work out whether you remember information better in written form or in the form of diagrams.

Active revision

Active revision involves you carrying out different sorts of activities and testing yourself to see if your revision has been successful.

- Revise with others, especially with classmates. Asking each other questions is a useful way of helping you remember things.
- Test yourself or get someone else to test you.
- Make a list of key areas that you find difficult and concentrate on these.
- Look through the syllabus and text book and list general areas that need revision, e.g., uses of chemicals / tests for different groups / definitions and key terms to learn, e.g., element, isotopes, relative atomic mass. You can test yourself by writing the terms and definitions on a sheet like this:

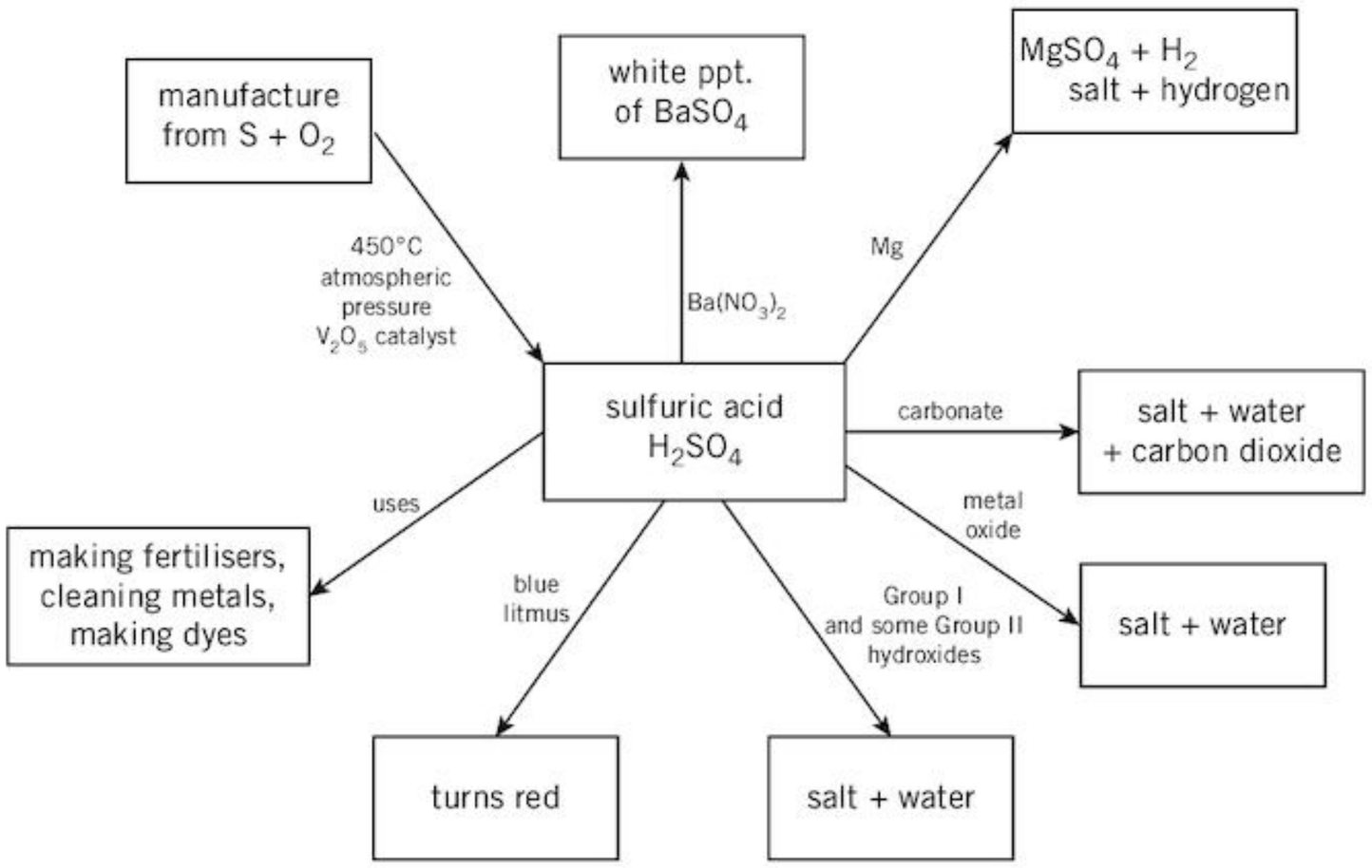
Term	Definition
isotopes	atoms with the same proton number having different numbers of neutrons
element	a substance which contains only one type of atom
empirical formula	a formula which shows the simplest ratio of atoms in a compound

When you think you have learnt the definitions, cover up or fold over the definition side and see if you can remember them.

- Work through calculations and extended exam questions and use the mark schemes, if available, to see where the marks are awarded.
- Make up mnemonics like OIL RIG for Oxidation Is Loss of electrons and Reduction Is Gain of electrons.

21.4 Mind mapping

Mind maps are simplified diagrams that show the main points of a topic in the form of a diagram. They are useful summaries because all the words that get in the way of learning the essential points are removed. They can be made as simple or as complicated as required but it is best to make them simple at the start. Mind maps can also be constructed to show links between different topic areas. An example is shown below.



Suggested mind maps that you could make are:

electrolysis; acids and bases; methods of purification; reaction rates; hydrocarbons; polymers; properties of the halogens; structure and bonding.

Try making a simple mind map in the space below.

1. Phosphorus is an element in Group V of the Periodic Table.

   a. Deduce the electron arrangement of an atom of phosphorus.

   ..... [1]

   b. An isotope of phosphorus has 15 protons and 31 nucleons.

   Deduce the number of neutrons in this isotope of phosphorus.

   ..... [1]

   c. Phosphorus has a simple molecular structure.

   Describe two physical properties of phosphorus.

   .....

   ..... [2]

   d. Phosphorus burns in excess oxygen to form an oxide with the formula P_2O_5.

   Write a balanced equation for this reaction.

   ..... [2]

   e. P_2O_5 reacts with sodium hydroxide to form sodium phosphate, Na_3PO_4.

   Deduce the formula of the phosphate ion.

   ..... [1]

   f. Phosphate ions are present in many fertilisers.

   Name another anion that is present in most fertilisers.

   ..... [1]

   g. Explain why farmers spread fertilisers on the soil where crop plants are grown.

   .....

   ..... [2]

   h. Draw the electronic structure of phosphine, PH_3. Show only the outer shell electrons. [2]

Total = 12

2. The structure of allyl alcohol is shown below.

$$CH_2=CH–CH_2–OH$$

a. What feature of allyl alcohol shows that it is an unsaturated compound?

..... [1]

b. Describe a test for an unsaturated compound.

Test .....

Result ..... [2]

c. Allyl alcohol can be reduced by hydrogen in a similar way to ethene.

i. Explain the term reduction in terms of electron transfer.

..... [1]

ii. State the conditions needed for this reduction.

.....

..... [3]

iii. Give the full structural formula of the compound formed by this reduction. Show all atoms and all bonds. [2]

d. Compounds with structures similar to allyl alcohol are found in green onion leaves.

i. Suggest how you could make a solution of the green pigments from onion leaves.

.....

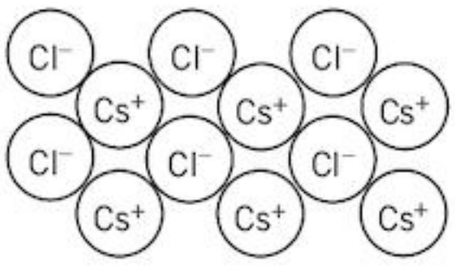
..... [2]

ii. Several green pigments are present in onion leaves. State the name of the method you would use to separate these pigments from each other.

..... [1]

Total = 12

3. The structure of caesium chloride is shown below.



a. Deduce the simplest formula for caesium chloride.

..... [1]

b. Explain in terms of structure and bonding why caesium chloride has a high melting point.

.....

..... [2]

c. Explain why aqueous caesium chloride conducts electricity.

..... [1]

d. Molten caesium chloride is electrolysed using graphite electrodes.

i. Give two reasons why graphite electrodes are used.

.....

..... [2]

ii. Write ionic half-equations (ion electron equations) for the reactions at:

the anode .....

the cathode ..... [3]

e. Caesium chloride is formed when caesium burns in chlorine.

$$2Cs + Cl_2 \rightarrow 2CsCl$$

When 5.32 g of caesium are burnt in excess chlorine, 6.4 g of caesium chloride are formed. Calculate the percentage yield of caesium chloride. [3]

Total = 12

4. A student investigated the reaction at r.t.p. between 0.05 g magnesium ribbon and excess hydrochloric acid of concentration 2.0 mol/dm^3.

a. At what time was the reaction just complete?

..... [1]

b. **i.** Deduce the volume of hydrogen released during the first minute of the reaction.

..... [1]

ii. Deduce the average rate of reaction during the first two minutes.

..... [1]

c. The experiment was repeated at r.t.p. using hydrochloric acid of concentration 2.5 mol/dm^3. On the grid above draw a line to show how the volume of hydrogen released changes with time. [2]

d. Explain, using the collision theory, why changing the concentration of acid affects the rate of reaction.

.....

.....

..... [2]

e. The experiment was repeated using 2 mol/dm^3 hydrochloric acid and 0.05 g magnesium powder. Would the reaction be faster or slower? Explain your answer.

.....

..... [2]

Total = 9

5. When 1 mole of calcium carbonate is heated, 1 mole of calcium oxide and 1 mole of carbon dioxide are formed.

a. Put a ring around **two** of the words below that describe this reaction.

addition **catalysed** **decomposition** **endothermic**

exothermic **oxidation** **reduction** [2]

b. Describe a test for carbon dioxide.

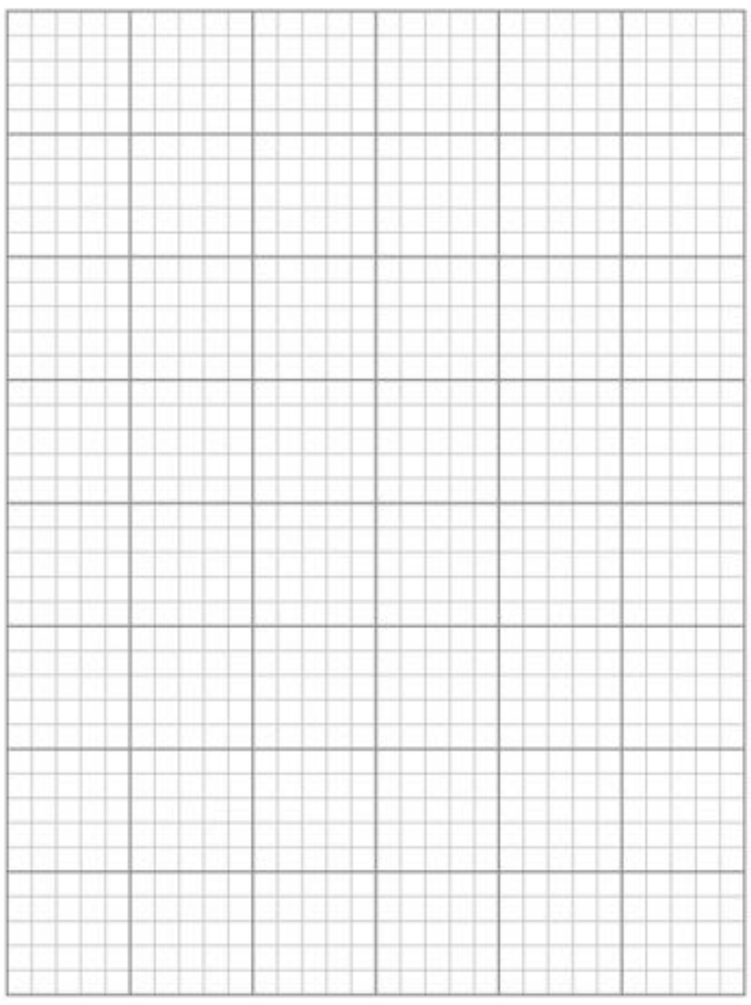
Test .....

Result ..... [2]

c. The table shows the mass of carbon dioxide formed when calcium carbonate is heated for 5 minutes at different temperatures. The same mass of calcium carbonate was used in each experiment.

temperature / °C	500	700	800	900	950	1000
mass / g	0.0	0.4	1.8	3.5	3.7	3.8

i. On the grid below draw a graph of these results.

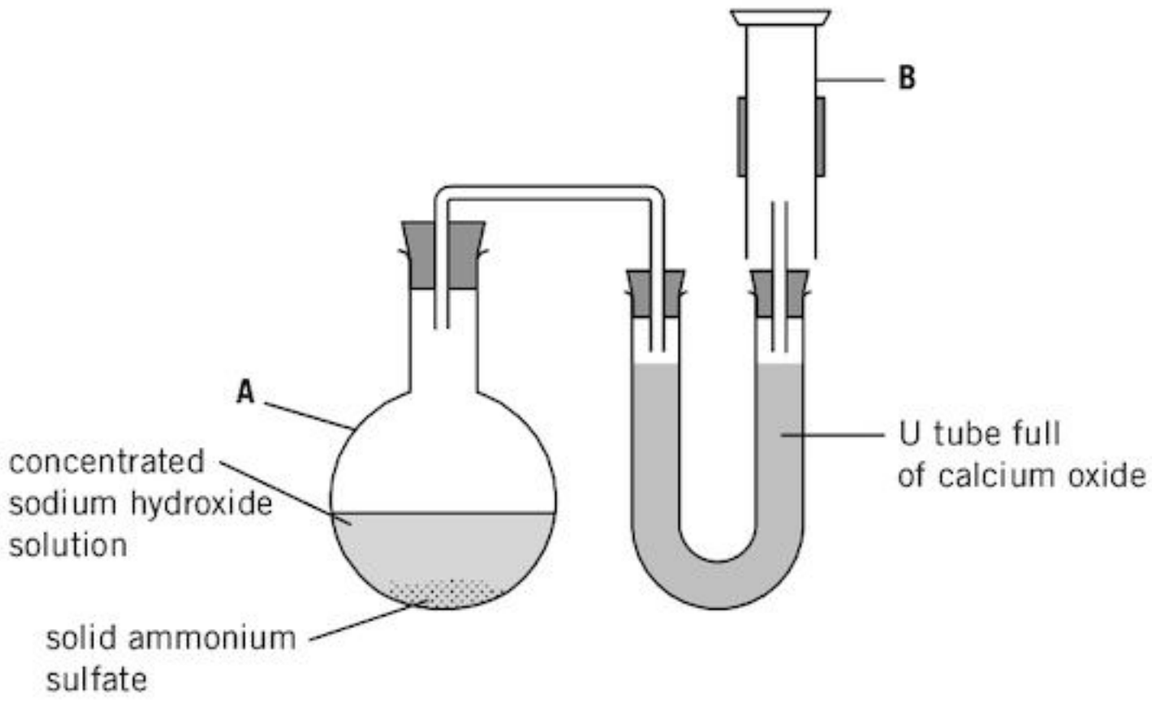


[3]

ii. Use your graph to help you calculate the volume of carbon dioxide formed when calcium carbonate is heated for 5 minutes at 850 °C. [3]

Total = 10

6. The diagram shows the preparation of ammonia by heating ammonium sulfate with concentrated sodium hydroxide.



a. i. On the diagram above, show where heat is applied. [1]

ii. State the names of the pieces of apparatus labelled **A** and **B**.

A .....

B ..... [2]

iii. What is the purpose of the calcium oxide?

..... [1]

iv. Explain how you can show when **B** is full of ammonia.

.....

..... [2]

b. Complete the equation for the reaction.

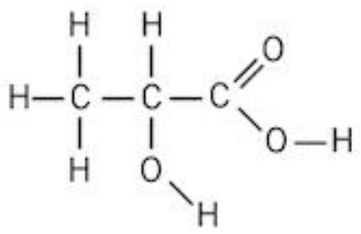
$(NH_4)_2SO_4$ + ... → ..... + ... + H_2O [2]

c. Hydrazine, $H_2N–NH_2$, like ammonia, contains hydrogen and nitrogen.

Draw the electronic structure of a molecule of hydrazine. Show only the electrons in the outer shells. [2]

Total = 10

7. The structure of lactic acid is shown below.



a. On the structure above put a ring around the alcohol functional group. [1]

b. Lactic acid can be made by fermenting the sugar lactose.

i. State the three different types of atom present in sugars.

..... [2]

ii. Give the name of another compound that can be made by fermentation.

..... [1]

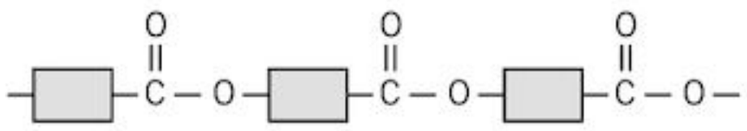
c. Calcium carbonate neutralises lactic acid. Complete the word equation for this reaction.

lactic acid + calcium carbonate → calcium lactate + ... + ... [2]

d. Calcium lactate is insoluble in water. Suggest how you could separate calcium lactate from a mixture of calcium lactate and aqueous salts.

..... [1]

e. The simplified structure of the polymer of lactic acid is shown below.



i. State the name of the linkage group.

..... [1]

ii. Explain why this is not an example of addition polymerisation.

.....

..... [2]

f. Lactic acid is oxidised to ethanoic acid by acidified potassium manganate(VII). What colour change would you observe when excess lactic acid is added to acidified potassium manganate(VII)?

..... to ..... [2]

Total = 12

8. The table shows some physical properties of four noble gases.

Gas	Melting point / °C	Boiling point / °C	Density at r.t.p. / g/dm^3	Atomic radius / nm
helium	–272	–269	0.18	0.050
neon	–248	–246	0.90	0.065
argon	–189	–186	1.78	
krypton	–157	–152	3.74	0.110

a. i. The density of air is 1.20 g/dm^3. Which of these gases could be used to fill a toy balloon to float in air?

..... [1]

ii. Deduce the atomic radius of argon.

..... [1]

iii. What is the state of krypton at –118 °C? Explain your answer.

..... [2]

iv. Describe the trend in boiling point down the group.

..... [1]

b. Xenon tetrafluoride, XeF_4, reacts with potassium iodide.

$$XeF_4 + 4KI \rightarrow Xe + 2I_2 + 4KF$$

i. Potassium salts are colourless. What is the final colour of the reaction mixture?

..... [1]

ii. Explain why potassium iodide is acting as a reducing agent in this reaction.

.....

..... [2]

iii. Calculate the maximum volume of xenon formed when 8.28 g of xenon tetrafluoride reacts with excess potassium iodide. [3]

Total = 11

9. Nitrogen dioxide, NO_2, is a brown gas that pollutes the atmosphere.

a. i. Give one source of nitrogen dioxide in the atmosphere.

..... [1]

ii. Describe one effect of nitrogen dioxide on the environment.

..... [1]

iii. Nitrogen dioxide is a gas at r.t.p. Describe the proximity (closeness) and motion of the particles in nitrogen dioxide at r.t.p.

.....

..... [2]

b. The colourless gas dinitrogen tetroxide, N_2O_4, forms an equilibrium mixture with nitrogen dioxide.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

i. Describe and explain what you would observe when the pressure on this equilibrium mixture is increased.

.....

.....

..... [3]

ii. Calculate the relative molecular mass of:

nitrogen dioxide .....

dinitrogen tetroxide ..... [2]

iii. At 55 °C the average relative molecular mass of the equilibrium mixture is 61.0 but at 140 °C the average relative molecular mass is 46.0.

Explain how this shows that the reaction is endothermic.

.....

.....

..... [2]

c. At temperatures above 150°C nitrogen dioxide decomposes to nitrogen(II) oxide and oxygen. Write a symbol equation for this reaction.

..... [2]

Total = 13

10. 25 cm^3 of aqueous potassium hydroxide was placed in a flask. A few drops of an acid–base indicator were then added. The solution was neutralised by 12.5 cm^3 of 0.2 mol/dm^3 sulfuric acid added from a burette.

$$2KOH(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$$

a. Suggest a suitable indicator that could be used in this reaction.

..... [1]

b. Give the name of the salt formed in this reaction.

..... [1]

c. Calculate:

i. The number of moles of sulfuric acid added from the burette. [1]

ii. The number of moles of potassium hydroxide in the flask.

..... [1]

iii. The concentration of potassium hydroxide in the flask in mol/dm^3. [1]

d. Write the simplest ionic equation for this reaction.

..... [1]

e. Sulfuric acid catalyses the reaction between butanol and ethanoic acid.

Draw the full structural formula for the ester formed in this reaction, showing all atoms and all bonds. [2]

Total = 8

23.1 Comparing the hardness of different samples of water

Introduction

This could be done at home or in the school laboratory.

- Hard water does not lather well with soap.
- Soft water lathers well with soap.
- Permanent hardness in water cannot be removed by boiling.
- Temporary hardness in water can be removed by boiling.

Purpose of the experiments

To find the volume of soap solution (or washing-up liquid) needed to form a permanent lather with different samples of water.

Sources of water

- Distilled water.
- Temporary hard water (bubble carbon dioxide through limewater until the white precipitate has disappeared).
- Permanent hard water (add some hydrated calcium sulfate to distilled water then filter).
- Natural sources of water, e.g. tap water, rainwater, seawater.

Carrying out the experiments

1. There are two ways in which the experiment can be carried out.
   a. Add the water sample to a flask and then see how many drops of soap solution (added from a burette or pipette) are needed to form a lather on shaking that does not disappear after leaving for a minute.
   b. Adding a certain number of drops of soap solution to a tube of water, shaking and measuring the height of the lather formed.
2. Make a list of all the equipment that you need including safety equipment / clothing.
3. What do you need to vary and what do you need to keep constant?

Analysing the results

- Draw a table of results for the number of drops (or height of lather) with different types of water including boiled hard water (temporary and permanent).
- Repeat your experiments to get consistent results.
- Suggest how you could improve your experiments.

Conclusions

1. Which samples of water are hard and which are soft?
2. Classify tap water, rainwater, seawater, and other sources of water you have analysed as hard or soft.
3. Which samples contain temporary hardness and which contain permanent hardness?

23.2 Comparing the energy released when burning different foods

Introduction

This could be done at home or in the school laboratory.

- The labels on packets of food usually state the amount of energy they contain in kilojoules or kilocalories. Make a list of these values for the foods you choose.
- When dry foods are burned, they release energy. The reaction is exothermic.
- The carbohydrates, fats, and proteins in the food burn to form carbon dioxide and water.

Purpose of the experiments

To compare the energy released by different foods.

Sources of foods

- The foods should be dry. You can dry wet foods in an oven but don't let them char (go black).
- Make a list of the energy values for the foods you choose by looking on the sides of the packets.
- Crisps, bread, nuts, and rice are good sources.
- Dried meats, beans, and cheese could also be used.
- It is possible to burn cooking oils if you use a cotton or string wick.

Carrying out the experiments

1. There are two ways in which the experiment can be carried out.
   a. Burning different foods of known mass on the end of a large needle. The burning foods heat a known volume of water in a test tube or beaker.
   b. Burning the food on a tin lid beneath a beaker or tin of water. This is more useful for fats and oils.
2. Make a list of all the equipment that you need including safety equipment / clothing.
3. What do you need to vary and what do you need to keep constant?
4. You could also investigate the relationship between the mass of a particular food burnt and the temperature rise.

Analysing the results

- Draw a table of results for the temperature rise on burning a known amount of food material using a fixed volume of water.
- Repeat your experiments to get consistent results.
- Suggest how you could improve your experiments.

Conclusions

1. Calculate the energy released in kJ per gram of food by using the relationship:
   energy released (joules) = mass of water (g) × 4.18 × temperature rise (°C).
2. Which foods released the most energy per gram?
3. Compare the energy values you obtained with the energy values on the labels of the foods you used. Were they in the same order of energy as the results of your experiments? If not, suggest why not.
4. Suggest reasons why your experiment may not be a fair test.

Introduction

This is best done in the laboratory.

- Many compounds are much more soluble in water at high temperatures than lower temperatures. Others do not show much difference in solubility as the temperature increases.

Purpose of the experiments

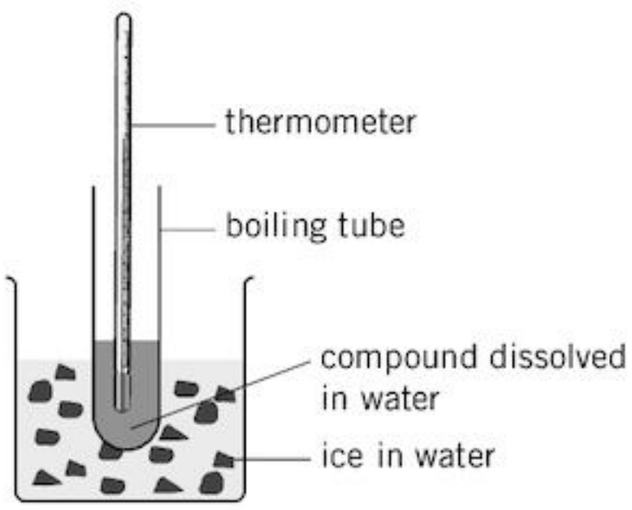
To find how the solubility of different compounds changes with temperature.

Suggested compounds to use

Potassium nitrate, sodium nitrate, potassium chloride, and sodium chloride.

Carrying out the experiments

1. **a.** Heat some water (4 or 5 cm^3) with the solute until the solute dissolves.
   b. The solution is then cooled using the apparatus shown below until crystallisation occurs. Keep the solution constantly stirred. The temperature of crystallisation is recorded.



   c. Then add more water (not more than 2 cm^3) to the solution in the boiling tube and heat to dissolve. The temperature when crystals reappear is recorded.
   d. Repeat step **c.** several times.
2. Make a list of all the equipment that you need including safety equipment / clothing.
3. What do you need to vary and what do you need to keep constant?

Analysing the results

- For each salt draw a table of results for the temperature at which crystallisation occurs.
- Repeat your experiments to get consistent results.
- Suggest how you could improve your experiments.

Conclusions

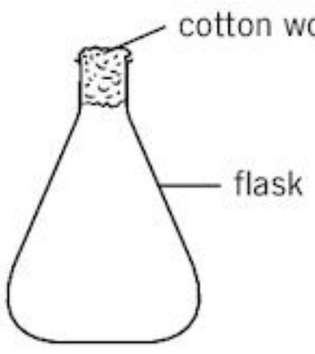
1. Which compounds show the greatest difference in crystallisation temperature?
2. Compare your results with tables showing the solubility of each of these compounds at different temperatures.
3. Suggest reasons why your experiment may not be a fair test.

23.4 Finding the percentage by mass of carbon in different carbonates

Introduction

This should be done in the laboratory.

- When carbonates react with acids carbon dioxide is released.
- The mass of the reaction mixture decreases as the reaction proceeds.
- The diagram below shows some of the apparatus that can be used to follow the rate of this reaction.



Purpose of the experiments

To find the percentage of carbon dioxide and hence the percentage by mass of carbon in different carbonates.

Suggested carbonates to use

Sodium carbonate, sodium hydrogencarbonate, calcium carbonate, copper(II) carbonate, barium carbonate.

Carrying out the experiments

1. The hydrochloric acid needs to be in excess. Why?
2. Deduce the amounts of hydrochloric acid and the mass of each carbonate you need.
3. Make a list of all the equipment that you need including safety equipment / clothing.
4. What do you need to vary and what do you need to keep constant?

Analysing the results

- Draw up a table of results for the mass or volume of carbon dioxide given off for each carbonate.
- Repeat your experiments to get consistent results.
- Suggest how you could improve your experiments.
- Calculate the mass of carbon released in each experiment.
- Calculate the percentage by mass of the carbon in the carbonate.

Conclusions

1. Put the carbonates in order of their percentage composition carbon by mass.
2. The CO_3^{2-} ion is common to all the carbonates. So why are the percentage compositions different?
3. Suggest reasons why your experiment may not be a fair test.

Glossary

Acid: A proton donor.

Acid–base indicator: A coloured compound or mixture of coloured compounds that changes colour over a specific pH range.

Acidic oxide: An oxide that reacts with alkalis to form a salt and water.

Acid rain: Rain that has a pH below about pH 5 due to the reaction of rainwater with acidic gases.

Activation energy: The minimum amount of energy particles must have to react when they collide.

Addition polymerisation: Polymerisation of monomers containing a C=C double bond to form a polymer and no other compound is formed.

Addition reaction: A reaction in which a single product is formed from two or more reactant molecules and no other product is made.

Alcohols: Organic compounds with branched or unbranched chains containing the –OH functional group.

Alkali: A base that is soluble in water.

Alkanes: Saturated hydrocarbons with the general formula C_nH_{2n+2}.

Alkenes: Hydrocarbons containing at least one C=C double bond.

Alkyl group: A group formed by the removal of a hydrogen atom from an alkane e.g. CH_3–, C_2H_5–.

Alloy: A mixture, within a metallic lattice, of two or more metals or a mixture of one or more metals with a non-metal.

Amphoteric oxide: An oxide that reacts with both acids and alkalis.

Anions: Negative ions.

Anode: The positive electrode.

Atom: The smallest particle that cannot be broken down by chemical means.

Atomic number: The number of protons in the nucleus of an atom.

Base: A proton acceptor.

Basic oxide: An oxide that reacts with acids to form a salt and water.

Brownian motion: The random bombardment of molecules on small suspended particles leading to a random irregular motion of the suspended particles.

Carboxylic acids: A homologous series of organic compounds with the –COOH group.

Catalyst: A substance that speeds up a chemical reaction but remains unchanged at the end of the reaction.

Catalytic converter: Part added to vehicle to reduce the emissions of carbon monoxide and nitrogen oxides from exhausts of petrol engines.

Cathode: The negative electrode.

Cations: Positive ions.

Collision theory: The theory that moving particles react when they collide with sufficient energy and in the correct orientation.

Compound: A substance made up of two or more different atoms (or ions) joined together by bonds.

Condensation polymerisation: Polymerisation occurring when monomers combine together with the elimination of a small molecule.

Condensing: The change of state from gas to liquid.

Conductors (electrical): Substances that have a low resistance to the passage of electricity.

Corrosion: The gradual reaction and 'eating away' of a metal inwards from its surface caused by another substance.

Covalent bond: A shared pair of electrons between two atoms.

Cracking: The decomposition of larger alkane molecules into a mixture of smaller alkanes and alkenes.

Delocalised electrons: Electrons that are not associated with any particular atom.

Diatomic: Molecules containing two atoms.

Diffusion: The spreading movement of one substance through another due to the random movement of the particles.

Displayed formula: Shows how all the atoms and all bonds in a compound are arranged.

Dot-and-cross diagram: A diagram showing the electronic configuration of molecules (or ions).

Double bond: Two covalent bonds between the same two atoms.

Ductile: Can be drawn into wires.

Electrochemical series: The order of reactivity of metals, with the most reactive at the top.

Electrodes: Rods that conduct electric current to and from an electrolyte.

Electrolysis: The decomposition of a compound when molten or in solution by an electric current.

Electrolyte: A molten ionic compound or a solution containing ions that conducts electricity.

Electron: The negatively charged particles arranged in electron shells (energy levels) outside the nucleus of an atom.

Glossary

Electron shells: Particular areas surrounding the nucleus, which contain one or more electrons.

Electroplating: Coating of the surface of one metal with a layer of another, usually less reactive, metal using electrolysis.

Element: A substance made up of only one type of atom that cannot be broken down into anything simpler by chemical reactions.

Empirical formula: Shows the simplest whole number ratio of atoms or ions in a compound.

Endothermic reaction: A reaction that absorbs energy from the surroundings.

Energy profile diagram: Diagram showing the heat energy content of the reactants and products on the vertical axis and the reaction pathway on the horizontal axis.

Enthalpy change: The heat energy exchanged between a chemical reaction and its surroundings at constant pressure.

Enzymes: Biological catalysts.

Ester: A compound with the formula R–COO–R' formed by the reaction of an alcohol with a carboxylic (alkanoic) acid.

Esterification: Making an ester by the reaction of an alcohol with a carboxylic acid.

Evaporation: The change of state from liquid to vapour that takes place below the boiling point of a liquid.

Exothermic reaction: A reaction that releases energy to the surroundings.

Fermentation: The breakdown of organic materials by microorganisms with effervescence and the release of heat energy.

Filtrate: The solution passing through a filter paper when a mixture of solid and solution are filtered.

Flue gas desulfurisation: Removal of sulfur dioxide in industry arising from burning fossil fuels containing sulfur.

Fraction: A product of petroleum distillation that is a mixture of hydrocarbons having a limited range of molar masses and boiling points.

Fractional distillation: A method used to separate two or more liquids with different boiling points from each other using a distillation column.

Freezing: The change of state from liquid to solid.

Functional group: A group that is characteristic of a given homologous series.

General formula: A formula that can be applied to all members of a given homologous series.

Giant molecular structure: A structure having a three-dimensional network of covalent bonds.

Global warming: The heating of the atmosphere caused by absorption of infrared radiation by greenhouse gases.

Greenhouse gases: Gases that are good absorbers of infrared radiation and cause global warming.

Group: A vertical column in the Periodic Table.

Half-equations: Equations showing the oxidation and reduction reactions separately to show the loss or gain of electrons.

Halogens: The elements in Group VII.

Homologous series: A group of compounds with the same general formula and the same functional group.

Hydrocarbons: Compounds containing only carbon and hydrogen atoms.

Hydrogenation: A reaction involving the addition of hydrogen to a compound.

Hydrolysis: The breakdown of a compound by water often catalysed by acids or alkalis.

Incomplete combustion: Combustion when air or oxygen is limiting.

Indicator: See acid–base indicator.

Insulators: Non-conductors.

Ion: A particle formed when an atom or group of atoms has lost or gained one or more electrons making the particle positively or negatively charged.

Ionic bond: The strong force of attraction between oppositely charged ions.

Ionic equation: A symbol equation that shows only those ions that take part in a reaction.

Isotopes: Atoms of elements with the same number of protons but different numbers of neutrons.

Kinetic particle theory: The idea that particles are in constant motion.

Lustrous: Having a shiny surface.

Macromolecules: Very large molecules made up of repeating units.

Malleable: Can be shaped by hitting.

Mass number: The number of protons + the number of neutrons in an atom.

Melting: The change of state from solid to liquid.

Metallic bond: A bond formed by the attractive forces between the delocalised electrons and the positive ions in a metallic structure.

Glossary

Metallic conduction: The movement of mobile electrons through the metal lattice when a voltage is applied.

Mixture: This consists of two or more elements or compounds that are not chemically bonded together and can usually be separated by physical means.

Molar concentration: The number of moles of solute dissolved in a solvent to make 1 dm^3 of a solution.

Molar gas volume: The volume of a mole of gas at r.t.p. or s.t.p.

Molar mass: The mass of a substance in moles.

Mole: The amount of substance that has the same number of particles (atoms, ions, or electrons) as there are atoms in exactly twelve grams of the carbon-12 isotope.

Molecular equation: A full symbol equation.

Molecular formula: Shows the number of atoms of each particular element in one molecule of a compound.

Molecule: A particle containing two or more atoms. The atoms can be the same or different.

Monomers: The small molecules that react and bond together to form a polymer.

Neutralisation: The reaction between an acid and a base to form a salt and water.

Neutral oxide: An oxide that does not react with acids or alkalis.

Neutron: The neutral particle in the nucleus of an atom.

Noble gas configuration: Atoms or ions having a complete outer shell of electrons so that the species have the electronic structure of one of the noble gases.

Nucleus: A group of particles in the centre of an atom containing protons and neutrons.

Oxidation: The gain of oxygen or loss of electrons by a substance.

Oxidation number: A number given to each atom or ion in a compound to show the degree of oxidation.

Oxidising agent: A substance that accepts electrons and gets reduced during a chemical reaction.

Paper chromatography: A method used to separate a mixture of different dissolved substances depending on the solubility of the substances in the solvent and their attraction to paper.

Percentage yield:

$$\frac{\text{amount of required product obtained}}{\text{maximum amount of product expected}} \times 100$$

Periodic Table: Arrangement of elements in order of increasing atomic number so that many groups contain elements with similar properties.

Periodicity: The regular occurrence of similar properties of the elements in the Periodic Table so that some groups have similar properties or a trend in properties.

Period: A horizontal row in the Periodic Table.

Petroleum: A thick liquid mixture of unbranched, branched, and ring hydrocarbons extracted from beneath the Earth's surface.

Photochemical reaction: A reaction that depends on the presence of light.

pH scale: A scale of numbers from 0 to 14 used to show how acidic or alkaline a solution is.

Physical properties: Properties which do not generally depend on the amount of substance present.

Pollution: Contaminating materials introduced into the natural environment (earth, air, or water).

Polyamide: Condensation polymer containing –NH–CO– linkages.

Polyester: Condensation polymer containing –COO– linkages.

Polymerisation: The conversion of monomers to polymers.

Polymers: Macromolecules made up by linking at least 50 monomers.

Precipitate: The solid obtained in a precipitation reaction.

Precipitation reaction: A reaction in which a solid is obtained when solutions of two soluble compounds are mixed.

Protons: The positively charged particles in the nucleus of an atom.

Radioactive isotopes: Isotopes with unstable nuclei, that break down.

Rate of reaction: The change in concentration of a reactant or product with time at a stated temperature.

Redox (reaction): A chemical reaction in which one reactant is oxidised and another is reduced.

Reducing agent: A substance that loses electrons and gets oxidised during a chemical reaction.

Reduction: The loss of oxygen or gain of electrons by a substance.

Relative atomic mass: The weighted average mass of naturally occurring atoms of an element on a scale where an atom of carbon-12 has a mass of exactly 12 units.

Relative formula mass: The relative mass of one formula unit of a compound on a scale where an atom of the carbon-12 isotope has a mass of exactly 12 units.

Glossary

Relative molecular mass: The relative mass of one molecule of a compound on a scale where an atom of the carbon-12 isotope has a mass of exactly 12 units.

Residue: The solid remaining on the filter paper when a mixture of solid and solution are filtered.

r.t.p.: Room temperature and pressure. (20 °C and 1 atmosphere pressure).

Rusting: Corrosion of iron and iron alloys caused by the presence of both water and oxygen.

Salt: A compound formed when the hydrogen in an acid is replaced by a metal or ammonium ion.

Saturated compounds: Organic compounds with only single carbon–carbon bonds.

Separating funnel: Piece of apparatus used to separate immiscible liquids which have different densities.

Simple distillation: The separation of a liquid from a solid that involves the processes of boiling and condensation using a condenser.

Solubility: The number of grams of solute needed to form a saturated solution per 100 grams of solvent used.

Solution: A uniform mixture of two or more substances (usually a solid dissolved in a liquid).

Solute: A substance that is dissolved in a solvent.

Solvent: A substance that dissolves a solute.

Sonorous: Rings when hit with a hard object.

Spectator ions: Ions that appear in a chemical equation but do not take part in the reaction.

Standard concentration: A concentration of 1 mole of substance in 1 dm^3 of solution under standard conditions.

State symbols: Letters put after a chemical formula showing whether it is a solid, liquid, gas, or aqueous solution.

Strong acid: An acid that ionises completely in solution.

Strong base: A base that ionises completely in solution.

Structural formula: Shows the way the atoms are arranged in a molecule with or without showing the bonds.

Structural isomers: Compounds with the same molecular formula but different structural formulae.

Sublimation: The direct conversion of a solid to a gas or gas to a solid without the liquid state being formed.

Substitution reaction: A reaction in which one atom or group of atoms replaces another.

Thermal decomposition: The breakdown of a compound when heated.

Titration: A method used to determine the amount of substance present in a given volume of solution of acid or alkali.

Titre: The final burette reading minus the initial burette reading in a titration.

Triple bond: Three covalent bonds between the same two atoms.

Unbranched hydrocarbons: Hydrocarbons with carbon atoms linked in a chain without alkyl side groups.

Unsaturated compounds: Organic compounds containing double or triple carbon–carbon bonds (in addition to single bonds).

Volatile: Easily evaporated at room temperature.

Weak acid: An acid which only partially ionises in solution.

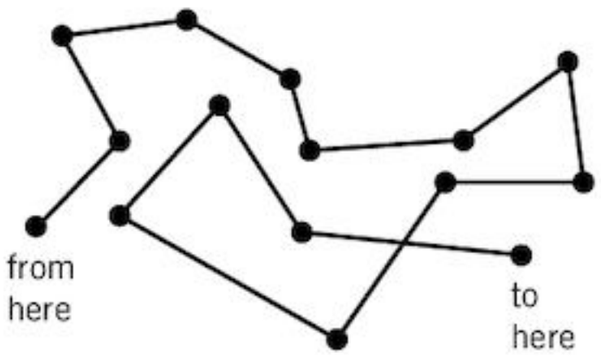
Weak base: A base which only partially ionises in solution.

Answers

Unit 1.1

1. a. Put your finger over the top of tube and lower (slowly) into the water [1]
   Drop the crystal down the tube then raise the tube slowly [1]
   b. i. Dissolving [1]
   ii. Diffusion [1]
   c. Particles (of dye and water) move randomly / move in any direction [1]
   Dye particles spread out [1]
   Overall movement of the dye is from area of high concentration (of the dye particles) to lower concentration (of dye particles) [1]

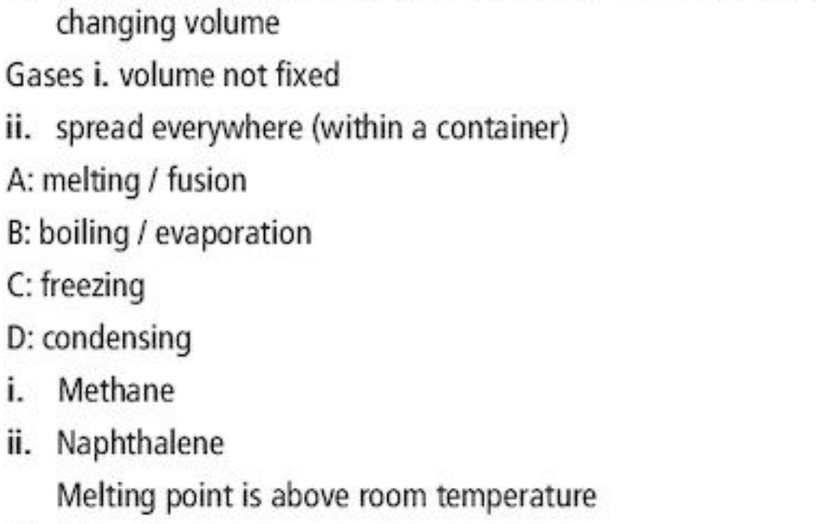
2. a.



   Random movement shown, e.g. particle moves in 4 or more different directions [1]
   All lines are straight [1] (arrows need not be shown)
   b. Dust [1]
   You can see dust particles but not particles of oxygen / nitrogen / gases in the air [1]
   c. More particles in the air bombard (hit) the dust particle on one side than on another (or hit with greater force) [1]
   Dust particles move in direction of the greater number of hits [1]
   Particles in the air move randomly so the direction of the movement of the dust particles is also random [1]

Unit 1.2

1. a. Liquids i. fixed volume [1]
   ii. take the shape of container only as far as it is filled / without changing volume [1]
   Gases i. volume not fixed [1]
   ii. spread everywhere (within a container) [1]
   b. A: melting / fusion [1]
   B: boiling / evaporation [1]
   C: freezing [1]
   D: condensing [1]
   c. i. Methane [1]
   ii. Naphthalene [1]
   Melting point is above room temperature [1]
   iii. Ethanol [1]
   Melting point is below room temperature **and** boiling point is above room temperature / room temperature is between melting point and boiling point [1]
   d. A: solid **and** liquid [1]
   B: liquid [1]
   C: liquid **and** vapour / liquid **and** gas [1]
   D: vapour / gas [1]
   e.



   Correct shape (from 120 °C to –10 °C) [2]
   (If these two marks not scored allow 1 mark for a vertical section followed by a horizontal section)
   100 °C at correct place [1]
   0 °C at correct place [1]
   f. i. The change in temperature is too rapid / goes from 114 to 184 too quickly [1]
   So the liquid state not noticed [1]
   ii. Heat iodine in bath of suitable liquid /liquid with higher boiling point than water [1]
   The temperature of the bath is kept between melting point and boiling point of iodine [1]

Unit 1.3

1. a. The particles in a solid are arranged in a **fixed** pattern (**lattice**). The forces of **attraction** between the particles are **strong** enough to keep them **together** and so the particles only **vibrate**. When a liquid evaporates, the particles with the **highest** energy leave the **surface** of the liquid first.
   (1 mark for each correct word)
   b. Box B: (solid): particles touching each other [1]
   particles arranged regularly / in more than 1 regular row [1]
   Box C: (liquid): particles touching each other [1]
   particles arranged irregularly / not in rows [1]
   c. The forces of attraction between the particles in a **liquid** are stronger than those between **gas** particles but weaker than those between the particles in a **solid**. Particles in a **solid** only vibrate. Particles in a **liquid** move more slowly than those in a **gas.**
   (1 mark for each correct word)
   d. Boiling only happens at the boiling point / in boiling bubbles of gas are seen throughout the liquid [1]
   Evaporation occurs at temperatures below the boiling point (and above the melting point) [1]
   e. i. (energy) absorbed [1]
   ii. (energy) released [1]
   iii. (energy) released [1]
   iv. (energy) absorbed [1]
   f. Arrangement goes from regular to irregular [1]
   Proximity goes from touching / close together to far apart [1]
   Motion goes from vibrating to moving freely / moving fast [1]
   g. Silicon has strong forces of attraction between the particles [1]
   A lot of energy is needed to overcome these forces / a high temperature is needed to overcome these forces [1]
   Phosphorus has weak forces of attraction between the particles [1]
   Only a little energy is needed to overcome these forces / a lower temperature is needed to overcome these forces [1]

Unit 1.4

1. a. Diagram showing plunger pushed down so volume smaller **and** the same number of particles randomly arranged [1]
   b. In Y fewer particles hit the wall [1]
   Every second [1]
   So the force on the wall is less [1]
2. As pressure doubles the volume halves [2]
   (If 2 marks not scored: 1 mark for increase in pressure decreases the volume)
3. a. White solid forms where hydrogen chloride reacts with ammonia [1]
   Hydrogen chloride has a higher relative molecular mass than ammonia [1]
   So rate of diffusion of hydrogen chloride less than that of ammonia [1]
   b. Any two of hydrogen fluoride / hydrogen bromide / hydrogen iodide (1 mark each)

c. White ring forms about halfway along the tube [1]
Because hydrogen chloride has a similar relative molecular mass to methylamine [1]
So rates of diffusion of the two gases are approximately equal [1]

Unit 2.1

1. a. i. Nitrates [1]
ii. Iron(II) hydroxide [1] silver chloride [1]
iii. Calcium hydroxide [1]
b. i. 132–135 g / 100 cm^3 [1]
ii. Potassium chloride [1]
iii. 105 g / 100 cm^3 [1]
iv. 18 °C [1]
v. At 80 °C there are 165 g per 100 cm^3 [1]
At 20 °C there are 32 g per 100 cm^3 [1]
Difference = 165 – 32 = 133 g [1]
For 200 cm^3 water = 133 × 2 = 266 g [1]
vi. Solubility at 90 °C = 200 g per 100 cm^3 [1]
For 50 g = $\frac{50 \times 100}{200}$ [1]
= 25 cm^3 [1]

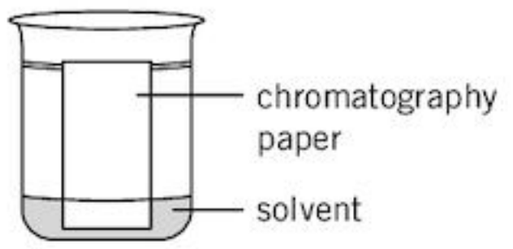
Unit 2.2

1. a. Oxygen gas [1] sodium chloride crystals [1]
b. Some impurities may be harmful [1]
c. i. Two or more substances present [1] that are not chemically combined [1]
ii. Any value from –15 °C to –1 °C
2. a. Pure sulfur: solidifies at 119 °C
Impure sulfur: melts over 4 °C temperature range
Impure sulfur: turns to a vapour at 450 °C
Pure sulfur: has sharp boiling point
(2 marks if all 4 correct; 1 mark if 2 correct)
b. i. In solder the tin is impure / the lead is impure [1]
Impurities lower the melting point [1]
ii. Less energy is used in melting the solder (than using tin or lead alone) [1]
3. a. Filtration [1]
b. Simple distillation [1]
c. Fractional distillation [1]
4. a. Salt lowers the melting point of water [1]
So ice does not form until temperature gets much lower than 0 °C [1]
So cars do not slip on the road [1]
b. Vapour pressure is the pressure exerted by the molecules in a vapour in equilibrium with a liquid [1]
Boiling point is when vapour pressure is equal to atmospheric pressure [1]
The particles of impurities in a liquid / water prevent the liquid / water from escaping so easily from the surface [1]
So the pressure of the vapour is less than normal [1]
It requires a higher temperature / more energy to get the same vapour pressure as the pure liquid [1]

Unit 2.3

1. a. i. In order down:
Filter paper [1]
Filter funnel [1]
Flask [1]
ii. Residue is on filter paper [1]
Filtrate is liquid in flask [1]
b. BGFEADC (2 marks) (1 mark if 1 pair reversed)
2. Add water to the mixture and stir. The calcium sulfate dissolves [1]
Filter the mixture. Calcium carbonate is the residue [1]
Rinse the calcium carbonate with water and dry in an oven [1]
Evaporate the water from the calcium sulfate solution / filtrate [1]
3. Add the mixture of crystals to the water and heat until all the mixture just dissolves (adding more water if needed) [1]
Cool the flask of solution in a beaker of cold water [1]
When crystals have formed filter the mixture [1]
The crystals formed contain more of the substance with the lower solubility [1]
Repeat the process with the crystals which have been collected [1]

Unit 2.4

1. a. i. Distillation flask on left [1]
Distillate in beaker on right [1]
Slanting tube labelled as condenser [1]
Cold water enters the bottom of the condenser [1]
ii. Arrow under the gauze [1]
b. i. Salt and water have very different boiling points / salt has a high boiling point and water has a low boiling point [1]
ii. The vapours would condense together / at the same time [1]
2. There is a range of **temperatures** in the distillation column, **lower** at the top and **higher** at the bottom. When **vaporised** the more **volatile** alcohols move **further** up the column than the less volatile alcohols. In the **condenser** the alcohol changes from vapour to **liquid**.
The alcohols are collected one by one in the **receiver**, those with the lower **boiling** points condensing before those with higher ones. [10]
3. 

Chromatography paper dipping in solvent [1]
Chromatography paper labelled [1]
Solvent labelled [1]
4. a. Any two examples (1 mark each) e.g. extracting lavender oil, extracting rose oil, preparation of phenylamine
b. Simple distillation may char / decompose substances [1]
c. Bubble steam through mixture to be distilled [1]
Condense the mixture of steam and oil [1]
Use a separating funnel to separate the oily layer from the water [1]

Unit 2.5

1. a. i. So that the ink doesn't spread up the paper / graphite / pencil 'lead' doesn't dissolve in solvent [1]
ii. 3 [1]
iii. Ser and Gly [1]
iv. Use a different solvent (that separates them) [1]
v. $\frac{\text{distance from centre of spot to baseline}}{\text{distance from solvent front to baseline}} = 0.6$ [1]
vi. About halfway between Cys and Ser/Gly [1]
b. Spray with locating agent / named locating agent [1]
Then develop spots by heating [1]
ALLOW: look under ultraviolet light [1]
Then spots appear as bright / fluorescent dots [1]
2. a. Dissolve the coin in concentrated hydrochloric acid / aqua regia (concentrated hydrochloric and nitric acids) [1]
b. Any 6 points of:
- Place resin in column (with solvent)
- Place mixture to be separated on top of column and let it soak in
- Add solvent to top of column and let mixture run through

Answers

- Different substances have different affinities for the resin / some substances are better absorbed onto the resin than others
- Substances less attracted to resin / more soluble in solvent move down column faster
- Substances collected one by one in separate tubes at the bottom of the column
- Substances analysed by ultraviolet / infrared spectroscopy / mass spectrometry

Unit 3.1

1. a. Carbon / tin [1]
   b. Rubidium / tin [1]
   c. Iron / cobalt / nickel / copper [1]
   d. Magnesium / Mg [1]
   e. H, B, C, N, O all shaded [2] 4 correctly shaded [1]
   f. VII / halogens [1]
   VIII / 0 / noble gases [1]
2. a. Most of the alpha particles went straight through the foil [1]
   b. Only a few alpha particles changed course [1]
   c. A few alpha particles reversed direction [1]
   The positive charge on the nucleus repels the positive charge on the alpha particle / like charges repel [1]
3. Any 5 of:
   No Groups / no Periods / some elements missing / cobalt and nickel are in the same place / no atomic numbers / no relative atomic masses [5]

Unit 3.2

1. No nucleus in Thomson's model [1]
   Positive charge spread out rather than being in the nucleus [1]
   Electrons not in shells [1]
2. a. (Number of) protons in the nucleus [1]
   b. (Number of) protons plus neutrons in the nucleus [1]
   c. Mass number [1]
3.

Subatomic particle	Relative mass	Relative charge
electron	0.00054	*1–* [1]
neutron [1]	1	***0 / none*** [1]
proton	***1*** [1]	1+

   (1 mark for each correct answer)
4. a. Protons: 6 [1] neutrons 6 [1]
   b.

Atom	Name of atom	Number of protons	Number of neutrons	Number of electrons
$^{19}_{9}H$	fluorine	9	10	9
$^{43}_{20}Ca$	calcium	20	23	20
$^{3}_{1}H$	hydrogen	1	2	1
$^{58}_{26}Fe$	iron	26	32	26

   (For each column: 4 correct = 2 marks, 2 or 3 correct = 1 mark)
5. a. 26 protons and 30 neutrons [1] 24 electrons [1]
   b. 16 protons and 18 neutrons [1] 18 electrons [1]
   c. 53 protons and 74 neutrons [1] 54 electrons [1]
   d. 19 protons and 22 neutrons [1] 18 electrons [1]

Unit 3.3

1. a. Isotopes are **atoms** of the same **element** with the same number of **protons** but different numbers of **neutrons**.
   (1 mark each correct word)
   b. i. 1 [1]
   ii. It has no neutrons [1]
   iii. The nucleus is unstable [1]
   And breaks down [1]
   To produce particles or radiation [1]
   c. i. As the time increases equally / every 14 days the mass decreases by a half [2]
   (1 mark for 'As time increases mass decreases')
   ii. 25 cpm [1]
2. uranium-235 → used to produce electrical energy
   cobalt-60 → used to kill bacteria in food
   carbon-12 → used to date ancient pieces of cloth
   (all correct for 1 mark)
3. a. $^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$
   (1 mark for He, 1 mark for 4 and 2 in the correct places)
   b. alpha particles [1] are helium nuclei [1]
   beta particles [1] are high-speed electrons [1]
   gamma rays [1] are high-energy electromagnetic radiation (waves) [1]

Unit 3.4

1. a. (main) energy levels [1]
   b.

Element	Number of electrons in an atom	Electron distribution
nitrogen	7	2,5
oxygen	8	2,6
fluorine	9	2,7
neon	10	2,8
sodium	11	2,8,1
argon	18	2,8,8
calcium	20	2,8,8,2

   (1 mark for correct number of electrons in column 1. 1 mark for each correct electron distribution)
2. A with F B with E C with D (1 mark if all correct)
3. (1 mark each correct structure) Electrons should be drawn in shells and paired.

2,8,3 aluminium	2,4 carbon	2,8,7 chlorine	2 helium
2,8,2 magnesium	2,8 neon	2,8,5 phosphorus	2,8,8,1 potassium

4. a. i. 0 [1]
   ii. 2,8 [1]
   iii. 2,8,8 [1]
   iv. 2,8 [1]
   v. 2,8 [1]
   b. ii, iv, and v [1]
   c. They have a complete outer electron shell [1]
   So they cannot easily gain or lose electrons / which is a stable electron distribution [1]

Unit 3.5

1. a. Does not conduct electricity / shatters when hit [1]
   b. Conducts heat / very high melting point [1]
   c. Conducts electricity / malleable [1]
   d. Low melting point [1]
   e. Any 2 of: has low melting point / does not conduct electricity / shatters when hit / does not conduct heat [1]
2. a. Aluminium [1] has the lowest density [1]
   b. Iron [1] has highest strength [1]
   c. Copper [1] is the best electrical conductor [1]

Answers

3. Any 6 points, one of which must refer to the Periodic Table, e.g.
   Position in Periodic Table: idea of the 'step line' between metals and non-metals [1]
   They have high melting points so are like many metals [1]
   They are poor electrical conductors so unlike metals [1]
   Electrical conduction increases with temperature / they are semiconductors so unlike metals [1]
   Generally shiny so like metals [1]
   Some exist in metallic and non-metallic forms [1]
   Some forms have a some degree of covalent bonding [1]

Unit 4.1

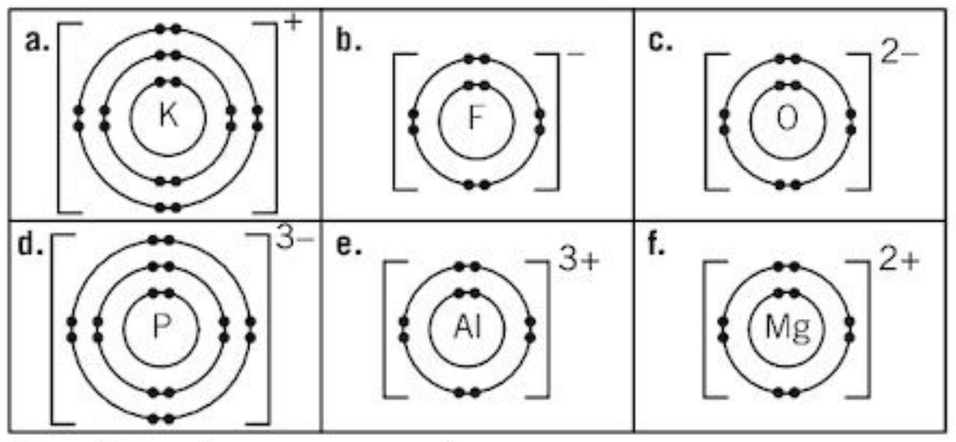
1. Separating iron from sulfur using a magnet [1]
   Melting zinc [1]
   Distilling plant oils from a mixture of plant oils and water [1]
2. 12 correct = 6, 10 or 11 correct = 5, 8 or 9 correct = 4, 6 or 7 correct = 3, 4 or 5 correct = 2, 2 or 3 correct = 1.

Compound	Mixture
The **elements** cannot be **separated** by **physical** means.	The substances in it can be **separated** by **physical** means.
The properties are **different** from those of the **elements** which went to make it.	The properties are the **average** of the substances in it.
The elements are **combined** in a **definite** proportion by mass.	The substances can be **present** in **any** proportion by mass.

3. A compound [1] B element [1] C element [1]
   D mixture [1] E compound [1] F mixture [1]
4. a. CH_4 [1]
   b. C_2H_6 [1]
   c. H_2S [1]
   d. NH_3 [1]
5. a. Any three physical properties of zinc (1 mark each), e.g. high melting point / conducts electricity / malleable
   Any three physical properties of sulfur (1 mark each), e.g. low melting point / dissolves in (some) organic solvents / insoluble in water / brittle
   Any three chemical properties of zinc (1 mark each), e.g. reacts with hydrochloric acid / oxidises slowly in oxygen / reacts with chlorine
   Any three chemical properties of sulfur (1 mark each), e.g. reacts with oxygen / reacts with chlorine / does not react with acids
   b. Any two workable methods (3 marks each), e.g.
   Dissolve sulfur in suitable organic solvent, e.g methylbenzene [1]
   Sulfur dissolves and zinc does not so filter off the zinc [1]
   Take the filtrate and evaporate the organic solvent in fume cupboard to get solid sulfur [1]
   AND
   Dissolve zinc in dilute hydrochloric acid [1]
   Sulfur does not dissolve so filter off the sulfur [1]
   Wash the sulfur residue with distilled water and dry in drying oven [1]

Unit 4.2

1. Any three (1 mark each) of:
   Colour of sodium chloride is different from the colours of chlorine and sodium [1]
   Sodium chloride is not acidic whereas chlorine is slightly acidic [1]
   Sodium chloride dissolves in water but sodium reacts with water [1]
   Heat is given out when the sodium chloride forms [1]
2. a. An ion is a **charged** particle [1]
   b. Ions have unequal numbers of **protons** and **electrons** / Ions have unequal numbers of **electrons** and **protons**
   (1 mark for each gap correctly filled)

3. 2,8 [1] 2,8,8 [1] 2 [1] 2,8,18,8 [1]
4. 

   (1 mark for each correct structure)
5. a. V^{2+} and V^{3+}, Fe^{2+} and Fe^{3+}, Co^{2+} and Co^{3+}, Cu^{+} and Cu^{2+}
   (2 marks for all correct, 1 mark for 6 correct or with 1 ion which is incorrect e.g. Fe^{+})
   b. Most form ions with charges of 2+ and 3+ [1] apart from Cu^{+} [1]
   (if no marks scored allow 1 mark for all form ions with different charges)

Unit 4.3

1. A sodium chloride **lattice** is a **regular** arrangement of **positive** sodium ions and **negative** chloride ions, which **alternate** with each other. The ions are held together by **strong** ionic **bonds**. This structure is called a **giant** ionic structure.
   (1 mark for each correct word)
2. Ionic compounds are formed ..... by the reaction of metals with non metals.
   Ionic compounds have no ..... overall charge.
   When a metal atom forms an ion ..... it loses one or more electrons.
   When a non-metal atom forms an ion ..... it gains one or more electrons
   (4 correct = 2 marks, 2 correct = 1 mark)
3. a. 8 electrons in outer shell of Mg [1]
   8 electrons in outer shell of S [1]
   2– charge on S [1]
   b. Lithium chloride:
   2 electrons in one shell around Li [1]
   2,8,8 electrons for chlorine [1]
   + charge for Li and – charge for Cl at top right of square brackets around each [1]
   Magnesium fluoride:
   2,8 electronic structure for Mg [1]
   2.8 electronic structure for each F [1]
   Each F has single negative (–) charge at top right of [] [1]
   Mg has 2+ charge at top right of [] [1]
   c. Calcium nitride:
   Three Ca ions and two nitride ions shown [1]
   Electronic structure is 2,8,8 for calcium [1]
   Electronic structure is 2,8 for nitride [1]
   2+ charge for Ca and 3– charge for nitride at top right of each [1]

Unit 4.4

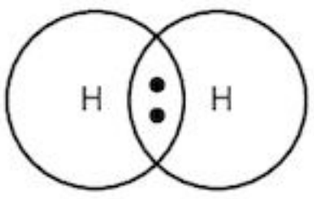
1. a. A $MgBr_2$ [1] B Na_2O [1] C HCl [1] D $AlCl_3$ [1]
   E K_3N [1] F CaS [1] G Al_2S_3 [1] H Fe_2O_3 [1]
   b. J $Mg(NO_3)_2$ [1] K K_2SO_4 [1] L NH_4NO_3 [1] M $(NH_4)_2SO_4$ [1]
   N $Ca(OH)_2$ [1] O $NaHCO_3$ [1] P $Al(NO_3)_3$ [1] Q Li_2CO_3 [1]
2. R magnesium iodide [1]
   S strontium hydroxide [1]
   T iron(II) sulfate [1]
   U zinc nitrate [1]
   V ammonium carbonate [1]
   W calcium hydrogencarbonate [1]
3. a. $KMnO_4$ [1]
   b. Na_2O_2 [1]

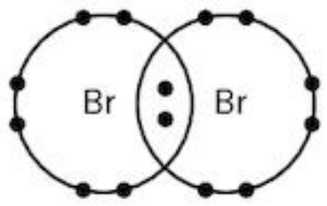
c. $Ca_3(PO_4)_2$ [1]

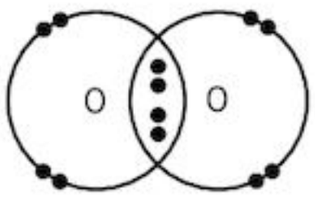
d. $CaSO_3$ [1]

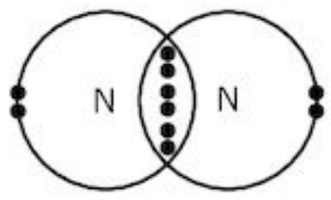
e. Na_3PO_4 [1]

Unit 4.5

1. A covalent bond is formed when **non-metal** atoms combine. It forms because of the **strong** force of **attraction** between the **nucleus** of one atom and the outer **electrons** of the atom next to it. A single **covalent** bond is formed by **sharing** one **pair** of electrons between two atoms.
   (1 mark each word)
2. a. A group of atoms held together by covalent bonds [1]
   b. CO Cl_2 N_2 O_2 [2]
   (1 mark if 3 correct)
3. a. i. 

[1]
ii. 

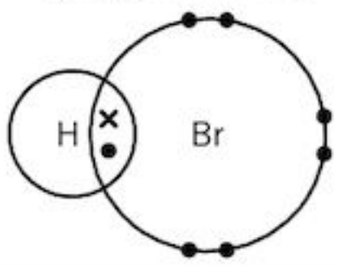
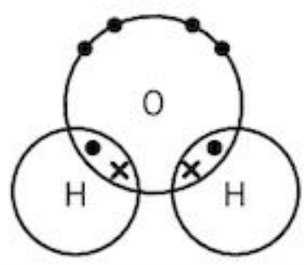
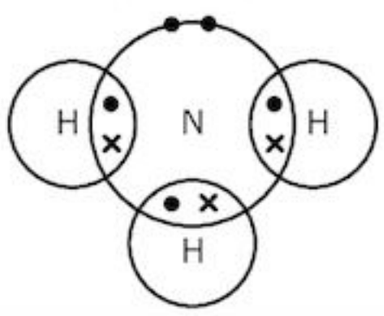
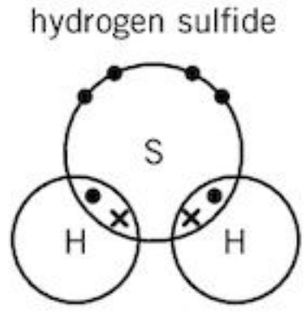
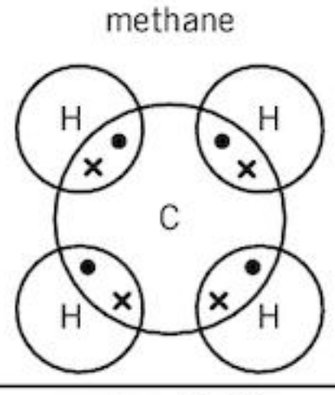
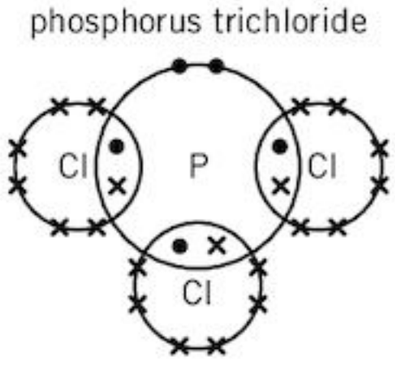
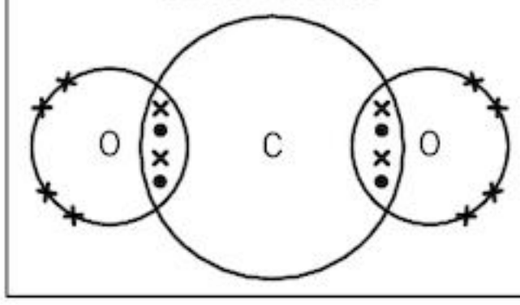
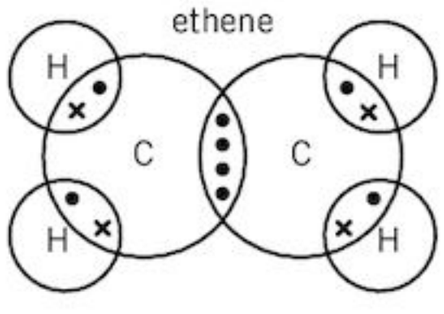
[1]
iii. 

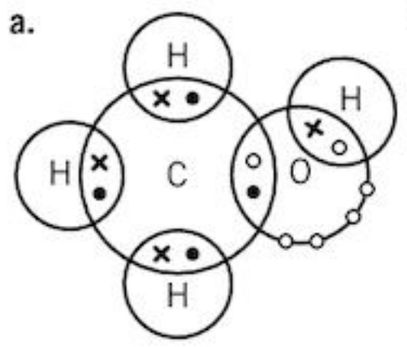
[1]
iv. 

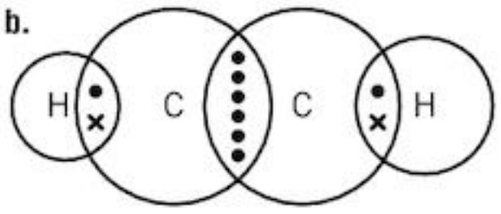
[1]
   b. 2 around the hydrogen and eight around the bromine, oxygen, and nitrogen [1]
   (You will not get this mark if you just write eight)
   c. The electron shells are complete / full [1]
   This is a stable structure / electrons cannot easily be lost or gained [1]
4. (1 mark for each up to a maximum of three) aluminium chloride (vapour) / beryllium chloride / tin tetrachloride / stannane, SnH_4 / plumbane, PbH_4

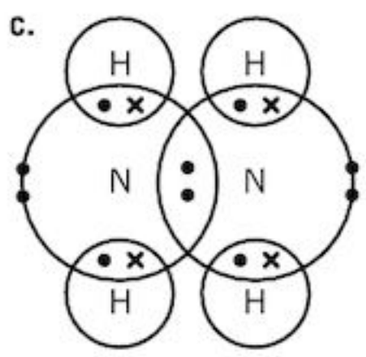
Unit 4.6

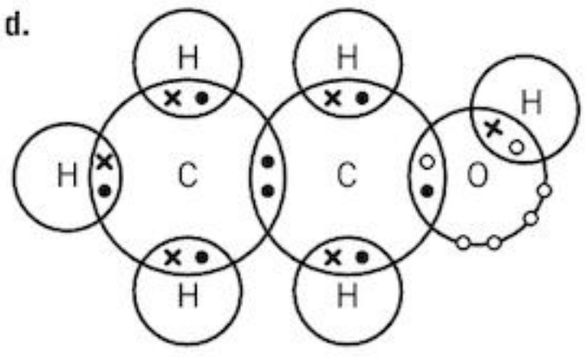
1. a. (1 mark for each correct structure)

hydrogen bromide 	water 
ammonia 	hydrogen sulfide 
methane 	phosphorus trichloride 
carbon dioxide 	ethene 

2. a. 

   b. 

   c. 

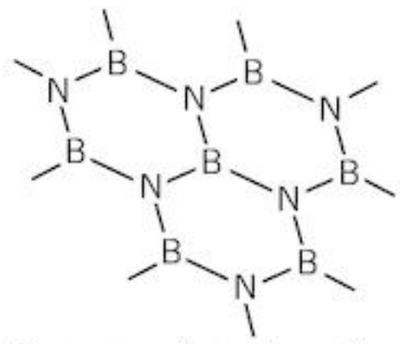
   d. 

   (1 mark each correct structure)

Unit 4.7

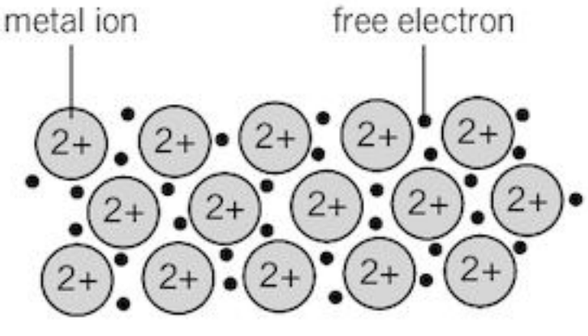
1. Magnesium oxide: ionic
   Carbon tetrachloride: covalent
   Potassium bromide: ionic
   Carbon disulfide: covalent
   Octane: covalent
   (2 marks if all correct and 1 mark if one error)
2. A with 4; B with 7; C with 1; D with 2; E with 6; F with 3; G with 5
   (All 7 correct = 3 marks, 5 or 6 correct = 2 marks, 3 or 4 correct = 1 mark)
3. CS_2, I_2, S_8 [1]
4. The ions are not free to move [1]
5. a. The molecules dissolving in water all have oxygen atoms / OH [1]
   b. 1 mark for each soluble substance, e.g. ammonia / methylamine / sucrose / other alcohols / ethanoic acid / many amino acids

Unit 4.8

1. Diamond: B, C, D [1]
   Graphite: A, D, F [1]
   Silicon dioxide: B, C, D [1]
2. A with 4; B with 1; C with 5; D with 2; E with 3
   (All correct = 2 marks but 3 or 4 correct = 1 mark)
3. a. 4 [1]
   b. 3 [1]
   c. 4 [1] 2 [1]
4. a. 

   Two or more layers drawn (two layers not shown in diagram above) [1]
   (Layers of) hexagons drawn similar to graphite structure [1]
   B atoms alternate with N atoms [1]
   b. Weak force between the layers [1]
   So the layers can slide when a force is applied [1]

Unit 4.9

1. a. 

Answers

Metal ions shown as + or 2+ [1]
Metal ions labelled [1]
Electrons shown as dots randomly dispersed between the metal ions [1]
Electrons labelled free electrons / delocalised electrons / mobile electrons [1]

b. i. Electrons are delocalised / free [1]
They move between the metal ions when voltage applied [1]

ii. When force applied the force of attraction between metal ions and mobile electrons is overcome [1]
The layers slide over each other [1]
(When force removed) new metallic bonds between metal ions and electrons formed [1]

iii. Strong forces of attraction between metal ions and mobile electrons [1]
A large amount of energy is needed to weaken these forces of attraction [1]

2. a. D [1]
b. A, B, and C [1] Idea that metals are to the left of Group IV / to the left of covalent giant structures (in the Periodic Table) [1]
c. E and F [1] They have low melting points / they are to the right of Group IV [1]

3. The large ions disrupt the regular arrangement of the metal ions [1]
The layers cannot slide as easily (compared with the pure metals) [1]

Unit 5.1

1. The formula for giant covalent and **ionic** compounds is the **ratio** of **atoms** or ions in the compound. The formula of a simple molecule shows exactly how many atoms are **bonded** together in each molecule. For example, ammonia has one **nitrogen** and three **hydrogen** atoms so its **molecular** formula is NH_3.
(1 mark for each correct word)

2. a.

			H 1								
Li 1						B 3	C 4	N 3	O 2	F 1	Ne 0
Na 1	Mg 2					Al 3			S 2	Cl 1	
K 1	Ca 2		transition elements variable		Zn 2					Br 1	

(1 mark for each column correct (= 8), 1 mark for H, 1 mark for transition elements)

b. Li, Na, K, Mg, Ca, Zn, Al Allow: H [1]
c. N, O, F, S, Cl, Br Allow: H [1]
d. Any suitable, e.g. C and N / O / S / F / Cl / Br [1]
H and O / N / O / S / F / Cl / Br
N and O / S and O
e. i. H_2S [1]
ii. B_2O_3 [1]
iii. CS_2 [1]
iv. CBr_4 [1]
v. Ca_3N_2 [1]
vi. Al_2O_3 [1]
vii. CH_4 [1]

3. a. (–)1 [1]
b. 3 [1]
c. 2 [1]
d. 1 [1]
e. 4 [1]
f. (–)1 [1]

Unit 5.2

1. a. $O_2 + 2H_2 \rightarrow 2H_2O$
Correct balance [1] correct use of + and → [1]

b. $2C + O_2 \rightarrow 2CO$
Correct balance [1] correct use of + and → [1]

2. a. atoms 2 × H + 2 × Cl 1 × H 1 × Cl [1]
balance $H_2 + Cl_2 \rightarrow 2$ HCl (1)

b. atoms 1 × Mg + 2 × O 1 × Mg 1 × O [1]
balance O 1 × Mg + 2 × O → 2 MgO [1]
balance Mg 2Mg + $O_2 \rightarrow$ 2MgO [1]

3. a. $2K + Br_2 \rightarrow 2KBr$ [1]
b. $4Al + 3O_2 \rightarrow 2Al_2O_3$ [1]
c. $4Na + O_2 \rightarrow 2Na_2O$ [1]
d. $N_2 + 3H_2 \rightarrow 2NH_3$ [1]
e. $2Rb + 2H_2O \rightarrow 2RbOH + H_2$ [1]
f. $I_2O_5 + 5CO \rightarrow I_2 + 5CO_2$ [1]
g. $MgO + 2HNO_3 \rightarrow Mg(NO_3)_2 + H_2O$ [1]
h. $Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$ [1]
i. $3PbO + 2NH_3 \rightarrow 3Pb + N_2 + 3H_2O$ [1]

Unit 5.3

1. Relative atomic mass (symbol A_r) is the **average** mass of naturally occurring **atoms** of an element on a scale where the **carbon-12** atom has a mass of exactly **twelve** units. The relative **molecular** mass (symbol M_r) is the **sum** of the relative atomic masses of the atoms in a molecule. For ionic substances we use the term relative **formula** mass. [9]

2. a. 2 marks for each correct M_r (If 2 not scored, 1 mark for correct number of atoms)

Compound	Number of each atom	A_r of atom	M_r calculation
phosphorus trichloride PCl_3	P = 1 Cl = 3	P = 31 Cl = 35.5	1 × 31 3 × **35.5** M_r = 137.5
magnesium hydroxide $Mg(OH)_2$	Mg = 1 O = 2 H =2	Mg = 24 O = 16 H =1	1 × 24 2 × 16 2 × 1 M_r = 58
ethanol C_2H_5OH	C = 2 H = 6 O = 1	C =12 H = 1 O = 16	2 × 12 6 × 1 1 × 16 M_r = 46
ammonium sulfate $(NH_4)_2SO_4$	N = 2 H = 8 S = 1 O = 4	N = 14 H = 1 S = 32 O =16	2 × 14 8 × 1 1 × 32 4 × 16 M_r = 132
glucose $C_6H_{12}O_6$	C = 6 H = 12 O = 6	C = 12 H = 1 O = 16	6 × 12 12 × 1 6 × 16 M_r = 180

b. i. 342 [1] ii. 183 [1] iii. 220 [1]
c. i. 284 [1] ii. 363 [1] iii. 393 [1] iv. 287 [1]

Unit 5.4

1. a. i. $2H_2 + O_2 \rightarrow 2H_2O$
2 × **2** + 1 × **32** → 2 × **18** [1]
4 g + **32** g → **36** g [1]

ii. $2Al + 3Cl_2 \rightarrow 2AlCl_3$
2 × **27** + 3 × **71** → 2 × **133.5** [1]
54 g + **213** g → **267** g [1]

Answers

b. i. $\frac{12}{48} \times 80 = 20$ g
[1] [1]

ii. 4.8 g [1]

iii. 280 g [1]

2. a. $\frac{2 \times 12}{(2 \times 12) + (6 \times 1)} \times 100 = 80\%$
(2 marks for correct answer, 1 mark if answer wrong but working correct)

b. $\frac{14}{17} \times 100 = 82.4\%$ (2 marks if correct, 1 mark if answer wrong but working correct)

c. $\frac{40}{100} \times 100 = 40\%$ (2 marks if correct,1 mark if answer wrong but working correct)

d. $\frac{3 \times 23}{164} \times 100 = 42\%$ (2 marks if correct,1 mark if answer wrong but working correct)

Unit 6.1

1. [11]

Element / compound	Formula	Number of atoms × A_r	Molar mass / g
iodine	I_2	2I	2 × 127 = **254** [1]
propane	C_3H_8	3C, 8H	(3 × **12**) + (8 × **1**) [1] = **44** [1]
magnesium oxide	MgO	1Mg, 1O	= **40** [1]
barium carbonate [1]	$BaCO_3$	**1Ba, 1C, 3O** [1]	= **197** [1]
potassium nitrate [1]	KNO_3	**1K, 1N, 3O** [1]	= **101** [1]
phosphorus(V) chloride	PCl_5	**1P, 5Cl** [1]	= **208.5** [1]

2. a. $\frac{m}{M}$ [1]

b.

Element or compound	Formula mass, M_r	Mass taken / g	Number of moles
O_2	32	4	**0.125** [1]
NaCl	**58.5** [1]	11.7	**0.2** [1]
$CaSO_4$	**136** [1]	27.2	**0.2** [1]
P_2O_5	**142** [1]	**56.8** [1]	0.4
CO_2	**44** [1]	**4.4** [1]	0.1
P_4	**124** [1]	86.8	**0.7** [1]
CH_4	**16** [1]	**384** [1]	24.0

3. a. $M_r = 296$ [1] mass = 118.4 g [1]

b. $M_r = 263$ [1] moles = 0.03 mol [1]

c. mol Cl^- = 0.5 mol [1] number of ions = 3.01×10^{23} mol^{-1} [1]

Unit 6.2

1. a. i. $2 \times 24 + 1 \times 32 \rightarrow 2 \times 40$ [1]
48 g + **32** g → **80** g [1]

ii. $4 \times 34 \rightarrow 1 \times 124 + 6 \times 2$ [1]
136 g → **124** g + **12** g [1]

iii. $1 \times 76 + 3 \times 71 \rightarrow 1 \times 154 + 1 \times 135$ [1]
76 g + **213**g → **154** g + **135** g [1]

b. i. 5 [1]

ii. 1 [1]

iii. 2 [1]

iv. mol I_2O_5 = 20.04 / 334 = 0.06 [1] So 5 × 0.06 = 0.30 mol CO_2 [1]
mass CO_2 = 0.30 × 44 = 13.2 g [1]

v. mol CO = 21/28 = 0.75 [1] So 0.75 / 5 = 0.15 mol I_2 [1]
mass of I_2 = 0.15 × 254 = 38.1 g [1]

2. a. 232 – 168 = 64 g [1]

b. 64/ 16 = 4 mol O [1]

c. 168/ 56 = 3 mol [1]

d. 3Fe:4O [1] Fe_3O_4 [1]

3. 2 moles Cl_2 produces 2/3 mole CCl_4 [1] = 2/3 × 154 g = 102.7 g CCl_4 [1]

Unit 6.3

1. a. 1000 cm^3 [1]

b. 24 dm^3 [1]

c. (number of) moles of gas × 24 [1]

d. $\frac{\text{volume of gas in dm}^3}{24}$ [1]

2.

Gas	M_r of gas	Mass of gas / g	Moles of gas / mol	Volume of gas / dm^3
ammonia	17	8.5	**0.5** [1]	**12** [1]
oxygen	32	**640** [1]	**20** [1]	480
carbon dioxide	44	3.08	**0.07** [1]	**1.68** [1]
hydrogen chloride	**36.5** [1]	292	8	**192** [1]
ethane	30	**3.75** [1]	**0.125** [1]	3

3. a. 50 cm^3 [1]

b. 75 cm^3 [1]

c. 2:3

d. $\underline{2}N_2O(g) \rightarrow \underline{2}N_2(g) + O_2(g)$ [1]

4. 8.8 g propane = 8.8/ 44 = 0.2 mol [1]
So 3 × 0.2 moles = 0.6 moles CO_2 [1]
Volume of CO_2 = 0.6 × 24 = 14.4 dm^3 [1]

Unit 6.4

1. a. concentration in mol / dm^3 = $\frac{\text{amount of solute in } \textbf{moles} \text{ [1]}}{\textbf{volume of solution} \text{ [1] in } \textbf{dm}^3 \text{ [1]}}$

b. amount of solute (moles) = concentration (mol / dm^3) × volume of solution (dm^3) [1]

c. volume (dm^3) = $\frac{\text{amount of solute (moles)}}{\text{concentration (mol/ dm}^3\text{)}}$ [1]

2. a. i. 200 cm^3 [1] ii. 40 cm^3 [1] iii. 3500 cm^3 [1] iv. 8 cm^3 [1]

b. i. 0.025 dm^3 [1] ii. 0.75 dm^3 [1] iii. 4.0 dm^3 [1]
iv. 0.156 dm^3 [1]

3.

Solute	M_r of solute	Mass of solute / g	Volume of solution cm^3 or dm^3	Concentration of solution mol / dm^3
sodium hydroxide	40	8	250 cm^3	**0.80** [1]
silver nitrate	170	**17** [1]	200 cm^3	0.5
copper(II) sulfate	160	40	**2.0 dm³** [1]	0.125
potassium sulfate	174	3.48	750 cm^3	**0.027** [1]
ammonium chloride	53.5	**214** [1]	5.0 dm^3	0.8
sulfuric acid	98	4.9	**25 cm³**[1]	2.0

4. Molar mass of CuF_2 = 102 [1]
   Solubility in g/dm³ = $(4.54 \times 10^{-1}) \times 102 = 46.3$ g/dm³ [1]
   Mass in 200 cm³ = 9.26 g [1]
   Mass remaining = 15 – 9.26 = 5.74 g [1]

Unit 6.5

1. a. moles of Pb = 0.1 mol moles of Cl = **0.4** mol [1]

Divide by lowest number of moles	Pb	$\frac{0.1}{0.1}$	Cl	$\frac{0.4}{0.1}$
Result of division		= 1		= 4

   Simplest ratio **1Pb:4Cl** [1] So empirical formula is **$PbCl_4$** [1]

   b. mole % of C = $\frac{85.7}{12}$ = **7.14** mole % of H = $\frac{14.3}{1}$ mol = **14.3** [1]

Divide by lowest number of moles	C	$\frac{7.14}{7.14}$	H	$\frac{14.3}{7.14}$
Result of division		= 1		= 2

   Simplest ratio **1C:2H** [1] So empirical formula is **CH_2** [1]

   c. mole % of N = $\frac{87.5}{14}$ = **6.12** mole % of H = $\frac{12.5}{1}$ mol = **12.5** [1]

Divide by lowest number of moles	N	$\frac{6.25}{6.25}$	H	$\frac{12.5}{6.25}$
Result of division		= 1		= 2

   So empirical formula is **NH_2** [1]

2. a. Weigh the tube [1]
   Weigh the aluminium powder accurately / weigh tube + aluminium powder [1]
   Pass the chlorine over the heated aluminium until reaction is complete [1]
   Weigh the tube + aluminium chloride [1]
   Find the mass of the aluminium chloride by subtraction [1]
   Deduce mass of chlorine (from mass of aluminium chloride – mass of aluminium) [1]
   Deduce moles of aluminium and moles of chlorine [1]
   Find simplest ratio in which aluminium and chlorine combine [1]
   b. Use of fume cupboard [1]
   Absorb excess chlorine in suitable chemical [1]
   Use of gloves setting up and manipulating apparatus [1]

Unit 6.6

1. The molecular formula of a **compound** shows the number of **atoms** of each type in one molecule. The empirical formula shows the **simplest** ratio of atoms which combine. The formula of an **ionic** compound is the same as its **empirical** formula.
   (1 mark each correct word)
2. a. HO b. CH_2 c. NO_2 d. Sb_2O_3 e. C_2H_5 f. P_2O_5 g. Na_2SO_4
   (1 mark each)
3. A empirical formula mass 110 [1] molecular formula P_4O_6 [1]
   B empirical formula mass 67.5 [1] molecular formula S_2Cl_2 [1]
   C empirical formula mass 30 [1] molecular formula $C_2H_4O_2$ [1]
   D empirical formula mass 83 [1] molecular formula C_4Cl_8 [1]
4. Mass of O = 360 – 168 = 192 [1]
   Dividing by atomic masses [1]
   C: 144/12 = 12, H 24/1 = 24, O = 192/ 16 = 12
   Dividing by 12 to get empirical formula, CH_2O [1]
   Empirical formula mass = 30 [1]
   Relative molecular mass = 180
   Molecular formula = $C_6H_{12}O_6$ [1]

Unit 6.7

1. a. 100 g/mol [1]
   b. 3.840 dm³ [1]
   c. 3.840/24 = 0.16 mol [1]
   d. 0.16 mol [1]
   e. 0.16 × 100 = 16 g [1]
   f. 16/18 (× 100) = 89% [1]
2. a. 122 g/mol [1]
   b. 24.4/122 = 0.2 mol [1]
   c. 0.2 mol [1]
   d. 136 g/mol [1]
   e. 0.2 × 136 = 27.2 g [1]
   f. 25.84/27.2 (× 100) = 95% [1]
3. Mol Al = 5.4/27 = 0.2 mol [1]
   Mol Al_2O_3 expected = 0.1 mol [1]
   Mass of Al_2O_3 expected = 0.1 × 102 = 10.2 g [1]
   % yield = 8.67/10.2 (× 100) = 85% [1]

Unit 7.1

1. Reactions that involve both oxidation and **reduction** are called **redox** reactions. Oxidation is the **gain** of oxygen, and reduction is the **loss** of oxygen. Combustion involves the **oxidation** of a substance, during which **heat** is given out and one or more of the **reactants** is a gas.
   (1 mark each word)
2. a. Arrow from hydrogen to water labelled oxidation [1]
   Arrow from oxygen to water labelled reduction [1]
   b. Arrow from lead oxide to lead labelled reduction [1]
   Arrow from hydrogen to water labelled oxidation [1]
   c. Arrow from iron oxide to iron labelled reduction [1]
   Arrow from carbon to carbon monoxide labelled oxidation [1]
   d. Arrow from carbon to carbon monoxide labelled oxidation [1]
   Arrow from water to hydrogen labelled reduction [1]
   e. Arrow from zinc oxide to zinc labelled reduction [1]
   Arrow from carbon to carbon monoxide labelled oxidation [1]
   f. Arrow from iron to iron oxide labelled oxidation [1]
   Arrow from water to hydrogen labelled reduction [1]
3. a. Arrows from methane to both carbon dioxide and water labelled oxidation [1]
   Arrows from oxygen to carbon dioxide and water labelled reduction [1]
   b. Arrow from carbon disulfide to carbon labelled reduction [1]
   Arrow from hydrogen to hydrogen sulfide labelled oxidation [1]

Unit 7.2

1. a. $Ca \rightarrow Ca^{2+} + 2e^-$ [1] oxidation [1]
   b. $Cl_2 + 2e^- \rightarrow 2Cl^-$ [1] reduction [1]
   c. $Al^{3+} + 3e^- \rightarrow Al$ [1] reduction [1]
   d. $Fe^{2+} \rightarrow Fe^{3+} + e^-$ [1] oxidation [1]
   e. $O_2 + 4e^- \rightarrow 2O^{2-}$ [1] reduction [1]
   f. $Pb^{4+} + 2e^- \rightarrow Pb^{2+}$ [1] reduction [1]
   g. $2Br^- \rightarrow Br_2 + 2e^-$ [1] oxidation [1]
2. a. Na^+ and OH^- [1] b. Mg^{2+} and Cl^- [1] c. Ba^{2+} and NO_3^- [1]
   d. Cu^{2+} and SO_4^{2-} [1] e. Al^{3+} and O^{2-} [1] f. Fe^{2+} and OH^- [1]
3. a. Ions $Cu^{2+} + 2Cl^-$ [1] $2Na^+ + 2OH^-$ [1]
   Cancel: $Cu^{2+} + \cancel{2Cl^-}$ and $\cancel{2Na^+} + 2OH^-$ [1]
   Equation: $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$ [1]
   b. Ions: $Ba^{2+} + 2Cl^- \; Mg^{2+} + SO_4^{2-}$ [1] $\rightarrow Mg^{2+} + 2Cl^-$ [1]
   Cancel: $Ba^{2+} + \cancel{2Cl^-} + \cancel{Mg^{2+}} + SO_4^{2-}$ [1] $\rightarrow \cancel{Mg^{2+}} + \cancel{2Cl^-}$ [1]
   Equation $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ [1]

Answers

4. a. $Pb^{2+}(aq) + 2Cl^-(aq) \rightarrow PbCl_2(s)$
(1 mark for reactants and products, 1 mark for balance and state symbols)
b. $Cl_2(aq) + 2I^-(aq) \rightarrow I_2(s) + 2Cl^-(aq)$
(1 mark for reactants and products, 1 mark for balance and state symbols)

Unit 7.3

1. Oxidation state (oxidation **number**) tells us how many **electrons** each atom of an element has gained, lost, or **shared** when forming a **compound**.
The oxidation state of **atoms** of an uncombined element is **zero**.
(1 mark for each correct word)
2. **a.** +2 **b.** +4 **c.** –2 **d.** +3 **e.** –1 **f.** + 4 **g.** +3 **h.** +1 **i.** +6
(1 mark each)
3. **a.** 0 to +3 [1] oxidation [1]
b. 0 to + 4 [1] oxidation [1]
c. +2 to 0 [1] reduction [1]
d. 0 to –1 [1] reduction [1]
e. 0 to + 3 [1] oxidation [1]
4. **a.** +7 **b.** +6 **c.** +3 **d.** +4 **e.** +5 (1 mark each)

Unit 7.4

1. A with 3, B with 4, C with 2, D with 1
(2 marks if all 4 correct, 1 mark if 2 correct)
2. Acidified potassium manganate(VII) is ..... an oxidising agent ..... that turns from purple ..... to colourless ..... in the presence of a reducing agent.
(2 marks if all correct, 1 mark if 1 error)
Acidified potassium iodide is ..... a reducing agent ..... that turns from colourless ..... to brown ..... in the presence of an oxidising agent.
(2 marks if all correct, 1 mark if 1 error)
3. a. $\underline{2Mg} + \textcircled{O_2} \rightarrow 2MgO$ [1]
b. $\textcircled{PbO} + \underline{H_2} \rightarrow Pb + H_2O$ [1]
c. $\underline{2I^-} + \textcircled{Cl_2} \rightarrow I_2 + 2Cl^-$ [1]
d. $\textcircled{H_2O_2} + \underline{2I^-} \rightarrow I_2 + 2H_2O$ [1]
e. $\textcircled{3CuO} + \underline{2NH_3} \rightarrow 3Cu + N_2 + 3H_2O$ [1]
f. $\underline{Zn} + \textcircled{Cu^{2+}} \rightarrow Zn^{2+} + Cu$ [1]

Unit 8.1

1. a. i. (Indicator) bulb / lamp labelled [1] cells / battery / power source labelled [1]
ii. Arrows in clockwise direction [1]
2. Electrolyte: liquid that conducts electricity [1]
Electrolysis: breakdown of ionic substance when molten or in solution [1] by passage of electricity [1]
Insulator: non-conductor [1]
3. A with 3; B with 1; C with 4; D with 2 (2 marks if 4 correct, 1 mark if 2 or 3 correct)
4. a. Good electrical conductor [1] low density / lightweight [1]
b. (Fairly good) electrical conductor [1] strong [1]
5. Four substances having delocalised electrons (1 mark for each two)
e.g. graphite / metal (only 1 allowed) / aromatic hydrocarbons, e.g. benzene, phenol, graphene / nanotubes
Some substances containing delocalised electrons are molecules [1]
So electrons cannot flow from one molecule to another. [1]

Unit 8.2

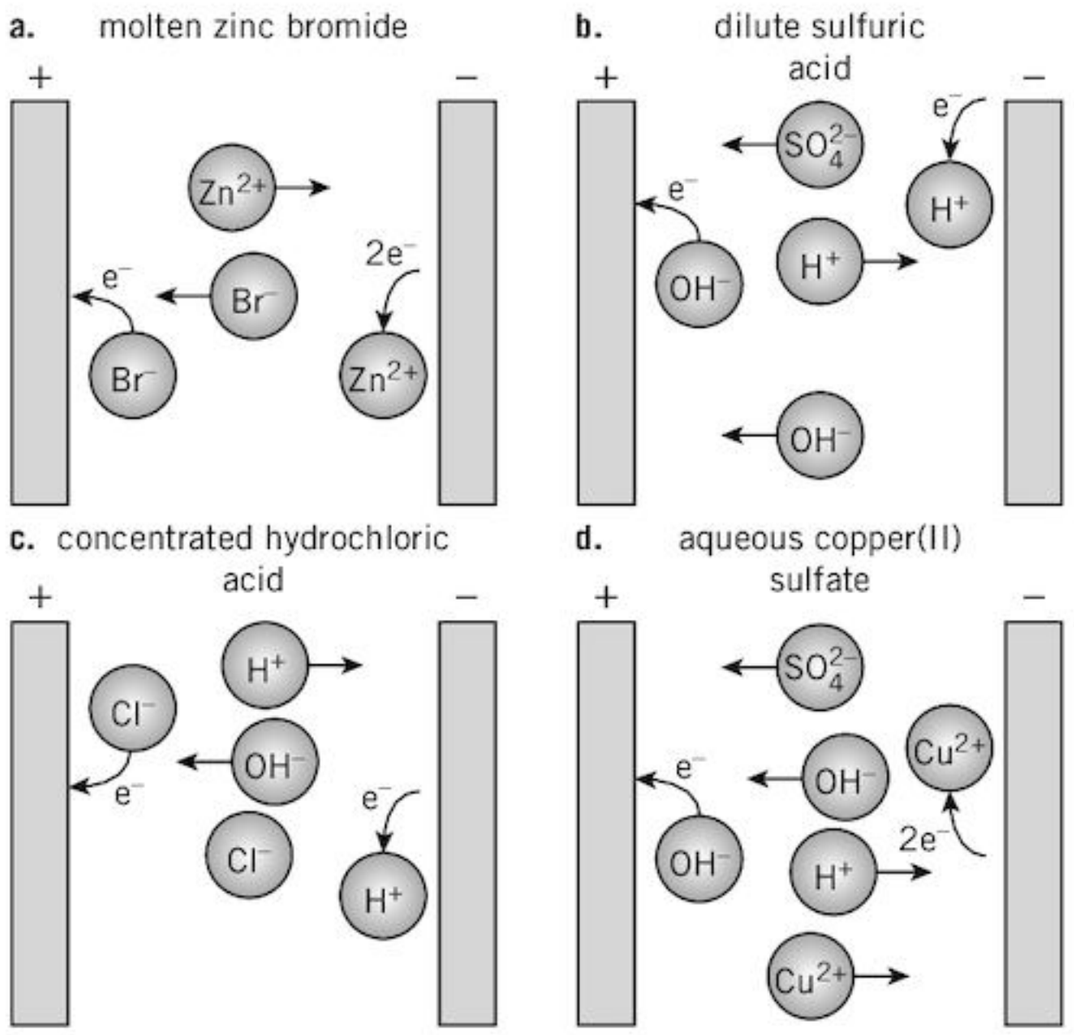
1. A battery / cell(s) / power supply [1]
B anode [1]
C cathode [1]
D electrolyte [1]
Arrows on external circuit from + electrode to power pack and power pack to – electrode (clockwise). [1]
2. Reactive elements such as **sodium** are **more** likely to form ions than **less** reactive elements such as **silver**. If a metal is more reactive than **hydrogen**, its **ions** stay in solution during electrolysis and hydrogen arising from hydrogen ions in **water** bubbles off. (1 mark for each correct word)
3. (1 mark for each 'cell' correct)

Electrolyte	Cathode (–) product	Anode (+) product	Observations at the anode
Concentrated KCl(aq)	hydrogen	chlorine	bubbles of gas, green when collected
ZnBr(l)	zinc	bromine	red-brown vapour
Dilute $H_2SO_4(aq)$	hydrogen	oxygen	colourless bubbles
Dilute NaCl(aq)	hydrogen	oxygen	colourless bubbles
Concentrated HCl(aq)	hydrogen	chlorine	bubbles of gas, green when collected
Dilute $AgNO_3(aq)$	silver	oxygen	colourless bubbles

4. a. Hydrogen formed at the cathode [1] because sodium is too high in the reactivity series to be discharged [1]
Bromine formed at the anode [1] because halogens are discharged more readily than hydrogen and the concentration is high [1]
b. Hydrogen formed at the cathode [1] because sodium is too high in the reactivity series to be discharged [1]
Mixture of chlorine and oxygen formed at the cathode [1] Neither concentrated, when largely chlorine would be discharged, nor dilute, when largely oxygen would be discharged [1]

Unit 8.3

1. a.



Zinc ions moving to cathode and bromide ions to anode [1]
Bromide ions donating electrons to anode and zinc ions taking electrons from cathode [1]
b. Hydrogen ions moving to cathode and hydroxide and sulfate ions to anode [1]
Hydroxide ions donating electrons to anode and hydrogen ions taking electrons from cathode [1]
c. Hydrogen ions moving to cathode and chloride and hydroxide ions to anode [1]
Chloride ions donating electrons to anode and hydrogen ions taking electrons from cathode [1]

Answers

d. Hydrogen ions and copper ions moving to cathode and hydroxide and sulfate ions to anode [1]
Hydroxide ions donating electrons to anode and copper ions taking electrons from cathode [1]

2. a. i. positive [1] gain [1]
ii. negative [1] lose [1]
iii. cathode, anode [1]
b. i. $Zn^{2+} + \underline{2e^-} \rightarrow Zn$ [1]
ii. $\underline{2}Cl^- \rightarrow \underline{Cl_2} + \underline{2e^-}$ (1 mark for 2 and Cl_2, 1 mark for balance with electrons)
iii. $\underline{2}H^+ + \underline{2e^-} \rightarrow \underline{H_2}$ (1 mark for 2 and H_2, 1 mark for balance with electrons)
iv. $Al^{3+} + \underline{3e^-} \rightarrow \underline{Al}$ [1]

3. a. $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$
(1 mark for correct formulae including electrons, 1 mark for balance)
b. $2O^{2-} \rightarrow O_2 + 4e^-$
(1 mark for correct formulae including electrons, 1 mark for balance)

Unit 8.4

1. a. i. Aqueous sodium chloride [1]
ii. $2\ \underline{NaCl(aq)} + 2H_2O(\underline{l}) \rightarrow 2NaOH(\underline{aq}) + \underline{Cl_2}(g) + H_2(\underline{g})$
(1 mark for NaCl and Cl_2, 1 mark for correct state symbols)
b. i. A chlorine [1] D hydrogen [1]
ii. R [1]
iii. Chlorine discharged more readily than oxygen [1]
from hydroxide ions in water [1]
iv. Sodium is higher in the reactivity series than hydrogen [1]
So hydrogen is discharged preferentially / discharged instead [1]
v. (Aqueous) sodium hydroxide [1]
vi. Ions present in solution in brine are chloride, hydroxide, hydrogen, and sodium [1]
Hydrogen and chloride ions are consumed at the electrodes [1]
Leaving sodium and hydroxide ions in solution [1]

2. Anode: $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$
(1mark for formulae including electron, 1 mark for balance)
Cathode: $2H^+ + 2e^- \rightarrow H_2$
(1mark for formulae including electron, 1 mark for balance)

Unit 8.5

1.

mass of the electrodes	anode: no change [1] cathode: increases slightly [1]	anode: decreases [1] cathode: large increase [1]
appearance	anode: none / bubbles given off [1] cathode: goes pink / brown [1]	anode: gets thinner [1] cathode: gets thicker with lighter colour pink deposit [1]
electrolyte	gets a lighter blue / fades [1]	remains same depth of colour [1]

2. a. A = rod, C = jug, E = solution in which the anode and cathode dip [1]
(3 correct = 2 marks, 1 or 2 correct = 1 mark)
b. gains mass (slightly) [1] becomes silvery [1]
silver ion is positive [1] So silver deposited on negative electrode [1]

3. a. $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$
(1 mark for correct formulae including electrons, 1 mark for balance)
b. $Ni^{2+} + 2e^- \rightarrow Ni$ (2 marks if completely correct, but if not, 1 mark for Ni^{2+})

Unit 9.1

1. a. endothermic [1] b. exothermic [1] c. endothermic [1]
d. exothermic [1] e. exothermic [1]

2. a. Energy on the vertical axis of both L and M [1]
Reactants on lines on the left of both L and M [1]
Products on the lines on the right of both L and M [1]
Downward arrow between the two lines in L [1]
Upward arrow between the two lines in M [1]
b. The energy of the reactants is greater than the energy of the products [1]
So energy is released [1]

3. Endothermic [1] The energy change / ΔH is positive [1]

4. a. 8.8 g propane = 8.8/44 = 0.2 mol [1]
$0.2 \times -2219 = -443.8$ kJ [1]
b. 4.8 dm^3 = 4.8/24 = 0.2 mol CO_2 [1]
For every mole of CO_2 only one-third of a mole of propane to be burnt
So moles of propane = 0.2/3 = 0.067 mol [1]
$0.067 \times -2219 = -147.9$ kJ [1]

Unit 9.2

1. In an exothermic reaction ..... the energy released ..... in forming new bonds ..... in the products ..... is greater ..... than the energy absorbed ..... in breaking the bonds ..... in the reactants. [1]
In an endothermic reaction ..... the energy released ..... in forming new bonds ..... in the products ..... is less ..... than the energy absorbed ..... in breaking the bonds ..... in the reactants. [1]

2.

Bonds broken (endothermic +) / kJ	Bonds formed (exothermic –) / kJ
$4 \times (C–H) = 4 \times 413 = \underline{1652}$ [1] $\underline{2} \times (O=O) = \underline{2 \times 498} = \underline{996}$ [1]	$2 \times (C=O) = 2 \times 805 = 1610$ [1] $4 \times (O–H) = 4 \times 464 = 1856$ [1]
Total + $\underline{2648}$	Total = –3466

Overall energy change = (+ 2648) + (–3466) = –818 kJ [1]

3.

Bonds broken (endothermic +) / kJ	Bonds formed (exothermic –) / kJ
$2 \times (H–H) = 2 \times 436 = 872$ [1] $1 \times (O=O) = 498 = 498$ [1]	$4 \times (O–H) = 4 \times 464 = 1856$ [1]
Total + 1370	Total = – 1856

Overall energy change = (+ 1370) + (– 1856) = – 486 kJ [1]

4. The CH_3 groups in propane [1] affect the bond energy of the C=O bond [1]

Unit 9.3

1. Graph with two axes with energy labelled in kJ (or J) on vertical axis [1]
$CH_4(g) + 2O_2(g)$ on horizontal line on left of diagram and $CO_2(g) + 2H_2O(l)$ on horizontal line on right of diagram, reactants higher than products [1]
Arrow drawn downwards from horizontal line on left to horizontal line on right [1]

2. a. D [1]
b. B [1]
c. i. B [1] it has the lowest density / it weighs least [1]
ii. Hazard of the fuel e.g. how combustible it is / how poisonous it is / its state / whether it is solid, liquid, or gas [1]
d. When fossil fuels such as **coal** burn, they produce **carbon dioxide**, which contributes to **global** warming. Burning coal in power stations also produces **sulfur dioxide**, which causes **acid rain**.
(4 marks if all correct, 3 marks if 6 or 7 correct, 2 marks if 4 or 5 correct, 1 mark if 2 or 3 correct)

3. Energy given out as heat in the decay [1]
This heats up a gas / liquid [1]
Hot gas / liquid used to heat up steam [1]
Steam used to power generator / turbine [1]
Motion of rotating generator / turbine and magnet produces electrical energy [1]

Answers

Unit 9.4

1. a. Magnesium is **more** reactive than copper. It forms **ions** more readily than copper. So in cell **P** magnesium loses electrons. Magnesium becomes the **negative** pole of the cell. The **electrons** flow along the **wires** to the **copper** strip. At the **positive** pole of the cell, **hydrogen** ions from the solution **gain** electrons and hydrogen gas is formed.
   (1 mark each correct word)
   b. i. magnesium [1] because the voltage difference between magnesium and copper is higher [1]
   ii. 2.26 V [1]
   c. i. lithium [1]
   ii. silver [1]
   iii. zinc / iron [1]
2. Negative pole: $2H_2(g) \rightarrow 4H^+(aq) + 4e^-$
   (1 for correct equation, 1 for correct state symbols)
   Positive pole: $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$
   (1 for correct equation, 1 for correct state symbols)

Unit 9.5

1. a. Reversible reaction / equilibrium reaction [1]
   b. It goes pink [1]
   c. Warm / heat gently [1]
   d. Heating hydrated cobalt chloride to get anhydrous cobalt chloride is endothermic [1]
   So the reverse reaction must be exothermic [1]
2. a. closed [1]
   b. rate, forward, rate, reverse/ backward OR rate, reverse / backward, rate, forward
   (1 mark for rate and rate, 1 mark for backward and forward in the correct positions)
3. Molecules randomly arranged in the mixture [1]
   All three types of molecule present [1]
   More molecules of hydrogen iodide than molecules of hydrogen and iodine [3]
4. a. Concentration on vertical axis and time on horizontal axis [1]
   Upward curve of decreasing gradient [1]
   Curve levelling off after time and remaining horizontal [1]
   b. Downward curve of decreasing gradient [1]
   Curve levelling off after time and remaining horizontal [1]
   Curve levels off at the same level as the one in part a. [1]

Unit 9.6

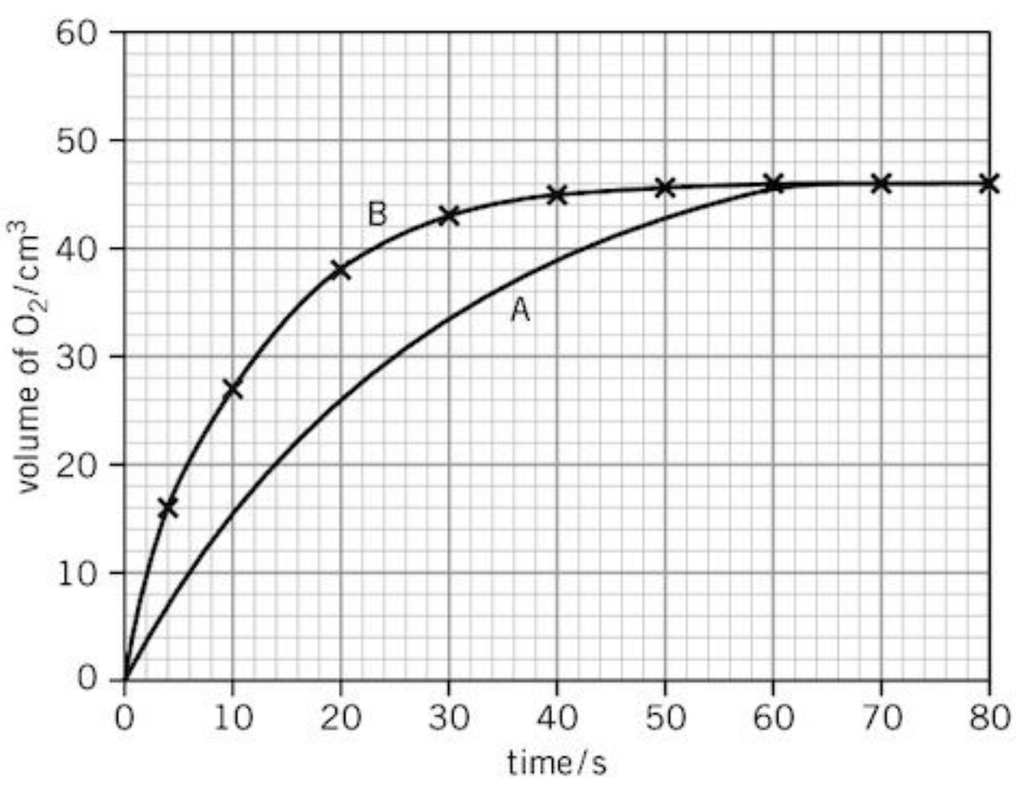
1. a. left [1]
   b. decreases [1]
   c. left [1] more [1] left [1] OR left [1] fewer [1] right [1]
   NOTE: third mark dependent on second being correct
   d. has no effect on position of equilibrium / ONLY affects rate [1]
2. a. to the right [1]
   b. to the left [1]
   c. to the right [1]
   d. no effect [1]
3. a. White precipitate disappears [1]
   b. Increase in amount of white precipitate [1]
   c. There are no gaseous reactants or products [1]
4. Temperature of 450 °C [1] Pressure just above atmospheric [1]
   The temperature is a compromise [1] between:
   A faster rate of reaction the higher the temperature [1]
   and a lower yield at higher temperature [1]
   because the reaction is exothermic [1]
   High pressure is not used because the yield is very high [1]
   So it would not be worthwhile spending extra money on expensive pressure equipment (compressors) [1]

Unit 10.1

1. a. Copper reducing in size [1]
   Solution getting darker [1]
   Gas given off [1]
   b. (1 mark each for any three)
   decrease in mass of copper per minute / increase in volume of gas per minute / increase in depth of colour of solution OR increase in copper compound per minute / decrease in concentration of acid per minute
   c. (1 mark each for the correct graph related to the method chosen)
   decrease in mass of copper per minute = A
   increase in volume of gas per minute = B
   increase in depth of colour of solution = B
   decrease in concentration of acid per minute = A
   d. i. Q = 30 cm^3/min [1] R = 18 cm^3/min [1] S = 25 cm^3/min [1]
   ii. R [1]
2. a. 120/24000 [1] = 5×10^{-3} mol in 2 min so $5 \times 10^{-3}/(2 \times 60)$ [1] = 4.17×10^{-5} mol/s [1]
   b. 9.2/46 mol [1] = 0.2 mol in 20 min so $0.2/(20 \times 60)$ [1] = 1.67×10^{-4} mol/s [1]

Unit 10.2

1. a. 64 s [1]
   b. 46 cm^3
   c. 33 cm^3 [1]
   d. 33/ 30 shown on graph [1] rate = 1.10 cm^3/s [1]
   e. Points all plotted correctly [1] Best-fit curve through the points [1]



2. Any three suitable methods (1 mark each) with reasons (1 mark each) e.g.
   Measure electrical conductivity [1] Ions have different conductivities and so the number and type of ions may be used to measure rate [1]
   Use a colorimeter [1] Intensity of a particular colour may change during the reaction [1]
   Sampling, quenching, then titrating sample [1] Concentration of reactant or product changes during reaction [1]

Unit 10.3

1. a. A gas syringe [1] B flask [1] C (dilute) hydrochloric acid [1]
   D magnesium [1]
   b. (1 mark each for any three) temperature / size of magnesium ribbon / volume of acid / mass of magnesium ribbon
   c. i. A [1]
   ii. 42/30 = 1.40 cm^3 / s [1]
   iii. At 20 s: 60–10/44 [1] = 1.14 cm^3/s [1] ALLOW: 1.0 to 1.2
   At 40 s: 60–25/53 [1] = 0.66 cm^3/s [1] ALLOW: 0.62 to 0.70

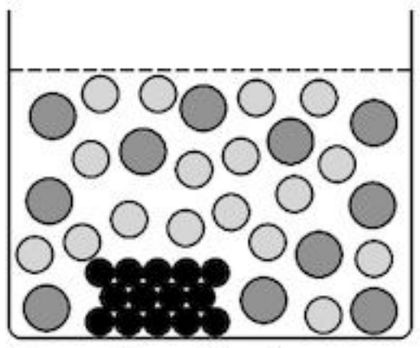
Answers

Unit 10.4

1. a. i. $2 \times 2 \times 6 = 24\ cm^2$ [1]
   ii. For 1 cube surface area $= 1 \times 1 \times 6 = 6\ cm^2$ [1]
   For 8 cubes $= 6 \times 8 = 48\ cm^2$ [1]
   iii. B [1]
   b. Three curves similar to those on page 53 and levelling off [1]
   Steepest curve labelled S and shallowest curve labelled L [1]
2. a. i. For one cube of side 0.1 cm,
   surface area $= 0.1 \times 0.1 \times 6 = 0.06\ cm^2$ [1]
   Number of cubes of side 0.1 cm in
   $1\ cm^3 = 10 \times 10 \times 10 = 1000$ [1]
   Total surface area $= 1000 \times 0.06 = 60\ cm^2$ [1]
   ii. For one cube of side 0.001 cm, surface area
   $= 0.001 \times 0.001 \times 6 = 6 \times 10^{-6}\ cm^2$ [1]
   Number of cubes of side 0.001 cm in $1\ cm^3$
   $= 1000 \times 1000 \times 1000 = 10^9$ [1]
   Total surface area $= 10^9 \times 6 \times 10^{-6} = 6000\ cm^2$ [1]
   b. Dust particles have very large surface area / volume ratio [1]
   Idea of many particles exposed to the air / oxygen [1]
   So reaction with air / oxygen is very fast [1]
   So fast that in the presence of spark there may be an explosion [1]

Unit 10.5

1. (1 mark for each correct word)
   In order to react, particles must **collide** with each other. The collisions must have enough **energy** to break **bonds** to allow a reaction to happen. Increasing the concentration of a reactant **increases** the **frequency** of collisions and so increases the **rate** of reaction. Increasing temperature makes particles move **faster** and increases the energy of the particles so that there are more **successful** collisions.
2. a.



   More acid particles drawn [1]
   Same number Mg particles remaining [1]
   Particles randomly spread out including water particles [1]
   b. Fewer acid particles drawn [1]
   Fewer magnesium particles drawn [1]
   Particles drawn randomly including water particles (and $MgCl_2$ particles) [1]
3. Powder has a larger total surface area / volume ratio than magnesium ribbon [1]
   Idea of more particles exposed to the acid in magnesium powder [1]
   So more frequent collisions between the magnesium particles and acid particles for the powder. [1]
4. Activation energy is the minimum energy / idea of minimum energy [1]
   Colliding particles need (energy) in order to react [1]
   The higher the temperature, the greater number of particles / more particles [1]
   have energy equal to or more than the activation energy [1]

Unit 10.6

1. a. Oxygen gas formed [1]
   Causes the detergent to bubble [1]
   b. Manganese(IV) oxide [1]
   c. There was half as much liver as copper(II) oxide in the tube [1]
   So the number of bubbles per g would be more [1]
   d. i. Enzyme [1]
   ii. Cut it into smaller pieces / grind it up [1]
   More enzymes would be released / more enzyme available [1]
   e. Measure volume of oxygen / gas given off [1]
   over a particular time interval [1]
   using gas syringe / other method of collecting gas, e.g. upturned measuring cylinder or burette filled with water [1]
2. Energy on vertical axis [1]
   Energy curve increases from reactants to a maximum and then decreases to the products (can be exothermic or endothermic) [1]
   Second energy curve of the same type but with lower maximum [1]
   Activation energy of catalysed reaction shown (upward arrow from reactants to highest point of energy curve) [1]
   Activation energy of uncatalysed reaction shown (upward arrow from reactants to highest point of energy curve for catalysed reaction) [1]

Unit 10.7

1. a. (1 mark for each word correct)
   Chemical reactions that **only** occur in the presence of **light** are called photochemical reactions. Photosynthesis is a photochemical reaction that uses **pigments** in plant **leaves** called **chlorophylls** to catalyse the conversion of **carbon** dioxide and **water** to glucose and oxygen.
   b. $6CO_2$ [1] $6H_2O$ [1]
2. a. As light intensity increases, rate increases [1]
   b. Some other factor is limiting / carbon dioxide is limiting / water is limiting [1]
3. $2Ag^+ + 2e^- \rightarrow 2Ag$ [1]
   $2Br^- \rightarrow Br_2 + 2e^-$ [1]
   Top equation is reduction **and** bottom equation is oxidation [1]
4. Any 5 of:
   Light splits chlorine molecule into two chlorine atoms / called free radicals / this step called initiation / free radicals react with methane to form methyl free radical / and hydrogen chloride / 2nd step is propagation / more free radicals formed (or example) / termination is the last step / when two free radicals combine (1 mark each)

Unit 11.1

1. a. i. pH 11 [1] ii. pH 3 [1] iii. pH 7 [1]
   iv. pH 3 [1] v. pH 11 ALLOW: pH 7 [1]
   b. A with 3, B with 5, C with 4, D with 1, E with 2
   (3 marks if all correct, 2 marks if 3 or 4 correct, 1 mark if 1 or 2 correct)
2. a. 1 mark each
   i. NH_3 ii. CH_3COOH iii. H_2CO_3 iv. H_2SO_4 v. $Ca(OH)_2$
   vi. H_3PO_4 vii. HNO_3 viii. NaOH
   b. OH [1]
3. a. Can 'eat away' at the surface of another substance [1]
   b. (1 mark each for any two of:)
   Sodium hydroxide: corrosive as solid and concentrations greater than 0.5 mol/dm³
   Irritant at concentrations 0.05–0.5 mol/dm³
   Low risk at concentrations less than 0.05 mol/dm³
   (1 mark each for any two of:)
   Hydrochloric acid: corrosive at concentrations greater than 6.5 mol/dm³
   Irritant at concentrations 2–6.5 mol/dm³
   Low risk at concentrations less than 2 mol/dm³
   (1 mark each for any two of:)
   Sulfuric acid: corrosive at concentrations greater than 1.5 mol/dm³
   Irritant at concentrations 0.5–1.5 mol/dm³

Low risk at concentrations less than 0.5 mol/dm^3

(1 mark each for any two of:)

Ammonia: corrosive at concentrations greater than 6 mol/dm^3

Irritant at concentrations 3–6 mol/dm^3

Low risk at concentrations less than 3 mol/dm^3

Unit 11.2

1. (1 mark for each correct answer)

   Aqueous solutions of acids contain **hydrogen** ions. In strong acids **all** the acid **molecules** are dissociated (**ionised**) to form hydrogen ions and **anions.** When weak acids are dissolved in **water** they become **partially** dissociated. We can write this as an **equilibrium** e.g. $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$.

2. pH: ethanoic = pH 2.9 [1] hydrochloric = pH 1.0 [1] sulfuric = pH 0.7 [1]

   Rate of reaction: ethanoic slow [1] hydrochloric fast [1] methanoic slow [1] sulfuric fast [1]

3. A strong [1] B weak [1] C weak [1] D strong [1]

4. OH^- ions are present [1]

5. Barium hydroxide is most soluble and magnesium hydroxide least soluble [1]

   pH of alkalis due to aqueous OH^- ions [1]

   Higher concentration of aqueous hydroxide ions in barium hydroxide than calcium hydroxide and higher concentration in calcium than in magnesium [1]

   The higher the concentration of OH^- ions, the higher the pH [1]

Unit 11.3

1. a. acid + metal → **salt** [1] + **hydrogen** [1]
   b. acid + metal oxide → **salt** [1] + **water** [1]
   c. acid + metal carbonate → **salt** [1] + **water** [1] + **carbon dioxide** [1]
   d. acid + metal hydroxide → **salt** [1] + **water** [1]
2. a. sodium hydroxide + nitric acid → sodium nitrate + water [1]
   b. zinc oxide + hydrochloric acid → zinc chloride + water [1]
   c. iron + sulfuric acid → iron sulfate + hydrogen [1]
   d. sulfuric acid + lead carbonate → lead sulfate + carbon dioxide + water [1]
   e. barium hydroxide + nitric acid → barium nitrate + water [1]
   f. hydrochloric acid + tin oxide → tin chloride + water [1]
3. a. $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$ [1]
   b. $MgO + 2HNO_3 \rightarrow Mg(NO_3)_2 + H_2O$ (1 for correct formula, 1 for balance)
   c. $CuCO_3 + 2HCl \rightarrow CuCl_2 + CO_2 + H_2O$ (1 for correct formula, 1 for balance)
   d. $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$ (1 for correct formula, 1 for balance)
   e. $Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$ (1 for correct formula, 1 for balance)
   f. $Ca + 2HCl \rightarrow CaCl_2 + H_2$ (1 for correct formula, 1 for balance)
   g. $Ca(OH)_2 + 2HNO_3 \rightarrow Ca(NO_3)_2 + 2H_2O$ (1 for correct formula, 1 for balance)
4. Neutralisation [1]
5. $Ca(OH)_2 + 2NH_4Cl \rightarrow CaCl_2 + 2H_2O + 2NH_3$ (1 for correct formula, 1 for balance)
6. Hydroxide ions react with ammonium salts when water present (from soil / rain) [1]

   Ammonia is released [1]

   Which escapes into the air / ammonia is a gas [1]

Unit 11.4

1. a. base [1] salt [1] water [1]
   b. acid [1] salt [1] water [1]
2. a. A positively charged particle in the nucleus of an atom [1]
   b. The hydrogen ion has no electrons [1]

   Only the proton remains (in H^+) [1]
   c. Proton acceptor [1]
3. a. $H^+(aq) + \cancel{NO_3^-(aq)} + \cancel{Na^+(aq)} + OH^-(aq) \rightarrow \cancel{NO_3^-(aq)} + \cancel{Na^+(aq)} + H_2O(l)$ [1]
   b. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ [1]
   c. Hydrogen ions have reacted with hydroxide ions to form water [1]
4. a. Done as example
   b. Arrow going from H of H_2O to N of NH_3 [1]
   c. Arrow going from H of H_2S to O of H_2O [1]
5. a. $HClO_2$ is acid [1] HCOOH is base [1]
   b. NH_4^+ is acid [1] H_2O is base [1]

Unit 11.5

1. (1 mark for each correct word)

   Oxides of many metals on the **left** of the **Periodic** Table react with acids. These are called **basic** oxides. Some of these oxides react with **water** to form **alkaline** solutions. Oxides of many non-metals on the **right** of the Periodic Table react with **alkalis**. These are called acidic oxides. Many of these oxides react with water to form **acidic** solutions.

2. a. $MgO + 2HCl \rightarrow MgCl_2 + H_2O$ (1 for correct formula, 1 for balance)
   b. $SO_2 + 2NaOH \rightarrow Na_2SO_3 + H_2O$ (1 for correct formula, 1 for balance)
   c. $CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$ [1]
   d. $CO_2 + 2NaOH \rightarrow Na_2CO_3 + H_2O$ (1 for correct formula, 1 for balance)
   e. $ZnO + 2HNO_3 \rightarrow Zn(NO_3)_2 + H_2O$ (1 for correct formula, 1 for balance)
   f. $CaO + H_2SO_4 \rightarrow CaSO_4 + H_2O$ [1]
3. a. $SO_2 + H_2O \rightarrow H_2SO_3$ [1]
   b. $CO_2 + H_2O \rightarrow H_2CO_3$ [1]
   c. $CaO + H_2O \rightarrow Ca(OH)_2$ [1]
   d. $P_4O_6 + 6H_2O \rightarrow 4H_3PO_3$ (1 for correct formula, 1 for balance)
   e. $Na_2O + H_2O \rightarrow 2NaOH$ (1 for correct formula, 1 for balance)
4. amphoteric [1]
5. a. $ZnO + 2KOH \rightarrow K_2ZnO_2 + H_2O$ (1 for correct formula, 1 for balance)
   b. $Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$ (1 for correct formula, 1 for balance)
   c. $Al_2O_3 + 2NaOH \rightarrow 2NaAlO_2 + H_2O$ (1 for correct formula, 1 for balance)

Unit 11.6

1. Filter off the excess zinc [1]
2. DBEAFC [2]

   (1 mark if one pair reversed)
3. Record the volume of acid added when the indicator just changed colour [1]

   Repeat the titration without the indicator, using the value of acid recorded [1]

   Evaporate to the point of crystallisation and leave to form crystals [1]
4. a. Copper(II) nitrate may lose its water of crystallisation [1]

   Copper(II) nitrate may decompose [1]
   b. Zinc oxide / zinc carbonate / zinc hydroxide are not alkaline [1]

   You could not tell when the reaction was complete very easily [1]

Unit 11.7

1. 1 mark for each correct word

   Salts such as **nitrates**, sodium salts, and **ammonium** salts are soluble in water.

Many **carbonates / hydroxides** and **hydroxides / carbonates** are insoluble, except those from Group I. An insoluble substance formed when two **solutions** of soluble **compounds** are mixed is called a **precipitate**.

2. BEADC [2] (1 mark if one pair in the incorrect order)

3. a. i. $Ag^+(aq) + \cancel{NO_3^-(aq)} + \cancel{K^+(aq)} + Br^-(aq) \rightarrow AgBr(s) + \cancel{NO_3^-(aq)} + \cancel{K^+(aq)}$ [1]

   ii. $Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$ [1]

   b. i. $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$
   (1 mark for correct ions, 1 mark for state symbols)

   ii. $Pb^{2+}(aq) + 2Cl^-(aq) \rightarrow PbCl_2(s)$
   (1 mark for correct ions, 1 mark for state symbols, 1 mark for balance)

   iii. $Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$
   (1 mark for correct ions, 1 mark for state symbols, 1 mark for balance)

   iv. $Mg^{2+}(aq) + CO_3^{2-}(aq) \rightarrow MgCO_3(s)$
   (1 mark for correct ions, 1 mark for state symbols)

Unit 11.8

1. Weigh out 40 g sodium hydroxide [1]
   into a 250 cm^3 volumetric flask [1]
   Add distilled water and dissolve the NaOH [1]
   Fill flask to the graduation mark with distilled water and shake [1]

2. a. (2 marks if all correct, 1 mark if one error.)

titre / cm^3	32.95	32.10	32.00	32.85	32.15

   b. 2nd, 3rd, and 5th [1]
   The figures are closest together / most consistent readings [1]

3. a. moles of acid = $\underline{0.10} \times \frac{12.2}{1000} = \underline{1.22 \times 10^{-3}}$ mol H_2SO_4 [1]

   b. i. 2 [1]

   ii. $1.22 \times 10^{-3} \times 2 = 2.44 \times 10^{-3}$ mol NaOH [1]

   c. $\frac{2.44 \times 10^{-3}}{0.025} = 0.098$ mol/dm^3
   (2 marks for correct answer, 1 mark for 0.025 if correct answer not obtained)

4. moles of $Ba(OH)_2 = 0.05 \times 25/1000 = 1.25 \times 10^{-3}$ mol [1]
   1 mol of $Ba(OH)_2$ reacts with 2 mol HCl [1]
   Mol HCl = $1.25 \times 10^{-3} \times 2 = 2.50 \times 10^{-3}$ mol [1]
   Concentration of HCl = $\frac{2.50 \times 10^{-3}}{15.5/1000}$ [1] = 0.16 mol/dm^3 [1]

Unit 12.1

1. a. i. Proton number / atomic number [1]
   ii. Nucleon number / mass number / number of neutrons + protons in an atom [1]
   b. i. Proton number [1]
   ii. I to VIII [1]
   iii. Electron shells [1]
   iv. Valency electrons [1]

2. They have a stable electron configuration (8 electrons in the outer shell, 2 for He) [1]
   So it is difficult for them to lose, gain, or share electrons [1]

3. Going across the period, from left to right there is a decrease in metallic character [1]
   Going down a group there is an increase in metallic character [1]
   Groups I and II are all metals [1]
   Groups VII and VIII are all non-metals [1]

4. One mark each for any two of:
   Hydrogen is a gas / Hydrogen usually behaves like a non-metal / When hydrogen loses its electron, there are no other electron shells present

5. a. Nitrogen and phosphorus are simple molecules [1]
   Arsenic and antimony have grey metallic forms [1]
   and molecular forms, As_4 or Sb_4 as vapour [1]
   Bismuth is a metal [1]
   b. Nitrogen oxides are either neutral (N_2O, NO) or acidic (NO_2) [1]
   Phosphorus oxides are acidic [1]
   Arsenic and antimony oxides are amphoteric [1]
   Bismuth oxide is basic [1]

Unit 12.2

1. a. i. Sodium: (One mark each for any three of:)
   Moves rapidly over the surface / Fizzes rapidly / Melts and goes into a ball / Does not burst into flame
   Rubidium: (One mark each for any three of:)
   Whizzes over the surface or moves faster than potassium / Fizzes extremely rapidly or fizzes more than potassium / Bursts into flame immediately / May explode [1]
   ii. Melting point of potassium ALLOW between 50 and 75 °C (actual = 63 °C) [1]
   Metallic radius of rubidium = ALLOW between 0.24 and 0.29 nm (actual = 0.250) [1]
   b. Any value between 1.7 and 2.0 g/cm^3 (actual = 1.88) [1]

2. Each sodium atom loses its single outer electron [1] to become a Na^+ ion [1] Each chlorine atom accepts one electron [1] to become a Cl^- ion [1]

3. (1 mark each for any 5 of:)
   The ease of removing an electron depends on the nuclear charge and the distance from the nucleus [1]
   The further away the outer electron is from the nucleus, the lower is the attractive force between nucleus and electron [1]
   The greater the nuclear charge, the greater is the attractive force between nucleus and the outer electron [1]
   The outer electron in potassium is further away from the nucleus than the outer electron in sodium [1]
   This effect is greater than the effect of increasing nuclear charge [1]
   Because there are more electrons preventing the nuclear charge being felt by the outer electron in potassium [1]

Unit 12.3

1. a. Melting point increases down the group [1]
   b. fluorine: gas [1] chlorine: liquid [1] bromine: solid [1] iodine: solid [1]
   c. Arrow going downwards from light to dark [1]
   d. Arrow going downwards from smaller to larger [1]

2. a. 1 mark for each correct word
   When aqueous **chlorine** is added to a **colourless** solution of potassium bromide, the solution turns **orange** because **bromine** has been displaced. This is because a **more** reactive **halogen** displaces a **less** reactive halogen from an aqueous solution of its **halide**.
   b. Orange solution turns brown [1] because iodine is formed [1]
   Bromine is more reactive than iodine [1]
   A more reactive halogen displaces a less reactive halogen from its halide [1]

4. $Cl_2(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2Cl^-(aq)$
   (1 mark for correct symbols, 1 mark for correct balance)
   $Br_2(aq) + 2At^-(aq) \rightarrow At_2(aq) + 2Br^-(aq)$
   (1 mark for correct symbols, 1 mark for correct balance)

Unit 12.4

1. A with 4, B with 3, C with 1, D with 2 (2 marks if all correct, 1 mark if 2 or 3 correct)

2. He and Ne [1]

Answers

3. a. Group VIII elements have a stable electron configuration [1]
   So they cannot share electrons to form diatomic molecules [1]
   b. $Ar \rightarrow Ar^+ + e^-$ [1]
   c. B, J, and R [1]
   Of all the elements in a period, these require the highest amount of energy to remove an electron [1]

Unit 12.5

1. a. A, C, E, G, I, (3 marks if all correct, 2 marks if 4 correct, 1 mark if 3 correct)
   b. Very hard / tough / very strong [1] form complex ions [1]
2. a. Much lower melting point than transition elements [1]
   Much lower density than transition elements [1]
   b. Increases steadily from K to Cu [1] Then decreases rapidly [1]
3. Relatively low melting point compared with transition elements [1]
   Does not form coloured compounds [1]
   Only has one oxidation state [1]
   Does not have catalytic activity [1]
   (Not: no complex ions / lower density)

Unit 12.6

1. a. 2,8,2; 2,8,3; 2,8,4; 2,8,5; 2,8,6; 2,8,7 [1]
   b. Al_2O_3 [1] SiO_2 [1] P_2O_3 [1]
   c. i. They increase to a maximum at Si then decrease [2]
   (They increase then decrease = 1 mark)
   ii. Metallic [1]
   iii. It is a giant structure / has a lattice [1]
   All the bonds are strong / it takes a lot of energy to break all the bonds [1]
   iv. They are simple molecules [1]
   Weak forces between (the molecules) / it doesn't take much energy to break the weak intermolecular forces [1]
2. a. 5 [1]
   b. P_2O_5 [1]
3. In forming ions Al needs to lose 3 electrons, Mg needs to lose 2 electrons, and Na needs to lose 1 electron [1]
   As more electrons are lost, the pull of the nucleus on the rest of the electrons becomes relatively larger [1]
   So it takes more energy to remove 3 electrons than 2 electrons and more energy to remove 2 electrons than 1 electron [1]

Unit 13.1

1. A with 5, B with 4, C with 2, D with 1, E with 3
   (3 marks if all correct, 2 marks if 3 or 4 correct, 1 mark if 1 or 2 correct)
2. mass (g) [1]
   volume (cm^3) [1]
3. a. i. salt and hydrogen [1]
   ii. chloride [1]
   b. i. $4Al + 3O_2 \rightarrow 2Al_2O_3$ (1 mark for correct formulae, 1 mark for balance)
   ii. $Mg + 2HCl \rightarrow MgCl_2 + H_2$ (1 mark for correct formulae, 1 mark for balance)
4. mol H_2 = 13.92/24 = 0.58 mol [1]
   mol H_2 = mol Mg (from equation) = 0.58 mol [1]
   Mass of Mg = 0.58 × 24 = 13.92 g [1]
   Density = 13.92/8 = 1.74 g/cm^3 [1]

Unit 13.2

1. a. i. $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$
   (1 mark for H_2, 1 mark for balance, 1 mark for state symbols)
   ii. $3Fe(s) + 4H_2O(g) \rightarrow Fe_3O_4(s) + 4H_2(g)$
   (1 mark for formulae, 1 mark for balance, 1 mark for state symbols)
   b. (1 mark for each correct word)
   The products formed by metals that react with **cold** water are a metal **hydroxide** and **hydrogen**. The hydroxides are alkaline and so turn **red** litmus **blue**. The products formed by metals that react only with steam are a metal **oxide** and **hydrogen**. Copper does not react with water because it is **less** reactive than **hydrogen** and cannot take the **oxygen** away from the hydrogen in the water.
2. a. Zinc, magnesium, calcium [1]
   b. Barium: gives of bubbles very rapidly with cold water [1]
   Barium disappears very quickly / immediately [1]
   Lead reacts slowly (when white hot) with steam / no reaction even when heated [1]
3. Lead, iron, magnesium, lithium [1]
4. $Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$ [1]
   $Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$ [1]
   $2H^+(aq) + 2e^- \rightarrow H_2(g)$ [1]
   $Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$ is oxidation and $2H^+(aq) + 2e^- \rightarrow H_2(g)$ is reduction [1]

Unit 13.3

1. a. B At start: solution blue [1]
   B After 20 min: metal brown / pink [1] solution colourless / lighter blue [1]
   C After 20 min: metal silvery-grey [1]
   D At start: metal grey [1] solution blue [1]
   D After 20 min: metal brown/ pink [1] solution colourless / lighter blue [1]
   b. Silver < copper < iron < zinc [1]
   c. Copper is lower in the reactivity series than zinc / zinc is higher than copper in the reactivity series [1]
2. a. Reducing agent is iron, oxidising agent is copper oxide [1]
   b. Reducing agent is magnesium, oxidising agent is iron oxide [1]
3. a. $Zn(s) + \rightarrow Zn^{2+}(aq) + 2e^-$ [1]
   $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ [1]
   Zn is the reducing agent [1]
   b. $Mg(s) + \rightarrow Mg^{2+}(aq) + 2e^-$ [1]
   $Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$ [1]
   Mg is the reducing agent [1]

Unit 13.4

1. (1 mark for each correct word)
   A **more** reactive metal will **reduce** the oxide of a **less** reactive metal. This reaction is **exothermic**. The more reactive metal loses **electrons** and forms **positive** ions more easily.
2. a. Strontium carbonate < calcium carbonate < magnesium carbonate < copper carbonate [1]
   b. A with 2, B with 5, C with 1, D with 3, E with 4
   (3 marks if all correct, 2 marks if 3 or 4 correct, 1 mark if 1 or 2 correct)
3. i. $2Mg(NO_3)_2(s) \rightarrow 2MgO(s) + 4NO_2(g) + O_2(g)$
   (1 mark for formulae, 1 mark for balance, 1 mark for state symbols)
   ii. $2KNO_3(s) \rightarrow 2KNO_2(s) + O_2(g)$
   (1 mark for formulae, 1 mark for balance, 1 mark for state symbols)

Unit 13.5

1. a. $Mg(s) + \rightarrow Mg^{2+}(aq) + 2e^-$ [1]
   b. Copper [1]
   Magnesium is more reactive than copper [1]
   So magnesium is more likely to lose electrons / form positive ions than is copper [1]
   c. Arrows shown on wires in the direction away from the magnesium and towards the copper [1]
2. a. 0.78 V [1] b. 0.32 V [1]

Answers

3. (Any 4 of:)
   Zinc is more reactive than iron [1]
   So it releases electrons more readily than iron [1]
   $Zn(s) + \rightarrow Zn^{2+}(aq) + 2e^-$ [1]
   The electrons are passed on to the iron and then accepted by oxygen and water to form OH^- ions / zinc hydroxide formed [1]
   The zinc corrodes instead of the iron [1]

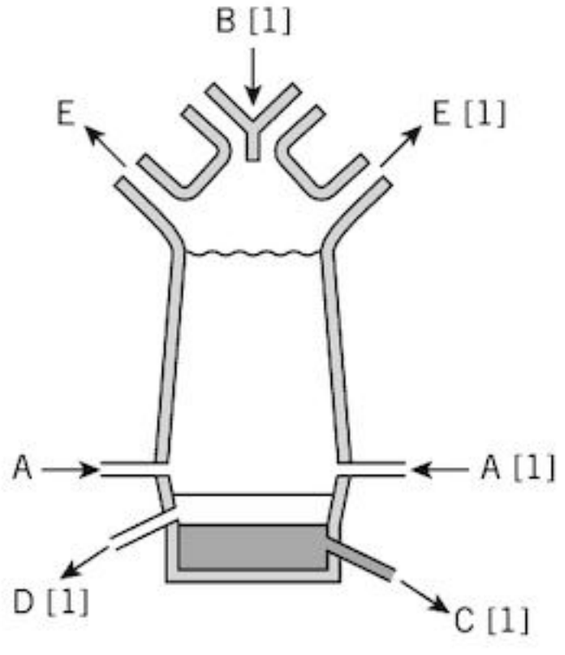
Unit 14.1

1. a. $100 \times 16/69 = 23.2\%$ Cu ore from rock. 15% of this = 3.5% [1]
   b. Only a small proportion of the rock is copper ore [1]
   c. It may be worth extracting the cobalt and gold which are rarer / get a better price [1]
   d. Cadmium and lead from extraction processes may get into river water / ground water / the air [1]
   Harmful material from waste rock may leach into rivers [1]
   These substances may poison fish and water animals / humans [1]
   e. (One mark each for any 2 of:) Employment of workers / better roads / more money in local economy (for spending in shops etc.)
   f. (One mark each for any 2 of:) Noise / pollution from dust / pollution of waterways / scarring of landscape / heavy traffic on roads / animal or plant habitats destroyed
2. (Any 4 of:) Aluminium and iron both reactive and both abundant / silver is least reactive and has lowest abundance / no pattern in metals of medium reactivity / iron and aluminium are most abundant and have low prices / silver and tin have lowest abundance and have highest prices / idea of higher abundance reflected by lower price since the metal is more available / There are exceptions e.g. copper has relatively high price for a relatively high abundance / idea of copper more in demand or demand for metal influences the price / idea that ease of extraction contributes to the price.

Unit 14.2

1. a. Upward arrow from gold to lithium [1]
   b. Li to Al extracted by electrolysis ALLOW: Zn [1] Zn to Cu extracted by heating with carbon [1]
   c. i. Upward arrow in 4th column [1] upward arrow in 5th column [1]
   ii. Any reasonable answer, e.g. some ores more complex than others / sulfur may have to be removed / other substances may have to be removed / some ores may require more purification than others [1]
   d. Silver and gold / copper, silver, and gold [1]
   e. Lead and copper [1]
2. manganese oxide + aluminium → aluminium oxide + manganese [1]
3. a. $Cr_2O_3 + 2Al \rightarrow 2Cr + Al_2O_3$
   (1 mark for correct formulae, 1 mark for balance)
   b. $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
   (1 mark for correct formulae, 1 mark for balance)

Unit 14.3

1. 

2. Burning coke in air to form carbon dioxide [1]
   Reaction of carbon dioxide with coke to form carbon monoxide [1]
3. At the high temperatures in the furnace the limestone undergoes thermal decomposition to form calcium oxide.
   The calcium oxide reacts with silicon dioxide (sand) which is an impurity in the ore.
   The calcium silicate formed is a slag, which runs down the furnace and floats on top of the molten iron.
   (3 marks if all correct, 2 marks if two sentences correct, 1 mark if one sentence correct.)
4. $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
   (1 mark for correct formulae, 1 mark for balance)
5. Any 3 suitable methods (1 mark each), e.g. reduction of iron(II) oxide with hydrogen / electrolysis of iron ammonium oxalate (or other suitable compound) / thermal decomposition of iron pentacarbonyl.

Unit 14.4

1. E = liquid in the cell into which rods are dipping [1]
   C = layer on the inside next to liquid [1]
   A = rods dipping into the liquid [1]
   M = layer at the bottom of the cell under E [1]
2. (1 mark for each correct word.)
   Aluminium oxide **melts** at a very high temperature. It would require too much **energy** to keep the aluminium oxide molten at this **temperature**. So the aluminium oxide is **dissolved** in molten **cryolite** and calcium fluoride. This lowers the operating temperature to about **950** °C. The temperature is kept relatively **low** by keeping the percentage of aluminium oxide in the mixture at 5%.
3. a. i. $Al^{3+} + 3e^- \rightarrow Al$
   (1 mark for correct formulae, 1 mark for balance)
   ii. $2O^{2-} \rightarrow O_2 + 4e^-$
   (1 mark for correct formulae, 1 mark for balance)
   b. $2Al_2O_3 \rightarrow 4Al + 3O_2$
   (1 mark for correct formulae, 1 mark for balance)
4. Oxygen reacts with the graphite / carbon electrode [1]
   Carbon dioxide formed which is given off as a gas [1]
5. $Al_2O_3 \rightarrow Al^{3+} + AlO_3^{3-}$ (1 mark for correct formulae, 1 mark for balance)
   $4AlO_3^{3-} \rightarrow 2Al_2O_3 + 3O_2 + 12e^-$
   (1 mark for correct formulae, 1 mark for balance)

Unit 14.5

1. Aluminium: 1 mark each for any 2 of: non-toxic / resistant to corrosion / low density or lightweight
   Aluminium alloy: 1 mark each for any 2 of: low density or lightweight / doesn't corrode / strong (for weight)
   Brass: hard [1] does not corrode [1]
   Bronze: statues / ship's propellers / bearings [1] hard / does not corrode [1]
   Cobalt alloy: 1 mark each for any two of: gas turbine blades / jet engines / high speed drills / moving parts that rub against each other
   Copper: electrical wiring: good conductor of electricity [1]
   Saucepan: good conductor of heat [1]
   Silver coinage metal: strong [1] does not corrode [1] ALLOW: hard, not toxic
2. Pure aluminium is too weak on its own [1]
   Different-sized atoms of iron and silicon in the alloy structure [1]
   Prevent the layers from sliding [1]

Unit 14.6

1. A with 5, B with 6, C with 1, D with 2, E with 4, F with 3
   (3 marks for all correct, 4 or 5 correct = 2, 2 or 3 correct = 1)
2. C 1, B6, F3, A5, E4, D2 (2 if all correct, 1 if one pair in wrong order)
3. Mild steel: Any two suitable (1 mark each) uses e.g. car bodies / bridges
   Property: hard / strong [1]

Answers

Stainless steel: Use (1 mark for each correct), e.g. chemical plant / cutlery / surgical instruments

Property: resistant to corrosion / very hard [1]

Tungsten steel: (1 mark for each correct property), e.g. resistant to wear / high melting point / hard

4. $P_4O_{10} + 6CaO \rightarrow 2Ca_3(PO_4)_2$
(1 mark for correct formulae, 1 mark for balance)

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
(1 mark for correct formulae, 1 mark for balance)

Unit 15.1

1. Carbon dioxide and methane [1]
2. a. 17.1 cm^3 [1]
   b. (17.1/80) × 100 [1] = 21.4%
   c. Higher [1] The apparatus had not cooled [1] So the volume of gas is greater than it would have been at a lower temperature [1]
3. $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$
(1 mark for correct formulae, 1 mark for balance)

Unit 15.2

1. a. CO_2, O_2, and N_2 [1]
   b. O_2 [1]
   c. The greater the molar mass, the higher the boiling point [1]
   d. Fractional distillation / fractionation [1] boiling points [1]
2. a. Acidic [1]
   b. Neutralisation [1]
3. Nitrogen has a lower boiling point [1]
4. a. To oxidise impurities [1] stated impurities, e.g. Si, P, C, S [1]
   b. To create a high temperature in the oxyacetylene flame [1]
   c. To help breathing / respiration of patients [1]
5. $2OH^- + CO_2 \rightarrow CO_3^{2-} + H_2O$
(1 mark for correct formulae, 1 mark for balance)

$CO_3^{2-} + H_2O + CO_2 \rightarrow 2HCO_3^-$
(1 mark for correct formulae, 1 mark for balance)

Unit 15.3

1. a. (1 mark for each correct word.)

   Carbon monoxide is formed when **carbon** compounds **burn** in a **limited** supply of air. Sulfur dioxide is formed when **fossil** fuels containing **sulfur** burn in air.

   b. i. Lightning [1] ii. Volcanoes [1]
2. a. Chemical erosion / pits the limestone [1]
   b. Breathing difficulties / irritates the throat / irritates the eyes [1]
   c. Poisonous / toxic / stops respiration [1]
3. During the morning there are more vehicles on the road [1]

   Nitrogen dioxide from vehicle exhausts goes into the atmosphere [1]

   Nitrogen dioxide concentration builds up during the day since there is still traffic on the roads [1]

   After about 12 midnight, very few vehicles about so the nitrogen oxides have time to disperse into the upper atmosphere [1]
4. To turn harmful carbon monoxide [1] and nitrogen oxides [1] into nitrogen and carbon dioxide, which are not harmful (to health) [1]
5. $2NO_2 + 4CO \rightarrow N_2 + 4CO_2$
(1 mark for correct formulae, 1 mark for balance)

$2NO + 2CO \rightarrow N_2 + 2CO_2$
(1 mark for correct formulae, 1 mark for balance)

Unit 15.4

1. a. Corrosion is fast at low pH [1]

   Corrosion rate decreases at very alkaline pH [1]

   Not much difference in corrosion rate between pH 3 and 9 [1]

   b. $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$

   (1 for correct formulae, 1 for balance, 1 for correct state symbols)

   c. i. Oxygen [1]

   ii. The rate of corrosion is lower at alkaline pH [1]
2. a. Salt is present in seawater [1] Salt speeds up the oxidation of iron to iron(III) oxide / idea that the oxidation reaction speeded up [1]
   b. There is very little water / water evaporates very quickly [1]
   c. Idea of a layer protecting the surface of the iron [1]

   So prevents oxygen and water from reaching the iron [1]
3. Any 4 of:

   Magnesium is more reactive than iron [1]

   So it releases electrons more readily than iron [1]

   $Mg(s) + \rightarrow Mg^{2+}(aq) + 2e^-$ [1]

   The electrons are passed on to the iron and then accepted by oxygen and water to form OH^- ions / magnesium hydroxide formed [1]

   The magnesium corrodes instead of the iron [1]

Unit 15.5

1. a. Sodium chloride [1]
   b. Ca^{2+} [1]
   c. NO_3^- [1] and SiO_3^{2-} [1] and K^+ [1] present in much higher concentration in river water
   d. Removal of salt / removal of minerals [1]
   e. NO_3^- [1] from fertilisers leaching into the water [1]
   f. Bacteria [1]
   g. Filtration: to get rid of suspended particles / clay particles / insoluble particles [1]

   Chlorination: to kill bacteria [1]
2. Any 4 of:

   Hard water forms scum with soap / does not form a lather easily with soap [1]

   Calcium hydrogencarbonate causes temporary hardness [1] calcium and magnesium sulfates cause permanent hardness [1]

   Adding sodium carbonate replaces calcium ions with sodium ions [1]

   The calcium carbonate precipitates (so is removed from the water) [1]

   Sodium sulfate is soluble in water [1]

Unit 16.1

1. a. Hydrogen increases in oxidation state and oxygen decreases [1]

   Increase in oxidation state is oxidation [1] Decrease is reduction [1]

   b. $CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(l)$
   (1 mark for equation, 1 mark for balance)

   c. Magnesium / zinc / iron / calcium (not sodium / potassium) [1]

   Added to an acid [1]

   Collect gas in gas syringe / upturned measuring cylinder over water [1]
2. a. Ammonium chloride [1] calcium chloride [1]
   b. Calcium hydroxide [1] ammonia [1]
   c. Water [1] ammonia [1]
   d. Because it is less dense than air / lighter than air [1]
   e. Damp red litmus [1] turns blue [1] OR concentrated HCl on glass rod at mouth of tube [1] white fumes [1]
3. a. $NH_4^+(s) + OH^-(s) \rightarrow H_2O(l) + NH_3(g)$

   (1 mark for correct formulae, 1 mark for balance)

   b. NH_4^+ is the acid and OH^- is the base [1]

   Proton donated from ammonium ion to the hydroxide ion [1]

Unit 16.2

1. (1 mark for each correct word)

   The hydrogen is made by reacting **natural** gas with **steam**. The nitrogen comes from the air after **oxygen** has been removed by reaction with **hydrogen**. The nitrogen and hydrogen are **compressed** and pumped into a **converter**, where they react at 450 °C in the presence of a catalyst of **iron**.

Answers

2. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ (1 mark for correct formulae, 1 mark for balance)
3. a. Increasing pressure increases % yield [1]
   b. The % yield decreases with increasing temperature [1]
   c. 52% [1]
   d. Advantage: % yield is higher [1]
   Disadvantage: rate of reaction is lower [1]
4. Reactant level above and to left of product level [1]
   Energy curve increases from reactants to a maximum and then decreases to the products [1]
   Second energy curve of the same type but with lower maximum (for catalysed reaction) [1]
   Activation energy of catalysed reaction shown (upward arrow from reactants to highest point of energy curve for catalysed reaction) [1]
   Activation energy of uncatalysed reaction shown (upward arrow from reactants to highest point of energy curve for uncatalysed reaction) [1]

Unit 16.3

1. (1 mark for each correct answer)
   For healthy growth crop plants need three major elements: nitrogen, **phosphorus**, and potassium. Plants take up these elements in the form of nitrates, **phosphates**, and potassium **salts**. The **nitrates** are needed to make **proteins** for growth. Farmers add **fertilisers** to the soil to add back the **nutrients** that plants have absorbed for growth.
2. a. NH_3 ammonia [1] HNO_3 nitric acid [1] NH_4NO_3 ammonium nitrate [1] H_2SO_4 sulfuric acid [1] H_3PO_4 phosphoric acid [1] KCl potassium chloride [1]
   b. ammonia + nitric acid → ammonium nitrate [1]
   c. i. ammonia [1] sulfuric acid [1]
   ii. potassium hydroxide / potassium carbonate [1] hydrochloric acid [1]
   NOT: potassium
   iii. sodium hydroxide / sodium carbonate [1] phosphoric acid [1]
   NOT: sodium
   d. natural gas [1] water [1] air [1]
3. Any 5 of: nitrates and phosphates cause excessive growth of algae / algae cover the water surface / and block the sunlight from reaching plants beneath / this causes water plants to die / aerobic bacteria feed on dead plants and algae / using up the dissolved oxygen in the water / so water animals also die [5]

Unit 16.4

1. a. When the fuels are burnt sulfur dioxide is produced [1]
   Which contributes to the formation of acid rain [1]
   b. To speed up the reaction / to lower the activation energy of the reaction [1]
   c. The other gases do not react with the solvent / the other gases are not soluble in the solvent [1]
   d. $2H_2S(g) + O_2(g) \rightarrow 2S(s) + 2H_2O(l)$
   (1 mark for correct formulae, 1 mark for balance)
2. a. Making sulfuric acid [1]
   b. As a bleach [1] As a food preservative [1]
3. a. Sulfur trioxide reacts with rain water / reacts with water in the atmosphere [1]
   (Not: dissolves in rainwater)
   b. Pits the stone / chemical erosion of the stone [1]
   Limestone is calcium carbonate [1]
   Acids reacts with carbonates to form salt (which could be soluble), carbon dioxide (and water) [1]
   c. Acid burn on leaves / kills roots (especially of conifers) [1]
4. Sulfites react with acids to give off sulfur dioxide [1]
   $SO_3^{2-} + 2H^+ \rightarrow 2SO_2 + H_2O$ (1 mark for formulae, 1 mark for balance)

Unit 16.5

1. a. Catalyst / to speed up the rate of reaction [1]
   b. i. As temperature increases from 300 to about 450 °C there is not much difference in yield / the yield gets a little less [1]
   At temperatures higher than about 450 °C the yield decreases markedly [1]
   ii. 92–93% [1]
   iii. For an exothermic reaction the yield decreases as temperature increases [1]
   c. i. Increasing pressure shifts the equilibrium to the right [1]
   There are fewer moles / smaller volume of gas on the right in the equation [1]
   ii. There is nearly 100% yield at just above atmospheric pressure [1]
2. a. $C + 2H_2SO_4 \rightarrow 2H_2O + 2SO_2 + CO_2$
   (1 mark for formulae, 1 mark for balance)
   b. $H_2S + H_2SO_4 \rightarrow 2H_2O + SO_2 + S$
   (1 mark for formulae, 1 mark for balance)

Unit 16.6

1. a. Respiration [1] release of carbon dioxide from oceans [1]
   b. Photosynthesis [1] dissolving of carbon dioxide in the oceans [1]
   c. Respiration is (slightly more than) balanced by photosynthesis [1]
   The dissolving of carbon dioxide in the oceans is balanced by the release of carbon dioxide (into the atmosphere) [1]
   d. Less carbon dioxide will dissolve in the oceans / more will be released into the atmosphere [1] Concentration of carbon dioxide in the atmosphere will increase [1]
   e. Cutting down trees / removing vegetation [1] Burning more fossil fuels [1]
2. carbon dioxide + oxygen → glucose + water (ALLOW: sugars / starch for glucose) [1]
   Light [1] chlorophyll(s) / chloroplasts [1]
3. Carbon dioxide dissolves in seawater forming carbonic acid [1]
   This weak acid forms an equilibrium mixture with hydrogencarbonate / $H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$ [1]
   Further equilibrium of hydrogencarbonate with carbonate ions / $H^+ + HCO_3^- \rightleftharpoons 2H^+ + CO_3^{2-}$ [1]
   Molluscs / sea creatures absorb the carbonate ions and calcium ions from seawater to form $CaCO_3$ in shells [1]

Unit 16.7

1. A with 4, B with 2, C with 1, D with 5, E with 3
   (5 correct = 3, 3 or 4 correct = 2, 1 or 2 correct = 1)
2. a. i. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
   (1 for balance of carbon dioxide and water, 1 for balance of oxygen)
   ii. $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$
   (1 for balance of carbon dioxide and water, 1 for balance of oxygen)
   b. i. $2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O$
   (1 for balance of carbon monoxide, water, and methane, 1 for balance of oxygen)
   ii. $2C_3H_8 + 7O_2 \rightarrow 6CO + 8H_2O$
   (1 for balance of carbon monoxide, water, and propane, 1 for balance of oxygen)
   c. Carbon / soot [1]
3. a. citric acid + sodium hydrogencarbonate → sodium citrate + carbon dioxide + water [1]
   b. Endothermic / positive [1]
4. $CaCO_3 \rightarrow CaO + CO_2$ [1]

Answers

5. $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$
(1 for balance of carbon dioxide, water, and ethanol, 1 for balance of oxygen)
$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
(1 for balance of carbon dioxide, water, and glucose, 1 for balance of oxygen)

Unit 16.8

1. a. Gas which absorbs and re-emits energy / heat / infrared radiation [1] in the atmosphere [1]
   b. The general trend is the same of increasing concentration of CO_2 and increasing temperature of the atmosphere [1]
   Reference especially to the years 1950 to 2000 [1]
   c. Between about 1895 and 1915 carbon dioxide was increasing but there was a decrease in mean temperature [1] similarly between 1940 and 1950 [1]
   d. i. Methane [1]
   ii. (1 mark each for any two) marshes / bacterial decomposition / thawing permafrost / product of animal digestion / rice paddy fields
2. (1 mark each for any 3) rise in sea level / desertification / more extreme weather / melting glaciers / warming of sea causing death of corals etc.
3. Pass the carbon dioxide through the mixture [1] Collect the potassium hydrogencarbonate formed [1] Allow water to evaporate from the hydrogencarbonate (do not heat because it will release some carbon dioxide) [1] Store underground away from heat source / vitrify (combine it with glass) [1].

Unit 16.9

1. a. T in the hole at the top [1] F near the passages to the kiln at the bottom [1]
   b. Through the passages into the kiln [1] It is needed to burn the coal / fuel [1] to provide heat (for the decomposition) [1]
   c. Limestone would decompose in the heat [1] Granite / silicon dioxide / aluminium oxide does not decompose in the heat [1]
   d. The kiln is open to the air [1] The carbon dioxide escapes [1] So the equilibrium shifts to the right [1]
2. Sulfur dioxide is acidic [1]
   Waste gases move through mixture of water and calcium carbonate / limestone / lime / calcium oxide [1]
   Carbonate / oxide neutralises the sulfur dioxide [1]
   Solid formed / calcium sulfite formed [1]
3. Limewater is aqueous calcium hydroxide [1]
   When CO_2 bubbled through, a white precipitate of calcium carbonate is formed [1]
   When more CO_2 bubbled through, the white precipitate dissolves [1]
   Because soluble calcium hydrogencarbonate is formed [1]

Unit 17.1

1. Coal [1] natural gas [1]
2. a. A, C, D, and E [1] They contain ONLY hydrogen and carbon [1]
   b. A, C, D, and E [1]
   c. i. A [1]
   ii. C [1]
   d. B C_3H_8O [1] C C_5H_{10} [1] D C_4H_{10} [1]
   E C_3H_6 [1] F $C_2HO_2Cl_3$ [1]
3. a. C [1]
   b. B [1]
4. They are smelly (have strong aromas) [1] They are ring compounds with delocalised electrons in the ring [1] One mark each for any two correct names, e.g. benzene, naphthalene, nitrobenzene, aniline etc. [2]

Unit 17.2

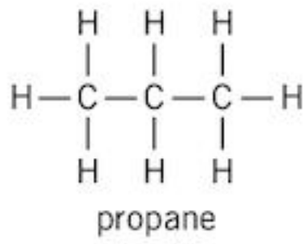
1. Heat the flask with flame of constant height [1]
   Collect first fraction in test tube over a particular temperature range [1]
   Replace test tube and continue to heat until another fraction is collected over a particular temperature range [1]
   Repeat until no more fractions can be collected [1]
2. a. Downward arrow [1]
   b. i. Easily vaporised / liquid has a low boiling point [1]
   ii. Upward arrow [1]
   c. Downward arrow [1]
   d. Upward arrow [1]
3. Shorter / smaller molecules have lower intermolecular forces than larger ones [1]
   So smaller molecules have lower boiling points [1]
   and vaporise more easily [1]
   Smaller molecules travel further up the tower than larger ones in the same time [1]
   Molecules condense at a point in the tower where the temperature falls just below their boiling point [1]

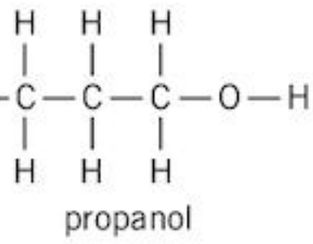
Unit 17.3

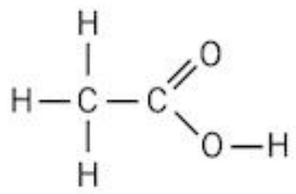
1. a. Residues [1]
   b. i. Gasoline/naphtha and diesel [1]
   ii. Kerosene, fuel oil, and residue [1]
2. a. P in the 'space' at the top of the collecting tube [1]
   b. Arrow to the ceramic wool [1] arrow under the aluminium oxide [1]
3. a. $C_{10}H_{22} \rightarrow C_4H_{10} + C_6H_{12}$ [1]
   b. $C_{14}H_{30} \rightarrow C_3H_8 + C_4H_8 + C_7H_{14}$ [1]
4. C_8H_{18} used for petrol [1] need for more petrol (gasoline) / demand for petrol more than supply [1]
   $C_{33}H_{68}$ is very viscous / almost solid fraction [1] takes too much energy to vaporise it / too much energy to crack it / will block up the chemical plant [1]

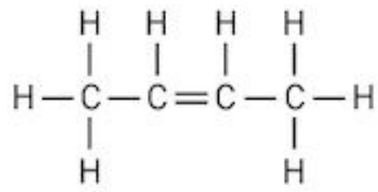
Unit 17.4

1. a. A family of similar compounds with similar chemical properties [1] due to the same functional group [1]
   b. Propene: alkenes [1] Butanol: alcohols/alkanols [1]
   Hexane: alkanes [1]
   Propanoic acid: carboxylic acids [1]
2. Molecular formulae: Methane CH_4 [1] Propanol: C_3H_8O [1]
   Ethanoic acid: $C_2H_4O_2$ [1] Butene: C_4H_8 [1]
   Simplified structural formulae: Methane CH_4 [1] Propane $CH_3CH_2CH_3$ [1]
   Ethanoic acid: CH_3COOH [1]
   Full structural formulae: (1 mark each)


propane


propanol


ethanoic acid


butene

3. Alkenes: C_nH_{2n} [1] Alcohols $C_nH_{2n+1}OH$ [1] Amines: $C_nH_{2n+1}NH_2$ [1]

Unit 17.5

1. a. Hydrocarbons [1]
   b. Single [1] covalent [1]

Answers

c. Saturated [1]

d. Combustion / burning [1] chlorine [1]

2. a. Pentane [1]

b. Butane [1]

c. Octane [1]

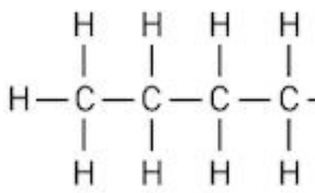
3. Boiling points increase as relative molecular mass increases [1]

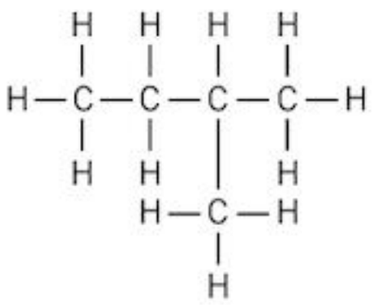
4. a. $C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$
(1 mark for balancing carbon dioxide and water, 1 mark for balancing oxygen)

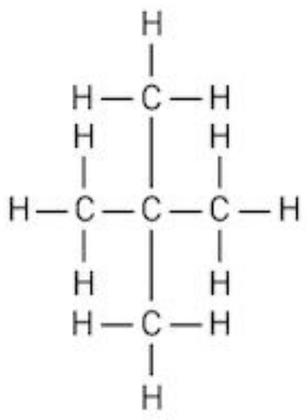
b. $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ [1]

5. Photochemical [1] substitution [1]

6. a.

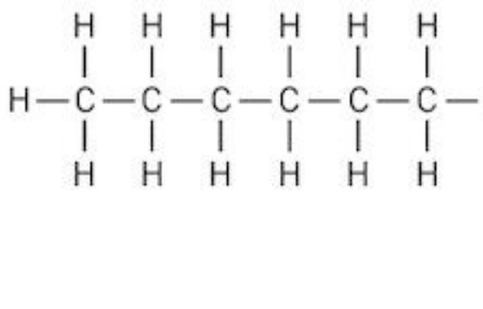


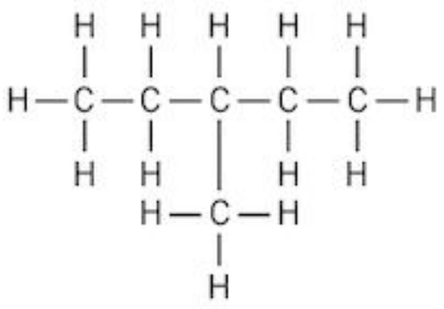


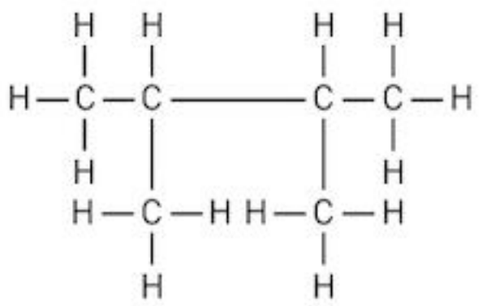


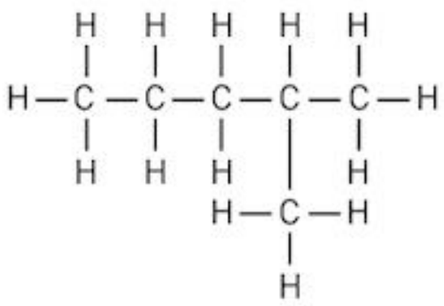
(1 mark each for any 2)

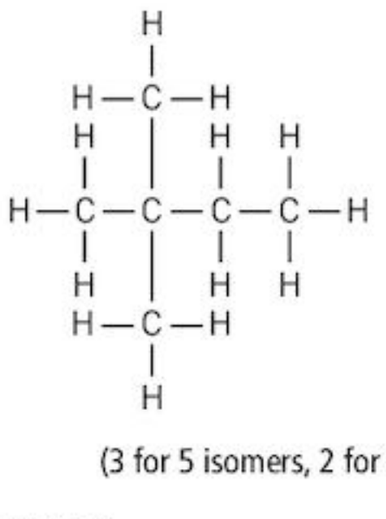
b.











(3 for 5 isomers, 2 for 4 isomers, 1 for 2 or 3 isomers)

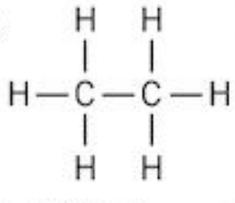
Unit 17.6

1. Alkenes: propene [1] butene [1]
Molecular formulae: C_2H_4 [1] C_4H_8 [1] C_5H_{10} [1]
Boiling point: butene –60 to –40 °C (actual – 48 °C) [1]

2. a. C=C ringed [1]

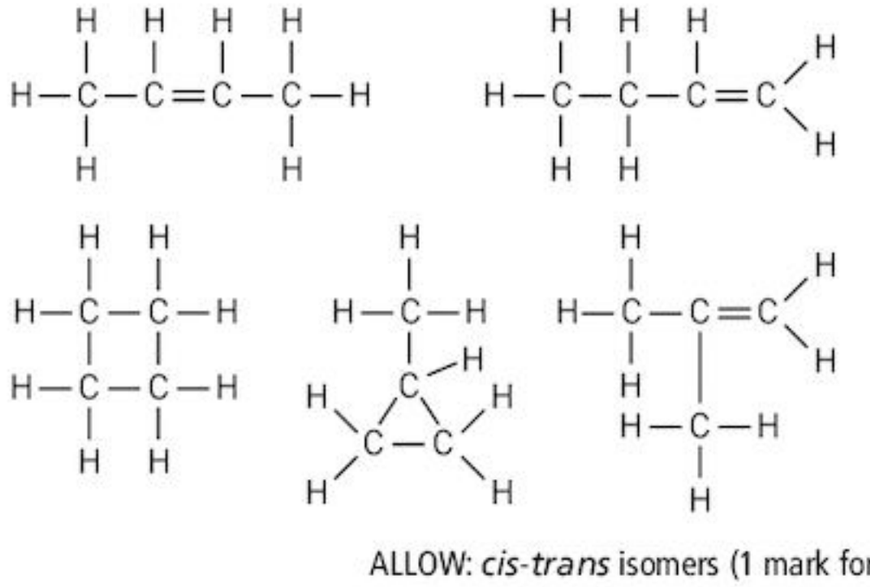
b. orange [1] to colourless [1]

3. a. A [1] B H_2O [1] (g) (NOT H_2O(l)) [1]



b. Heat [1] high pressure [1] catalyst [1]

4.



ALLOW: *cis-trans* isomers (1 mark for each)

Unit 17.7

1. a. Fermentation: reagents glucose [1]
temperature ALLOW between 10 and 40 °C [1]
Pressure atmospheric / 1 atm [1] Catalyst enzymes / yeast [1]
Hydration: reagents ethene and steam [1] temperature 500–600 °C [1]
Pressure 60–70 atmospheres [1] catalyst phosphoric acid [1]

b. (1 mark each for any two) takes a long time / ethanol is dilute / need to distil off the ethanol / batch process is inefficient / lot of waste

c. (1 mark each for any two) uses renewable resources / relatively cheap / does not require very high temperature and pressure

d. (1 mark each for any two) reaction is fast / reaction can be run continuously / gives pure ethanol or atom economy is (nearly) 100%

2. a. $C_4H_9OH + 6O_2 \rightarrow 4CO_2 + 5H_2O$
(1 mark for balance of carbon dioxide and water, 1 mark for balance of oxygen)

b. Calorimeter / tin can suspended [1] over spirit burner with alcohol in it [1]
Calorimeter / tin can about half full of water [1] Thermometer dipping into water in can [1] At least two correct labels [1]

3. Molar mass of ethanol = 46 [1] moles of ethanol = 9.2/46 = 0.2 mol [1]
So mol $H_2O = 0.2 \times 3 = 0.6$ mol [1] $= 0.6 \times 18 = 10.8$ g [1]

Unit 17.8

1. a. Arrow under flask [1]

b. Oxidising agent [1]

c. Purple [1] to colourless [1]

d. To condense the vapours / to stop loss of vapour [1] of ethanol / ethanoic acid [1]

2. a. The reaction is an equilibrium reaction [1] Both unionised acid molecules and (ethanoate) ions are present [1]

b. It is accepting a proton [1] from ethanoic acid [1]

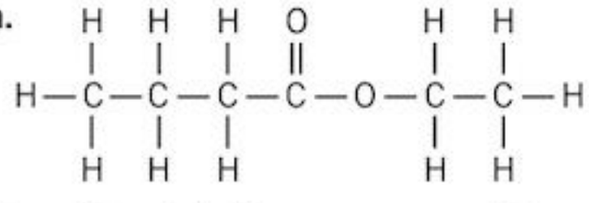
3. a. $2CH_3COOH + 2Na \rightarrow 2CH_3COO^-Na^+ + H_2$
(1 mark for formula of each product ALLOW CH_3COONa, 1 mark for balance)

b. $2CH_3COOH + Mg \rightarrow (CH_3COO^-)_2Mg^{2+} + H_2$
(1 mark for formula of each product ALLOW $(CH_3COO)_2Mg$, 1 mark for balance)

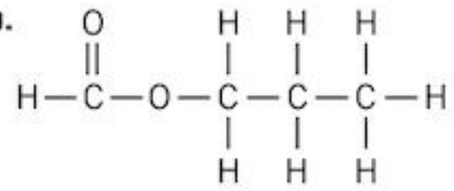
c. $CH_3COOH + NaOH \rightarrow CH_3COO^-Na^+ + H_2O$
(1 mark for each correct product)

d. $CH_3COOH + CH_3OH \rightarrow CH_3COOCH_3 + H_2O$
(1 mark for each correct reactant and 1 mark for H_2O)

4. a.



(1 mark for alcohol fragment, one mark for carboxylic acid fragment including ester bond)

b. 

(1 mark for alcohol fragment, one mark for carboxylic acid fragment including ester bond)

Unit 18.1

1. (1 mark for each correct word)

   A polymer is a substance that has very large **molecules** formed when lots of small molecules called **monomers** join together. This process is called **polymerisation**. When poly(ethene) is formed, one of the C=C **bonds** of **ethene** is broken and the monomers **join** together in a chain. A reaction in which two or more molecules join and no **other** molecule is formed is called an **addition** reaction.

2. 8 carbon atoms in a chain with two hydrogens attached to each [1]

   Continuation bonds shown on the end carbon atoms [1]

3. B because for the same number of chains / same mass [1] there are more spaces between the chains [1]

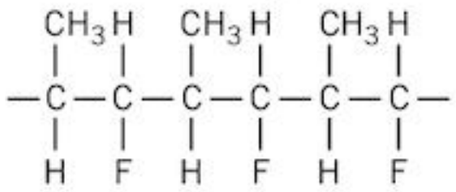
4. Molar mass of ethene = 28 [1] moles of ethene = 56000 / 28 = 2000 mol [1]

   20000 C atoms equivalent to 10000 ethene monomers [1]

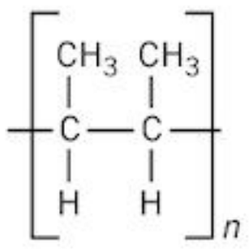
   10000 mol ethene → 1 mol polymer so 2000 mol gives 2000 / 10000 = 0.2 mol [1]

Unit 18.2

1. a. Brackets round a $CH_3CH–CHCl$ section or $CHCl–CH_3CH$ section [1]

   b. 

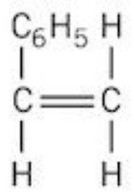
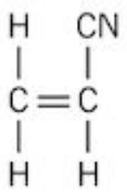
   (1 mark for correct number of C atoms, 1 mark for rest of structure, 1 mark for continuation bonds on end carbon atoms)

   c. 

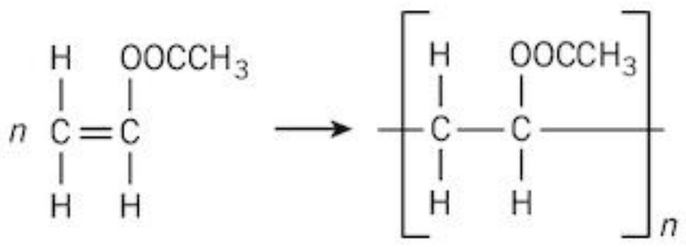
   (1 mark for structure, 1 mark for brackets and *n*, 1 mark for continuation bonds on end carbon atoms)

2. A double bond [1] rest of structure correct [1]

   B double bond [1] rest of structure correct [1]

   A  B 

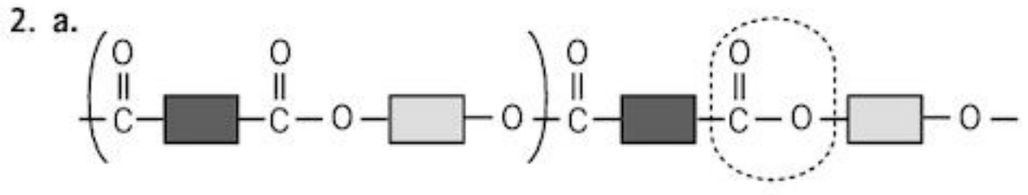
3. Correct structure of monomer [1] Structure of polymer (allow errors carried forward from monomer) [1] Continuation bonds, brackets, and *n* for polymer [1]

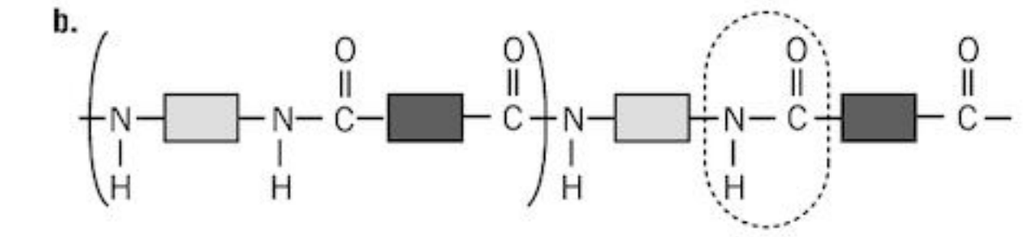
   

Unit 18.3

1. (1 mark for each correct word)

   In condensation polymerisation, molecules with different **functional** groups react together. A **small** molecule such as **water** or hydrogen **chloride** is **eliminated**.

2. a. 

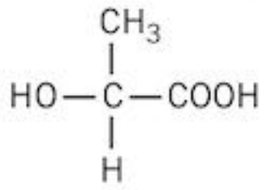
   b. 

   (1 mark each) [2]

   b. i. ester [1]

   ii. amide [1]

3. a. Alcohol [1] carboxylic acid [1]

   b. 

   COOH and OH group [1] rest of molecule correct [1]

4. $–OC–(CH_2)_3–CONH–(CH_2)_6–NH–$

   CONH group [1] rest of molecule correct [1]

Unit 18.4

1. a. A with 2, B with 1, C with 5, D with 3 (or 4), E with 4 (or 1 or 5)

   (All correct = 3, 3 or 4 correct = 2, 1 or 2 correct = 1)

   b. i. Nylon: clothes / fishing lines / ropes / fishing nets / tents / curtains [1]

   ii. Poly(ethene): plastic bags / clingfilm / bowls / chairs / dustbins [1]

2. a. (1 mark each for any three) waterproof / unreactive / can be moulded / strong / low density

   b. (1 mark each for any three) strong / flexible / waterproof / unreactive

3. The longer the chains the more tangled they become (so stronger) [1]

   The longer the chains the greater intermolecular forces (so stronger) [1]

4. Any 6 of:

   Thermosetting plastics have polymer chains that are cross-linked [1] by covalent bonds [1] This prevents the chains from moving [1] So the plastic keeps its shape / it is hard / tough [1] Thermosetting plastics only char on heating / do not melt on heating [1] Thermoplastics are not cross-linked [1] Weak forces between the chains [1] allow the chains to move over each other [1] so the plastic can be moulded when heated [1] Melts when heated [1]

Unit 18.5

1. They cannot be broken down / be decomposed [1] by living organisms / bacteria / fungi [1]

2. a. (1 mark each for any two) saves raw material / saves energy / can be made into new objects / could be cracked to different chemicals / reduces amount of landfill

   b. (1 mark each for any two) they have to be sorted (into their different types) / transported / washed (this may cost more than making new plastic) / the plastic may be weaker than the original

   c. Plastics do not have to be sorted [1] cheap [1]

   d. Heat can be used to generate electricity (via turbine) / saves burning fossil fuels / heat can be used directly e.g. to heat greenhouses [1]

3. a. i. Acidic gas produced / irritates eyes / irritates throat [1]

   ii. Acid rain / effect of acid rain, e.g. erodes limestone buildings / kills trees [1]

   b. i. Carbon dioxide [1] water [1]

   ii. Incomplete combustion [1] produces soot / carbon [1]

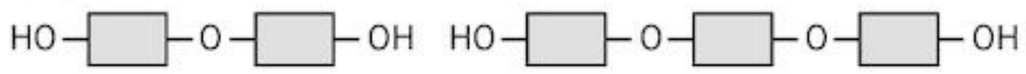
Answers

4. Any 5 of:
Some plastics are brittle [1] Plasticisers make them less brittle [1] by getting in between the chains [1] So that the chains move more easily [1] Over time plasticisers may come out of the plastic [1] Some plasticisers are harmful [1]

Unit 18.6

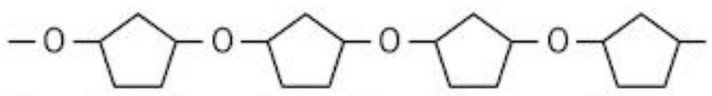
1. (1 mark for each correct word)
Plants make a **sugar** called glucose from carbon dioxide and **water** by photosynthesis. In plant cells glucose **monomers** are **polymerised** to make **starch** and cellulose. This polymerisation is **catalysed** by proteins called **enzymes**.

2. a.



(1 mark each)

b. i. 6 [1]
ii. condensation [1]

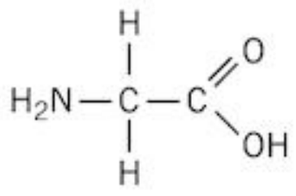
3. 
(1 mark for 4 repeat units, 1 mark for correct structure, 1 mark for continuation bonds)

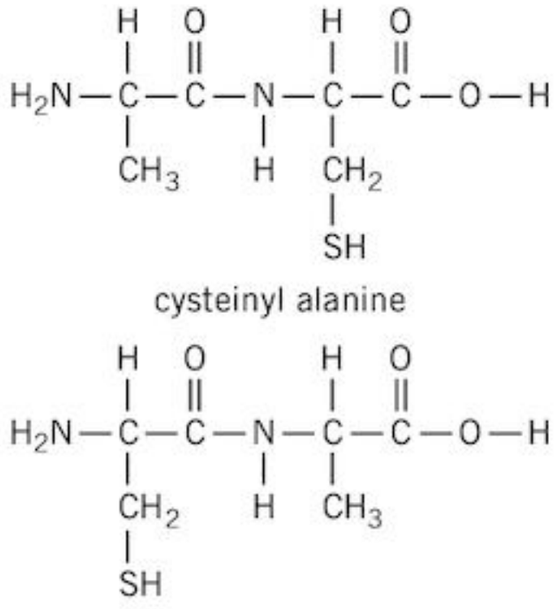
4. Reduces Cu^{2+} ions in Fehling's solution to copper(I) oxide [1] Colour change is from blue to orange / red [1] Reduces silver nitrate from Ag^{+} ions to metallic silver [1] Colour change from colourless to silver mirror on side of tube [1]

Unit 18.7

1. (1 mark for each word correct)
All amino acids contain carbon, hydrogen, **nitrogen (or oxygen)**, and **oxygen (or nitrogen)**. Two simple amino acids found in proteins contain **sulfur** as well. Proteins are **condensation** polymers formed by the reaction of carboxylic acid and **amine** groups from amino acids. Most proteins are formed by the polymerisation of about **twenty** types of amino acids.

2. a. Correct repeat unit, e.g. first bracket between the first N and CHR from the left, second bracket between the next N and CHR to the right [1]
b. Amide / peptide [1]

3. 
COOH and NH_2 groups [1] rest of structure correct [1]

4. 
cysteinyl alanine

alanyl cysteine

NH–C=O group shown in both [1] cysteinyl alanine shown [1] alanyl cysteine shown [1]
ALLOW: reaction of SH group with COOH group to form an ester

Unit 18.8

1. a. Protein [1] catalyst [1]
b. Breakdown of a substance [1] using water (or acid or alkali as catalysts) [1]

c. i. protein + water → amino acids [1]
ii. starch + water → glucose [1]

d. Temperature: body 35–37 °C [1] laboratory 100–200 °C [1]
Pressure: body 1 atmosphere / atmospheric [1] laboratory atmospheric [1]
Catalyst: body enzymes [1] laboratory (strong) acid [1]
Rate: body fast [1] laboratory slower [1]

2. a. In at the bottom (←), out at the top (←) [1]
b. To stop vapour escaping [1] to stop HCl escaping [1]

3. Fats are esters [1] of glycerol [1] with long-chain fatty acids / long-chain carboxylic acid [1] Converted to soaps by hydrolysis [1] with concentrated sodium hydroxide [1]

Unit 19.1

1. a. Time [1]
b. Volume of carbon dioxide [1]
c. (1 mark each for any two) temperature / mass of magnesium / surface area of magnesium / concentration of acid

2. a. Type of fuel burnt [1]
b. Temperature rise [1]
c. (1 mark each for any two) distance of burner from can / same copper can / same volume of water in can / same height of flame / same wick used in burner

3. Independent variable: time (or current) [1]
Dependent variable: mass of copper removed [1]
Control variable: 1 mark each for any 2 of current (or time if current is independent variable) / concentration of copper(II) sulfate / volume of copper(II) sulfate / depth at which electrode is immersed / size of electrodes

Unit 19.2

1. a. Thermometer [1] Beaker [1] Top pan balance and weighing boat [1] Water bath with temperature control ALLOW: Bunsen burner and tripod and gauze [1] Stirring rod [1]
b. Independent variable: temperature of the water [1]
Dependent variable: mass of solid added [1]
c. (1 mark each for any two) volume of the water / rate at which heat is applied, e.g. from water bath or Bunsen / rate of stirring [1]

2. Place 50 cm^3 / 100 cm^3 water in beaker [1]
Heat water to fixed temperature [1]
Add small weighed amounts of solid potassium chloride to the water and stir [1]
Keep adding small weighed amounts until no more dissolves [1]
Repeat at different temperatures [1]

3. a. (1 mark each for any two) If using Bunsen, the water will cool while the substance is being added / If using water bath, temperature control depends on sensitivity of thermostat / Heat may be given out or absorbed when substance dissolves in water.
b. (1 mark each for any two) Use a temperature-controlled water bath OR more sensitive temperature control / Use larger volume of water so that inaccuracies due to adding small amounts of solid are reduced / Use insulated container so heat losses reduced / Add solid to the water until saturated solution formed, then allow to cool and take temperature when crystals first appear

4. (1 mark each for any three) So that they get the credit for their work / To allow other scientists to check their experiments or results / To allow other scientists to develop the work further / To add to the amount of knowledge

Unit 19.3

1. a. C or D [1] b. B [1] c. D [1] d. A [1]
2. a. A [1] b. D [1]
3. A with 2, B with 4, C with 5, D with 6, E with 1, F with 3
(3 marks if all correct, 2 marks if 4 or 5 correct, 1 mark if 2 or 3 correct)

4. a. slightly soluble [1]
   b. soluble (reacts) [1]
   c. insoluble [1]
   d. slightly soluble [1]
   e. soluble [1]
   f. slightly soluble [1]
   g. insoluble [1]

Unit 19.4

1. $Al^{3+}(aq)$ with sodium hydroxide: white precipitate [1] which dissolves in excess [1]
   with ammonia: white precipitate [1] insoluble in excess [1]
   $Cr^{3+}(aq)$ with sodium hydroxide: green precipitate [1] which dissolves in excess [1]
   with ammonia: grey-green precipitate [1] insoluble in excess [1]
   $Cu^{2+}(aq)$ with sodium hydroxide: light blue precipitate [1] insoluble in excess [1]
   with ammonia: light blue precipitate [1] dissolves in excess to form a dark blue solution [1]
   $Fe^{3+}(aq)$ with sodium hydroxide: red-brown precipitate [1] which is insoluble in excess [1]
   with ammonia: red-brown precipitate [1] insoluble in excess [1]
2. Add excess sodium hydroxide [1] Only the precipitate containing zinc dissolves [1]
   OR
   Add ammonia [1] only zinc ions form a(n obvious) precipitate [1]
3. a. Red [1] b. lilac [1]
4. a. $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$
   (1 mark for correct formulae, 1 for balance, 1 for state symbols)
   b. Allow any of the following:
   $Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$
   $Al^{3+}(aq) + 4OH^-(aq) \rightarrow Al(OH)_4^-(aq)$
   $Al^{3+}(aq) + 4OH^-(aq) \rightarrow AlO_2^-(aq) + 2H_2O(l)$
   (1 mark for correct formulae, 1 for balance, 1 for state symbols)

Unit 19.5

1. A with 5, B with 4, C with 1, D with 3, E with 2
   (3 marks if all correct, 2 marks if 3 or 4 correct, 1 mark if 1 or 2 correct)
2. a. $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$
   (1 mark for correct formulae,1 for state symbols)
   b. $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
   (1 mark for correct formulae,1 for state symbols)
3. **A** must be a nitrate because ammonia given off / turns red litmus blue [1]
   B is a chloride because formed chlorine at the anode when electrolysed / bleaches litmus [1]
   B sodium as yellow flame in flame test [1]
   B sodium chloride [1]
   A silver or lead nitrate since white precipitate when added to chloride / **B** [1]
4. a. $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$
   (1 mark for correct formulae,1 for state symbols)
   b. $SO_3^{2-}(aq) + 2H^+(aq) \rightarrow SO_2(g) + H_2O(l)$
   (1 mark for correct formulae, 1 for balance, 1 for state symbols)

Unit 19.6

1. Funnel has no tap [1] Gas would escape from funnel [1]
   Tube of water [1] Sulfur dioxide is soluble in / reacts with water [1]
   Gas jar wrong way up [1] Hydrogen chloride is heavier than air [1]
2. a. Bubbles of gas given off too quickly / reaction too violent [1]
   Too much hydrogen gas given off could cause explosions / idea of loss of sulfate solution / loss of acid [1]
   b. Filter funnel and label [1]
   Filter paper inside filter funnel and label [1]
   Beaker below filter funnel [1]
   If no labels, allow 1 mark for drawing of filter funnel and filter paper
   c. Warm solution to crystallisation point / Leave in a warm place to form crystals [1]
   Filter off crystals [1]
3. Add dilute hydrochloric acid to solid sodium sulfite [1] In a flask with tap funnel [1]
   Lead sulfur dioxide through drying agent / Silicon dioxide / Acidic drying agent [1]
   Collect in a gas jar [1] By upward displacement of air [1]

Unit 19.7

1. Repeating the results several times until consistent results are obtained [1]
   Using equipment that measures accurately, e.g. burette instead of measuring cylinder [1]
2. B [1]
3.

Volume	Temperature
0.2	21
4.2	23
8.6	27
12.4	31

   (For each column: 2 marks if all correct, 1 mark if 2 or 3 correct)
4. Accuracy: Values obtained are close to the true values and repeat readings are generally close together [1]
   Precision: The results are exact for the instruments used but are not necessarily near the true value even though the repeat readings may be close together. [1]

Unit 19.8 Drawing tables

1.

Time / s	0	10	20	30	40	50	60	70	80	80
Mass change / g (first set)	0.0	0.5	0.89	1.24	1.44	1.56	1.68	1.79	1.82	1.82
Mass change / g (second set)	0.0	0.72	1.04	1.24	1.44	1.52	1.62	1.74	1.78	1.78
Average / g	0.0	0.61	0.965	1.24	1.44	1.54	1.65	1.765	1.80	1.80

   (1 mark for time, masses, and average in column 1, 1 mark for correct units, 1 mark for correct values, 1 mark for correct averages)
2.

Temperature / °C	Time / s	$\frac{1}{\text{Time}}$ / s^{-1}

   (1 mark for temperature, time, and rate, 1 mark for correct units)
3. moles of $CO_2 = \frac{1.80}{44} = 0.041$ mol [1]
   volume = 0.041 × 24 [1] = 0.98 dm^3 [1]

Unit 20.1

1. a. 2 Na and 1 O [1]
   b. 3 Mg and 2 N [1]
   c. 5 P and 15 Cl [1]
   d. 4 Al and 6 O [1]
   e. 8 H, 4 S, and 16 O [1]
   f. 6 Li, 3 C, and 9 O [1]
2. a. 1 Sn, 2 S, and 8 O [1]
   b. 2 N, 8 H, 1 S, and 4 O [1]
   c. 1 Ni, 2 Cl, and 8 O [1]
   d. 2 Ba, 4 I, and 12 O [1]

Answers

3. 1 Co, 2 Cl, 12 H, and 6 O [1]
4. 104 + 288 = 392 [1]

Unit 20.2

1. a. actual yield = $\frac{\%\ \text{yield}}{100} \times$ theoretical yield [1]
   b. theoretical yield = $\frac{\text{actual yield}}{\%\ \text{yield}} \times 100$ [1]
2. a. moles = concentration (in mol / dm^3) × volume (in dm^3) [1]
   b. volume (in dm^3) = $\frac{\text{moles}}{\text{concentration (in mol / dm}^3\text{)}}$ [1]
3. mass = density × volume
4. mass = $\frac{\text{energy}}{\text{specific heat capacity} \times \text{temperature rise}}$.

Unit 20.3

1. a. 1×10^6 [1]
   b. 70 000 [1]
   c. 3.3×10^3 [1]
2. a. 1×10^{-5} [1]
   b. 0.005 [1]
   c. 3.5×10^{-3} [1]
3. a. 1.4 [1]
   b. 3.6×10^{-5} [1]
4. 1.14×10^{-5} [1]

Unit 20.4

1. a. i. 6 [1]
      ii. 16 cm^2 [1]
      iii. 96 cm^2 [1]
   b. i. 8 [1]
      ii. $6 \times 2 \times 2 = 24\ cm^2$ [1]
      iii. $8 \times 24 = 192\ cm^2$
      iv. The surface area is much greater / the surface area to volume ratio is larger [1]
      More particles are exposed for reaction [1]
2. a. i. 100 [1]
      ii. 10 [1]
      iii. Volume of 1 dm^3 is $10 \times 10 \times 10\ cm^3$ [1] = $1000\ cm^3$ [1]

Unit 20.5

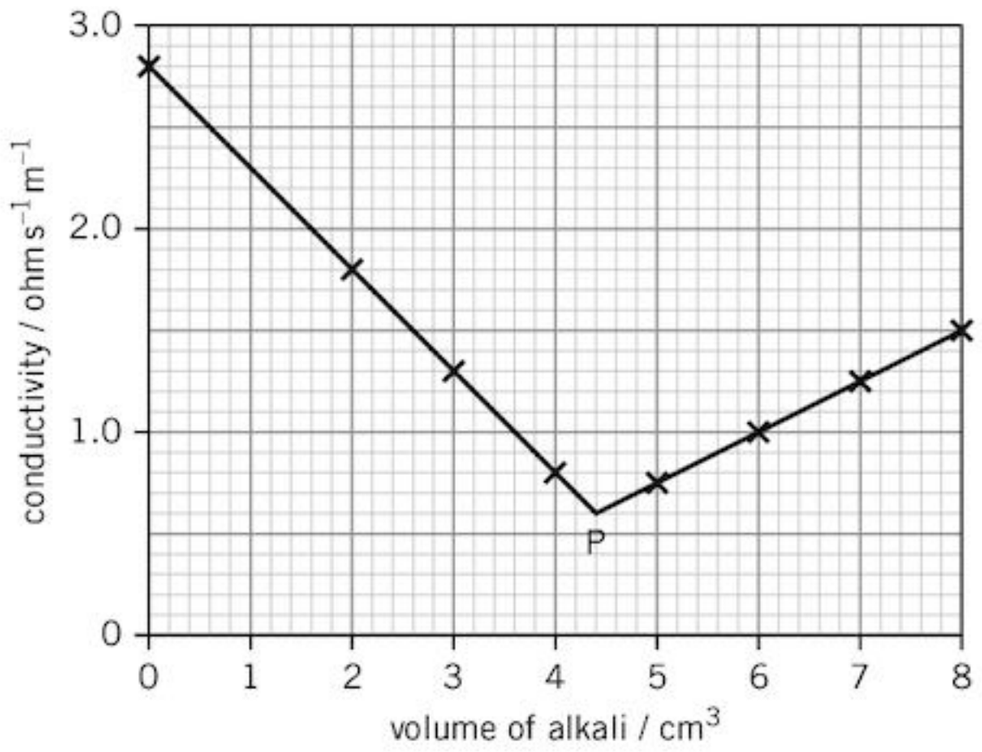
1. a. i. 4.36 [1]
      ii. 0.0873 [1]
      iii. 137 [1]
      iv. 0.00550 [1]
   b. i. 440 [1]
      ii. 3.4 [1]
      iii. 57 [1]
      iv. 0.0055 [1]
2. mol pentane 0.0926388 [1] rounded 0.09 [1]
   × 5 0.4631944 [1] rounded 0.5 [1]
   × 24 11.1 [1] 13.2 [1]

Unit 20.6

1. a. Line not continued to 0–0 point [1] Line not a continuous curve [1] Line has more points above it than below it [1]
   b. Points not clear [1] No labels / units on *y*- or *x*-axis [1] Full grid not used / lot of grid is space [1]
   c. Anomalous point included in the line [1]
   Straight lines between points / not a smooth curve [1]
2. a. 34–34.5 cm^3 [1] b. 44 cm^3 [1]

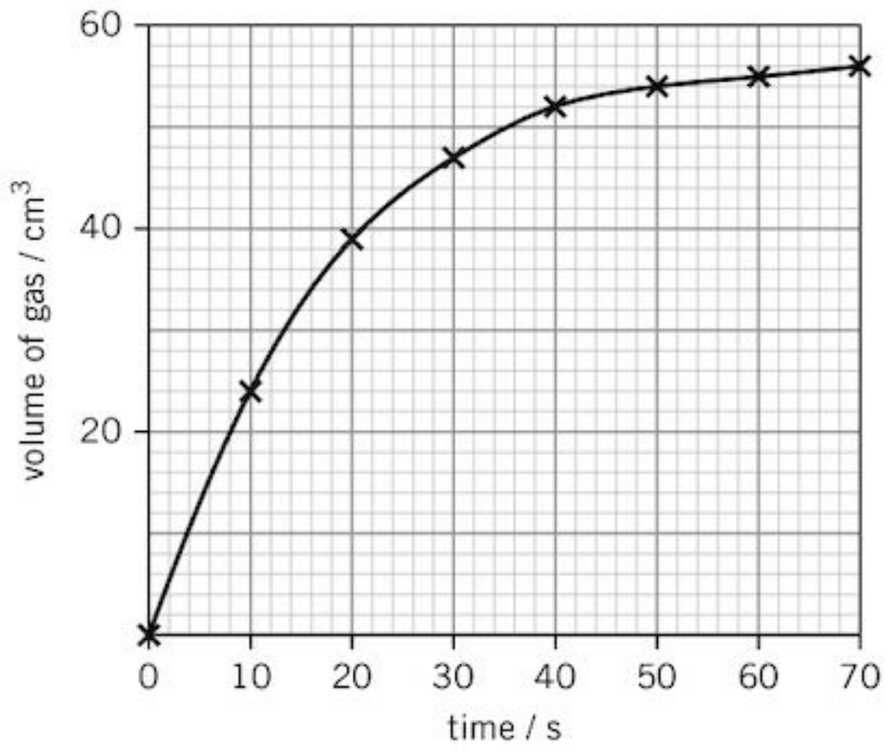
Unit 20.7

1.



   a. Axes correctly labelled [1]
   Points all correct [2] (1 mark if one point incorrect or missing)
   b. Lines correct (two straight intersecting lines) [1]
   Lines intersect between 4 and 5 cm^3 and P labelled [1]
   c. P is 4.4 cm^3 [1]

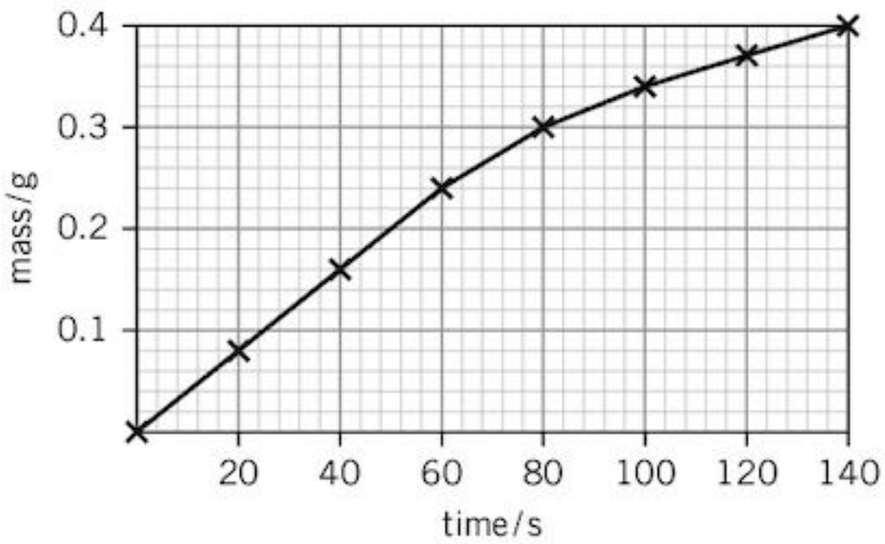
2.



   Axes correctly labelled and full grid used [1]
   Points all correct [2] (1 mark if one point incorrect or missing)
   Smooth curve between the points [1]

Unit 20.8

1.



   a. Axes correctly labelled and full grid used [1]
   Points all correct [2] (1 mark if one point incorrect or missing)
   Smooth curve between the points [1]
   b. 0.16/40 [1] 4×10^{-3} g/s [1]
   c. The line starts to curve / the rate is not constant [1]

Answers

Unit 22.1

a. 2,8,5 [1]

b. 16 [1]

c. Does not conduct electricity / does not conduct heat [1]
Low melting point / low boiling point [1]

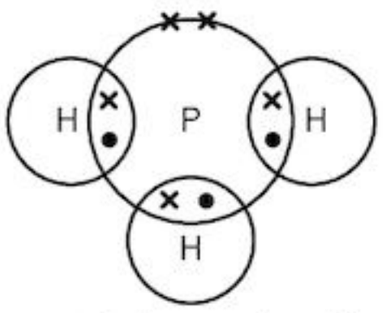
d. P_4 (or 4P) + $5O_2 \rightarrow 2P_2O_5$
(1 mark for correct formulae, 1 mark for balance)

e. PO_4^{3-} [1]

f. Nitrate / NO_3^- [1]

g. Fertilisers needed for plant growth / for plant proteins [1]
Sources of nitrogen / phosphorus / potassium in soil used up by growing plants [1]

h.



1 pair of electrons shared between each of the 3 H atoms and the central P atom [1]
Lone pair on the P atom [1]

Unit 22.2

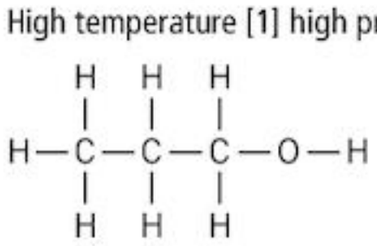
a. Double C=C bond [1]

b Bromine water / bromine ALLOW acidified potassium manganate(VII) [1]
Decolourised [1]

c. i. Reduction is gain of electrons [1]

ii. High temperature [1] high pressure [1] catalyst [1]

iii.



(2 marks for full structure, 1 mark if OH drawn instead of O–H)

d. i. Grind up the onion leaves in a solvent / water / alcohol [1]
Filter [1]

ii. Chromatography [1]

Unit 22.3

a. CsCl / Cs^+Cl^- [1]

b. Giant structure / ionic structure [1]
All the bonds are strong / strong electrostatic forces between all ions [1]
(Mention of atoms / intermolecular forces = maximum 1 for question)

c. The ions are free to move (from place to place) [1]

d. i. Conduct electricity [1] unreactive / inert [1]

ii. Anode: $2Cl^- \rightarrow Cl_2 + 2e^-$
(1 mark for formulae, 1 mark for balance)
Cathode: $Cs^+ + e^- \rightarrow Cs$ [1]

e. Mol Cs = 5.32/133 = 0.04 mol (= mol CsCl) [1]
Actual yield of CsCl = 6.4/168.5 = 0.038 [1]
% yield = 0.038 / 0.04 = 95% [1]
(or calculation based on masses)

Unit 22.4

a. 6.4–6.5 min [1]

b. i. 16 cm^3 [1]

ii. 27/2 = 13.5 cm^3/min [1]

c. Initial gradient steeper [1] ends up at the same volume of gas [1]

d. Increasing concentration increases the number of particles per unit volume / particles closer together [1]
Frequency of collisions increases / number of collisions per second increases [1]

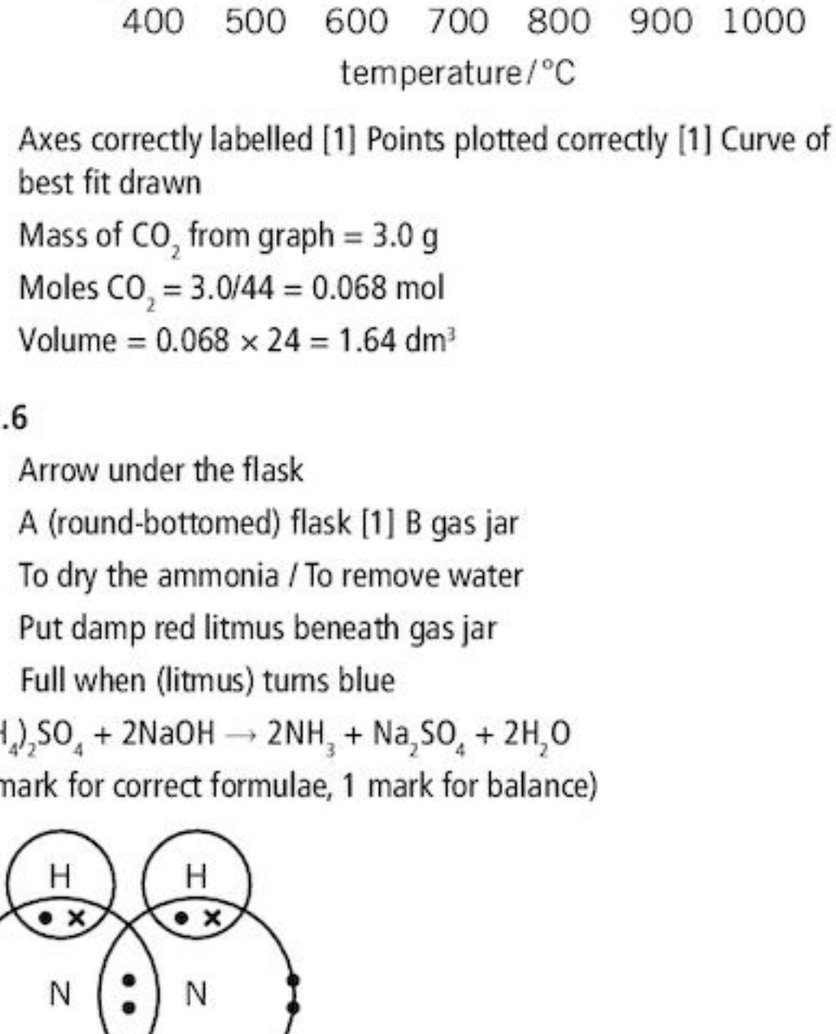
e. Faster because greater surface area of powder [1]
More particles of magnesium exposed to hydrochloric acid [1]

Unit 22.5

a. Decomposition [1] endothermic [1]

b. Bubble through limewater [1] limewater turns milky / cloudy [1]

c. i.



Axes correctly labelled [1] Points plotted correctly [1] Curve of best fit drawn [1]

ii. Mass of CO_2 from graph = 3.0 g [1]
Moles CO_2 = 3.0/44 = 0.068 mol [1]
Volume = 0.068 × 24 = 1.64 dm^3 [1]

Unit 22.6

a. i. Arrow under the flask [1]

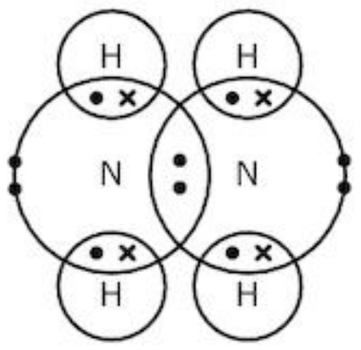
ii. A (round-bottomed) flask [1] B gas jar [1]

iii. To dry the ammonia / To remove water [1]

iv. Put damp red litmus beneath gas jar [1]
Full when (litmus) turns blue [1]

b. $(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH_3 + Na_2SO_4 + 2H_2O$
(1 mark for correct formulae, 1 mark for balance)

c.



(1 mark for bonding pairs of electrons, 1 mark for the lone pairs on each nitrogen atom)

Unit 22.7

a. Circle around the O–H group [1]

b. i. Carbon, hydrogen, and oxygen [2] Any two of these [1]

ii. Ethanol [1]

c. Carbon dioxide [1] Water [1]

d. Filtration [1]

e. i. Ester [1]

ii. No continuous carbon chain [1]
Idea of the COO groups being formed by condensation reactions [1]

f. Purple [1] to colourless [1]

Unit 22.8

a. i. Helium and neon [1]

ii. ALLOW: values between 0.08 and 0.1 [1]

iii. Gas [1] –118 °C is above the boiling point [1]

iv. Increases down the Group [1]

b. i. brown [1] ALLOW: grey / black

ii. iodide is being converted to iodine / oxidation number of iodine increases [1] oxidation number of Xe decreases [1]

iii. mol XeF_4 = 8.28/207 = 0.04 mol [1]

0.04 mol Xe [1]

0.04 × 24 = 0.96 dm^3 Xe [1]

Unit 22.9

a. i. Car exhausts / High temperature furnaces / Lightning [1]

ii. Acid rain / Kills trees / Acidifies lakes / Erodes limestone / Corrodes metal structures etc. [1]

iii. Proximity: Far apart [1] Motion: fast / random [1]

b. i. Colour gets lighter [1] Position of equilibrium moves to the left [1]

In direction of fewer gas molecules / fewer moles in the equation [1]

ii. NO_2 = 46 [1] N_2O_4 = 92 [1]

iii. Entirely NO_2 at 140 °C / more NO_2 at higher temperature [1]

The higher the temperature the more the equilibrium goes to the right [1]

For an endothermic reaction the position of equilibrium moves to the right with increase in temperature / increase in temperature favours the endothermic reaction [1]

c. $2NO_2 \rightarrow 2NO + O_2$

(1 mark for correct formulae, 1 mark for balance)

Unit 22.10

a. Any suitable indicator e.g. methyl orange / litmus / phenolphthalein [1]

b. Potassium sulfate [1]

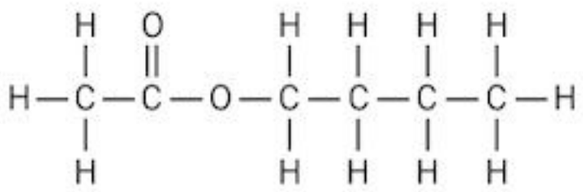
c. i. (12.5/1000) × 0.2 = 2.5 × 10^{-3} mol [1]

ii. 5.0 × 10^{-3} mol [1]

iii. 5.0 × 10^{-3} × 1000/25 = 0.20 mol/dm^3 [1]

d. $H^+ + OH^- \rightarrow H_2O$ [1]

e.



(2 marks if all correct, 1 mark if ester group shown as COO)

Group																	
I	II	III										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 178	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 livermoriu –		

Key

atomic number
atomic symbol
name
relative atomic mass

lanthanoids	57 La lanthanum 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 –

The symbols and proton numbers of the elements

Element	Symbol	Proton number	Element	Symbol	Proton number	Element	Symbol	Proton number	Element	Symbol	Proton number
actinium	Ac	89	calcium	Ca	20	francium	Fr	87	lawrencium	Lr	103
aluminium	Al	13	californium	Cf	98	gadolinium	Gd	64	lead	Pb	82
americium	Am	95	carbon	C	6	gallium	Ga	31	lithium	Li	3
antimony	Sb	51	cerium	Ce	58	germanium	Ge	32	lutetium	Lu	71
argon	Ar	18	chlorine	Cl	17	gold	Au	79	magnesium	Mg	12
arsenic	As	33	chromium	Cr	24	hafnium	Hf	72	manganese	Mn	25
astatine	At	85	cobalt	Co	27	helium	He	2	mendelevium	Md	101
barium	Ba	56	copper	Cu	29	holmium	Ho	67	mercury	Hg	80
berkelium	Bk	97	curium	Cm	96	hydrogen	H	1	molybdenum	Mo	42
beryllium	Be	4	dysprosium	Dy	66	indium	In	49	neodymium	Nd	60
bismuth	Bi	83	einsteinium	Es	99	iodine	I	53	neon	Ne	10
boron	B	5	erbium	Er	68	iridium	Ir	77	neptunium	Np	93
bromine	Br	35	europium	Eu	63	iron	Fe	26	nickel	Ni	28
cadmium	Cd	48	fermium	Fm	100	krypton	Kr	36	niobium	Nb	41
caesium	Cs	55	fluorine	F	9	lanthanum	La	57	nitrogen	N	7

The symbols and proton numbers of the elements (continued)

Element	Symbol	Proton number	Element	Symbol	Proton number	Element	Symbol	Proton number
nobelium	No	102	rhodium	Rh	45	thallium	Tl	81
osmium	Os	76	rubidium	Rb	37	thorium	Th	90
oxygen	O	8	ruthenium	Ru	44	thulium	Tm	69
palladium	Pd	46	samarium	Sm	62	tin	Sn	50
phosphorus	P	15	scandium	Sc	21	titanium	Ti	22
platinum	Pt	78	selenium	Se	34	tungsten	W	74
plutonium	Pu	94	silicon	Si	14	uranium	U	92
polonium	Po	84	silver	Ag	47	vanadium	V	23
potassium	K	19	sodium	Na	11	xenon	Xe	54
praseodymium	Pr	59	strontium	Sr	38	ytterbium	Yb	70
promethium	Pm	61	sulfur	S	16	yttrium	Y	39
protactinium	Pa	91	tantalum	Ta	73	zinc	Zn	30
radium	Ra	88	technetium	Tc	43	zirconium	Zr	40
radon	Rn	86	tellurium	Te	52			
rhenium	Re	75	terbium	Tb	65			

Relative atomic masses (A_r) for calculations

Element	Symbol	A_r
aluminium	Al	27
bromine	Br	80
calcium	Ca	40
carbon	C	12
chlorine	Cl	35.5
copper	Cu	64
fluorine	F	19
helium	He	4
hydrogen	H	1
iodine	I	127
iron	Fe	56
lead	Pb	207
lithium	Li	7
magnesium	Mg	24
manganese	Mn	55
neon	Ne	20
nitrogen	N	14
oxygen	O	16
phosphorus	P	31
potassium	K	39
silver	Ag	108
sodium	Na	23
sulfur	S	32
zinc	Zn	65

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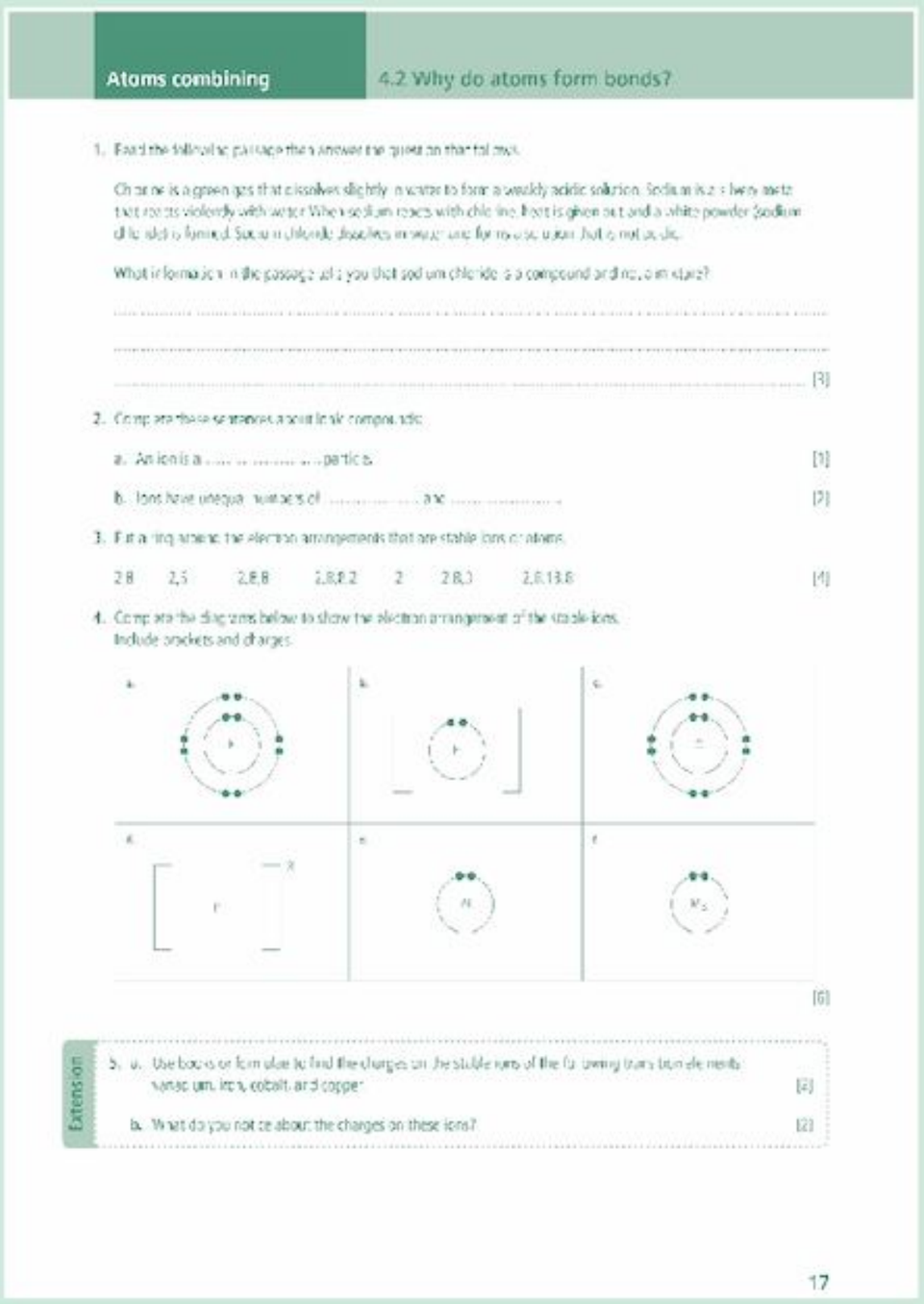

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