WORKBOOK

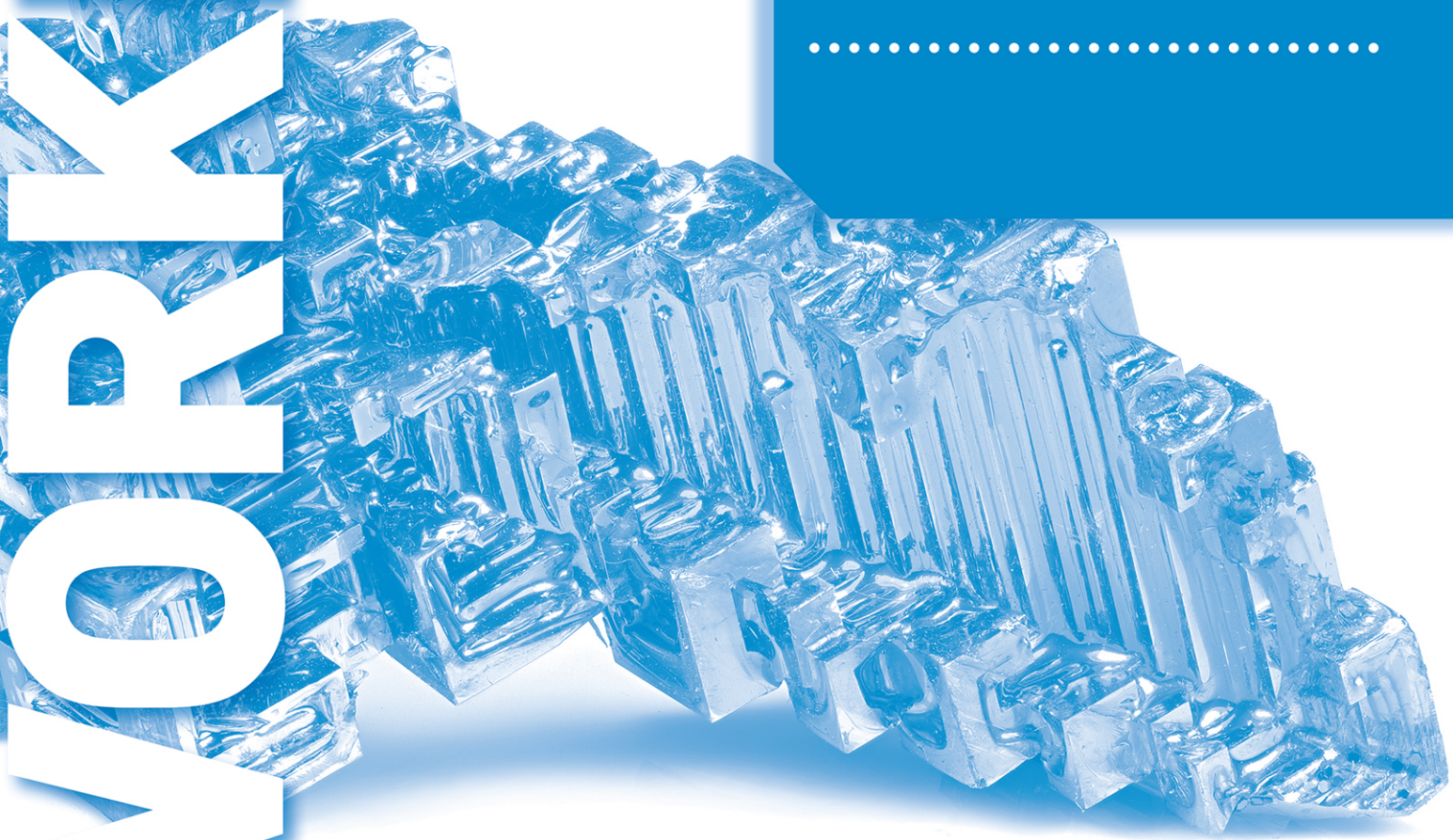
Cambridge Assessment International Education

Endorsed for learner support

Cambridge IGCSE™

Chemistry

Third Edition



HODDER EDUCATION

WORKBOOK

Working for over 25 YEARS with Cambridge Assessment International Education

Cambridge Assessment International Education

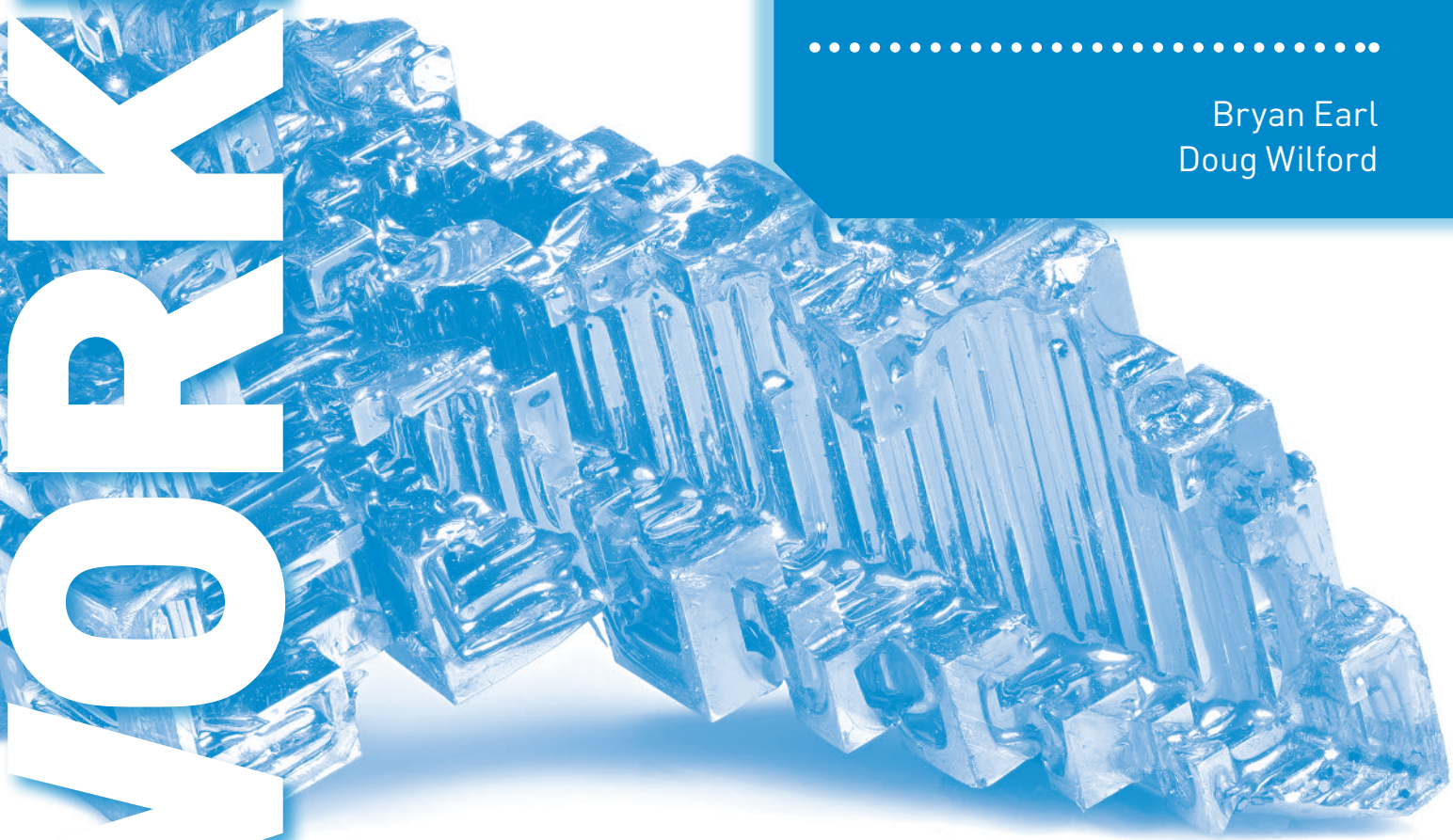
Endorsed for learner support

Cambridge IGCSE™

Chemistry

Third Edition

Bryan Earl
Doug Wilford



HODDER EDUCATION

Orders: please contact Hachette UK Distribution, Hely Hutchinson Centre, Milton Road, Didcot, Oxfordshire, OX11 7HH. Telephone: +44 (0)1235 827827. Email education@hachette.co.uk Lines are open from 9 a.m. to 5 p.m., Monday to Friday. You can also order through our website: www.hoddereducation.com

First edition published in 2012

Second edition published in 2015

This edition published in 2021 by

Hodder Education

An Hachette UK Company

Carmelite House, 50 Victoria Embankment, London EC4Y0DZ

This third edition published 2021

Impression number 5 4 3 2 1

Year 2025 2024 2023 2022 2021

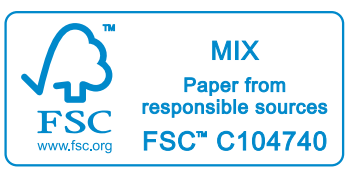
Cover photo © Björn Wylezich - stock.adobe.com

Typeset in India by Integra Software Services Pvt. Ltd, Pondicherry

Printed and bound in the UK

A catalogue record for this title is available from the British Library

ISBN 9781398310537



Contents

Preface

This Workbook has been written to help you in your further understanding of chemistry for the Cambridge IGCSE and IGCSE (9-1) Chemistry syllabuses (0620/0971) for examination from 2023. This Workbook should be used alongside the 4th edition of the Cambridge IGCSE Chemistry Student's Book, written by the same authors.

In this Workbook the chapters have the same names as those in the Student's Book and are organised by syllabus topic. They contain questions related to the content of the equivalent chapters in the IGCSE Chemistry Student's Book. The questions may be related to:

- the Core of the Cambridge IGCSE syllabus
- both the Core and the Supplement parts of the syllabus–if you are to be entered for the extension paper you should try to do the Core as well as the Supplement questions
- the Supplement part of the Cambridge IGCSE syllabus, so that you practise key skills required in the study of this syllabus.

Chapter 14 has questions that relate to the 'Alternative to Practical' examination paper.

To ensure your answers to the questions are kept together in one place, there are spaces provided in this book for you to write your answers in. This will help when you come to revise for your examination. Answers can be found in the Teacher's Guide on Boost.

This Workbook is intended to be used throughout the Cambridge IGCSE Chemistry course, and its structure mirrors the Student's Book in this series. It should be used as extra practice to apply the ideas you have met in the Student's Book. The Workbook covers a fairly representative selection of the syllabus content, although not every item in the syllabus has a specific question related to it.

Bryan Earl and Doug Wilford

The Periodic Table of Elements

Group																	
I	II										III	IV	V	VI	VII	VIII
							1 H Hydrogen 1									2 He Helium 4
3 Li Lithium 7	4 Be Beryllium 9										5 B Boron 11	6 C Carbon 12	7 N Nitrogen 14	8 O Oxygen 16	9 F Fluorine 19	10 Ne Neon 20
11 Na Sodium 23	12 Mg Magnesium 24										13 Al Aluminium 27	14 Si Silicon 28	15 P Phosphorus 31	16 S Sulfur 32	17 Cl Chlorine 35	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 226	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 -	113 Nh Nihonium -	114 Fl Flerovium -	115 Mc Moscovium -	116 Lv Livermorium -	117 Ts Tennessine -	118 Og Oganesson -

Key

a X Element name b

a = proton (atomic) number

X = atomic symbol

b = relative atomic mass

lanthanoids	57 La Lanthanum 139	58 Ce Cerium 140	59 Pr Praseodymium 141	60 Nd Neodymium 144	61 Pm Promethium 144	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 volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).

1 States of matter

Core

1 Imagine that you are a water molecule in an ice cube. Describe what happens to you, giving the reasons why it happens, as the ice cube is heated up to a temperature of 100°C.

.....

.....

.....

.....

.....

.....

2 **a** Explain the meaning of each of the following terms.

i melting .....

ii chemical change .....

iii condensation .....

iv evaporation .....

v freezing .....

vi boiling .....

b Which of the terms given in part **a** best describes what is taking place in each of the following?

i The formation of water droplets on the inside of a window on a cold day. .....

ii The formation of liquid potassium chloride from solid potassium chloride using strong heat. .....

3 Use ideas about kinetic particle theory to describe the following:

a Diffusion does not occur in solids.

.....

.....

b Gases can be compressed more than liquids.

.....

.....

c It is possible for a liquid to flow but a solid cannot.

.....

.....

Supplement

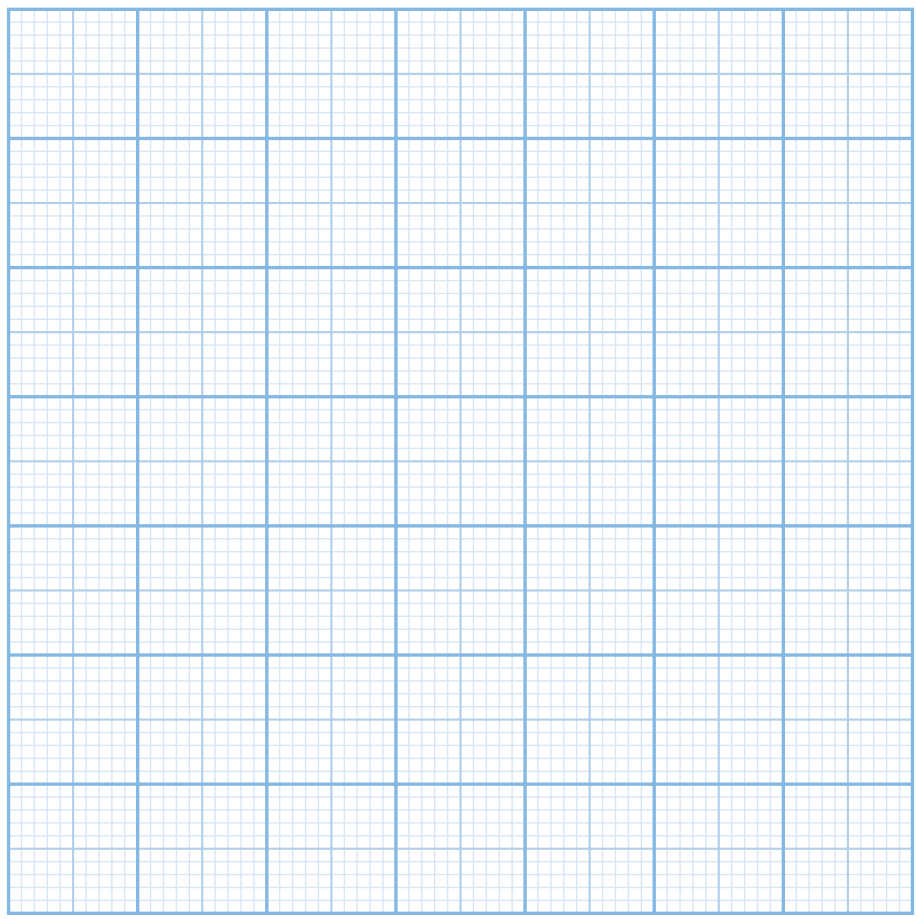
4 A sample of a solid substance, which had been cooled to –5°C, was put into a test-tube.

The test-tube was then heated in a water bath. The temperature of the substance was taken every 5 minutes for an hour. The results obtained are shown in Table 1.1.

Table 1.1

Time/min	0	5	10	15	20	25	30	35	40	45	50	55	60
Temperature/°C	–5	–1	5	5	7	13	28	45	62	76	79	82	82

a Plot the results on the graph grid provided, putting time on the horizontal axis and temperature on the vertical axis.



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

c What is the boiling point of the substance? .....

5 When the experiment shown in Figure 1.1 is set up, a cloud of fine white powder can be seen as the ammonia gas reacts with the hydrogen chloride gas.

Hydrogen chloride particles are more than twice as heavy as ammonia particles.

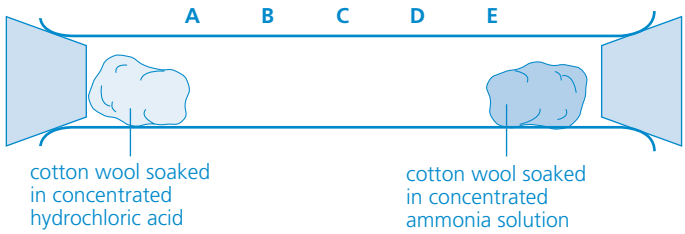


Figure 1.1

a Which of the particles will move faster? .....

b At which point, **A** to **E**, along the tube will the white cloud be seen? Explain your answer in terms of the movement of the particles.

.....

c How do the particles of hydrogen chloride and ammonia gas move along the tube?

.....

Exam-style questions

Core

1 a i Give two properties shown by:

a solid ..... ***[2]***

a liquid ..... ***[2]***

a gas ..... ***[2]***

ii Draw diagrams in the boxes provided to show how the particles are arranged in each of the physical states. ***[3]***

solid **liquid** **gas**

b The melting and boiling points of five substances are given in Table 1.2.

(Take room temperature as being 25°C.)

Table 1.2

Substance	Melting point/°C	Boiling point/°C
Oxygen	–218	–183
Bromine	–7	59
Mercury	–39	357
Phosphorus	44	280
Iron	1535	2862

i Which element/s is/are a gas at room temperature? ..... ***[1]***

ii Which element/s is/are a solid at room temperature? ..... ***[1]***

iii Which of the elements will boil first if the temperature is raised from room temperature? ..... ***[1]***

[Total: 12]

2 Use the kinetic particle theory to describe the following.

a Walking along the street in front of a coffee shop, it is possible to smell the coffee. ***[2]***

.....

.....

b When laying railway track, gaps have to be left between the lengths of track. ***[2]***

.....

.....

c When a tea bag is placed in a cup of hot water, the colour of the water changes. ***[2]***

.....

.....

d In cold weather, the amount of water found running down the inside of windows increases. ***[2]***

.....

.....

e A bubble of methane rises from the bottom of the Pacific Ocean. As it rises, the bubble gets bigger. ***[2]***

.....

.....

[Total: 10]

Supplement

3 A weather balloon, full of helium gas, is prepared for take-off. The amount of helium gas in the balloon has to be carefully monitored before it is sealed.

a i As the balloon rises, what happens to the external pressure? ***[1]***

.....

ii What effect will this change in pressure have on the volume of the balloon? ***[1]***

.....

iii Explain in terms of the kinetic particle theory why the volume of the balloon changes in the way you have stated. ***[2]***

.....

.....

b i What happens to the external temperature as the balloon rises? ***[1]***

.....

ii What effect will this have on the volume of the balloon? Explain your answer using the kinetic particle theory. ***[3]***

.....

.....

.....

[Total: 8]

2 Atoms, elements and compounds

Core

1 a Distinguish between the terms *compound* and *mixture*, using specific examples.

.....

.....

.....

b Look at the list of substances.

stainless steel	**carbon monoxide**	**lemonade**	**sulfuric acid**	**cement**
methane	**sodium hydroxide**	**limestone**	**beer**	**brass**

Which of these substances are:

i compounds?

.....

.....

ii mixtures?

.....

.....

c Pick the 'odd one out' in each of the following groups and explain why it is different from the others.

i petrol, oil, water, air, brass

Odd one out .....
Explanation

.....

ii lead nitrate, potassium oxide, chromium, hydrochloric acid, silicon dioxide

Odd one out .....
Explanation

.....

iii HCl, F_2, MgO, FeS, CO_2

Odd one out .....
Explanation

.....

d Water, H_2O, is a *molecule*. What do you understand by the term *molecule*?

.....

2 a A mixture of zinc metal powder and sulfur was heated strongly in a test-tube. A bright red glow spread very quickly throughout the mixture during the reaction. At the end of the experiment, a white powder was produced.

i What safety precautions should be taken when carrying out this experiment?

.....

ii Explain what the 'bright red glow' indicates.

.....

iii Give the chemical name of the 'white powder'. .....

iv Write a word equation and a balanced chemical equation for the reaction that has taken place.

.....

.....

v The white solid is a compound. Explain the difference between the mixture of zinc and sulfur and the compound formed by the chemical reaction between them.

.....

.....

.....

b The metal copper can be extracted from its ore, copper sulfide, in a two-stage process:

Copper sulfide reacts with oxygen at a high temperature to form copper oxide and sulfur dioxide gas.

Then the copper oxide is reacted with carbon, again at high temperature, to form copper metal and carbon dioxide gas.

i Name the elements mentioned in the passage above.

.....

ii Name the compounds mentioned in the passage.

.....

iii Write word equations and balanced chemical equations for the reactions described in the passage.

.....

.....

.....

.....

3 a Table 2.1 shows the formulae for some compounds. Complete the table by writing in:

i the symbols present in each formula and the elements they represent

ii the number of atoms of each element present in the formula

iii the total number of atoms present in the formula.

The first one has been done for you.

Table 2.1

Formula of substance	Elements present			Total number of atoms
	Symbol	Name	Number of atoms	
$LiNO_3$	Li	Lithium	1	5
	N	Nitrogen	1	
	O	Oxygen	3	
$CaCO_3$				
Mg_3N_2				
Ag_2CrO_4				

b Balance the following equations. Some of the spaces could be left blank.

i ..... Pb(s) + ... O_2(g) → ..... PbO(s)

ii ..... H_2(g) + ... O_2(g) → ..... H_2O(l)

iii ..... C_2H_4(g) + ... O_2(g) → ..... CO_2(g) + ... H_2O(l)

4 a Complete Table 2.2. It shows the proton number and number of neutrons and electrons in the atoms of some common elements. It also shows the atoms' nucleon number.

Table 2.2

Element	Proton number	Number of neutrons	Number of electrons	Nucleon number
Lithium		3		7
Boron	5			11
Aluminium		14	13	
Nitrogen	7			14
Calcium		20		40

b Complete the electronic configurations for the following elements.

i $^{23}_{11}$Na: 2, ...

ii $^{32}_{16}$S: 2, ...

iii $^{39}_{19}$K: 2, ...

5 a Define the term *relative atomic mass* (A_r).

.....

Supplement

b Given that the percentage abundance of a naturally occurring sample of carbon consists of 1.10% $^{13}_{6}$C and 98.90% $^{12}_{6}$C, calculate the A_r of this sample of carbon. Show each step of your working.

c Using the example of different atoms of carbon shown, explain the meaning of the term *isotope* in terms of the numbers of protons and neutrons.

$^{12}_{6}$C and $^{14}_{6}$C

.....

.....

Supplement

d Why do the different carbon isotopes have the same chemical properties?

.....

.....

Supplement

6 The metal zinc can be extracted from its ore, zinc sulfide (zinc blende), in a two-stage process.

The second part of the process involves a redox reaction in which zinc oxide is reacted with carbon, at a high temperature, to form zinc metal and carbon monoxide gas.

In this process there is an *oxidising agent* and a *reducing agent*.

$ZnO(s) + C(s) \rightarrow Zn(s) + CO(g)$

a What do you understand by the terms *oxidising agent* and *reducing agent?*

.....

.....

b Which of the substances shown in the chemical equation above is acting as the:

i oxidising agent? .....

ii reducing agent? .....

Exam-style questions

Core

1 Table 2.3 shows some information about four different elements, **W**, **X**, **Y** and **Z**. (Note that **W**, **X**, **Y** and **Z** are *not* chemical symbols.)

a Complete the table. ***[3]***

Table 2.3

Element	Metal or non-metal?	Shiny?	Conductor of electricity?	Melting point
W	Metal		Yes	High
X	Non-metal	No	No	Low
Y		Yes	Yes	High
Z	Non-metal	No		Low

b Zinc is a metal. Give **one** property of zinc, *not shown in the table*, which shows that it is a metal. ***[1]***

.....

c Sparklers are a type of firework. They usually consist of a chemical mixture that has been moulded onto a thin wire. One of the main substances found in the mixture is iron powder.

The word equation for one of the main reactions that takes place during the burning of a sparkler is:

iron + oxygen → iron oxide

i Give the name of one of the *reactants* present in the word equation above. ***[1]***

.....

ii Give the name of the *compound* present in the word equation above. ***[1]***

.....

iii Write a balanced chemical equation for the reaction of iron with oxygen. ***[3]***

.....

[Total: 9]

Supplement

2 Iron is usually extracted from its ore hematite (iron(III) oxide). The following is a brief outline of the reactions involved in this extraction.

i coke + oxygen → carbon dioxide

ii carbon dioxide + coke → carbon monoxide

iii iron(III) oxide + carbon monoxide → iron + carbon dioxide

a Write balanced chemical equations for:

i reaction i ***[2]***

.....

ii reaction ii ***[3]***

.....

b Which substance is being oxidised in reaction i? ..... ***[1]***

c Which substance is being reduced in reaction ii? ..... ***[1]***

d Complete and balance the following equation for reaction iii. Some spaces may be left blank. ***[4]***

..... $Fe_2O_3(s)$ + ... → ..... Fe(l) + ...

e In reaction iii, which substance is acting as the reducing agent and which is acting as the oxidising agent? ***[2]***

.....

[Total: 13]

3 Bonding and structure

Core

1 For each of the following statements about ionic/covalent bonding and ionic/covalent compounds, write either 'T' for 'true' or 'F' for 'false'.

a Ionic bonds are formed between non-metals only. .....

b Ionic bonds are formed by transfer of electrons between the elements forming the bond. .....

c Ionic compounds usually have low melting points and high boiling points. .....

d Covalent bonds are formed between non-metals only. .....

e Covalent bonds are formed by sharing of electrons between the elements forming the bond. .....

f Covalent compounds usually have low melting and boiling points. .....

2 Figure 3.1 shows two different forms of carbon, **A** and **B**.

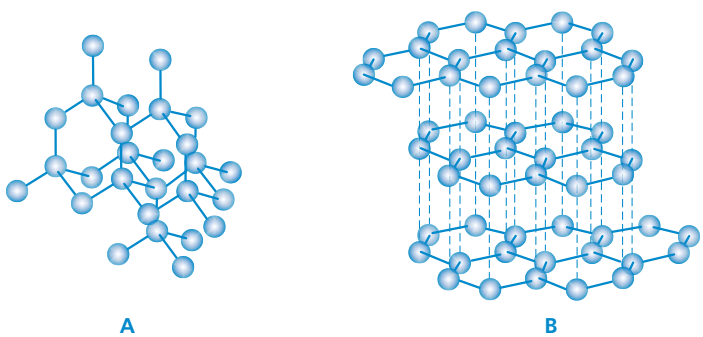


Figure 3.1

a Name the two forms of carbon shown.

.....

b i What type of bonding is present in these forms of carbon?

.....

ii What type of structure is represented by these forms of carbon?

.....

c i How many other carbon atoms are linked to each carbon atom in form **A**? .....

ii How many other carbon atoms are linked to each carbon atom in form **B**? .....

.....

d Give a use of each of the two forms of carbon.

e Complete Table 3.1, which relates to the properties of the metal copper and the two forms of carbon, **A** and **B**.

Table 3.1

Substance	Electrical conductivity	Melting point	Hardness
Copper	Good	High	High
A			
B			

3 a Complete the following paragraph about bonding using the words or phrases below. These words may be used more than once.

transferred	**cations**	**structure**	**ionic**	**electrostatic force**	**metal**
anions	**force**	**non-metals**	**oppositely**	**metals**	**non-metal**

Ionic bonds are usually found in compounds that contain ..... combined with ..... . When this type of bond is formed, electrons are ..... from the ..... atoms to the ..... atoms during the chemical reaction. In doing this positive ..... ions and negative ..... ions are formed. The positive ions are known as ..... . The negative ions are known as ..... . When ..... charged ions form a crystal ..... they have a strong attractive ..... between them called an ..... of attraction. This is known as the ..... bond.

b Draw dot-and-cross diagrams to show the bonding in each of the following ionic compounds.

i lithium chloride (LiCl)

ii calcium sulfide (CaS)

4 Draw dot-and-cross diagrams to show the bonding in each of the following covalent compounds.

a hydrogen fluoride (HF)

b nitrogen trichloride (NCl_3)

Supplement

5 Table 3.2 shows the oxidation states of some common ions. Use the information in the table to work out the formula of each of the compounds listed below it.

Table 3.2

	Oxidation number (valency)		
	1	2	3
Metals	Sodium (Na^+) Potassium (K^+) Silver (Ag^+)	Magnesium (Mg^{2+}) Lead (Pb^{2+}) Barium (Ba^{2+}) Copper (Cu^{2+})	Aluminium (Al^{3+}) Iron (Fe^{3+})
Non-metals	Fluoride (F^-) Chloride (Cl^-) Bromide (Br^-)	Oxide (O^{2-}) Sulfide (S^{2-})	
Groups of atoms	Hydroxide (OH^-) Nitrate (NO_3^-) Ammonium (NH_4^+)	Carbonate (CO_3^{2-}) Sulfate (SO_4^{2-})	Phosphate (PO_4^{3-})

a copper(II) fluoride .....

b sodium carbonate .....

c silver phosphate .....

d ammonium sulfate .....

e magnesium phosphate .....

f aluminium hydroxide .....

g iron(III) bromide .....

6 The bonding in metals can be described in the following way:

'It is an electrostatic force of attraction between the sea of (or free) electrons and the regular array of positive metal ions in a lattice within the solid metal. The bonding in metals gives rise to certain properties.'

Complete the following passage about the properties of metals by writing in words from the list.

energy levels	**ductile**	**energy**	**attractive**	**delocalised**
high	**malleable**	**ions**	**conductors**	**negative**

Metals are good ..... of electricity and heat, because the free electrons from the outer ..... of metal atoms carry a ..... charge or heat ..... through the metal. The free electrons are often described as ..... . The free electrons allow metal ..... to slide over each other, so metals are ..... and ..... . They have ..... melting and boiling points due to the strong ..... forces within the structure of the metal.

Exam-style questions

Core

1 One of our most important fuels is natural gas (methane, CH_4). Figure 3.2 shows the bonding in a methane molecule.

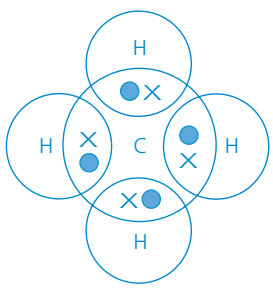


Figure 3.2

a What type of bonding is shown in the methane molecule? ..... ***[1]***

b What type of particle is represented by the dots and crosses? ..... ***[1]***

c Why are four hydrogen atoms needed for each carbon atom in the methane molecule? ***[2]***

.....

.....

d i What noble gas electron configuration do the hydrogen atoms have? *[1]*

.....

ii What noble gas electron configuration does the carbon atom have? *[1]*

.....

iii When atoms within a molecule form chemical bonds, they normally end up with eight electrons in their outer shell. Why do the hydrogen atoms have only two? *[1]*

.....

.....

[Total: 7]

Supplement

2 Figure 3.3 shows the structure of sodium chloride (salt).

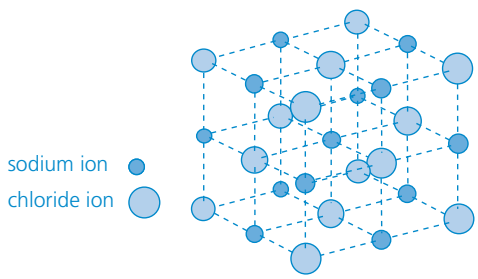


Figure 3.3

a How does the electron configuration of a sodium atom differ from that of a sodium ion? *[2]*

.....

b How does the electron configuration of a chlorine atom differ from that of a chloride ion? *[2]*

.....

c What type of chemical bond is found in sodium chloride? ..... *[1]*

d Using the diagram of sodium chloride in Figure 3.3, explain why sodium chloride:

i forms crystals that are cubic in shape. *[2]*

.....

.....

ii has a high melting point (801°C). *[2]*

.....

.....

iii acts as an insulator when solid, but will conduct electricity when molten. *[2]*

.....

.....

[Total: 11]

4 Stoichiometry – chemical calculations

Use the Periodic Table on page 4 to look up any values for relative atomic mass that you may need in this chapter.

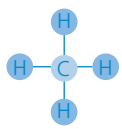
Core

1 a Define the molecular formula of a compound.

.....

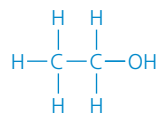
.....

b Look at the diagrams of molecules in Figure 4.1. For each diagram, write its molecular formula underneath.



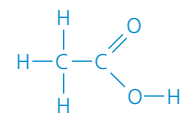
A

.....



B

.....



C

.....

Figure 4.1

2 Which of these units are used to measure the concentration of a solution?

» mol » g/dm^3 » mol/cm^3 » mol/dm^3

.....

3 a Calculate the relative molecular mass of each of the following compounds.

i C_2H_5OH .....

ii $CH_3COOCH_2CH_3$ .....

iii CH_3CH_2COOH .....

iv $CH_3CH{=}CH_2$ .....

b Calculate the relative formula mass of each of the following compounds.

i Na_2CO_3 .....

ii $Ca(OH)_2$ .....

iii $(NH_4)_2SO_4$ .....

Supplement

4 A student carried out a reaction between iron and hydrochloric acid to make some iron(II) chloride crystals. She started with 5.6 g of iron and used an excess of hydrochloric acid.

a i Write a balanced chemical equation for the reaction.

.....

ii How many moles of iron did she start off with?

.....

.....

iii What mass of iron(II) chloride could she have expected to obtain from this reaction? Show your working.

.....

.....

iv She actually obtained 9.17 g of the iron(II) chloride. What was her percentage yield? Show your working.

.....

.....

b Iron is extracted from its ore hematite (Fe_2O_3) in the blast furnace. The reaction that produces the iron is shown in the equation below.

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$$

100 tonnes of hematite gave 7 tonnes of iron. Calculate the percentage yield of the process, showing your working.

5 a Calculate the number of moles of the element in:

i 54 g of aluminium

ii 0.4 g of calcium

b Calculate the number of moles of the compound in:

51 g of aluminium oxide (Al_2O_3)

c Calculate the number of particles in 0.5 moles of sodium chloride (NaCl).

.....

6 Calculate the mass of:

a **i** 2 moles of calcium carbonate

ii 0.25 mole of water

b Calculate the relative formula mass of the compound below, using the information given.

0.1 moles of a sample of calcium carbonate is found in 10 g of the solid.

.....

c Calculate the molar mass of the compound below, using the information given.

0.05 moles of a sample of calcium oxide is found in 2.8 g of the solid.

.....

7 **a** What is the empirical formula of a compound?

.....

.....

b Calculate the empirical formulae of the compound with the following composition by mass:

2.18 g of carbon, 0.36 g of hydrogen and 1.46 g of oxygen

c Calculate the empirical formulae of the compound with the following percentage composition by mass:

27.4% sodium, 1.2% hydrogen, 14.3% carbon and 57.1% oxygen

8 a Calculate the number of moles of solute in each of the following solutions.

i 0.5 dm^3 of 0.25 mol/dm^3 NaOH

ii 100 cm^3 of 0.5 mol/dm^3 NaCl

b Calculate the concentration (in mol/dm^3) of each of the following solutions.

i 0.5 mole of sodium hydroxide in 500 cm^3

ii 0.25 mole of copper(II) sulfate in 250 cm^3

9 To find out the concentration of a solution of hydrochloric acid, a student carried out a titration. She found that 18.95 cm^3 of the hydrochloric acid was needed to neutralise 25 cm^3 of a 0.1 mol/dm^3 sodium carbonate solution.

a Write a balanced chemical equation for the reaction between hydrochloric acid and sodium carbonate.

.....

b Describe how the titration procedure was carried out.

.....

.....

.....

.....

.....

.....

c Use the information given to find the concentration of the hydrochloric acid solution. Show the steps of your calculation.

.....

.....

.....

Exam-style questions

Supplement

1 a Copper(II) oxide can be reduced to copper by passing hydrogen gas over the oxide, as shown in the equation below. A student started the experiment with 8 g of copper(II) oxide and passed hydrogen gas over the heated oxide to produce copper metal.

$CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(g)$

i What volume of hydrogen gas would be needed to react with all the copper(II) oxide? (1 mole of any gas at room temperature and pressure has a volume of 24 dm^3.) ***[3]***

ii What mass of copper metal could be obtained from this reaction? ***[2]***

iii The student obtained 5.8 g of copper. What was his percentage yield? ***[2]***

.....

b The hydrocarbon propane (C_3H_8) undergoes complete combustion as shown by the equation below.

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

i What volume of oxygen gas would be needed to react completely with 10 dm^3 of propane gas? ***[3]***

ii What would be the total volume of gases produced from the reaction of excess propane with 10 dm^3 of oxygen? ***[3]***

[Total: 13]

2 This question is about a titration involving the neutralisation reaction of 25 cm^3 of dilute sodium hydroxide with dilute sulfuric acid.

The initial concentration of the dilute sodium hydroxide was 0.25 mol/dm^3. The solution in the burette was dilute sulfuric acid. The indicator used was thymolphthalein. Table 4.1 shows the titration results.

Table 4.1

	Rough	1	2	3
Final burette reading/cm^3	21.75	28.25	22.35	27.30
Initial burette reading/cm^3	0.00	6.00	0.00	5.00
Volume of sulfuric acid used/cm^3				

a Complete the table by calculating the volume of dilute sulfuric acid used in each titration. ***[1]***

b From the three most accurate results, calculate the average volume of sulfuric acid used. ***[2]***

c Write a balanced chemical equation for the reaction. ***[3]***

.....

d From the information given, calculate the number of moles of sodium hydroxide in 25 cm^3 of solution. ***[2]***

e How many moles of sulfuric acid were neutralised? ***[1]***

.....

f Calculate the concentration of the dilute sulfuric acid in mol/dm^3. ***[2]***

[Total: 11]

5 Electrochemistry

Core

1 Table 5.1 shows the results of testing a number of solid and liquid substances to see if they conducted an electric current. The electrodes used were made from platinum in each case.

Table 5.1

Substance	Physical state	Conductivity	Products
T	Liquid	Yes	Hydrogen and chlorine
U	Liquid	Yes	Silvery metal and green vapour
V	Liquid	No	None
W	Liquid	Yes	Hydrogen and oxygen
X	Liquid	Yes	None
Y	Solid	Yes	None
Z	Liquid	Yes	Pink-brown metal and oxygen

a Which of these substances, **T** to **Z**, are electrolytes? .....

b Which of these substances, **T** to **Z**, may be metals? .....

c Which of these substances, **T** to **Z**, may be molten sodium chloride? .....

d Which of these substances, **T** to **Z**, may be mercury? .....

e Which of these substances, **T** to **Z**, may be sugar solution? .....

f Give the name of a substance that **W** may be. .....

g Give the name of a substance that **Z** may be. .....

2 Complete Table 5.2 about a series of electrolysis experiments.

Table 5.2

Substance	Material of electrodes	Substance formed at the cathode	Substance formed at the anode
Molten lead(II) chloride	Carbon		
	Platinum	Hydrogen	Oxygen
Molten calcium bromide			
		Sodium	Chlorine

3 Complete the passage about electroplating, using each of the words below once.

salt	**corrosion**	**metal**	**cell**	**protective**
cathode	**electrolyte**	**shiny**	**electrolysis**	

Electroplating is the process that uses ..... to plate (or coat) one metal with another. Often, the purpose of electroplating is to give a ..... coating to the surface beneath. For example, bath taps are chromium plated to prevent ....., and at the same time are given a ....., more attractive finish. The electroplating process is carried out in a ..... . This is often known as the 'plating bath' and it contains a suitable ....., usually a solution of a .... For silver plating, the electrolyte is a solution of a silver salt. The article to be plated is made the ..... in the cell so that the ions move to it when the current is switched on.

4 Explain the following.

a In the electrolysis of water, it is essential that a little dilute sulfuric acid is added to the water.

.....

b In the industrial electrolysis of concentrated sodium chloride solution, it is necessary to keep the chlorine gas and sodium hydroxide separated.

.....

.....

c In the electrolysis of lead(II) bromide, the lead(II) bromide should be in the molten state.

.....

.....

Supplement

5 Complete and balance the following ionic half-equations for processes that take place at the electrodes during electrolysis.

a $Na^+ + \text{.....} \rightarrow Na$

b ..... $Br^- \rightarrow$ ..... $+ 2e$

c $Ca^{2+} +$ ..... $\rightarrow$ .....

d ..... $+$ ..... $e^- \rightarrow Cu$

e ..... $I^- \rightarrow$ ..... + ...

f ..... $OH^- \rightarrow$ ..... H_2O + ... + ... e^-

6 Figure 5.1 shows an electrolysis cell.

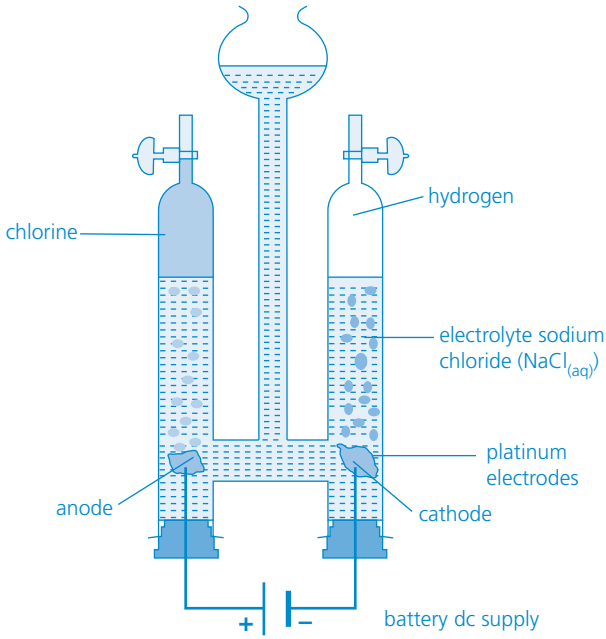


Figure 5.1

a i Hydrogen is produced at the cathode. Balance the following electrode equation for this process. Some spaces may need to be left blank.

..... $H^+(aq)$ + ... $e^- \rightarrow H_2(g)$

ii Chlorine is produced at the anode. Balance the following electrode equation for this process. Some spaces may be left blank.

..... $Cl^-(aq) \rightarrow Cl_2$ + ... e^-

b The overall chemical equation that represents what is happening in the electrolysis cell in Figure 5.1 is:

$2NaCl(aq) + 2H_2O(l) \rightarrow 2NaOH(aq) + Cl_2(g) + H_2(g)$

If 234 g of sodium chloride was electrolysed, calculate the mass of each of the following substances that would be formed, showing your working. (A_r values: H = 1; O = 16; Na = 23; Cl = 35.5)

i sodium hydroxide .....

ii chlorine .....

iii hydrogen .....

Exam-style questions

Supplement

1 Aluminium is an extremely useful metal. It is extracted by electrolysis from its ore, bauxite. Pure aluminium oxide is separated chemically from bauxite and dissolved in molten cryolite. It is then electrolysed in a steel cell lined with carbon.

a Why is aluminium extracted from its oxide by electrolysis rather than by using a chemical reducing agent such as the element carbon? ***[2]***

.....

.....

b The electrolysis cell operates at about 1000°C. This is well below the melting point of aluminium oxide, which is 2070°C. How is the molten state maintained so that electrolysis can take place? ***[2]***

.....

.....

c i At which electrode is the aluminium produced? ..... ***[1]***

ii Balance the following ionic half-equation for the depositing of aluminium.

Al^{3+} + ... $e^- \rightarrow Al$ ***[1]***

d i Oxygen gas is produced at the other electrode. What is this electrode made from? ***[1]***

.....

ii Balance the following ionic half-equation for the production of oxygen gas at this electrode.

..... $O^{2-} \rightarrow O_2$ + ... e^- ***[2]***

e i What further chemical reaction takes place at the electrode where oxygen is produced? ***[2]***

.....

.....

ii Write a balanced chemical equation for this reaction. ***[2]***

.....

f Large amounts of aluminium are recycled. Suggest two advantages of doing this. ***[2]***

.....

.....

[Total: 15]

2 Food cans are usually made from mild steel with a thin layer of tin deposited on its surface by electrolysis. Figure 5.2 is a simplified diagram of the electroplating process.

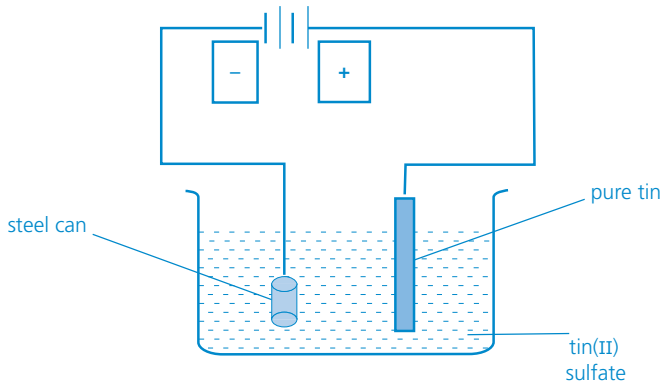


Figure 5.2

a i How does the mass of the cathode change during the process? ***[1]***

.....

ii Why does the mass of the cathode change? ***[1]***

.....

b i What charge do the tin ions in the tin(II) sulfate solution carry? ..... ***[1]***

ii How did you decide on your answer to part **i**? ***[1]***

.....

c i Does the concentration of the tin(II) sulfate solution differ at the end of the process compared to the beginning? ..... ***[1]***

ii Explain your answer to part **i**. ***[2]***

.....

.....

d i Write a balanced ionic half-equation for the electrode process that takes place at the cathode for the depositing of tin. ***[3]***

.....

ii Write a balanced ionic half-equation for the electrode process that takes place at the anode. ***[3]***

.....

e Suggest a reason why food cans are made from mild steel electroplated with tin rather than from mild steel alone. ***[1]***

.....

[Total: 14]

6 Chemical energetics

Core

1 Petroleum is a very important mixture. There are many substances in this mixture that are used as fuels or as the starting materials for the production of a variety of important chemicals. Oil can be separated by fractional distillation. Figure 6.1 is a simplified diagram of this process.

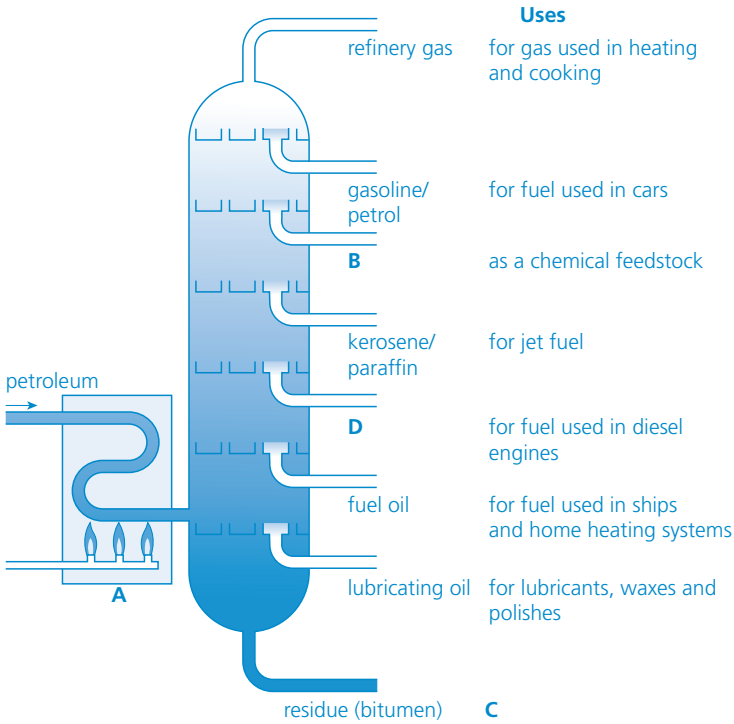


Figure 6.1

a Why are oil refineries usually found near ports?

.....

b **i** What change to the petroleum takes place in part **A**? Give two key facts.

.....

.....

ii Name the fraction **B**. .....

iii Give the use of **C**. .....

iv Name the fraction **D**. .....

c Which of the fractions shown in Figure 6.1 contains:

i the biggest molecules? .....

ii the smallest molecules? .....

d Which of the fractions represents liquids with the lowest boiling points?

.....

e The gasoline is itself a mixture of substances. How are these different substances separated?

.....

2 **a** Explain what a *fuel* is, including two key facts.

.....

.....

b Name:

i a liquid fuel .....

ii a solid fuel .....

iii a gaseous fuel. .....

c Write word and balanced chemical equations for the burning of the gaseous fuel you have named in your answer to part **b iii**.

.....

.....

Supplement

3 The reaction between methane and oxygen is exothermic. The standard heat of combustion of methane is –728 kJ/mol.

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l) \qquad \Delta H = -728\ kJ/mol$

a Calculate the amount of energy produced when each of the following amounts of methane is completely combusted.

i 2 moles of methane

ii 0.25 mole of methane

iii 8 g of methane

iv 64 g of methane

b Draw a reaction pathway diagram to represent the complete combustion of 1 mole of methane.

4 Use the bond energy data given in Table 6.1 to answer this question.

Table 6.1

Bond	Bond energy in kJ/mol
C–H	413
O=O	498
C=O	805
H–O	464
C–C	347

a Calculate the enthalpy of combustion of propane, showing each step of your working.

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

b i Draw a reaction pathway diagram to represent this combustion process. On your diagram show the enthalpy change for the reaction and the activation energy.

ii What is the activation energy, E_a, of a chemical reaction?

.....

c How much energy is released when each of the following amounts of propane is burned? (A_r values: H = 1; C = 12)

i 0.5 mole of propane

ii 5 moles of propane

iii 11 g of propane

5 Water is formed and energy is released when hydrogen combines with oxygen.

a Write a balanced chemical equation, including state symbols, for this reaction.

.....

b In this reaction, the covalent bonds in the molecules of hydrogen and oxygen are broken. Is the bond breaking process exothermic or endothermic? Explain your answer.

.....

.....

c Use the bond energies in Table 6.2 to calculate the energy change for the reaction you have shown in part **a**.

Table 6.2

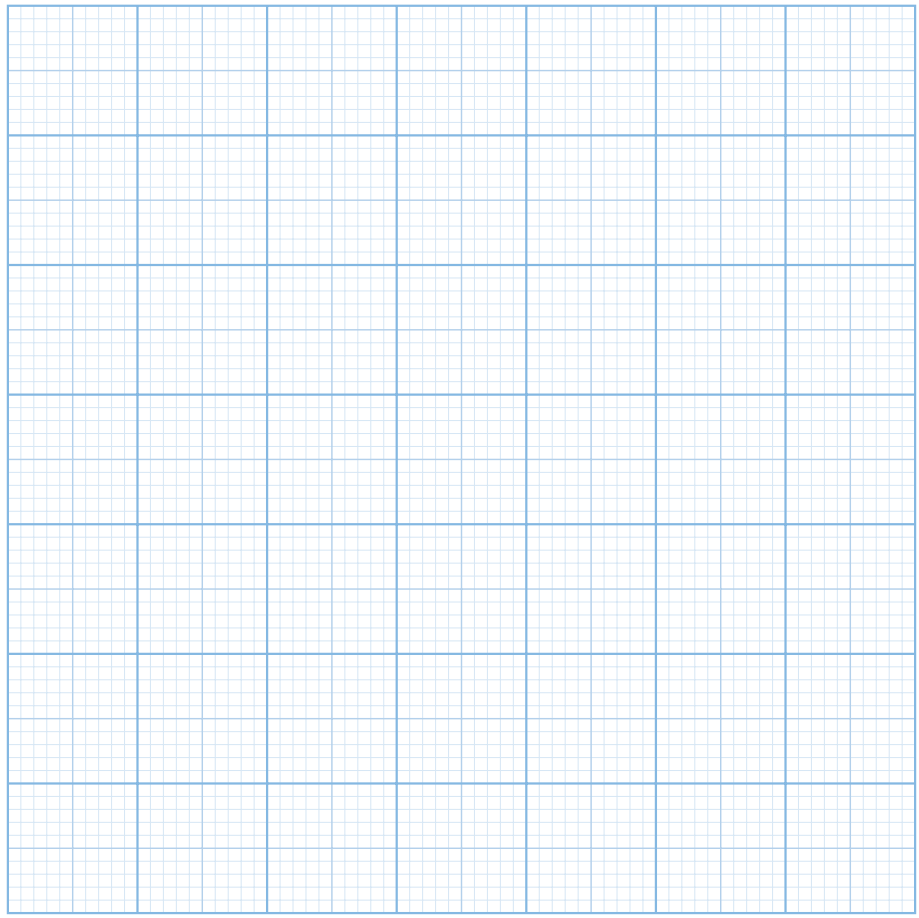
Bond	Bond energy in kJ/mol
H–H	436
O=O	498
O–H	464

6 Table 6.3 gives the enthalpies of combustion of four alcohols.

Table 6.3

Alcohol	Molecular formula	Energy released per mole
Methanol	CH_3OH	726
Ethanol	C_2H_5OH	1370
Propan-1-ol	C_3H_7OH	2010
Butan-1-ol	C_4H_9OH	2670

a Plot a graph of the enthalpy of combustion against relative molecular mass for these four alcohols.



b **i** From your graph, predict the enthalpy change of combustion of pentan-1-ol.

.....

ii Explain how you obtained your answer to part **i**.

.....

.....

.....

c What can you say about the energy produced when alcohols of progressively higher molecular mass are burned in air?

.....

Exam-style questions

Core

1 Look at the reaction pathway diagrams in Figure 6.2.

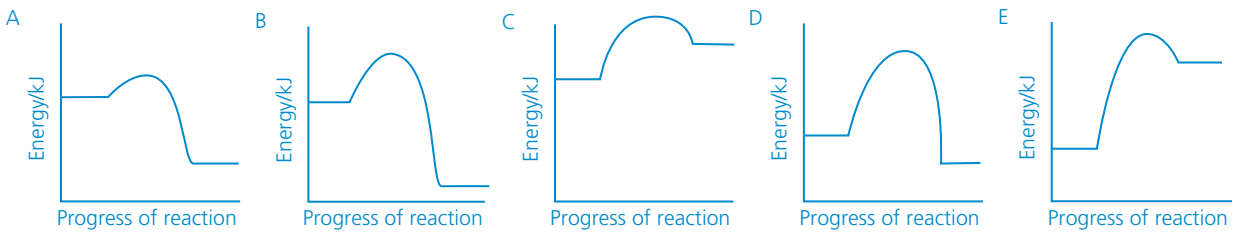


Figure 6.2

a i What is an exothermic reaction? ***[2]***

.....

.....

ii Which of the reaction pathway diagrams above show reactions that are exothermic? ***[1]***

.....

iii Which of the diagrams shows the most exothermic reaction? ..... ***[1]***

iv Explain why you have chosen this to be the most exothermic. ***[1]***

.....

b i What is an endothermic reaction? ***[2]***

.....

.....

ii Which of the reaction pathway diagrams shows the most endothermic reaction? ***[1]***

.....

iii Explain why you have chosen this diagram to be the most endothermic. ***[2]***

.....

.....

[Total: 10]

Supplement

2 An experiment was carried out to determine the enthalpy of combustion of butan-1-ol. The apparatus used is shown in Figure 6.3. The heat source was a spirit burner containing butan-1-ol.

The mass of the spirit burner and butan-1-ol was recorded. It was allowed to burn for 4 minutes under a copper beaker that contained 500 cm^3 of water. The initial temperature of the water was also recorded.

After 4 minutes, the mass of the spirit burner and the remaining butan-1-ol was recorded, as well as the final temperature of the water.

The results are:

Initial mass of spirit burner and butan-1-ol = 29.42 g

Final mass of spirit burner and butan-1-ol = 27.51 g

Initial temperature of the water = 21.2°C

Final temperature of the water = 42.0°C

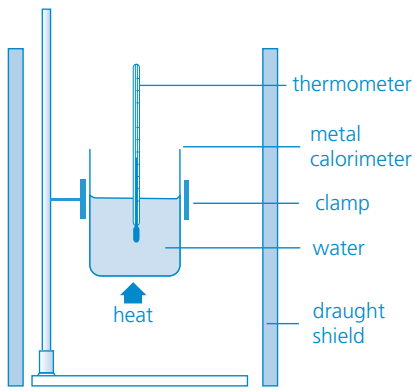


Figure 6.3

a What mass of butan-1-ol was burned during the experiment? ..... ***[1]***

b What was the temperature rise of the water during the experiment? ..... ***[1]***

c Use the following relationship to find the energy transferred during the experiment in joules. (The density of water is 1 g cm^3) ***[3]***

energy transferred = mass of water × 4.2 × temperature rise

d How many moles of butan-1-ol were burned during the experiment? (A_r values: H = 1; C = 12; O = 16) ***[3]***

e Using the results from this experiment, what is the enthalpy of combustion of butan-1-ol? ***[3]***

[Total: 11]

7 Chemical reactions

Core

1 State whether the following are chemical or physical changes.

a Iron rusting .....

b Ice melting .....

c Water boiling .....

d Cooking an egg .....

2 When excess magnesium metal reacts with hydrochloric acid, a solution of magnesium chloride is formed and hydrogen gas.

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

a Describe a practical method that could be used to follow the rate of this reaction.

.....

.....

b The graph in Figure 7.1 was obtained using one of the methods that could be used to follow the rate of reaction, using the same mass of magnesium each time but in different forms: as granulated magnesium, powdered magnesium and magnesium ribbon.

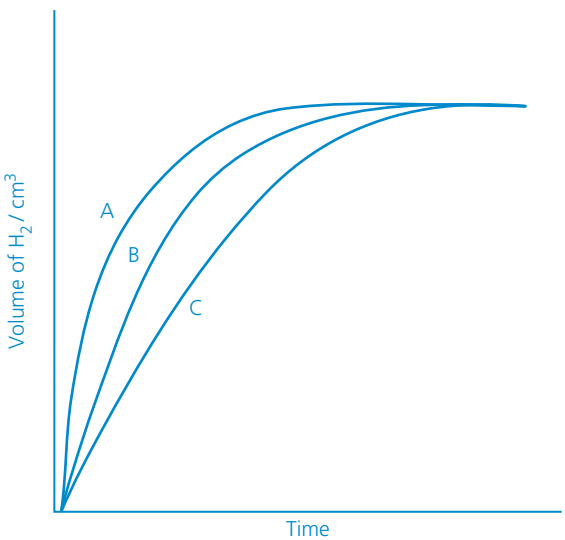


Figure 7.1

i Which line on the graph shows the reaction with the greatest rate?

.....

ii How can you tell this from the graph?

.....

iii Was the same amount of hydrochloric acid used each time? Explain your answer in terms of the graph.

.....

.....

3 A student carried out a reaction between dilute hydrochloric acid and marble chips (calcium carbonate, $CaCO_3$) of different sizes. He placed a conical flask containing 50 cm^3 of hydrochloric acid solution onto a digital balance and then added 10 g of large marble chips. He inserted a piece of cotton wool into the neck of the flask. He recorded the loss in mass (in grams) against time.

He repeated the experiment but this time used 10 g of smaller marble chips.

His results are shown in Table 7.1.

Table 7.1

Time/min		0	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	$6\frac{1}{2}$
Loss in mass/g	10 g of large marble chips	0	0.22	0.41	0.59	0.78	0.93	1.07	1.14	1.23	1.28	1.35	1.40	1.44	1.47
	10 g of small marble chips	0	0.45	0.82	1.15	1.35	1.50	1.61	1.66	1.68	1.69	1.70	1.70	1.70	1.70

a Write a balanced chemical equation for the reaction between the marble chips and hydrochloric acid.

.....

b What was the purpose of the cotton wool that the student placed into the neck of the flask?

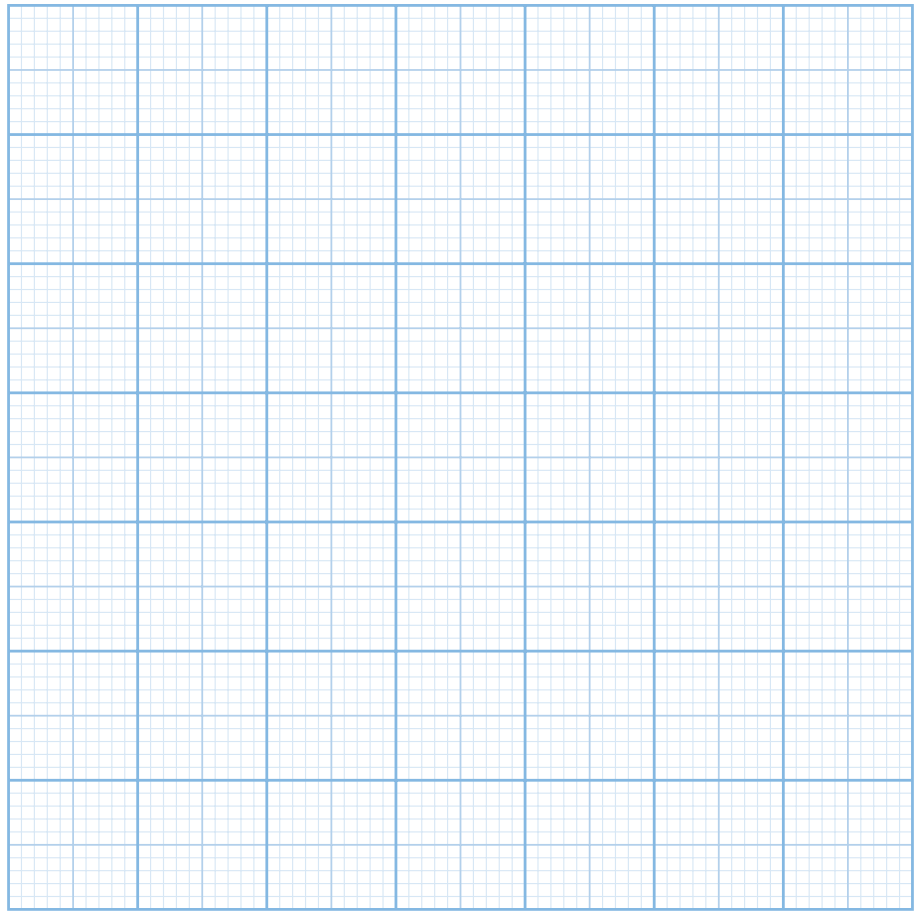
.....

.....

c Why did the mass decrease?

.....

d Plot a graph of the loss in mass (vertical axis) against time (horizontal axis). You will need to draw two lines on the same axes, one for the small chips and one for the large chips.



e Which of the reactions was the fastest? How can you tell this from the graph?

.....

.....

4 Hydrated copper(II) sulfate is a blue solid. When it is heated the colour changes from blue to white, as anhydrous copper(II) sulfate is formed and water is lost. This change can be described using the equation below.

hydrated copper(II) sulfate (blue) ⇌ anhydrous copper(II) sulfate (white) + water

a What does the symbol ⇌ indicate?

.....

b How could the hydrated copper(II) sulfate be reformed from anhydrous copper(II) sulfate?

.....

c What is the difference between hydrated copper(II) sulfate and anhydrous copper(II) sulfate?

.....

.....

Supplement

5 The graphs in Figure 7.2 were produced by carrying out reactions between sulfuric acid and 2 g of magnesium in five different experiments.

The experiments carried out involved:

I: 2 g of magnesium ribbon and 40 cm^3 of 0.1 mol/dm^3 sulfuric acid at 25°C

II: 2 g of magnesium ribbon and 40 cm^3 of 0.05 mol/dm^3 sulfuric acid at 25°C

III: 2 g of magnesium powder and 40 cm^3 of 0.1 mol/dm^3 sulfuric acid at 25°C

IV: 2 g of magnesium powder and 20 cm^3 of 0.1 mol/dm^3 sulfuric acid at 25°C

V: 2 g of magnesium powder and 20 cm^3 of 0.1 mol/dm^3 sulfuric acid at 50°C

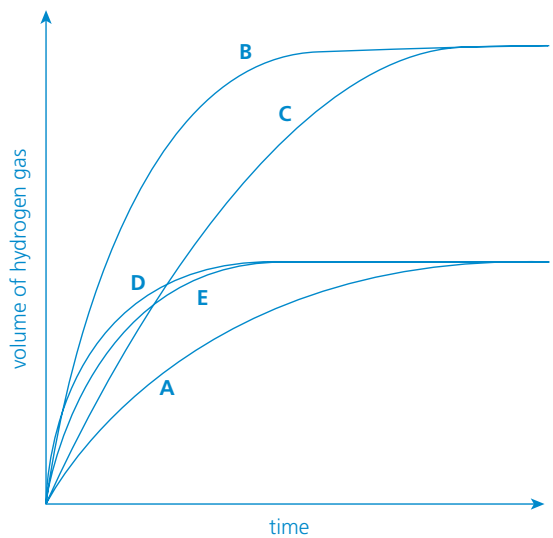


Figure 7.2

a Which of the two reactants is in excess? Explain your answer.

.....

.....

b In Table 7.2, write in the number of the experiment that is represented by each of the lines on the graph.

Table 7.2

Line	A	B	C	D	E
Experiment					

c Explain, using collision theory, why the reaction shown by line **B** occurs more rapidly than the reaction shown by line **C**.

.....

.....

.....

d Explain, using collision theory, why the reaction shown by line **D** occurs more rapidly than the reaction shown by line **E**.

.....

.....

6 Cars are now fitted with catalytic converters to prevent carbon monoxide and nitrogen monoxide gases from passing into the atmosphere with the exhaust gases. The catalyst speeds up the reaction between carbon monoxide and nitrogen monoxide to produce carbon dioxide and nitrogen.

a Write a balanced chemical equation for the reaction between carbon monoxide and nitrogen monoxide gases.

.....

b The reaction you have written in part **a** shows both oxidation and reduction. Which of the reactants has been:

i oxidised? .....

ii reduced? .....

c **i** What catalyst is used in the catalytic converter?

.....

ii Explain how a catalyst increases the rate of a chemical reaction, including three key facts.

.....

.....

d 5 dm^3 of petrol is combusted in a car engine. Assume that it is octane (C_8H_{18}), which has a density of 0.70 g/cm^3.

i Write a balanced chemical equation for the combustion of octane.

.....

ii Calculate the mass of carbon dioxide that would be produced, showing each step of your working.

iii What would be the total volume of carbon dioxide gas that would be produced? (1 mole of gas occupies 24 dm^3 at room temperature and pressure.)

iv If the car produced 100 g of carbon monoxide, what mass of carbon dioxide would this be converted to in the catalytic converter? Show each step of your working.

Exam-style questions

Core

1 One way of increasing the rate of a chemical reaction is to use a catalyst. When a black powder is added to hydrogen peroxide solution, the gas oxygen is produced. The word equation for this reaction is:

$$\text{Hydrogen peroxide} \xrightarrow{\text{Black powder}} \text{water} + \text{oxygen}$$

The results in Table 7.3 were obtained by carrying out this reaction with different masses of the black powder. The volume of oxygen gas produced was recorded against time.

At the end of the experiments the mass of black powder remained unchanged.

Use the graph in Figure 7.3 to answer the questions that follow.

Table 7.3

Time/s	0	30	60	90	120	150	180	210
Volume of oxygen for 0.5 g of black powder/cm^3	0	16	29	40	49	57	65	71
Volume of oxygen for 1.0 g of black powder/cm^3	0	46	85	119	146	163	175	183

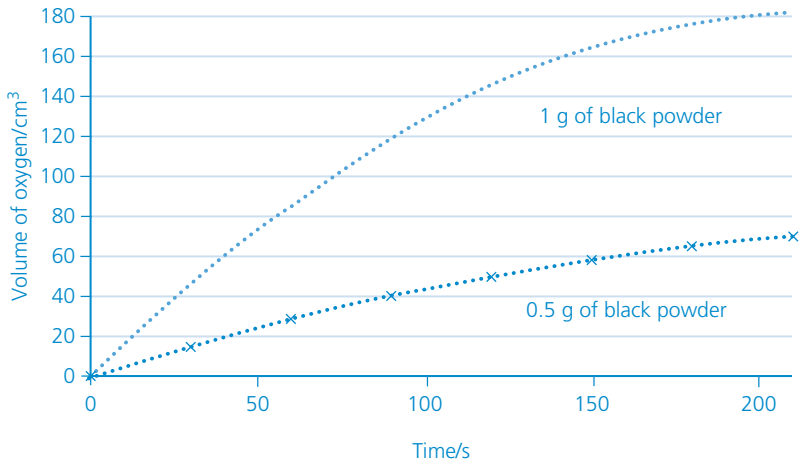


Figure 7.3

a i Is the black powder acting as a catalyst in the breakdown of hydrogen peroxide? ***[1]***

.....

ii Explain the answer you have given. ***[2]***

.....

.....

b i Looking at the line produced using 1 g of the black powder, where is the rate of the reaction the greatest, and how can you tell this from the graph? ***[2]***

.....

.....

ii Why is the reaction quickest at this point? ***[1]***

.....

iii Why do the slopes of the graphs become less steep as the reaction proceeds? ***[1]***

.....

iv What volume of gas has been produced by by 0.5 g of black powder after 100 seconds? ***[1]***

.....

v How long did it take for 70 cm^3 of the gas to be produced when the experiment was carried out using 1 g of the black powder? ***[1]***

.....

[Total: 9]

Supplement

2 This question is about a series of experiments involving the reaction between sodium thiosulfate and dilute hydrochloric acid.

$$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + SO_2(g) + S(s)$$

The same amount of dilute hydrochloric acid was used in each experiment but the concentration of sodium thiosulfate was changed.

The volumes of water and sodium thiosulfate shown in Table 7.4 were put into a conical flask, which was placed on a pencil cross on a piece of paper. The acid was added and a stopwatch started. The student carrying out the experiment looked down through the flask at the cross and stopped the stopwatch when she could no longer see it.

Table 7.4

Experiment	Volume of 0.2 mol/dm^3 sodium thiosulfate/cm^3	Volume of water/cm^3	Concentration of sodium thiosulfate in mol/dm^3	Time for cross to become invisible/s	Rate of reaction/ per sec
1	100	0	0.2	25	4.0×10^{-2}
2	80	20	0.16	43	
3	60	40	0.12	65	
4	40	60	0.08	102	
5	20	80	0.04	160	

a Why was it important to keep the total volume of solution used in each experiment the same? ***[2]***

.....

.....

b Why did it become more difficult to see the cross on the paper as the reaction proceeded? ***[2]***

.....

.....

c Complete the table by calculating and writing in the rate of reaction for each of experiments **2** to **5**. ***[4]***

d Plot a graph of the rate of reaction (vertical axis) against concentration of sodium thiosulfate (horizontal axis). ***[4]***

e Use your graph to find:

i the concentration of sodium thiosulfate at which the cross would become invisible after 50 seconds. ..... ***[1]***

ii the volume of sodium thiosulfate for which the cross would become invisible after 90 seconds. ..... ***[1]***

iii the time you would expect the experiment to take if the concentration of sodium thiosulfate in the conical flask was 0.10 mol/dm^3. ..... ***[1]***

[Total: 15]

3 A student carried out a series of reactions between zinc metal and dilute sulfuric acid. In each of the reactions he used the same mass of zinc (an excess) and the same volume of sulfuric acid. The graph in Figure 7.4 shows his results.

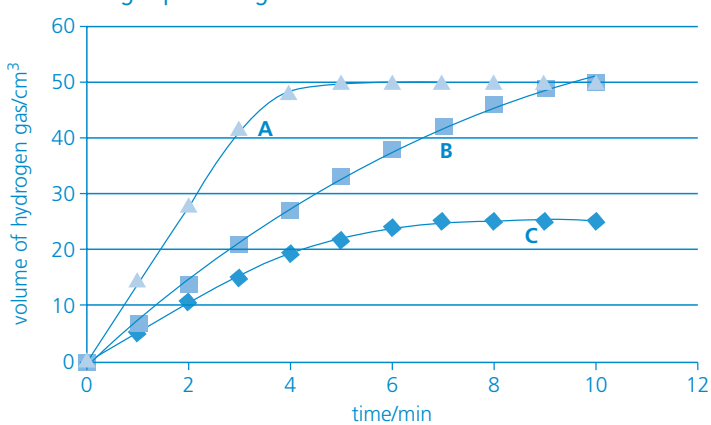


Figure 7.4

a Which was the fastest reaction? Explain how you can tell this from the graph. ***[2]***

.....

b Which of the reactions was carried out:

i at the highest temperature? ..... ***[1]***

ii using sulfuric acid of half the concentration used in the other two? ..... ***[1]***

c How could the rate of reaction **A** have been increased? ***[1]***

.....

d What volume of 0.05 mol/dm^3 sulfuric acid was used for reaction **C**? ***[3]***

.....

.....

.....

e What was the total mass of hydrogen gas produced in reaction **A**? ***[2]***

.....

.....

[Total: 10]

4 Gaseous ammonia is manufactured in large quantities. The process by which it is manufactured was developed by Fritz Haber in 1911 and first used industrially in 1913. The production of this important chemical is affected both by the temperature and by the pressure at which the process is run. An iron catalyst is used.

The graph in Figure 7.5 shows how the percentage yield of ammonia changes with temperature and pressure. The equation that represents the synthesis of ammonia is:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

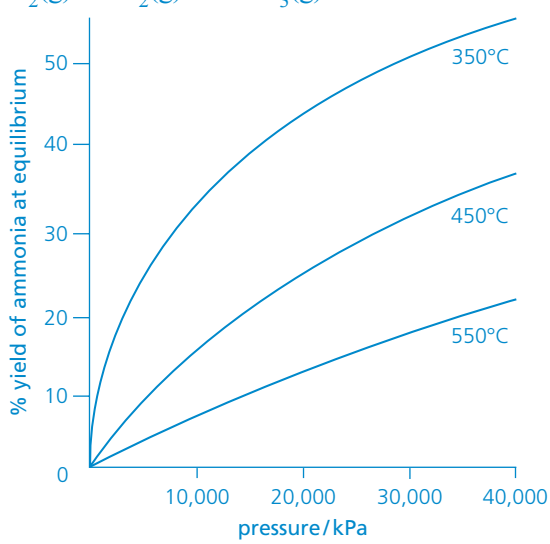


Figure 7.5

a The ⇌ symbol shows that this reaction is reversible. In a closed system the reaction will come to an equilibrium. What is an equilibrium? ***[2]***

.....

b Using the graph, state:

i the effect of increasing the pressure on the yield of ammonia. ***[2]***

.....

.....

ii the effect of decreasing the temperature on the yield of ammonia. ***[1]***

.....

c Explain why the change you have described in part **b i** occurs with increasing pressure. ***[3]***

.....

.....

d Using your answer to part **b ii**, deduce the sign of the energy change that occurs during the production of ammonia. Explain your answer. ***[3]***

.....

.....

e The conditions used in industry for the production of ammonia are a pressure of 20,000 kPa and a temperature of 450°C. What is the percentage yield of ammonia under these conditions? ..... ***[1]***

f Why is a temperature lower than 450°C not used? ***[2]***

.....

.....

.....

g Why is a pressure higher than 20,000 kPa not used? ***[2]***

.....

h How would the position of equilibrium be affected if extra nitrogen gas was introduced into the reaction vessel? ***[2]***

.....

.....

i How does the iron catalyst affect the position of equilibrium and the rate of the forward and reverse reactions? ***[2]***

.....

.....

[Total: 20]

5 The Contact Process is the industrial process that manufactures one of the most important chemicals in the world, sulfuric acid, H_2SO_4.

In the first stage of the process sulfur is converted into sulfur dioxide gas, SO_2. The sulfur dioxide then reacts with oxygen gas, in a reversible reaction, to produce sulfur trioxide gas, SO_3. This reaction is exothermic.

Finally, the sulfur trioxide gas reacts with steam to produce sulfuric acid.

a i Write a balanced chemical equation to show the reaction of sulfur dioxide with oxygen to form sulfur trioxide gas. ***[2]***

.....

.....

ii Looking at the equation you have written and the information given in the question, how will the position of equilibrium be affected, and explain your answer, if:

» the temperature of the reaction is increased? ***[2]***

.....

.....

.....

» the pressure of the reaction is increased? ***[2]***

.....

.....

.....

b How could sulfur dioxide gas be produced from sulfur? ***[1]***

.....

c State the typical conditions used for the Contact Process: ***[3]***

i Pressure (kPa) .....

ii Temperature (°C) .....

iii Catalyst used .....

[Total: 10]

8 Acids, bases and salts

Core

1 Complete Table 8.1 to show the effect of hydrochloric acid and the alkali sodium hydroxide on the indicators shown.

Table 8.1

Indicator	Colour with hydrochloric acid	Colour with sodium hydroxide
Red litmus		
Blue litmus		
Thymolphthalein		
Methyl orange		

2 Ammonia gas, NH_3, can be produced by heating any ammonium salt, such as ammonium chloride, with a base, such as calcium hydroxide. This reaction can be used to make ammonia in a laboratory.

Write a word equation for the reaction described above.

.....

3 Write word and balanced chemical equations for the reactions between each of the following pairs of substances.

a sodium carbonate and nitric acid

.....

.....

b magnesium and hydrochloric acid

.....

.....

4 Complete Table 8.2, which is about the different methods of preparing soluble and insoluble salts.

Table 8.2

Substances used to make the salt		Salt prepared	Other products
Calcium oxide	Hydrochloric acid		
	Sulfuric acid	Sodium sulfate	Water
Potassium carbonate		Potassium nitrate	Water and carbon dioxide
	Hydrochloric acid	Zinc chloride	Hydrogen
Lead nitrate	Sodium chloride		Sodium nitrate
Barium chloride	Potassium sulfate		

5 Explain how you would identify the presence, in solution, of each of the following ions.

a chloride, bromide and iodide ions

i Cl^-

.....

.....

ii Br^-

.....

.....

iii I^-

.....

.....

b carbonate ions

.....

.....

c sulfate ions

.....

.....

d iron(II) and iron(III) ions

i Fe^{2+}

.....

.....

ii Fe^{3+}

.....

.....

6 Complete the following Rules of Solubility.

a Sodium, potassium and ..... salts are soluble.

b Chlorides are ..... except for lead and ..... .

c Nitrates are ..... .

d ..... are soluble except for barium, calcium and ..... .

e Carbonates and hydroxides are ..... except for sodium, potassium and ammonium.

Supplement

7 Figure 8.1 shows some reactions of iron. Name and give the formulae of the substances **P** to **T** shown in the diagram.

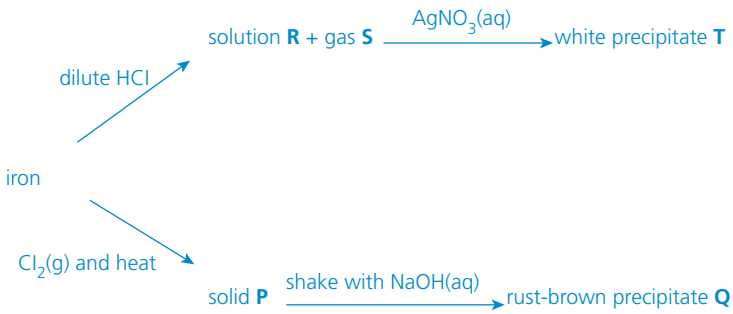


Figure 8.1

a solid **P** .....

b rust-brown precipitate **Q** .....

c solution **R** .....

d gas **S** .....

e white precipitate **T** .....

8 **a** Draw pencil lines to match up each substance with its pH.

0.1 mol/dm^3 HCl	13.0
0.1 mol/dm^3 NaOH	7.0
0.1 mol/dm^3 CH_3COOH	1.0
Pure H_2O	11.0
0.1 mol/dm^3 NH_3 solution	2.9

b Explain in detail why the pHs of 0.1 mol/dm^3 HCl and 0.1 mol/dm^3 CH_3COOH are not the same.

.....

.....

c i What is a proton?

.....

ii Define an acid in terms of protons.

.....

iii Define a base in terms of protons.

.....

9 a Write down the names of two chemical solutions that could be added together to form each of the following insoluble salts by a precipitation reaction.

i silver chloride

.....

ii barium sulfate

.....

iii calcium carbonate

.....

b Give full experimental details to explain how you could prepare a sample of the yellow insoluble salt lead(II) iodide. In your account, you should name the reactants and give a balanced *ionic* equation, with state symbols, for the reaction you would carry out.

.....

.....

.....

.....

.....

.....

.....

10 a What is the characteristic feature of an acid?

.....

b Describe what is meant by each of the following terms.

i a weak acid

.....

.....

ii a strong acid

.....

.....

c Write equations to show:

i the ionisation of hydrochloric acid

.....

ii the ionisation of ethanoic acid.

.....

d Explain the difference between the terms *strong* and *weak acids* compared with *concentrated* and *dilute acids*.

.....

.....

.....

.....

Exam-style questions

Core

1 a Complete the following paragraph. ***[7]***

Acids dissolve in water to produce ..... ions, which can be written as ..... . Bases are oxides or ..... of metals. Alkalis are soluble ..... . They dissolve in water to produce ..... ions, which can be written as ..... . Acids and alkalis react together to produce solutions with a pH of 7; these are called ..... reactions.

b Write an ionic equation for the neutralisation reaction that takes place when an acid reacts with an alkali. ***[3]***

.....

c In a reaction between potassium carbonate and hydrochloric acid to produce potassium chloride crystals, the following method was used.

25 cm^3 of hydrochloric acid was placed in a beaker. Solid potassium carbonate was added to the acid and effervescence was seen. The mixture was stirred and potassium carbonate was added until some remained at the bottom of the beaker. The mixture was then filtered and the filtrate collected in an evaporating basin. The filtrate was heated until about one half had evaporated and crystals were starting to form. The solution that remained was allowed to cool, and crystals formed.

i Write a balanced chemical equation for the reaction. ***[3]***

.....

ii Why was potassium carbonate added until some remained at the bottom of the beaker? ***[1]***

.....

iii What was the name of the filtrate? ..... ***[1]***

iv What name is given to a solution that has crystals starting to form from it?

..... ***[1]***

[Total: 16]

Supplement

2 a A reaction is carried out to prepare a sample of sodium sulfate crystals, starting from dilute sodium hydroxide and dilute sulfuric acid. The reaction is carried out using a titration. Explain clearly how you would prepare the sodium sulfate crystals. ***[7]***

.....

.....

.....

.....

.....

.....

.....

b Write a balanced chemical equation for the reaction between sodium hydroxide and sulfuric acid. ***[3]***

.....

[Total: 10]

9 The Periodic Table

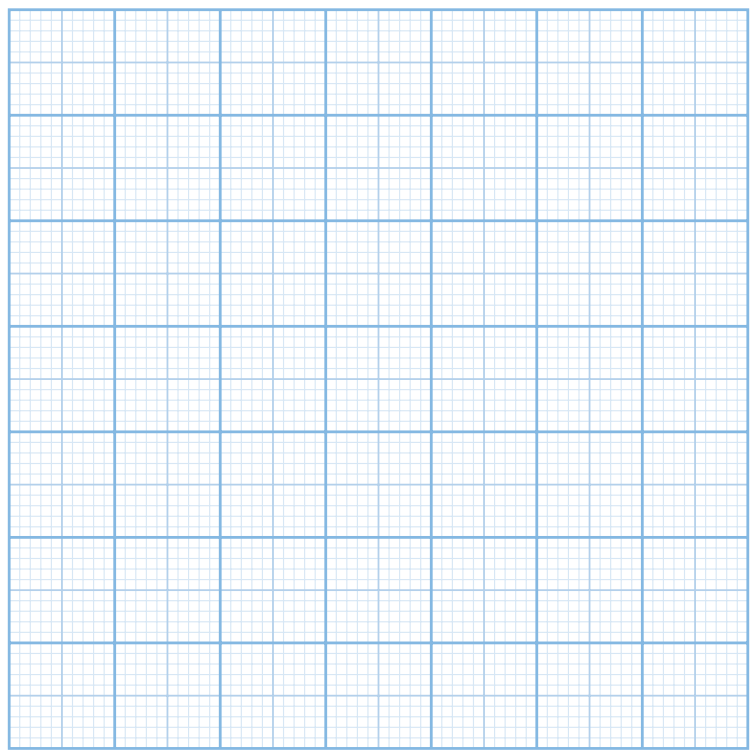
Core

1 There are five elements in Group VII of the Periodic Table. They are known as the halogens. Table 9.1 gives the melting and boiling points of the halogens. However, one of the values is missing.

Table 9.1

Element	Atomic number	Melting point/°C	Boiling point/°C
F	9	–219	–188
Cl	17	–101	–34
Br	35	–7	
I	53	114	185
At	85	303	337

a Plot a graph of the melting and boiling points of the halogens against their atomic numbers. Join the plotted points for the melting points together and, in a different colour, the plotted points for the boiling points.



b Use your graph to estimate the boiling point of bromine. .....

Supplement

c What is the trend in the melting points of the halogens?

.....

d Which of the halogens would be a gas at room temperature (25°C)? .....

2 Chlorine gas will react with aluminium metal using the apparatus shown in Figure 9.1.

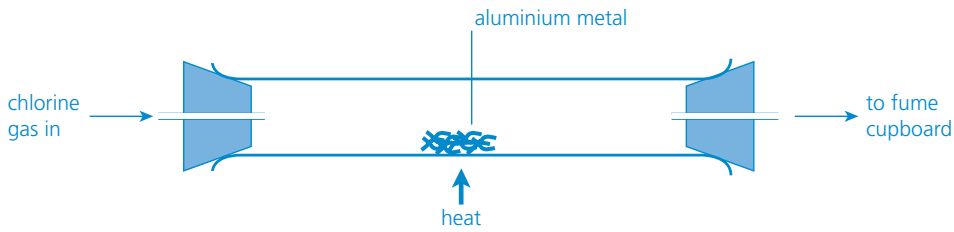


Figure 9.1

a Write word and balanced symbol equations for the reaction between aluminium metal and chlorine gas.

.....

.....

b Why is it necessary to ensure that the unreacted chlorine gas is passed into a fume cupboard? .....

c Name a halogen that would react with aluminium metal more quickly than chlorine does. .....

d Name a metal that would react with chlorine gas more quickly than aluminium does. .....

3 Complete the following passage.

The modern Periodic Table has been credited to the work of the Russian chemist ..... . After many years of chemists across the world trying to classify the elements in a useful way, he came up with the table that we have been using for nearly 150 years. He arranged the elements in order of increasing ..... . Occasionally he had to swap elements around so that they were in the same ..... as other elements with similar properties, for example swapping tellurium (Te) and ..... (.....). The major change that he introduced to his classification was that he left ..... for elements that had not been discovered at the time. Today, the elements in the modern Periodic Table are arranged in order of increasing ..... . Going across a period, from left to right, in the modern Periodic Table elements change from being metallic to ..... .

4 Element **Y** has a proton number of 19 and a relative atomic mass of 39.

a i How many electrons, protons and neutrons are there in an atom of element **Y**?

.....

ii What is the electronic configuration of this element? .....

iii In which group of the Periodic Table would you find this element? Explain your answer.

.....

iv What would be the symbol for the ion that element **Y** forms? .....

b The proton number of bromine (Br) is 35. It is in Group VII of the Periodic Table – it is a halogen. How many electrons will bromine have in its outer energy level? .....

c When potassium metal is heated and lowered into a gas jar of bromine vapour, a chemical reaction occurs, which produces white fumes.

i What do the white fumes consist of? .....

ii Write word and balanced chemical equations for the reaction.

.....

.....

iii When potassium is reacted with chlorine gas, the reaction is more vigorous. Explain this observation in terms of the reactivity of the halogens, giving three key facts.

.....

.....

.....

5 Figure 9.2 shows part of the Periodic Table.

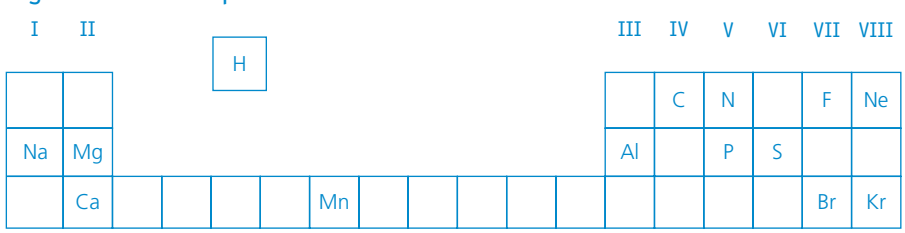


Figure 9.2

Using the elements shown in Figure 9.2, write down the symbol for an element that:

a is a transition element .....

b has four electrons in its outer energy level .....

c is a liquid at room temperature and pressure .....

d is stored under oil .....

e has a full outer electron energy level .....

f has an electronic configuration of 2,8,5 .....

g is a Group I metal .....

h is a gaseous Group VII element. .....

6 This question is about the transition elements.

a Complete Table 9.2 to compare transition metals to Group I metals.

Table 9.2

	Group I metals	Transition metals
Density		
Melting points		
Colour of solid compounds		
Good catalysts?		

b Give two physical properties of transition elements that make them more useful to us than the Group I metals.

.....

.....

c **i** What type of chemical bonding is present in all transition elements? .....

ii Draw a labelled diagram to show the type of chemical bonding present in transition elements.

d The transition elements, and their compounds, often make very good catalysts and are used extensively in industrial processes.

i Give two reasons why a catalyst would be used in an industrial process.

.....

.....

ii Name one industrial process and the catalyst that is used in the process.

.....

.....

Supplement

7 Use the information given in Table 9.3 to answer the following questions about elements **A**, **B**, **C**, **D** and **E**.

Table 9.3

Element	Proton number	Nucleon number	Electronic configuration
A	10	20	2,8
B	19	39	2,8,8,1
C	13	27	
D	8	16	
E		35	2,8,7

a Complete Table 9.3 by writing in:

i the electronic configuration of elements **C** and **D**

ii the proton number of element **E**.

b i Which of these elements, **A** to **E**, is a noble gas? .....

ii Which of these elements, **A** to **E**, is a Group I element? .....

iii Which of these elements, **A** to **E**, is a Group VII element? .....

iv Which of these elements, **A** to **E**, is aluminium? .....

c i Which of these elements, **A** to **E**, will form an ion with a +3 charge? .....

ii Which of these elements, **A** to **E**, will form an ion with a –2 charge? .....

iii Which of these elements, **A** to **E**, will not form an ion? .....

Exam-style questions

Core

1 Displacement reactions occur when a solution containing a halide ion reacts with a more reactive halogen. This type of reaction can be seen when a solution of potassium bromide reacts with chlorine.

a Write word and balanced chemical equations for the reaction that occurs between potassium bromide solution and chlorine. ***[3]***

.....

.....

b Why is chlorine more reactive than bromine? ***[2]***

.....

.....

c Which other halogen would react with potassium bromide? ..... ***[1]***

d Would there be a reaction between a solution of sodium fluoride and bromine? Explain your answer. ***[2]***

.....

[Total: 8]

2 In the Periodic Table, elements are arranged in vertical columns called *groups*. Within each group, the elements have similar chemical reactions but show a trend in their physical properties such as reactivity and melting point.

Consider the three elements lithium, potassium and sodium, which are found in Group I of the Periodic Table.

Table 9.4 gives some information about these elements. Use the information in it and your Periodic Table to help you to answer the questions that follow.

Table 9.4

	Colour	Density / g/cm^3	Melting point /°C	Electronic configuration
Lithium	Silver	0.53	181	2, 1
Potassium	Silver	0.86	64	2, 8, 8, 1
Sodium	Silver	0.97	98	

a Give the electronic configuration of sodium. ..... ***[1]***

b Which of the elements potassium, lithium and sodium is the most reactive when added to water? Explain your answer in terms of their atomic structure. ***[3]***

.....

.....

.....

c Write a balanced chemical equation for the reaction of sodium with water. ***[3]***

.....

d Which of the six Group I metals would be the most reactive when added to water? Explain your answer. ***[2]***

.....

.....

[Total: 9]

3 In Group VII there are five elements, all of which have the same number of electrons in their outer energy level.

Table 9.5 gives some information about these elements.

Table 9.5

Element	Physical state	Colour	Melting point /°C
Fluorine	Gas	Pale yellow	–219
Chlorine			
Bromine			–7
Iodine			114
Astatine			302

a Complete Table 9.5 to state the physical state and colour of chlorine, bromine and iodine. ***[3]***

b How many electrons do these elements have in their outer energy level? ..... ***[1]***

c What do all of these elements do when they react and form ions? ***[1]***

.....

d What would be the charge on an ion of any of the Group VII ions? ..... ***[1]***

e Which of the Group VII elements would be the most reactive? Explain your answer. ***[3]***

.....

.....

f Using the information in Table 9.5, predict:

i the colour and physical state of astatine. ..... ***[2]***

ii the melting point of chlorine. ..... ***[1]***

[Total: 12]

Supplement

4 Transition metals have ions with variable oxidation numbers. Complete Table 9.6, giving the oxidation numbers of the transition metal ions in the following ionic compounds and name the compound. ***[8]***

Table 9.6

Formula of compound	Oxidation number	Name of compound
$FeCl_2$		
Fe_2O_3		
CuO		
$CoCl_2$		

[Total: 8]

10 Metals

Core

1 Complete Table 10.1 to compare the general properties of metals and non-metals.

Table 10.1

Physical property	Metals	Non-metals
Thermal conductivity		
Electrical conductivity		
Malleability and ductility		
Melting and boiling points		

2 This question concerns the extraction of iron from its ore, hematite (Fe_2O_3), in the blast furnace.

a Different metals are extracted from their ores using different methods. Describe the two different ways by which iron and aluminium are extracted and explain why they are different.

.....

.....

b The coke that is added to the furnace fulfils two functions. What are they?

.....

.....

c Why is limestone added as a raw material to the furnace?

.....

d Write word equations for each of the following processes, which occur in the blast furnace.

i the thermal decomposition of limestone

.....

ii the oxidation of carbon (coke)

.....

iii the formation of carbon monoxide

.....

iv the extraction of iron from the hematite

.....

v the formation of calcium silicate (slag)

.....

Supplement

e Write balanced equations for the processes in part **d i** to **v**

i .....

ii .....

iii .....

iv .....

v .....

f What role does the carbon monoxide play in the extraction process?

.....

3 Table 10.2 gives the compositions and properties of some different types of steel and cast iron.

Table 10.2

Type of steel	Composition	Properties
Cast iron	96% Fe, 4% C	Very brittle, easily moulded, hard
Mild steel	99.5% Fe, 0.5% C	Easily worked, little brittleness, springy
Hard steel	99% Fe, 1% C	Tougher than mild steel, brittle
Stainless steel	74% Fe, 18% Cr, 8% Ni	Tough, does not rust
Tungsten steel	95% Fe, 5% W	Tough even at high temperatures

a i Which element is present in steels and cast iron that makes them brittle? .....

ii How is the amount of the element you have named in your answer to part **i** reduced during the steel-making process?

.....

.....

b i Stainless steel is a mixture of three different metals. What name do we give to substances such as stainless steel? .....

ii Why are these substances often more useful than pure metals?

.....

iii Stainless steel is used to make cutlery and surgical instruments. Give two reasons why it is used in these ways.

.....

.....

c Cars and ships made from steel often suffer from rusting. Stainless steel, however, does not rust. Give two reasons why we do not make cars or ships out of stainless steel.

.....

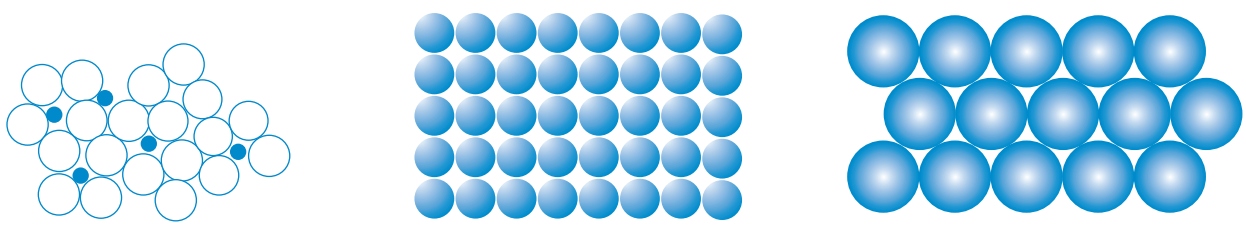
.....

d Complete Table 10.3 to give the properties required for the objects listed and the type of steel you would *choose* to make them out of.

Table 10.3

Object	Properties	Steel
Car body		
Axe		
Surgical knife		

e Which of the diagrams in Figure 10.1 represents the structure of an alloy? .....



A B C

Figure 10.1

4 A student sets up an experiment as shown in Figure 10.2, to find out what conditions were needed for rusting to occur.

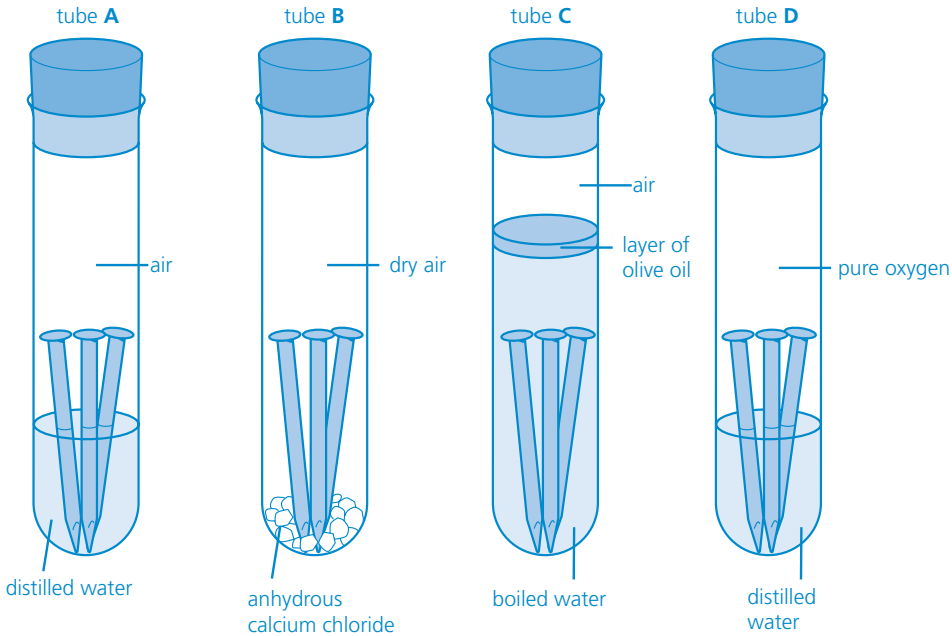


Figure 10.2

a Explain the purpose of:

i the anhydrous calcium chloride in tube B

.....

ii boiling the water in tube C

.....

.....

iii the layer of oil in tube C

.....

.....

b What conditions were present in each of the tubes? Put ticks in Table 10.4 to show if oxygen or water were present in each of the tubes.

Table 10.4

Tube	Water	Oxygen
A		
B		
C		
D		

c i In which tube(s) will the nails not rust? .....

ii Explain your answer to part **i**.

.....

.....

d i In which tube will the nails rust the most? .....

ii Explain your answer to part **i**.

.....

e i Name a method by which the nails in tube A could have been treated to prevent them from rusting in this experiment.

.....

ii Describe how the method you have described in part **i** would prevent the nails from rusting.

.....

Supplement

f i The nails could also be prevented from rusting by wrapping some zinc wire around the nails at the beginning of the experiment. Explain why this would prevent the nails from rusting.

.....

ii Often, iron objects are sprayed with a thin layer of zinc to prevent them from rusting. What name is given to this method of protection and how does it prevent the iron object from rusting?

.....

.....

Supplement

5 Complete and balance the following chemical equations.

a ..... + $H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l)$ + ...

b $2Ca(s) + O_2(g) \rightarrow$ .....

c $Mg(s)$ + ... $\rightarrow MgSO_4(aq) + Zn(s)$

d ..... + ... $\rightarrow 2MgO(s)$

e $Zn(s) + 2$ ..... $(aq) \rightarrow$ ..... $+ H_2(g)$

6 Write balanced chemical equations for the reactions between each of the following pairs of substances.

a potassium metal and water

.....

b zinc metal and hydrochloric acid

.....

c magnesium and copper(II) oxide

.....

d magnesium metal and steam

.....

e magnesium metal and water

.....

7 A student carried out an experiment to find the order of reactivity of six different metals, labelled **A** to **F**. Small strips of each metal were placed into solutions of the nitrates of the other five metals. The student looked for a reaction occurring in each case.

a What would the student be looking for to see if a reaction was occurring?

.....

b If a reaction did occur, what type of reaction would the student be observing?

.....

c Table 10.5 shows a record of the student's results.

✓ = reaction occurred ✗ = no reaction — = reaction not done

Put the metals **A** to **F** in order of their reactivity, with the least reactive metal first.

.....

Table 10.5

Metal	A nitrate	B nitrate	C nitrate	D nitrate	E nitrate	F nitrate
A	—	✓	✗	✗	✓	✓
B	✗	—	✗	✗	✓	✓
C	✓	✓	—	✓	✓	✓
D	✓	✓	✗	—	✓	✓
E	✗	✗	✗	✗	—	✗
F	✗	✗	✗	✗	✓	—

8 When a mixture of copper(II) oxide and zinc metal reacts, a pink-brown solid is formed along with a yellow solid that changes colour to white when it gets cold.

a Write word and balanced chemical equations for the reaction that occurs.

.....

.....

b Name the pink-brown solid that is formed in the reaction. .....

c Name the solid that is yellow when hot and white when cold. .....

d i Which of the reactants is being oxidised in this reaction? .....

ii Explain why this reactant is being oxidised. .....

iii What is happening to the other reactant when the reaction occurs?

.....

Exam-style questions

Core

1 Look at the flow diagram, Figure 10.3.

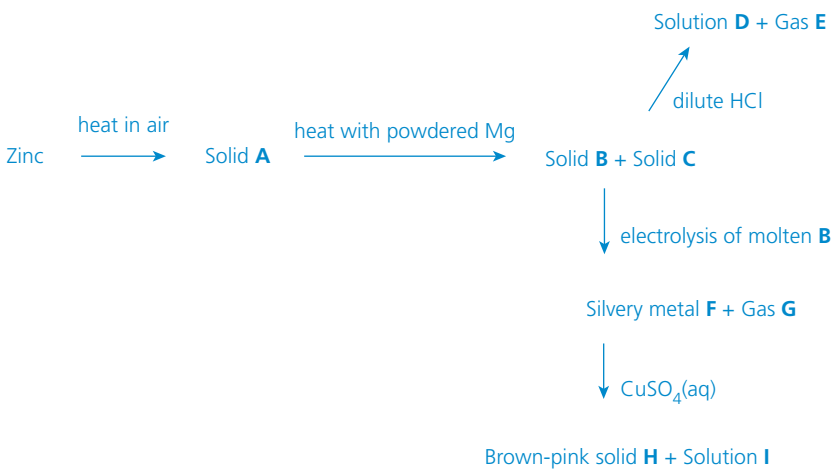


Figure 10.3

a Name and give the formulae of substances **A** to **I**.

A ..... *[1]*

B ..... *[1]*

C ..... *[1]*

D ..... *[1]*

E ..... *[1]*

F ..... *[1]*

G ..... *[1]*

H ..... *[1]*

I ..... *[1]*

b Write word equations for the reactions in which:

i solid **B** was formed *[2]*

.....

ii solution **D** and gas **E** were formed. *[3]*

.....

c Write anode and cathode reactions for the processes that take place during the electrolysis of molten **B**. *[6]*

.....

.....

[Total: 20]

Supplement

2 When copper(II) oxide reacts with zinc, copper metal and zinc oxide are formed.

a Write a balanced chemical equation for the reaction. *[2]*

.....

.....

b What is the oxidation number of the copper and zinc before and after the reaction has occurred? *[2]*

	Oxidation state before reaction	Oxidation state after reaction
Copper		
Zinc		

c What is the oxidation number of an element in its uncombined state? ..... *[1]*

d Write an ionic half-equation to show what has happened to the copper ion during the reaction. *[1]*

.....

e What name is given to this process? What happens to the oxidation number of the copper? *[2]*

.....

f Write an ionic half-equation to show what has happened to the zinc during the reaction. *[2]*

.....

g What name is given to this process? And what happens to the oxidation number of the zinc? ***[2]***

.....

h What type of reaction occurs between copper(II) oxide and zinc metal? ***[1]***

.....

[Total: 13]

3 Alloys can be much harder and stronger than the pure metals they are made from.

a Draw a diagram to show the structure of a pure metal and another diagram to show the structure of an alloy. ***[2]***

Pure metal **Alloy**

b Explain, using your diagrams to help, why alloys can be much harder and stronger than pure metals. ***[3]***

.....

.....

.....

[Total: 5]

11 Chemistry of the environment

Core

1 For each of the following statements, write either 'T' for 'true' or 'F' for 'false'.

a Distilled water is used in the laboratory because it contains a lot of chemical impurities. .....

b Water from natural sources contains several dissolved substances including oxygen, metal compounds and nitrates from fertilisers. .....

c Sewage contains microbes that prevent disease. .....

d Dissolved oxygen and some metal compounds, such as calcium salts, found in natural water are beneficial to life. .....

e Dissolved nitrates and phosphates lead to oxygenated water. .....

f The percentage of oxygen in the air is 15%. .....

g Photosynthesis is the reaction between carbon dioxide and water with urea as a catalyst. .....

h The word equation for photosynthesis is:

Water + carbon dioxide → glucose + oxygen .....

2 Water pollution has become a real problem. Water is such a good solvent that many substances will dissolve in it, including fertilisers.

a Explain how fertilisers get into rivers, including two key facts.

.....

.....

b Give the names and formulae of each of the nitrogen-containing ions, from chemical fertilisers, that pollute water in rivers.

.....

c Name and give the formula of an artificial fertiliser that contains the ions you have named in your answer to part **b**. .....

d **i** What types of organisms are encouraged to grow in rivers by the presence of artificial fertilisers?

.....

ii How does the growth of these organisms affect life in the river?

.....

.....

3 As well as the substances you would expect in pure dry air, other substances called *pollutants* are found in the atmosphere. These pollutants cause air pollution.

a i Explain the term *pollutant gases*. Give two key facts.

.....

ii Name two pollutant gases other than sulfur dioxide and state where each of those gases may come from.

.....

.....

b Sulfur dioxide is a pollutant. Major sources of this gas are 'heavy industry' and 'power stations'.

i From which substances would sulfur dioxide be produced in these industries?

.....

ii The word and balanced chemical equations for the production of sulfur dioxide are given below.

$$\text{sulfur} + \text{oxygen} \rightarrow \text{sulfur dioxide}$$

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

Calculate the mass of sulfur dioxide produced by 32 kg of sulfur. (A_r values: O = 16);

S = 32 .....

iii The sulfur dioxide dissolves in water in the atmosphere and produces an acid. This acid is then oxidised to give a different acid. What are the names and formulae of the initial acid and the final acid produced on oxidation?

.....

.....

iv Name three problems that substances produced from sulfur dioxide in the air cause in the environment.

.....

.....

v Units are being added to some power stations to prevent the emission of sulfur dioxide.

What is the name given to these units? .....

4 Water is very good at dissolving substances. It is, therefore, very unusual to find really pure water on this planet. The questions that follow are about the purification of water from a reservoir.

a i How is filtration of the water from the reservoir carried out? .....

ii What is the purpose of filtering at this stage? .....

b Chlorine is added to the water near the end of the purification process. Why is chlorine added? .....

c Chlorine produces an acidic solution containing two acids. The incomplete chemical equation is shown below. The acid shown as a product is called chloric(I) acid.

..... $Cl_2(g) + H_2O(l) \rightarrow$ ..... (aq) + HOCl(aq)

What are the name and formula of the other common acid that is produced?

.....

d Why is sodium hydroxide added after chlorination? .....

e Give two reasons why carbon is added. .....

f To prevent tooth decay, an ion is often added to the water before it is supplied to homes.

Name this ion and give its formula. .....

Supplement

5 a Ammonium salts and nitrates are used as fertilisers. Calculate the percentage of nitrogen in each of these nitrogen-containing compounds used by farmers. (A_r values: H = 1; N = 14; O = 16; Na = 23; P = 31; S = 32)

i sodium nitrate, $NaNO_3$ .....

ii ammonium phosphate, $(NH_4)_3PO_4$ .....

iii ammonium sulfate, $(NH_4)_2SO_4$ .....

b Name and give the symbols of the two elements, other than nitrogen, that are required to improve plant growth.

.....

c A fertiliser that contains phosphorus is calcium phosphate.

Calcium phosphate contains the ions Ca^{2+} and PO_4^{3-}. What is the formula of this substance?

.....

6 a Burning fossil fuels makes a large contribution to the amount of carbon dioxide in the atmosphere.

i The balanced chemical equation for burning methane in air is shown below.

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

Calculate the mass of carbon dioxide produced when 32 g of methane is burned, showing your working. (A_r values: H = 1; C = 12; O = 16)

.....

.....

ii What volume of carbon dioxide would be produced when 32 g of methane is burned? Show your working.

(1 mole of gas occupies 24 dm^3 at room temperature and pressure.)

.....

.....

b The formula of the major constituent of petrol is C_8H_{18}. Explain why you would expect petrol to produce more carbon dioxide than methane when it is burned inside car engines.

.....

Exam-style questions

Core

1 In recent years, scientists have detected an increase in the amount of carbon dioxide in the atmosphere. Carbon dioxide is a *greenhouse gas* and has been linked to *global warming*.

a What do you understand by each of the following terms?

i greenhouse gas ***[2]***

.....

.....

ii global warming ***[2]***

.....

.....

b Describe the effect that global warming will have on the Earth over time. ***[3]***

.....

.....

c It is not only carbon dioxide that is a greenhouse gas. Name and give the formula of another major greenhouse gas. ..... ***[2]***

d List the possible ways that the problems being created worldwide by global warming can be addressed. ***[6]***

.....

.....

.....

.....

[Total: 15]

Supplement

2 Oxides of nitrogen are atmospheric pollutants. Motor vehicles are responsible for much of the pollution by these oxides that is found in the atmosphere in towns and cities.

a Nitrogen monoxide is formed by the reaction of nitrogen and oxygen inside the car engine. The word and symbol equations are given below.

nitrogen + oxygen → nitrogen(II) oxide

$N_2(g) + O_2(g) \rightarrow 2NO(g)$

i Calculate the volume of nitrogen monoxide produced at room temperature from 48 dm^3 of nitrogen. (1 mole of gas occupies 24 dm^3 at room temperature and pressure.) ***[1]***

.....

ii As it exits the exhaust, the nitrogen monoxide produced in the car engine then reacts with oxygen from the air and forms the brown gas nitrogen(IV) oxide. This is an acidic gas. The word and symbol equations are given below.

Balance the chemical equation. ***[2]***

nitrogen(II) oxide + oxygen → nitrogen(IV) oxide

$NO(g) + O_2(g) \rightarrow NO_2(g)$

.....

iii What device has been attached to a car to help eliminate the problem of pollution by oxides of nitrogen? ..... ***[1]***

b When nitrogen(IV) oxide reacts with water from the atmosphere, an acid is produced along with some nitrogen monoxide.

i Name and give the formula of the acid produced. ..... ***[2]***

ii Write word and balanced chemical equations for the production of this acid. ***[4]***

.....

.....

[Total: 10]

12 Organic chemistry 1

Core

1 The *functional group* of the alkanes is based around the homologous series having only single bonds between the hydrogen and carbon atoms. Alkane molecules even though they are unreactive will undergo cracking. *Cracking* using a *catalyst* is one of the most important chemical processes carried out by the oil industry. Cracking involves the *thermal decomposition* of the *hydrocarbon* fractions containing the larger *alkane* molecules. The process produces a mixture of *saturated* and *unsaturated* molecules.

Explain the meaning of each of the following terms, giving two key facts for each.

a cracking

.....

b catalyst

.....

c thermal decomposition

.....

d alkane

.....

e saturated

.....

f unsaturated

.....

g functional group

.....

h hydrocarbon

.....

2 a Use the words below to complete the following passage about plastics.

addition polymer	**polymerisation**	**monomers**
polymers	**ethene**	**chains**

When small molecules such as ..... join together to form long ..... of atoms, called ....., the process is called ..... . These small molecules that can join together in this way are called ..... . The polymer formed with ethene is an ..... .

b The displayed formula of an ethene molecule is shown in Figure 12.1.

Use this molecule to draw part of the polyethene polymer chain. Include at least 3 molecules of ethene.

Figure 12.1

c Describe the reaction that takes place between bromine water and ethene.

.....

d Plastics like polyethene can be recycled but many cannot. Why can some plastics be recycled whilst others cannot?

.....

.....

3 a Ethene, C_2H_4, is the starting material for making plastic carrier bags.

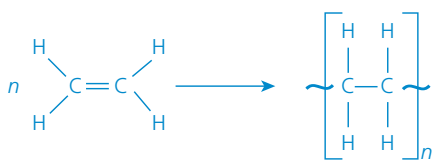


Figure 12.2

i Name the type of chemical change taking place in Figure 12.2.

.....

ii Name the product formed by this reaction. .....

iii What is the general formula of the alkene homologous series? .....

b The majority of carrier bags are difficult to dispose of.

i Explain, including four key facts, why carrier bags should not just be thrown away.

.....

.....

.....

.....

ii Give two reasons why the majority of plastic carrier bags are recycled.

.....

.....

iii Not all plastics can be recycled. Explain why.

.....

.....

iv Other than recycling, name three problems associated with plastic disposal.

.....

.....

.....

4 a i The alkanes form a homologous series of hydrocarbons obtained from petroleum. Explain the terms *homologous series* and *hydrocarbons* including five key facts.

.....

.....

.....

.....

.....

ii The alkanes are generally unreactive. Name two types of reaction they can undergo.

.....

b i The first four members of the alkane family are shown in Table 12.1. Complete the table by filling in the missing formulae and displayed structures.

Table 12.1

Alkane	Formula	Displayed structure
Methane		
Ethane	C_2H_6	
Propane		
Butane		

ii Name the type of bonding present in alkanes. .....

iii By showing the outer electron shells, draw a dot-and-cross diagram to show the chemical bonding in a molecule of ethane.

iv All the alkanes shown in Table 12.1 are gases. What would be the physical difference between these four alkanes and the alkane decane, $C_{10}H_{22}$? .....

v What is the general formula for the alkane series? .....

Supplement

5 a The most important property of alkanes is that they will generally burn quite easily. The gaseous alkanes are some of the most useful fuels. When a gas like methane burns in a plentiful supply of air, which type of combustion does it undergo?

.....

b The balanced chemical equation for the burning of methane in a plentiful supply of air is given below.

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) \qquad \Delta H = -ve$

i What does the sign of ΔH tell you about the reaction? .....

ii How many moles of carbon dioxide are produced by 1 mole of methane? .....

iii What mass of carbon dioxide would be produced by 64 g of methane burning in a plentiful supply of air? (A_r values: H = 1; C = 12; O = 16)

.....

iv What volume of carbon dioxide would be produced when 100 dm^3 of methane is burned in a plentiful supply of air? (1 mole of any gas occupies 24 dm^3 at room temperature and pressure.)

.....

6 a What structural feature does an alkene possess that an alkane does not?

.....

b Figure 12.3 shows the outer electron shells of the elements present in the compound ethene. Complete the bonding diagram by drawing dots and crosses to show the electrons in each of the overlap areas.

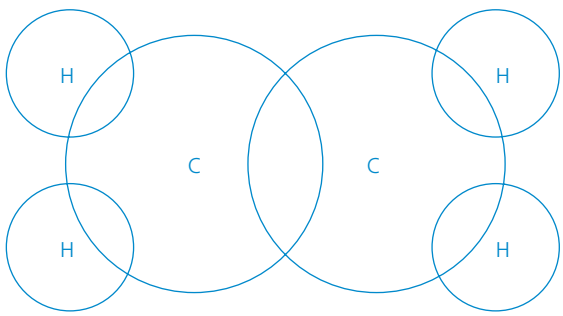


Figure 12.3

c Alkenes like ethene will undergo addition reactions. In an addition reaction, how many products are formed? .....

7 Give the name and displayed formula of the main organic product(s) formed when each of the following chemical procedures is carried out.

a A mixture of methane and chlorine is exposed to ultraviolet light.

b A mixture of ethene and steam is passed over an acid catalyst at high temperature and pressure.

c A mixture of ethene and hydrogen is passed over a metal catalyst at a high temperature.

d Ethene is bubbled through a solution of bromine.

e Decane is passed over a heated catalyst.

Exam-style questions

Core

1 Figure 12.4 shows the apparatus used in the laboratory for the cracking of a liquid alkane. Some of the labels have been replaced with letters.

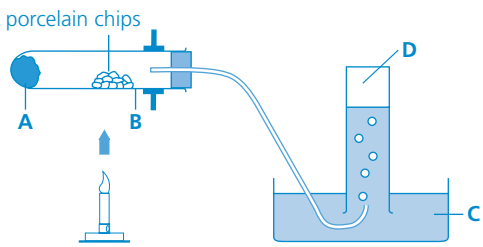


Figure 12.4

a For each letter A to D, write down the correct label from the list below.

gaseous alkene **hard glass boiling tube** **paraffin-soaked mineral wool** **water**

A ..... ***[1]***

B ..... ***[1]***

C ..... ***[1]***

D ..... ***[1]***

b What is the purpose of the porcelain chips in this experiment? ***[2]***

.....

c Give an explanation of the following observation:

'The substance collected in the test-tube was found to decolourise bromine water.' ***[3]***

.....

.....

.....

d Draw a star on Figure 12.4 to show the position where you would introduce a further piece of apparatus to collect any liquid product. ***[1]***

e An explosive element gas can also be produced in this process. Give the name and formula of this gas. ..... ***[2]***

f **i** Complete the following symbol equation for a possible cracking of dodecane.

$C_{12}H_{26} \rightarrow C_4H_8 +$..... ***[1]***

ii Name the products of the reaction shown in the equation in part **i**.

..... ***[2]***

g Why is the process of cracking an important process in the petrochemical industry? ***[3]***

.....

.....

[Total: 18]

Supplement

2 **a** Explain the meaning of the term *isomer* with reference to the molecule C_4H_{10}. Name and draw the displayed structures of any substances you include in your answer. ***[6]***

.....

.....

b **i** What would you expect to be the relative boiling points of the isomers you have drawn in part **a**? ***[1]***

.....

ii Explain why the isomers you have drawn in part **a** have different boiling points. ***[2]***

.....

.....

.....

[Total: 9]

13 Organic chemistry 2

Core

1 For each of the following statements about alcohols and carboxylic acids, write either 'T' for 'true' or 'F' for 'false'.

a Ethanol can be manufactured at a temperature of 300°C and 6000 kPa pressure by adding steam to ethene in the presence of an alkaline catalyst. .....

b Ethanoic acid reacts with magnesium and produces hydrogen gas. .....

c Ethanol is a useful solvent and fuel. .....

d Ethanoic acid produces carbon monoxide when it reacts with a carbonate. .....

e Fermentation of glucose takes place at a temperature of 25–35°C in the presence of yeast and absence of oxygen. .....

2 Match each substance in the left-hand column of Table 13.1 with the correct description on the right-hand column by drawing a line.

Table 13.1

CH_3COOH	Catalyst used in the manufacture of ethanol
C_2H_5OH	A salt of ethanoic acid
CO_2	Ethanoic acid
$(CH_3COOH)_2Mg$	General formula for alcohols
Phosphoric acid	Produced when ethanol burns completely in air
$C_nH_{2n+1}OH$	Has an M_r (relative molecular mass) of 46

3 The first member of the homologous series of carboxylic acids is methanoic acid (HCOOH).

In some areas, when water is boiled the inside of the kettle becomes coated with a layer of calcium carbonate. This type of water is known as *temporary hard water*. This deposit of calcium carbonate can be removed by adding methanoic acid.

a Complete the equation for the reaction between calcium carbonate and methanoic acid.

$CaCO_3 + \ldots\ldots\ldots HCOOH \rightarrow Ca(HCOO)_2 + \ldots\ldots\ldots\ldots + \ldots\ldots\ldots\ldots$

b Methanoic acid reacts with most metals above hydrogen in the reactivity series.

Complete the chemical equation for the reaction between methanoic acid and magnesium.

$\ldots\ldots\ldots HCOOH + Mg \rightarrow \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$

Supplement

4 Butanol is the fourth member of the alcohols and has a molecular formula C_4H_9OH. Biobutanol is a fuel of the future. It can be made by the fermentation of almost any form of biomass such as grain, straw or leaves.

a Draw the displayed formula of butanol.

b Write a word and a balanced symbol equation for the complete combustion of butanol.

.....

.....

5 All alcoholic drinks contain ethanol (alcohol).

a Explain why alcoholic drinks go sour if left open for some time. Write a word and a balanced chemical equation to help with your explanation.

.....

.....

.....

.....

b Alcohols react with carboxylic acids to produce which type of compound? .....

6 Figure 13.1 shows the structure of the cholesterol molecule.

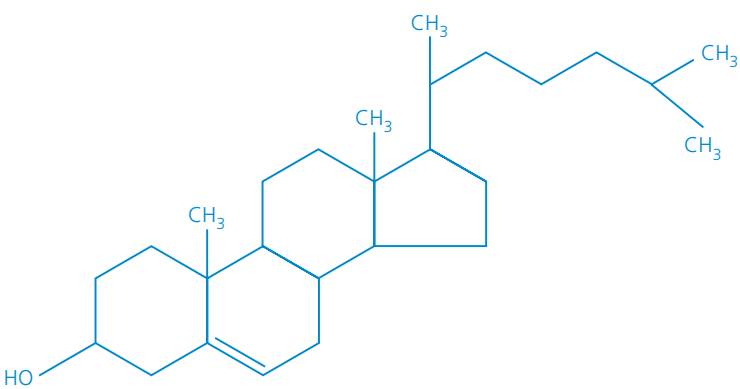


Figure 13.1

a What type of bonding is present in this molecule? .....

b Which part of the molecule will react with:

i steam in presence of an acid catalyst?

.....

ii ethanoic acid?

.....

c If a condensation polymer like PET was to be made with cholesterol, which part of the molecule would be likely to react?

.....

7 a Name the polymerisation process that is used to make both nylon and PET.

.....

b Name the starting materials for making:

i nylon

.....

ii PET.

.....

c Give the name and formula of the small molecule produced during the polymerisation reactions used to produce both nylon and PET. .....

d Give the name of the chemical link that holds together:

i nylon .....

ii PET. .....

e Give two uses each for:

i nylon .....

ii PET. .....

f Explain the difference between the type of polymerisation you have named in part **a** and addition polymerisation.

.....

.....

.....

8 a There are two straight chain isomers that exist for the molecule C_4H_9OH because of the presence of the functional group. Name them and draw their displayed structures.

.....

b i What would you expect to be the relative boiling points of the isomers you have drawn in part **a**?

.....

.....

ii Explain why the isomers you have drawn in part **a** have different boiling points.

.....

.....

.....

Exam-style questions

Core

1 Ethanol (alcohol) is a product of many fermentation reactions and of the hydration of ethene. The molecular formula of ethanol is C_2H_5OH.

a Draw the displayed formula of ethanol. ***[1]***

b i Balance the following chemical equation for the fermentation reaction. Some spaces may be left blank.

..... $C_6H_{12}O_6(aq)$ → ..... $C_2H_5OH(l)$ + ... $CO_2(g)$ ***[2]***

ii Name the substance $C_6H_{12}O_6$. ..... ***[1]***

iii Calculate the M_r (relative molecular mass) for $C_6H_{12}O_6$. (A_R: H = 1, C = 12, O = 16). ***[1]***

.....

c When ethanol is heated with potassium manganate(VII), it is oxidised to ethanoic acid.

$C_2H_5OH(l) \rightarrow CH_3COOH(l)$

i Ethanoic acid belongs to a homologous series of organic acids. What is the name given to this homologous series of acids? ..... ***[1]***

ii What is the general formula for this homologous series? ..... ***[1]***

[Total: 7]

Supplement

2 a Each amino acid contains two functional groups. What are the names of these functional groups? ..... ***[2]***

b The structure of the first amino acid, glycine, is shown in Figure 13.2.

Redraw the structure to show a dot-and-cross bonding diagram for this substance, showing the outer electron shells only. ***[10]***

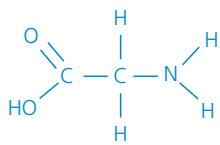


Figure 13.2

c Amino acids are the building blocks for proteins. Proteins are long-chain molecules or natural polymers.

i Name the type of polymerisation process that is required to form proteins. ***[1]***

.....

ii Which industrial polymer contains the same link as that found in proteins? ***[1]***

.....

iii Figure 13.3 shows a substance produced when two amino acids react with one another forming what is called a *dipeptide*.

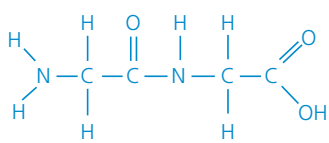


Figure 13.3

Draw the part of the dipeptide that is produced from the reaction between the two amino acids that form the dipeptide. ***[1]***

[Total: 15]

14 Experimental techniques and chemical analysis

1 a What do you understand by the phrase *accuracy of experimental work*?

.....

.....

b Name the appropriate apparatus for the measurement of the following:

i time .....

ii temperature .....

iii mass .....

iv volume of liquids (name three) .....

v volume of gases .....

c In experiments you will require the use of accurate measuring instruments. What accuracy would you expect of:

i a stopwatch .....

ii a thermometer .....

iii an electronic balance .....

iv a burette? .....

2 a Figure 14.1 shows the apparatus used for fractional distillation. The labels have been replaced with numbers 1–8. For each number, write down the correct label from the list.

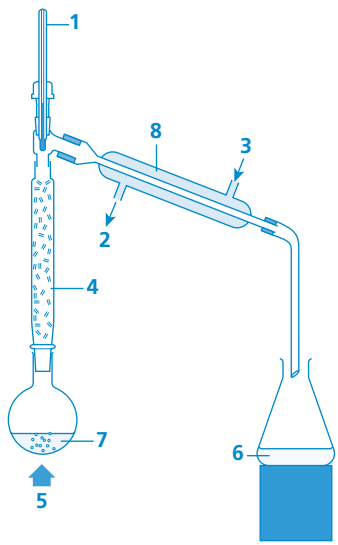


Figure 14.1

Liebig condenser
fractionating column
cold water in
thermometer
cold water out
distillate
mixture of liquids
heat

1 .....

2 .....

3 .....

4 .....

5 .....

6 .....

7 .....

8 .....

b Which of the following mixtures can be separated successfully by fractional distillation? Explain your answers.

petroleum	**magnesium and sulfur**	**a mixture of dyes**	**liquid air**

.....

.....

c Figure 14.2 shows a simple apparatus used for chromatography. The labels have been replaced with numbers 1–5. For each number, write down the correct label from the list in the box.

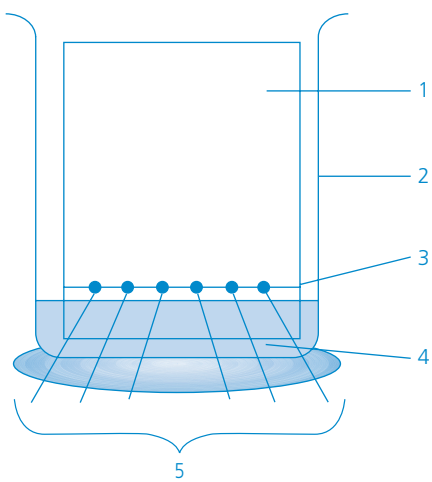


Figure 14.2

pencil line

beaker

solvent

samples

chromatography paper

1 .....

2 .....

3 .....

4 .....

5 .....

3 Concentrated sodium chloride solution was broken down by the passage of electricity using the apparatus shown in Figure 14.3.

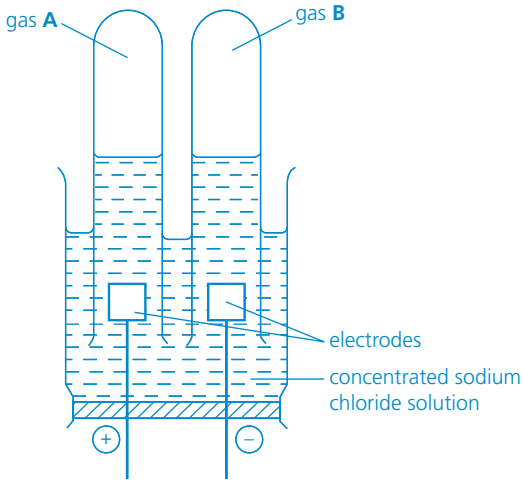


Figure 14.3

a What is the name of this process? .....

b Suggest a suitable material from which to make the electrodes. .....

c Gas **A** bleached moist indicator paper. What is gas **A** and what is its formula?

.....

d Gas **B** is hydrogen. Suggest a chemical test to prove this.

.....

4 Ethene can be obtained by passing liquid paraffin vapour over hot aluminium oxide or broken pot. The experiment is shown in Figure 14.4.

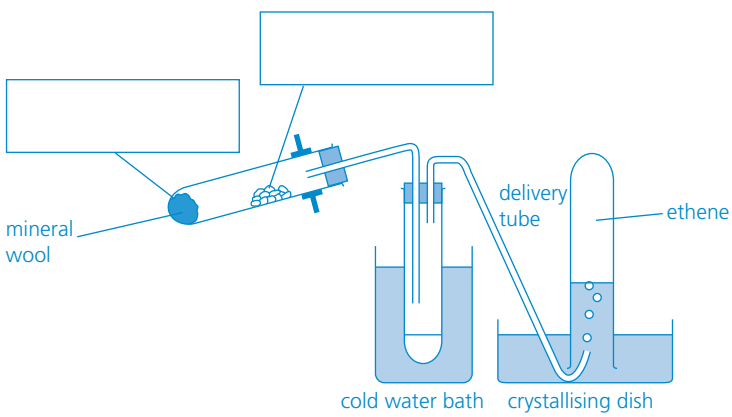


Figure 14.4

a Complete the boxes in Figure 14.4 to show the chemicals used in this experiment.

b Use two arrows on Figure 14.4 to show where the heat is applied during the experiment.

c Why must the delivery tube be removed from the water before the heating is stopped?

.....

d Ethene is an unsaturated hydrocarbon. Describe a chemical test you could use to test for this unsaturation.

.....

.....

5 Name and give the formula of the gas that:

a relights a glowing splint .....

b gives a squeaky pop when ignited .....

c decolourises potassium manganate(VII) solution .....

d turns damp indicator blue .....

e bleaches moist indicator paper .....

6 An analytical chemist was asked to identify two colourless solutions, **A** and **B**, and a green solid, **C**. She carried out various tests in an attempt to identify the solutions. The results of her tests are shown in Table 14.1.

Table 14.1

Substance	Flame test colour	Dilute HCl(aq)	Addition of NH_3(aq)		Dilute HNO_3(aq) + $AgNO_3$(aq)	Dilute HCl(aq) + $BaCl_2$(aq)
			Few drops	Excess		
A	Brick red	No reaction	White precipitate	Precipitate dissolves	White precipitate	No reaction
B	Lilac	No reaction	No reaction	No reaction	No reaction	White precipitate
C	Green	Fizzes	Blue precipitate when added to solution from effect of HCl(aq)	Precipitate dissolves	Fizzes	Fizzes

a Look at the results that were obtained for solution **A**.

i Which metal ion is present in the solution? .....

ii What does the formation of a white precipitate when acidified silver nitrate is added tell you? .....

Supplement

iii Write a balanced ionic equation for the formation of the white precipitate, including state symbols.

.....

b Look at the results that were obtained for solution **B**.

i Which metal ion is present in the solution? .....

ii Which anion must be present for a white precipitate to form when dilute hydrochloric acid and barium chloride solution are added to solution **B**? .....

Supplement

iii Write a balanced ionic equation for the formation of the white precipitate, including state symbols.

.....

c Look at the results that were obtained for solid **C**.

i Which metal ion is present in the solid? .....

ii Which anion must be present to give fizzing when hydrochloric acid is added to solid C?

.....

d Using the information in Table 14.1, give the formula of the chemical present in each of solutions **A** and **B** and solid **C**.

i solution **A** .....

ii solution **B** .....

iii solid **C** .....

7 In each of the qualitative analysis stages below, identify the substances **G** to **L** by name and formula.

a When a white zinc compound, G, was heated in a dry test-tube, a gas, H, was produced. When bubbled through limewater, gas H gave a white precipitate.

.....

.....

b A yellow solid residue, **I**, was left behind, which turned white on cooling. When some dilute hydrochloric acid was added to the white residue, the residue dissolved. There was no effervescence and a colourless solution, **J**, was produced.

.....

.....

c When a few drops of dilute sodium hydroxide was added to a small portion of **J**, a white precipitate, **K**, was formed. This precipitate dissolved in excess of the dilute sodium hydroxide.

.....

.....

d Upon adding a few drops of nitric acid followed by silver nitrate solution to a further portion of **J**, a white precipitate, **L**, was produced. This went grey on standing in sunlight.

.....

.....

8 A banknote was handed into a bank. The bank thought it might be a fake and it was sent to a forensic science laboratory to check whether it was indeed a fake. They decided to use chromatography to check if it was genuine or not.

a Describe, with the aid of a labelled diagram, the steps in the process to identify whether or not the banknote was genuine.

.....

.....

.....

.....

.....

.....

.....

.....

Supplement

b If the sample spots had been colourless how could you identify them?

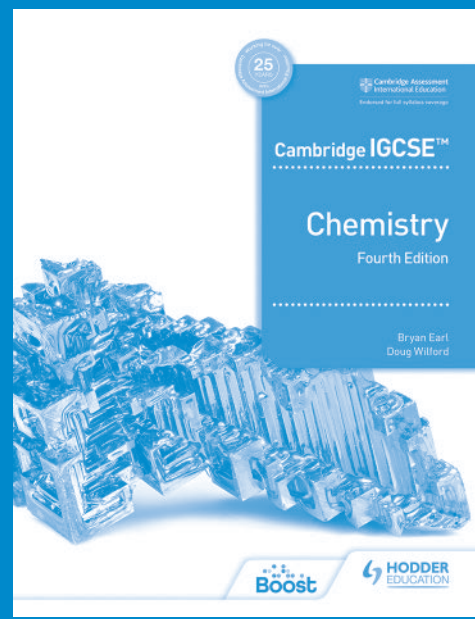
.....

c Sometimes it is necessary to obtain R_f values for the spots on the chromatogram. This requires the use of a formula. Complete the formula for R_f.

$R_f =$

Reinforce learning and deepen understanding of the key concepts in this Workbook, which provides additional support for the accompanying Cambridge IGCSE™ Chemistry Student's Book.

- **Develop understanding and build confidence:** the Workbook is in syllabus order, topic-by-topic, with each section containing a range of shorter questions to test knowledge and its application to different scientific contexts. Exam-style questions are also provided in each section.
- **Differentiated content:** Core and Supplement content is clearly flagged within the workbook.
- **Provide extra practice and self-assessment:** each Workbook is intended to be used by students for practice and homework. Once completed, it can be kept and used for revision.



Use with *Cambridge IGCSE™ Chemistry Student's Book Fourth Edition*

9781398310506

For over 25 years we have been trusted by Cambridge schools around the world to provide quality support for teaching and learning. For this reason we have been selected by Cambridge Assessment International Education as an official publisher of endorsed material for their syllabuses.

This resource is endorsed by Cambridge Assessment International Education

- ✓ Provides learner support for the Cambridge IGCSE and IGCSE (9–1) Chemistry syllabuses (0620/0971) for examination from 2023
- ✓ Has passed Cambridge International's rigorous quality-assurance process
- ✓ Developed by subject experts
- ✓ For Cambridge schools worldwide

HODDER EDUCATION
e: education@hachette.co.uk
w: hoddereducation.com

ISBN 978-1-398-31053-7

MIX
Paper from responsible sources
FSC™ C104740