



Cambridge IGCSE™ (9–1)

CANDIDATE
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CHEMISTRY

0971/42

Paper 4 Theory (Extended)

May/June 2023

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 80.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.

This document has **12** pages.

1 A list of oxides, **A** to **H**, is shown.

- A** calcium oxide
- B** aluminium oxide
- C** silicon(IV) oxide
- D** sulfur dioxide
- E** carbon dioxide
- F** iron(III) oxide
- G** silver oxide
- H** carbon monoxide

Answer the following questions about the oxides, **A** to **H**.
Each letter may be used once, more than once or not at all.

State which of the oxides, **A** to **H**:

(a) is responsible for acid rain

..... [1]

(b) has a giant covalent structure

..... [1]

(c) is a reducing agent in the blast furnace

..... [1]

(d) is the main constituent of bauxite

..... [1]

(e) is the main impurity in iron ore

..... [1]

(f) can be reduced by heating with copper.

..... [1]

[Total: 6]

2 Fluorine, chlorine and bromine are in Group VII of the Periodic Table.

(a) State the name given to Group VII elements.

..... [1]

(b) Explain why Group VII elements have similar chemical properties.

..... [1]

(c) Complete Table 2.1 to show the colour and state at r.t.p. of some Group VII elements.

Table 2.1

element	colour	state at r.t.p.
fluorine	pale yellow	
chlorine		
bromine		liquid

[3]

(d) Bromine has two naturally occurring isotopes, ^{79}Br and ^{81}Br .

(i) State the term given to the numbers 79 and 81 in these isotopes of bromine.

..... [1]

(ii) Complete Table 2.2 to show the number of protons, neutrons and electrons in the atom and ion of bromine shown.

Table 2.2

	^{79}Br	$^{81}\text{Br}^-$
protons		
neutrons		
electrons		

[3]

- (iii) Table 2.3 shows the relative abundances of the two naturally occurring isotopes of bromine.

Table 2.3

isotope	^{79}Br	^{81}Br
relative abundance	55%	45%

Calculate the relative atomic mass of bromine to **one** decimal place.

relative atomic mass = [2]

- (e) Chlorine displaces bromine from aqueous potassium bromide but does **not** displace fluorine from aqueous sodium fluoride.

- (i) Write the symbol equation for the reaction between chlorine and aqueous potassium bromide.

..... [2]

- (ii) State why chlorine does **not** displace fluorine from aqueous sodium fluoride.

..... [1]

- (f) Aqueous silver nitrate is a colourless solution containing $\text{Ag}^+(\text{aq})$ ions.

- (i) Describe what is seen when aqueous silver nitrate is added to aqueous sodium chloride.

..... [1]

- (ii) Write the ionic equation for the reaction between aqueous silver nitrate and aqueous sodium chloride.

Include state symbols.

..... [3]

[Total: 18]

3 Over 200 million tonnes of sulfuric acid are manufactured every year.

(a) State the name of the process used to manufacture sulfuric acid.

..... [1]

(b) Part of the manufacture of sulfuric acid involves converting sulfur dioxide to sulfur trioxide.

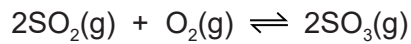
(i) Describe **two** methods by which sulfur dioxide is obtained.

1

2

[2]

The conversion of sulfur dioxide to sulfur trioxide is a reversible reaction which can reach equilibrium.



(ii) State **two** features of an equilibrium.

1

2

[2]

(iii) State the typical conditions and name the catalyst used in the conversion of sulfur dioxide to sulfur trioxide.

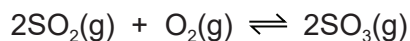
temperature °C

pressure kPa

catalyst

[3]

- (iv) Complete Table 3.1 to show the effect, if any, when the following changes are applied to the conversion of sulfur dioxide to sulfur trioxide.



The forward reaction is exothermic.

Only use the words **increases**, **decreases** or **no change**.

Table 3.1

change	effect on the rate of the forward reaction	effect on the concentration of $\text{SO}_3(\text{g})$ at equilibrium
temperature decreases	decreases	
pressure increases		
no catalyst	decreases	

[4]

- (v) Explain in terms of collision theory why reducing the temperature decreases the rate of the forward reaction.

.....

.....

.....

.....

.....

..... [3]

- (c) Sulfuric acid contains SO_4^{2-} ions.

The oxidation number of O atoms in SO_4^{2-} ions is -2 .

Determine the oxidation number of S atoms in SO_4^{2-} ions. Show your working.

oxidation number = [2]

[Total: 17]

4 Solid sodium hydroxide is a base which dissolves to form an aqueous solution, NaOH(aq).

(a) State what is meant by the term base.

..... [1]

(b) State the term given to a base which dissolves to form an aqueous solution.

..... [1]

(c) State the colour of thymolphthalein in NaOH(aq).

..... [1]

(d) Complete the word equation for the reaction of NaOH(aq) with ammonium chloride.



[3]

(e) Some metal oxides react with NaOH(aq).

(i) State the term given to metal oxides which react with bases such as NaOH(aq).

..... [1]

(ii) Name a metal oxide which reacts with NaOH(aq).

..... [1]

(f) Ethanoic acid, CH_3COOH , is a weak acid.

(i) Complete the dot-and-cross diagram in Fig. 4.1 of a molecule of ethanoic acid.

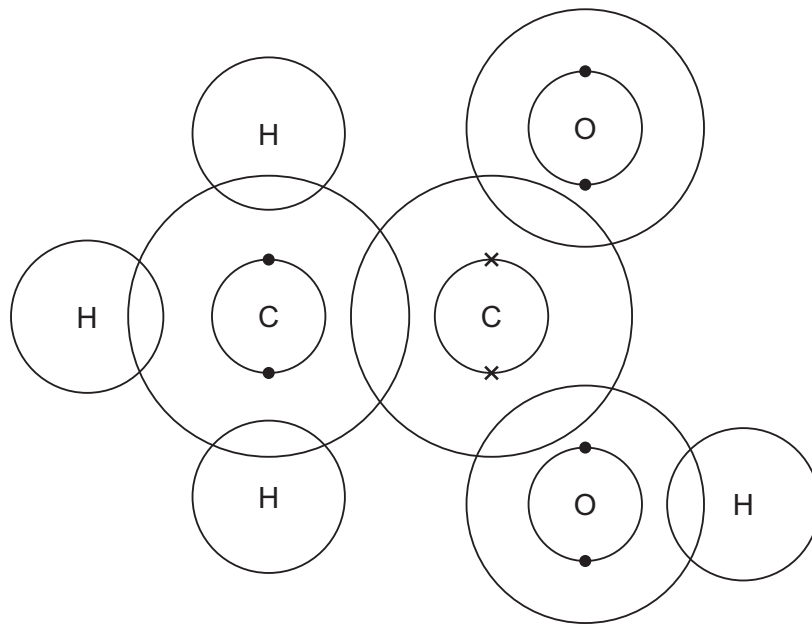


Fig. 4.1

[3]

(ii) Suggest the pH of dilute ethanoic acid.

..... [1]

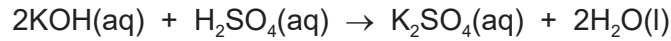
(iii) Complete the symbol equation to show the dissociation of ethanoic acid.

CH_3COOH [3]

(iv) Write the ionic equation for the reaction when an acid neutralises a soluble base.

..... [1]

- (g) In a titration, 25.0 cm³ of 0.0800 mol/dm³ aqueous potassium hydroxide, KOH(aq), is neutralised by 20.0 cm³ of dilute sulfuric acid, H₂SO₄(aq).



Calculate the concentration of H₂SO₄, in g/dm³ using the following steps.

- Calculate the number of moles of KOH used.

..... mol

- Determine the number of moles of H₂SO₄ which react with the KOH.

..... mol

- Calculate the concentration of H₂SO₄ in mol/dm³.

..... mol/dm³

- Calculate the concentration of H₂SO₄ in g/dm³.

..... g/dm³

[5]

[Total: 21]

5 Propane and propene both react with chlorine.

(a) When a molecule of propane, C_3H_8 , reacts with chlorine in the presence of ultraviolet light, one atom of hydrogen is replaced by one atom of chlorine.

(i) State the term given to reactions in which one atom in an alkane is replaced by another atom.

..... [1]

(ii) State the purpose of ultraviolet light in this reaction.

..... [1]

(iii) State the term given to any reaction which requires ultraviolet light.

..... [1]

(iv) Write the symbol equation for the reaction between propane and chlorine.

..... [2]

(b) A molecule of propene, C_3H_6 , is unsaturated and will react with chlorine at room temperature.

(i) State why propene is an unsaturated molecule.

..... [1]

(ii) Give the structural formula of the product of this reaction.

..... [1]

(c) Propene undergoes addition reactions with steam.
There are two possible products, **A** and **B**.

Draw the displayed formula and name each product.

displayed formula of product **A**

name of product **A**

displayed formula of product **B**

name of product **B**

[4]

[Total: 11]

6 Carboxylic acids can be converted to esters.

(a) Name the ester formed when butanoic acid, $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$, reacts with ethanol, $\text{CH}_3\text{CH}_2\text{OH}$.

..... [1]

(b) Identify the other product formed in this reaction.

..... [1]

(c) Deduce the empirical formula of the ester formed.

..... [1]

(d) PET is a polyester. Part of the structure of PET is shown in Fig. 6.1.

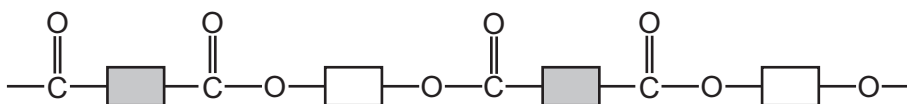


Fig. 6.1

(i) Circle **one** repeat unit of this polymer. [1]

(ii) Draw the structures of the monomers which make up PET. Draw the functional groups using displayed formulae.

[2]

(iii) State the type of polymerisation used in making PET.

..... [1]

[Total: 7]

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The Periodic Table of Elements

		Group																																																																																							
I	II	III	IV	V	VI	VII	VIII																																																																																		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18																																																																								
Li lithium 7	Be beryllium 9	B boron 11	C carbon 12	Al aluminium 13	Si silicon 14	P phosphorus 15	S sulfur 16	Cl chlorine 17	Ar argon 18	K potassium 19	Ca calcium 20	Sc scandium 21	Ti titanium 22	V vanadium 23	Cr chromium 24	Mn manganese 25	Fe iron 26	Co cobalt 27	Ni nickel 28	Cu copper 29	Zn zinc 30	Ga gallium 31	Ge germanium 32	As arsenic 33	Se selenium 34	Br bromine 35	Kr krypton 36	Rb rubidium 37	Sr strontium 38	Y yttrium 39	Zr zirconium 40	Nb niobium 41	Mo molybdenum 42	Tc technetium 43	Ru ruthenium 44	Rh rhodium 45	Pd palladium 46	Ag silver 47	Cd cadmium 48	In indium 49	Sn tin 50	Sb antimony 51	Te tellurium 52	I iodine 53	Xe xenon 54	Cs caesium 55	Ba barium 56	La lanthanoids 57-71	Hf hafnium 72	Ta tantalum 73	W tungsten 74	Re rhenium 75	Os osmium 76	Ir iridium 77	Pt platinum 78	Au gold 79	Hg mercury 80	Tl thallium 81	Pb lead 82	Bi bismuth 83	Po polonium 84	At astatine 85	Rn radon 86	Fr francium 87	Ra radium 88	Ac actinoids 89-103	Rf rutherfordium 104	Db dubnium 105	Sg seaborgium 106	Bh bohrium 107	Hs hassium 108	Mt meitnerium 109	Ds darmstadtium 110	Rg roentgenium 111	Cn copernicium 112	Nh nihonium 113	Nl nihonium 114	Fl flerovium 115	Lv livermorium 116	Ts tennessine 117	Og oganesson 118								
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57-71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89-103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
H hydrogen 1	He helium 4	B boron 11	C carbon 12	Al aluminium 13	Si silicon 14	P phosphorus 15	S sulfur 16	Cl chlorine 17	Ar argon 18	K potassium 19	Ca calcium 20	Sc scandium 21	Ti titanium 22	V vanadium 23	Cr chromium 24	Mn manganese 25	Fe iron 26	Co cobalt 27	Ni nickel 28	Cu copper 29	Zn zinc 30	Ga gallium 31	Ge germanium 32	As arsenic 33	Se selenium 34	Br bromine 35	Kr krypton 36	Rb rubidium 37	Sr strontium 38	Y yttrium 39	Zr zirconium 40	Nb niobium 41	Mo molybdenum 42	Tc technetium 43	Ru ruthenium 44	Rh rhodium 45	Pd palladium 46	Ag silver 47	Cd cadmium 48	In indium 49	Sn tin 50	Sb antimony 51	Te tellurium 52	I iodine 53	Xe xenon 54	Cs caesium 55	Ba barium 56	La lanthanoids 57-71	Hf hafnium 72	Ta tantalum 73	W tungsten 74	Re rhenium 75	Os osmium 76	Ir iridium 77	Pt platinum 78	Au gold 79	Hg mercury 80	Tl thallium 81	Pb lead 82	Bi bismuth 83	Po polonium 84	At astatine 85	Rn radon 86	Fr francium 87	Ra radium 88	Ac actinoids 89-103	Rf rutherfordium 104	Db dubnium 105	Sg seaborgium 106	Bh bohrium 107	Hs hassium 108	Mt meitnerium 109	Ds darmstadtium 110	Rg roentgenium 111	Cn copernicium 112	Nh nihonium 113	Nl nihonium 114	Fl flerovium 115	Lv livermorium 116	Ts tennessine 117	Og oganesson 118								

Key

atomic number
atomic symbol
name
relative atomic mass

lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium —	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium —	94 Pu plutonium —	95 Am americium —	96 Cm curium —	97 Bk berkelium —	98 Cf californium —	99 Es einsteinium —	100 Fm fermium —	101 Md mendelevium —	102 No nobelium —	103 Lr lawrencium —

The volume of one mole of any gas is 24 dm³ at room temperature and pressure (r.t.p.).