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CHEMISTRY **0620/43**

Paper 4 Theory (Extended) **October/November 2025**

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 **16** pages. Any blank pages are indicated.

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[Turn over

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1 Atoms and ions are made from particles called electrons, neutrons and protons.

(a) Complete Table 1.1.

Table 1.1

particle	relative charge	relative mass
electron	–1	$\frac{1}{1840}$
neutron		
proton		

[2]

(b) Table 1.2 shows information about some atoms or ions.

Complete Table 1.2.

Table 1.2

atom or ion	number of electrons	number of neutrons	number of protons
$^{40}_{20}Ca^{2+}$		20	20
$^{19}_{9}F$	9		9
	10	9	8

[5]

(c) **(i)** The relative atomic mass, A_r, of an element is the average mass of its isotopes compared to one atom of isotope **X**.

Identify isotope **X**.

..... [1]

(ii) A sample of magnesium consists of two isotopes with mass numbers 24 and 26. [A_r: Mg, 24.3]

Calculate the percentage abundance of the isotope of magnesium with mass number 24.

percentage abundance = ... [1]

[Total: 9]

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2 Table 2.1 shows the melting points, boiling points and electrical conductivities of seven substances, **A**, **B**, **C**, **D**, **E**, **F** and **G**.

Table 2.1

substance	melting point / °C	boiling point / °C	electrical conductivity when solid	electrical conductivity when molten
A	1600	2230	poor	poor
B	–219	–183	poor	poor
C	770	1420	poor	good
D	–39	357	good	good
E	–7	58	poor	poor
F	44	280	poor	poor
G	1085	2562	good	good

(a) Identify which substance, **A**, **B**, **C**, **D**, **E**, **F** or **G**, is:

(i) a gas at 25 °C

..... [1]

(ii) a solid consisting of simple molecules at 25 °C

..... [1]

(iii) a metal which is liquid at 25 °C.

..... [1]

(b) (i) Identify which substance, **A**, **B**, **C**, **D**, **E**, **F** or **G**, has a giant covalent structure.

Use the information in Table 2.1 to give **two** reasons for your choice.

substance .....

reason 1 .....

reason 2 .....

[3]

(ii) Identify which substance, **A**, **B**, **C**, **D**, **E**, **F** or **G**, is an ionic compound.

Use the information in Table 2.1 to give **one** reason for your choice.

substance .....

reason .....

[2]

[Total: 8]

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3 This question is about aluminium and other metallic elements.

(a) Aluminium is extracted from purified bauxite by electrolysis. Fig. 3.1 shows a diagram of the electrolytic cell used.

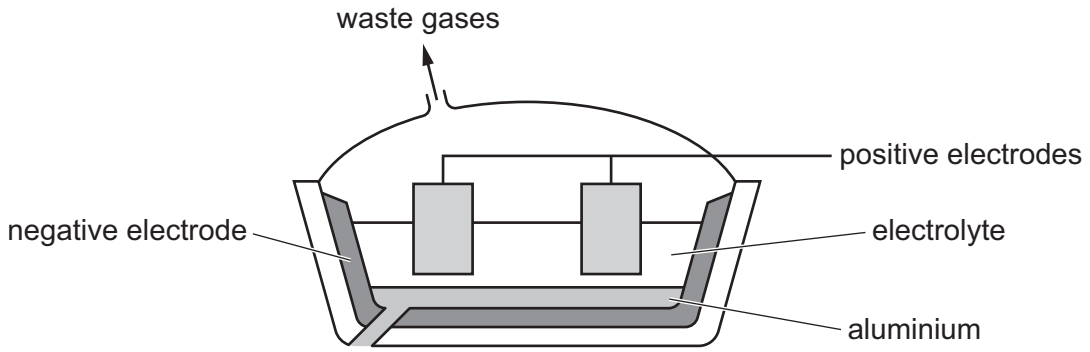


Fig. 3.1

(i) State the name of the aluminium compound present in bauxite.

..... [1]

(ii) Name the substance that purified bauxite is dissolved in before electrolysis is carried out.

..... [1]

(iii) Name the substance that is used for the positive electrodes.

..... [1]

(iv) Write the ionic half-equation for the production of aluminium at the negative electrode.

..... [2]

(b) Aluminium is above zinc in the reactivity series.

(i) When a piece of aluminium foil is added to aqueous zinc sulfate, a reaction is **not** immediately observed even though aluminium is above zinc in the reactivity series.

Explain why a reaction is **not** immediately observed.

.....

..... [1]

(ii) After a few minutes, a displacement reaction occurs between aluminium and aqueous zinc ions.

Complete the ionic equation for this reaction.

$$.....Al + ...Zn^{2+} \rightarrow .....Al^{3+} + ...Zn$$

[1]

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(iii) State the oxidation number of zinc in:

Zn^{2+} .....

Zn. .....

[2]

(iv) Define the term reduction in terms of oxidation number.

..... [1]

(c) Aluminium reacts with iron(III) oxide. The equation is shown.

$$2Al + Fe_2O_3 \rightarrow Al_2O_3 + 2Fe \qquad \Delta H = -850\,kJ/mol$$

(i) State the meaning of the symbol ΔH.

..... [1]

(ii) State what can be deduced about the reaction from the negative sign in $\Delta H = -850\,kJ/mol$.

..... [1]

(d) Gallium has many similarities to aluminium. Gallium(III) oxide is an amphoteric oxide.

State what is meant by the term amphoteric.

.....

..... [1]

(e) The reaction of gallium(III) oxide, Ga_2O_3, with aqueous sodium hydroxide forms a salt which contains the negative ion GaO_2^-. The only other product is water.

Write a symbol equation for this reaction.

..... [2]

(f) Deduce the formula of:

- gallium(III) bromide .....
- gallium(III) sulfate. .....

[2]

[Total: 17]

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4 This question is about chlorine and compounds of chlorine.

(a) Gaseous chlorine reacts with gaseous phosphorus(III) chloride to form gaseous phosphorus(V) chloride. The reaction is a reversible reaction.

When the three gases are in a closed container the system reaches equilibrium.

$$Cl_2(g) + PCl_3(g) \rightleftharpoons PCl_5(g)$$

(i) Describe a reversible reaction at equilibrium in terms of:

- the rate of the forward reaction and the rate of the reverse reaction

.....

- the concentrations of reactants and products.

.....

[2]

(ii) Complete Table 4.1 using only the words **increases**, **decreases** or **no change**.

Table 4.1

change to condition	effect on the rate of the forward reaction	effect on the equilibrium concentration of PCl_5
the pressure is decreased		
a catalyst is added	increases	

[3]

(iii) When the temperature of the equilibrium mixture is increased, the equilibrium concentration of PCl_5 decreases.

State what conclusion about the forward reaction can be made from this information.

..... [1]

(b) Ethene, C_2H_4, reacts with chlorine, Cl_2, to form 1,2-dichloroethane, CH_2ClCH_2Cl.

The equation for this reaction can be represented as shown.

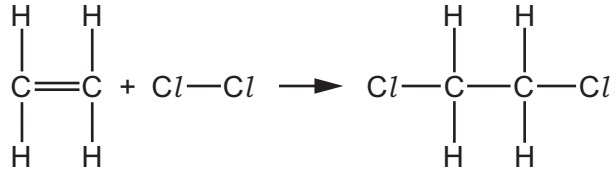


Table 4.2 shows some bond energies.

Table 4.2

bond	bond energy in kJ / mol
C–C	350
C=C	610
C–H	410
Cl–Cl	240
C–Cl	340

Use the bond energies in Table 4.2 to calculate the enthalpy change, in kJ / mol, of the reaction.

Use the following steps.

- Calculate the total energy needed to break the bonds in C_2H_4 and Cl_2.

..... kJ

- Calculate the total energy released when the bonds form in CH_2ClCH_2Cl.

..... kJ

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- Calculate the enthalpy change of the reaction.
  Your answer should include a sign.

.....kJ/mol
[3]

(c) Chlorine reacts with nitrogen to form nitrogen trichloride, NCl_3.

Complete the dot-and-cross diagram in Fig. 4.1 of a molecule of NCl_3.

Show outer shell electrons only.

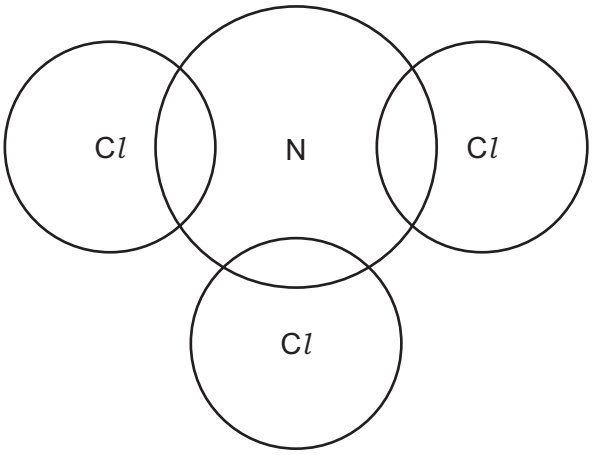


Fig. 4.1

[3]

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(d) When solid magnesium carbonate, $MgCO_3$, is added to dilute hydrochloric acid, HC*l*, a chemical reaction occurs. The equation for the reaction is shown.

$$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + CO_2(g) + H_2O(l)$$

(i) Give **two** observations when solid magnesium carbonate is added to dilute hydrochloric acid.

1 .....

2 .....

[2]

(ii) Calculate the volume, in cm^3, of $CO_2(g)$ that is produced at room temperature and pressure (r.t.p.) when 50.0 cm^3 of 0.100 mol / dm^3 HC*l* reacts with excess $MgCO_3$.

The volume of 1 mol of any gas is 24 000 cm^3 at r.t.p.

Use the following steps.

- Calculate the number of moles of HC*l* in 50.0 cm^3 of 0.100 mol / dm^3 HC*l*.

..... mol

- Deduce the number of moles of $CO_2(g)$ produced.

..... mol

- Calculate the volume, in cm^3, of $CO_2(g)$ produced at r.t.p.

..... cm^3

[3]

[Total: 17]

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5 This question is about metallic compounds.

(a) Insoluble metal salts, such as lead(II) sulfate, are made by precipitation.

When aqueous lead(II) ions react with aqueous sulfate ions, a precipitate of lead(II) sulfate forms.

A sample of pure lead(II) sulfate can be obtained from the precipitate formed.

(i) Write an ionic equation for this precipitation reaction. Include state symbols.

..... [3]

(ii) State the name of an aqueous solution containing lead(II) ions.

..... [1]

(iii) State the name of an aqueous solution containing sulfate ions.

..... [1]

(iv) The lead(II) sulfate precipitate is separated from the rest of the reaction mixture by filtration. The impure lead(II) sulfate remains on the filter paper.

State the general term given to an insoluble substance that remains on the filter paper during filtration.

..... [1]

(v) Describe how the lead(II) sulfate is purified after filtration.

.....

..... [2]

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(b) Copper is a transition element.

A list of properties of copper is shown.

- It has good electrical conductivity.
- It has variable oxidation states.
- It forms soluble salts.
- It forms coloured compounds.
- It forms basic oxides.
- It acts as a catalyst.

(i) Give **two** properties from the list that show how copper is similar to metals in Group I of the Periodic Table.

1 .....

2 .....

[2]

(ii) Give **two** properties from the list that show how copper is different from metals in Group I of the Periodic Table.

1 .....

2 .....

[2]

[Total: 12]

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6 This question is about organic compounds.

(a) Organic compound **Q** has the following composition by mass.

C, 50.00%; H, 5.56%; O, 44.44%

Calculate the empirical formula of compound **Q**.

empirical formula = ... [3]

(b) Organic compound **R** has the empirical formula CHO and a relative molecular mass of 116.

Determine the molecular formula of compound **R**.

molecular formula = ... [1]

(c) Carboxylic acids react with alcohols to form esters.

(i) Name the other product that is formed when a carboxylic acid reacts with an alcohol.

..... [1]

(ii) Name the **type** of catalyst that is used when a carboxylic acid reacts with an alcohol.

..... [1]

(iii) Ester **S** has the structural formula $CH_3CH_2COOCH_2CH_2CH_2CH_3$.

Name the carboxylic acid and the alcohol which react together to form ester **S**.

carboxylic acid .....

alcohol .....

[2]

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(d) Fig. 6.1 shows part of a polymer structure.

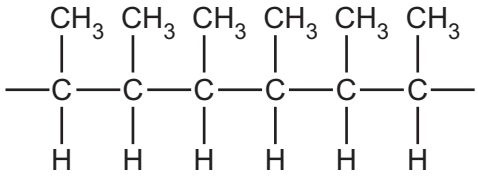


Fig. 6.1

(i) Name the type of polymerisation that is used to produce this polymer.

..... [1]

(ii) Suggest why it is **not** possible to write the molecular formula of this polymer.

..... [1]

(iii) State the number of monomer units that are needed to make the part of the polymer structure shown in Fig. 6.1.

..... [1]

(iv) Draw the displayed formula of the monomer used to make this polymer.

[2]

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(e) Fig. 6.2 shows part of the general structure of an amino acid.

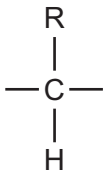


Fig. 6.2

(i) Complete Fig. 6.2 to show all the atoms and all the bonds in the two functional groups of the amino acid. [2]

(ii) Part of a natural polyamide structure is shown in Fig. 6.3.

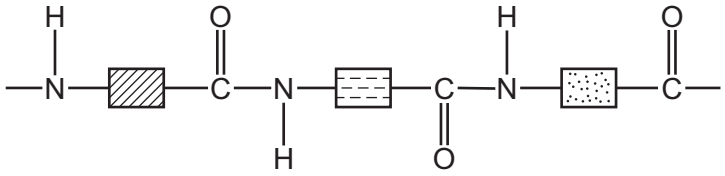


Fig. 6.3

On Fig. 6.3, draw a circle around **one** amide linkage. [1]

(iii) State the name given to natural polyamides made from amino acids.

..... [1]

[Total: 17]

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The Periodic Table of Elements

Group I	Group II											Group III	Group IV	Group V	Group VI	Group VII	Group VIII
							1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9											5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24											13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

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 dm^3 at room temperature and pressure (r.t.p.).

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