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CHEMISTRY **0620/42**

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 The three states of matter are solid, liquid and gas.

(a) Complete Table 1.1 to describe the structures of solids, liquids and gases in terms of particle separation, particle arrangement and particle motion.

Table 1.1

state of matter	particle separation	particle arrangement	particle motion
solid	touching		
liquid			
gas		random	random

[3]

(b) Substances can physically change.

Name each physical change:

- solid to liquid .....
- gas to liquid .....
- solid to aqueous. .....

[3]

(c) Gases diffuse.

(i) Describe, in terms of particles, why gases diffuse.

..... [1]

(ii) State what determines the relative rate of diffusion of gases at constant temperature.

..... [1]

(d) Gaseous oxides of nitrogen are atmospheric pollutants. One adverse effect of oxides of nitrogen is the formation of acid rain.

State **two other** adverse effects of oxides of nitrogen.

1.....

2.....

[2]

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(e) In a catalytic converter, oxides of nitrogen are removed by reaction with the toxic gaseous product of the incomplete combustion of hydrocarbon fuels. Two non-toxic gases are formed in this reaction.

(i) Name the toxic gaseous product of the incomplete combustion of hydrocarbon fuels.

..... [1]

(ii) Name the **two** non-toxic gases formed in the catalytic converter.

1 .....

2 .....
[2]

[Total: 13]

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2 Iron is extracted from iron ore in a blast furnace.

(a) The iron compound in the main iron ore used in the blast furnace is iron(III) oxide.

(i) State the name of the main iron ore used in the blast furnace.

..... [1]

(ii) State how the main source of heat is provided in the blast furnace.

..... [1]

(iii) Name the gaseous reducing agent in the blast furnace.

..... [1]

(iv) Write a symbol equation for the reduction of iron(III) oxide by the gaseous reducing agent in **(a)(iii)**.

..... [2]

(v) The main impurity in iron ore is silicon(IV) oxide.

Write **two** symbol equations to show the role of limestone in removing silicon(IV) oxide from iron ore.

1 .....

2 .....

[2]

(b) Table 2.1 shows four different isotopes of iron, **A**, **B**, **C** and **D**.

Table 2.1

A	B	C	D
^{54}Fe	^{56}Fe	^{57}Fe	^{58}Fe

Explain why **A**, **B**, **C** and **D** are isotopes of iron.

.....

..... [2]

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(c) Iron can form two different ions, Fe^{2+} and Fe^{3+}.

(i) Complete Table 2.2 to show the number of protons, neutrons and electrons in the two iron ions shown.

Table 2.2

	$^{54}Fe^{2+}$	$^{58}Fe^{3+}$
protons		
neutrons		
electrons		

[3]

(ii) Describe a test for aqueous Fe^{2+} ions.

test .....

observations .....

.....

[2]

(d) An oxidising agent converts Fe^{2+} ions to Fe^{3+} ions.

(i) Define the term oxidising agent.

.....

..... [2]

(ii) Explain why the conversion of Fe^{2+} ions to Fe^{3+} ions is described as oxidation.

..... [1]

(iii) The oxidising agent for the conversion of Fe^{2+} ions to Fe^{3+} ions is aqueous potassium manganate(VII).

State **one** condition needed for the oxidation to take place.

..... [1]

(e) Iodide ions, I^-, reduce Fe^{3+} ions to Fe^{2+} ions in aqueous solution.

Suggest the identity of the other product formed in this reaction.

..... [1]

[Total: 19]

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3 A student prepares a sample of the insoluble salt barium sulfate, $BaSO_4$.
The student adds aqueous sodium sulfate, $Na_2SO_4(aq)$, to aqueous barium chloride, $BaCl_2(aq)$.

The student carries out the following steps.

step 1 Dissolve 0.100 moles of solid $BaCl_2$ in 100 cm^3 of distilled water in a beaker to form $BaCl_2(aq)$.

step 2 Add an aqueous solution which contains 0.100 moles of $Na_2SO_4(aq)$ to the beaker containing the $BaCl_2(aq)$ from **step 1**.

step 3 Stir the mixture and then filter it.

step 4 Dry the solid left in the filter paper.

(a) Complete the symbol equation for the reaction. Include state symbols.

$$BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(.....) + ...(.....)$$

[2]

(b) Calculate the mass of solid $BaCl_2$ dissolved in **step 1**.

mass = ... g [2]

(c) The concentration of $Na_2SO_4(aq)$ in **step 2** is 1.25 mol/dm^3.

Calculate the volume, in cm^3, of 1.25 mol/dm^3 $Na_2SO_4(aq)$ added in **step 2** which contains 0.100 moles of Na_2SO_4.

volume = ... cm^3 [1]

(d) State the colour of the solid formed in **step 2**.

..... [1]

(e) The mixture is filtered in **step 3**.

State the general term given to a solid left in the filter paper after filtration.

..... [1]

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(f) The actual mass of dry $BaSO_4$ collected in **step 4** is greater than the expected mass. This is because the student should do an additional step between **step 3** and **step 4**.

Suggest what the student should do in this additional step, and explain why the actual mass collected is greater than the expected mass.

.....

.....

.....

..... [2]

(g) State the name of this method of salt preparation.

..... [1]

(h) State the name of a different:

- barium salt that can be used in place of $BaCl_2$ .....
- sulfate salt that can be used in place of Na_2SO_4 .....
- barium salt that can be made by this method. .....

[3]

[Total: 13]

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4 Nitric acid, HNO_3, and sulfuric acid, H_2SO_4, are strong acids. Ethanoic acid, CH_3COOH, is a weak acid.

(a) One mole of each acid is added separately to 1000 cm^3 of distilled water to form a dilute solution. All three acids dissociate in distilled water.

(i) State the formula of the common cation produced when each of the three acids dissociates in water.

..... [1]

(ii) Explain, in terms of dissociation, why:

- nitric acid is described as a strong acid

.....

- ethanoic acid is described as a weak acid.

.....
[2]

(iii) State which of the three dilute acids will have the highest pH value.

..... [1]

(iv) State the colour of thymolphthalein in all three dilute acids.

..... [1]

(v) Give the formula of the anion formed when:

- sulfuric acid dissociates in water

.....

- ethanoic acid dissociates in water.

.....
[2]

(vi) Name the **two** gaseous products formed during the electrolysis of dilute sulfuric acid using inert electrodes.

..... and ..... [2]

(vii) Name the salt formed when calcium reacts with ethanoic acid.

..... [1]

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(b) Aluminium nitrate, $Al(NO_3)_3$, is made when dilute nitric acid reacts with aluminium hydroxide, $Al(OH)_3$.

(i) $Al(OH)_3$ acts as a base in this reaction.

Define the term base.

..... [1]

(ii) $Al(OH)_3$ is **not** an alkali.

State what this tells you about the solubility of $Al(OH)_3$.

..... [1]

(iii) Name **one other** compound which forms aluminium nitrate when added to dilute nitric acid.

..... [1]

(iv) The oxidation number of the O atoms in $Al(NO_3)_3$ is –2.
The formula of the aluminium ion in $Al(NO_3)_3$ is Al^{3+}.

Determine the oxidation number of the N atoms in $Al(NO_3)_3$.
Show your working.

oxidation number of N = ... [2]

[Total: 15]

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5 This question is about the homologous series of alkanes.

Three general characteristics of alkanes are:

- they are generally unreactive because they do **not** have a functional group
- they show trends in their physical properties, such as melting points and boiling points
- they have similar chemical properties.

(a) Describe **two other** general characteristics of the homologous series of alkanes.

1.....

2.....
[2]

(b) **(i)** State the trend in the boiling points of the alkanes as the carbon chain length increases.

..... [1]

(ii) Name **one other** physical property of alkanes that shows a trend, other than melting points and boiling points.

Describe this trend as the carbon chain length of alkanes increases.

name .....

description .....
[2]

(c) State why alkanes are described as saturated.

..... [1]

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(d) Propane has the structural formula $CH_3CH_2CH_3$.

When propane undergoes a monosubstitution reaction with chlorine at room temperature, **two** organic products can be formed.

(i) State **one** condition needed for this substitution reaction to take place.

..... [1]

(ii) Give the structural formula and state the name of each organic product formed.

- structural formula of product 1

name of product 1 .....

- structural formula of product 2

name of product 2 .....

[4]

(iii) The two products formed are structural isomers of each other.

Define the term structural isomers.

.....

..... [1]

[Total: 12]

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6 Compound **E** shown in Fig. 6.1 is an ester.

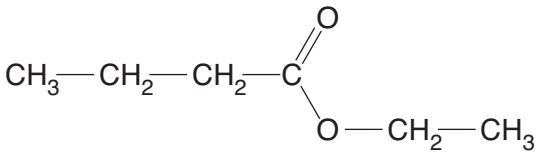


Fig. 6.1

(a) **On Fig. 6.1**, draw a circle around all the atoms which make up the ester linkage. [1]

(b) Name compound **E**.

..... [1]

(c) Deduce the empirical formula of compound **E**.

..... [1]

(d) Compound **E** is produced when two different compounds react together in the presence of a catalyst.

(i) Name the **two** compounds that react together to produce compound **E**.

1 .....

2 .....

[2]

(ii) Suggest a suitable catalyst for this reaction.

..... [1]

(e) Determine the number of unbranched esters which have the molecular formula $C_5H_{10}O_2$.

..... [1]

(f) All unbranched esters with the molecular formula $C_5H_{10}O_2$ combust completely to form carbon dioxide and water only.

Write the symbol equation for the complete combustion of $C_5H_{10}O_2$.

..... [1]

[Total: 8]

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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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