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CHEMISTRY **0620/41**

Paper 4 Theory (Extended) **May/June 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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1 A list of substances is shown.

bauxite **calcium oxide** **ethanol** **graphite** **methane**

nitrogen **oxygen** **propane** **propene** **sulfur dioxide**

Answer the questions using the list of substances.

Each substance may be used once, more than once, or not at all.

State which of the substances:

(a) is a basic oxide

..... [1]

(b) contains carbon atoms only

..... [1]

(c) is manufactured by fermentation

..... [1]

(d) is produced by the decomposition of vegetation

..... [1]

(e) contains aluminium oxide

..... [1]

(f) causes acid rain

..... [1]

(g) is a simple molecule with 11 atoms

..... [1]

(h) is produced when limestone thermally decomposes in the blast furnace

..... [1]

(i) is a gas that is approximately 21% of clean, dry air

..... [1]

(j) is a monomer in addition polymerisation.

..... [1]

[Total: 10]

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2 Atoms are made of electrons, neutrons and protons.

(a) Complete Table 2.1.

Table 2.1

particle	relative charge	relative mass
electron		$\frac{1}{1840}$
neutron	0	
proton		

[2]

(b) Atoms of the same element are known as isotopes.

$^{39}_{19}K$ and $^{41}_{19}K$ are isotopes of potassium.

(i) Complete Table 2.2 to show the number of electrons, neutrons and protons in one atom or ion of these isotopes.

Table 2.2

isotope	electrons	neutrons	protons
$^{39}_{19}K$			
$^{41}_{19}K^{+}$			

[3]

(ii) Table 2.3 shows the relative masses and the percentage abundances of the two isotopes in a sample of potassium.

Table 2.3

relative mass of isotope	percentage abundance of isotope
39	90
41	10

Calculate the relative atomic mass of this sample of potassium to **one** decimal place.

relative atomic mass = ... [2]

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(iii) An isotope of aluminium has a nucleon number of 27.

Aluminium has a relative atomic mass of 27.

State what conclusion can be made from this information.

.....

..... [1]

(c) A calcium atom has the electronic configuration of 2,8,8,2.

Give the formula of one atom and one negative ion that has the same electronic configuration as Ca^{2+}.

- atom .....
- negative ion .....

[2]

[Total: 10]

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3 This question is about copper and compounds of copper.

(a) **(i)** Describe the bonding in a metallic element such as copper.

.....

.....

.....

.....

..... [3]

(ii) Explain how solid copper conducts electricity.

..... [1]

(b) Copper is in alloys such as brass.

(i) State **one** reason why alloys are more useful than pure metals.

..... [1]

(ii) Name the substance that is present in brass, other than copper.

..... [1]

(c) Copper(II) sulfate crystals are made by the reaction between copper(II) carbonate and dilute sulfuric acid, using the following steps.

The sulfuric acid has a concentration of 0.100 mol / dm^3.

step 1 Powdered copper(II) carbonate is added to dilute sulfuric acid. The mixture is stirred. A reaction occurs.

step 2 More copper(II) carbonate is added, with stirring, until the reaction stops.

step 3 Unreacted copper(II) carbonate is separated from aqueous copper(II) sulfate by filtration.

step 4 Aqueous copper(II) sulfate is heated until some of the water evaporates.

step 5 The remaining solution is allowed to cool and crystallise.

step 6 The crystals are removed and dried.

(i) Give **two** observations in **step 1**.

1 .....

2 .....
[2]

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(ii) State why the reaction stops in **step 2**.

..... [1]

(iii) Name the residue in **step 3**.

..... [1]

(iv) Name a substance, other than copper(II) carbonate, that can be added to dilute sulfuric acid to produce aqueous copper(II) sulfate.

..... [1]

(v) The solution at the end of **step 4** contains the maximum amount of copper(II) sulfate that will dissolve at that temperature.

State the term used to describe this type of solution.

..... [1]

(vi) **Step 1** is repeated using sulfuric acid of concentration 0.200 mol / dm^3 instead of 0.100 mol / dm^3.

All other conditions are the same.

The rate of reaction increases.

Explain why the rate of reaction increases. Give your answer in terms of particles.

.....

.....

..... [2]

(vii) Copper(II) sulfate crystals have the formula $CuSO_4 \cdot 5H_2O$.

State the term used to describe a substance that is chemically combined with water.

..... [1]

[Total: 15]

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4 This question is about nitrogen and its compounds.

Nitrogen contains molecules with the formula N_2.

(a) Complete the dot-and-cross diagram in Fig. 4.1 to show the electronic configuration in a nitrogen molecule. Show outer-shell electrons only.

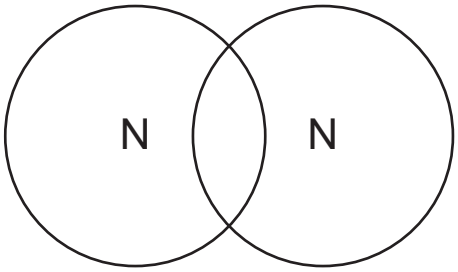

Fig. 4.1

[2]

(b) Ammonia, NH_3, is manufactured by reacting nitrogen with hydrogen, H_2, in the Haber process.

(i) State **three** typical conditions for the reaction between nitrogen and hydrogen in the Haber process.

1 .....

2 .....

3 .....

[3]

(ii) Write the symbol equation for the chemical reaction in the Haber process.

..... [1]

(c) Ammonia is converted into nitric acid in a two-step process.

In step 1, ammonia and oxygen are passed over a catalyst.

(i) Balance the symbol equation for this reaction.

$$4NH_3 + ...O_2 \rightleftharpoons .....NO + ...H_2O$$

[1]

(ii) Give the oxidation number of nitrogen in:

- NH_3 .....
- NO. .....

[2]

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(iii) Define oxidation in terms of oxidation number.

..... [1]

(iv) In step 2, oxygen and water react with NO to produce nitric acid as the only product.

Write a symbol equation for this chemical reaction.

..... [2]

(d) Ammonia is converted into ammonium sulfate, $(NH_4)_2SO_4$.

$$2NH_3(g) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(s)$$

360 dm^3 of ammonia gas, measured at r.t.p., reacts with excess sulfuric acid.

Calculate the mass of ammonium sulfate produced, using the following steps.

- Calculate the number of moles of $NH_3(g)$ in 360 dm^3.

  One mole of any gas occupies 24 dm^3 at r.t.p.

  ..... mol

- Calculate the number of moles of $(NH_4)_2SO_4$ produced.

  ..... mol

- Calculate the mass of $(NH_4)_2SO_4$ produced.

  The M_r of $(NH_4)_2SO_4$ is 132.

  ..... g
  [3]

[Total: 15]

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5 Methanol, CH_3OH, is manufactured by the reaction between hydrogen and carbon monoxide.

An equilibrium mixture is produced.

$$2H_2(g) + CO(g) \rightleftharpoons CH_3OH(g)$$

(a) State what happens to the concentration of CH_3OH when the reaction is at equilibrium.

Explain your answer in terms of rate of forward and reverse reactions.

.....

.....

..... [2]

(b) The reaction is carried out at a pressure of 75 atmospheres and a temperature of 250 °C.

(i) State **two** disadvantages of using a pressure **below** 75 atmospheres.

1 .....

2 .....
[2]

(ii) Complete Table 5.1 using **only** the words **increases**, **decreases** or **no change**.

Table 5.1

	effect on the concentration of $CH_3OH(g)$ at equilibrium	effect on the rate of the reverse reaction
catalyst is added		

[2]

(iii) If a temperature of more than 250 °C is used, the yield of methanol decreases.

State what can be deduced about the forward reaction.

..... [1]

(iv) Suggest which of the elements from the list is a suitable catalyst for the reaction. Give a reason for your answer.

barium **carbon** **copper** **potassium** **sulfur**

catalyst .....

reason .....
[2]

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(c) Methanol is a member of the homologous series of alcohols.

(i) State **two** characteristics of all members of a homologous series.

1 .....

2 .....
[2]

(ii) State the molecular formula of an alcohol that contains five carbon atoms.

..... [1]

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

(i) Draw the displayed formula of an ester which contains three carbon atoms.

[2]

(ii) Butyl ethanoate is an ester.

Name the alcohol and the carboxylic acid that react to produce butyl ethanoate.

alcohol .....

carboxylic acid .....
[2]

(e) An organic compound has the following composition by mass:

C, 64.87%; H, 13.51%; O, 21.62%.

Calculate the empirical formula of the compound.

empirical formula = ... [2]

[Total: 18]

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6 This question is about the Periodic Table.

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

..... [1]

(b) State which Group VII element is most reactive.

..... [1]

(c) Give the physical state and colour of iodine at room temperature and pressure.

state .....

colour .....
[2]

(d) When bromine is added to aqueous potassium iodide a displacement reaction occurs.

The equation for the reaction is shown.

$$Br_2 + 2KI \rightarrow 2KBr + I_2$$

(i) Write an ionic equation for the reaction.

..... [2]

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(ii) Iodine and bromine react at high temperatures to form iodine monobromide, IBr.

The equation is shown.

$$I_2(g) + Br_2(g) \rightarrow 2IBr(g)$$

The structures of the molecules involved in the reaction are I–I, Br–Br and I–Br.

Table 6.1

bond	bond energy in kJ / mol
I–I	150
Br–Br	193
I–Br	175

Calculate the enthalpy change, ΔH, for the reaction using the bond energies in Table 6.1.

Use the following steps.

- Calculate the **total** amount of energy required to break the bonds in 1 mol of $I_2(g)$ and 1 mol of $Br_2(g)$.

..... kJ

- Calculate the total amount of energy released when the bonds in 2 mol of IBr(g) are formed.

..... kJ

- Calculate the enthalpy change, ΔH, for the reaction.
  Your answer should include a sign.

..... kJ / mol
[3]

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(e) Sodium is in Group I of the Periodic Table.

When sodium is added to water a chemical reaction occurs.

(i) Give **two** observations when sodium is added to water.

1 .....

2 .....
[2]

(ii) Thymolphthalein is added to the solution when the reaction has finished.

State the final colour of the thymolphthalein in the solution.

..... [1]

[Total: 12]

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The Periodic Table of Elements

Key

atomic number
atomic symbol
name
relative atomic mass

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 35.5	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 –

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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