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CHEMISTRY **0620/41**

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 Protons, neutrons and electrons are particles found in atoms.

(a) Complete Table 1.1 to show the relative mass and relative charge of a proton, a neutron and an electron.

Table 1.1

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

[2]

(b) Some elements have many isotopes.

(i) Define the term isotopes.

.....

.....

..... [2]

(ii) Explain why all isotopes of the same element have the same chemical properties.

.....

..... [1]

(c) Complete Table 1.2.

Table 1.2

atom or ion	number of protons	number of neutrons	number of electrons
$^{40}_{18}Ar$	18		18
$^{32}_{16}S^{2-}$		16	
	22	28	20

[5]

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(d) The term mass number is defined as the total number of protons and neutrons in the nucleus of an atom.

State the name of **one other** term which is defined as the total number of protons and neutrons in the nucleus of an atom.

..... [1]

(e) Calculate the number of atoms in 2.00 g of argon.

Give your answer in standard form.

number of atoms = ... [2]

[Total: 13]

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2 Calcium is an element in Group II of the Periodic Table.

(a) Identify the element in Group II which has only five occupied electron shells.

..... [1]

(b) Name and describe the type of bonding found in elements in Group II.

name .....

description .....

.....

.....

.....

[4]

(c) When a piece of calcium is added to some cold water containing universal indicator a reaction takes place.

(i) Give **three** observations when this reaction takes place.

1 .....

2 .....

3 .....

[3]

(ii) Name the **two** products of this reaction.

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

(d) Calcium burns in oxygen.

(i) State the colour of the flame.

..... [1]

(ii) Write the symbol equation for this reaction.

..... [2]

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(e) Crystals of hydrated calcium nitrate contain water molecules.

The formula of hydrated calcium nitrate is $Ca(NO_3)_2 \cdot \mathbf{x}H_2O$.
x is a whole number.

(i) State the term given to the water molecules present in hydrated crystals.

..... [1]

(ii) When hydrated calcium nitrate is heated gently, the following reaction occurs.

$$Ca(NO_3)_2 \cdot \mathbf{x}H_2O \rightarrow Ca(NO_3)_2 + \mathbf{x}H_2O$$

A sample of hydrated calcium nitrate is heated gently. 3.28 g of $Ca(NO_3)_2$ forms and the mass of the crystals decreases by 1.44 g.

[M_r: $Ca(NO_3)_2$, 164; H_2O, 18]

Determine the value of **x** in $Ca(NO_3)_2 \cdot \mathbf{x}H_2O$ using the following steps.

- Calculate the number of moles of $Ca(NO_3)_2$ that remain.

..... mol

- Calculate the number of moles of H_2O given off.

..... mol

- Determine the value of **x**.

x = ...
[3]

[Total: 17]

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3 A student makes crystals of the salt sodium sulfate, Na_2SO_4. The student reacts 0.200 mol / dm^3 dilute sulfuric acid, $H_2SO_4(aq)$, with aqueous sodium hydroxide, NaOH(aq).

The student uses the following steps.

step 1 The student places 40.0 cm^3 of NaOH(aq) into a conical flask. This volume contains 0.0100 moles of NaOH.

step 2 The student adds a few drops of methyl orange indicator to the NaOH(aq) in the conical flask.

step 3 The student adds 0.200 mol / dm^3 $H_2SO_4(aq)$ to the flask until the end-point is reached.

step 4 The student transfers the mixture from the conical flask to an evaporating basin and obtains dry crystals.

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

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(.....) + ...(.....)$$

[2]

(b) State the type of exothermic reaction taking place.

..... [1]

(c) Calculate the concentration of NaOH(aq) used in **step 1**.

concentration of NaOH(aq) = ... mol / dm^3 [1]

(d) Name the item of apparatus the student uses to add $H_2SO_4(aq)$ in **step 3**.

..... [1]

(e) Calculate the volume of $H_2SO_4(aq)$, in cm^3, added in **step 3**.

volume of $H_2SO_4(aq)$ = ... cm^3 [2]

(f) State the colour change observed in **step 3**.

from ..... to ..... [2]

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(g) The dry crystals formed in **step 4** are coloured and **not** white. 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 to produce white crystals.

.....

..... [1]

(h) In **step 4**, the student gently heats the solution in the evaporating basin until the solution is saturated. The student then stops heating and leaves the hot solution to cool. Crystals start to appear.

(i) Explain the term saturated solution.

.....

.....

..... [2]

(ii) Explain why crystals start to appear as the hot solution cools.

.....

..... [1]

(iii) Suggest the effect, if any, on the mass of crystals collected in **step 4** if the solution in the evaporating basin is allowed to dry without gentle heating.

..... [1]

[Total: 14]

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4 Gaseous sulfur tetrafluoride, SF_4, reacts with steam in a reversible reaction.

$$SF_4(g) + 2H_2O(g) \rightleftharpoons SO_2(g) + 4HF(g) \qquad \Delta H = -54\,kJ/mol$$

(a) Complete the reaction pathway diagram in Fig. 4.1 for this reaction.

Include in your diagram:

- the position and the formulae of the products
- an arrow, labelled E_a, to show the activation energy
- an arrow, labelled ΔH, to show the enthalpy change of the reaction.

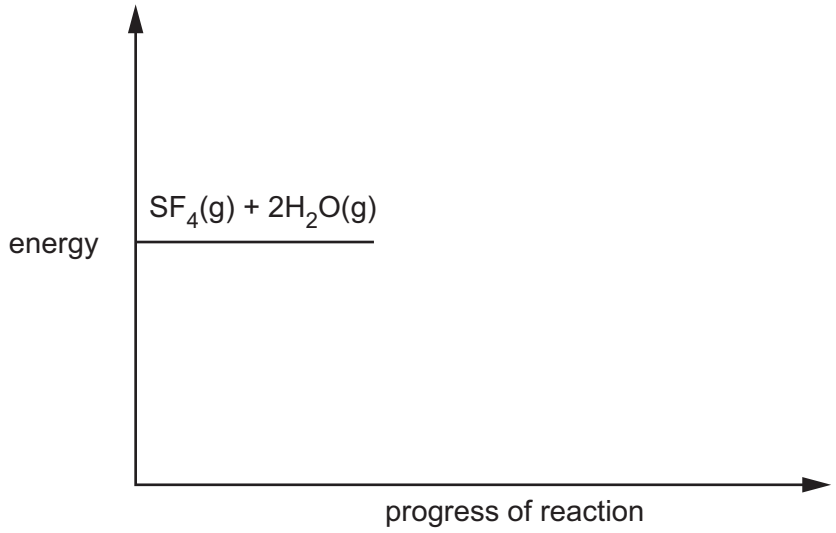


Fig. 4.1

[4]

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(b) The equation for the reaction can be represented as shown in Fig. 4.2.

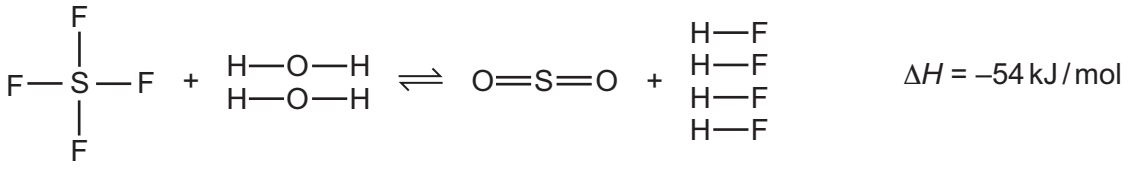


Fig. 4.2

Table 4.1 shows some bond energies.

Table 4.1

bond	S–F	O–H	H–F
bond energy in kJ / mol	330	460	570

Use the bond energies in Table 4.1 and the value of ΔH of the reaction to calculate the S=O bond energy in kJ / mol.

Use the following steps.

- Calculate the energy needed to break the bonds in the reactants.

..... kJ

- Calculate the energy released when the bonds in the products form.

..... kJ

- Calculate the S=O bond energy.

..... kJ / mol
[4]

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(c) The equation for the reaction is shown.

$$SF_4(g) + 2H_2O(g) \rightleftharpoons SO_2(g) + 4HF(g) \qquad \Delta H = -54\,kJ/mol$$

State the effect, if any, on the position of equilibrium when the following changes are made.

Give a reason for each of your answers.

- The temperature is increased.

.....

.....

- The pressure is increased.

.....

.....

- A catalyst is added.

.....

.....

[5]

(d) Explain, in terms of collision theory, why reducing the temperature decreases the rate of the reverse reaction.

.....

.....

.....

.....

..... [3]

[Total: 16]

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Question 5 starts on the next page.

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5 This question is about the homologous series of alcohols.

(a) A homologous series is a family of organic compounds whose members have the same general formula.

(i) State the general formula for alcohols.

..... [1]

(ii) Give **one other** characteristic that is the same for all members of a homologous series.

..... [1]

(b) Ethanol can be manufactured by two methods:

- **method 1** uses glucose as the starting material
- **method 2** uses ethene as the starting material.

(i) Complete Table 5.1.

Table 5.1

	method 1 glucose as starting material	**method 2** ethene as starting material
typical temperature used / °C		
two other essential conditions	1	1
	2	2

[6]

(ii) Write the symbol equation for the reaction in **method 1**.

..... [2]

(iii) Write the symbol equation for the reaction in **method 2**.

..... [2]

(c) Butane-1,4-diol has the structural formula HO—CH_2—CH_2—CH_2—CH_2—OH.

(i) Deduce the molecular formula of butane-1,4-diol.

..... [1]

(ii) Butane-1,4-diol reacts with ethanoic acid.

Determine the number of moles of ethanoic acid which react fully with **one** mole of butane-1,4-diol.

..... [1]

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(d) Butanedioic acid has the structural formula HOOC—CH_2—CH_2—COOH.

(i) Deduce the empirical formula of butanedioic acid.

..... [1]

(ii) Name the gas formed when butanedioic acid reacts with sodium.

..... [1]

(e) Butane-1,4-diol can be represented as shown.



Butanedioic acid can be represented as shown.



Butane-1,4-diol reacts with butanedioic acid to form a polymer.

(i) Draw **two** repeat units of the polymer formed from the reaction of butane-1,4-diol with butanedioic acid.

Show all the atoms and all the bonds in the ester linkages.

[3]

(ii) State the type of polymerisation when butane-1,4-diol reacts with butanedioic acid.

..... [1]

[Total: 20]

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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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