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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

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CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **February/March 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 60.
- The number of marks for each question or part question is shown in brackets [ ].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

This document has **12** pages.

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[Turn over

1 Phosphorus and chlorine are elements in Period 3 of the Periodic Table.

(a) Chlorine forms three different compounds with phosphorus.

The most common compounds are PCl_3 and PCl_5.

(i) Complete Table 1.1.

Table 1.1

compound	oxidation number of P	oxidation number of Cl
PCl_3		
PCl_5		

[2]

(ii) In a closed system, PCl_3 and PCl_5 exist in an equilibrium mixture as shown in reaction 1.

reaction 1 $PCl_3(l) + Cl_2(g) \rightleftharpoons PCl_5(s)$ $\Delta H = -124\,kJ\,mol^{-1}$

Deduce **two** conditions that favour the production of PCl_5 in reaction 1.

1 .....

2 .....

[2]

(iii) The third compound of phosphorus and chlorine, **W**, has a relative molecular mass, M_r, between that of PCl_3 and PCl_5. The compound contains 69.6% by mass of chlorine.

Determine the molecular formula of **W**.

molecular formula of **W** = ... [2]

(iv) **W** is a liquid at room temperature and pressure. It reacts vigorously with water to form an acidic solution.

Suggest the structure and bonding in **W**. Explain your answer.

.....

.....

..... [2]

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(b) Fig. 1.1 shows a reaction scheme involving P_4 and Cl_2.

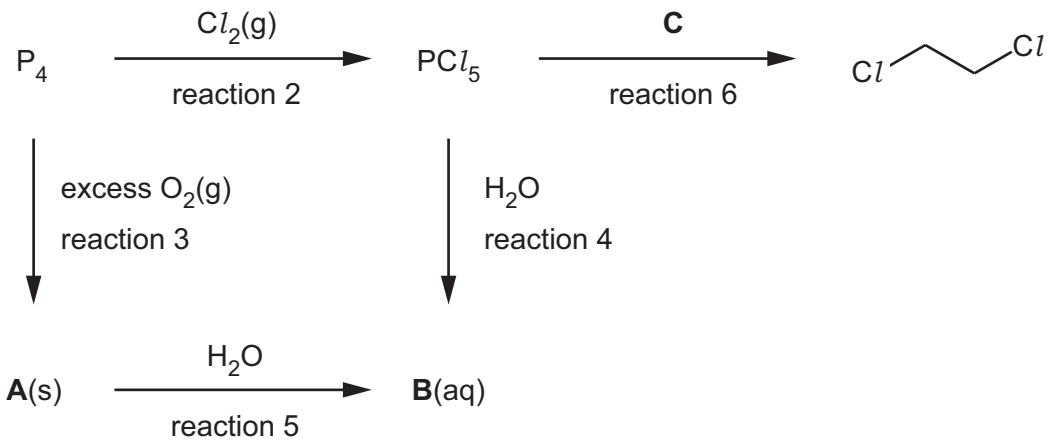

Fig. 1.1

(i) Suggest what is observed in reaction 2.

..... [1]

(ii) Predict the shape of a molecule of PCl_5.

..... [1]

(iii) Write an equation for the formation of **A** in reaction 3.

..... [1]

(iv) Name **B**, which is formed in both reactions 4 and 5.

..... [1]

(v) Draw the structure of **C**, used in reaction 6.

[1]

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(c) 1,2-dichloroethane, $ClCH_2CH_2Cl$, reacts with NaOH to produce an unsaturated compound, C_2H_3Cl, as shown in reaction 7.

reaction 7 $\quad ClCH_2CH_2Cl + NaOH \rightarrow C_2H_3Cl + H_2O + NaCl$

(i) State what is meant by unsaturated.

.....

..... [1]

(ii) State the conditions for reaction 7.

..... [1]

(d) Compound **D** contains carbon, hydrogen and chlorine **only**.

Fig. 1.2 shows the mass spectrum of **D**.

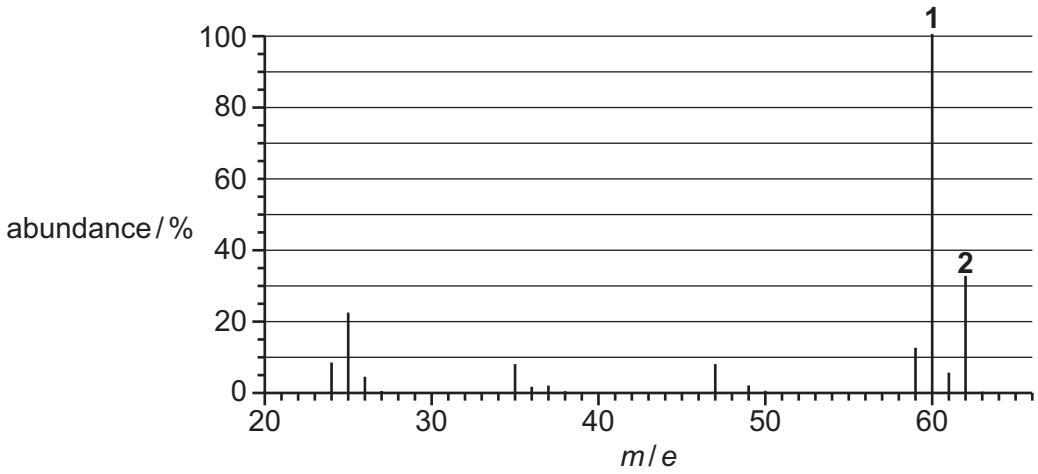

Fig. 1.2

(i) Explain the relative abundance of peaks **1** and **2** in the mass spectrum in Fig. 1.2.

.....

..... [1]

(ii) Suggest the structure of **D**.

[1]

[Total: 17]

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2 **(a)** The Group 2 elements show metallic bonding.

Define metallic bonding.

.....

..... [2]

(b) The Group 2 elements form stable 2+ cations.

(i) State and explain the variation in ionic radius of the Group 2 elements down the group.

.....

.....

.....

..... [2]

(ii) Table 2.1 shows successive ionisation energy values for beryllium, Be.

Table 2.1

	1st	2nd	3rd	4th
ionisation energy / kJ mol^{-1}	900	1760	14 800	21 000

Use Table 2.1 to state and explain:

- the general trend in these values
- the significance of the large difference between the 2nd and 3rd ionisation energies.

.....

.....

.....

..... [2]

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(c) All the Group 2 elements except beryllium have more than one stable isotope.

(i) Beryllium exists as the single isotope $^{9}_{4}Be$.

Describe the distribution of mass within an atom of $^{9}_{4}Be$.

.....

.....

.....

..... [2]

(ii) Complete Table 2.2 to show the numbers of protons and neutrons in the isotopes of magnesium.

Table 2.2

isotope	number of protons	number of neutrons
magnesium-24		
magnesium-25		
magnesium-26		

[2]

(iii) Fig. 2.1 shows the behaviour of a beam of protons in an electric field.

Complete Fig. 2.1 to show the behaviour of separate beams of neutrons and electrons in the same electric field.

Label your diagram clearly. Assume that the beams of each particle are moving at the same velocity.

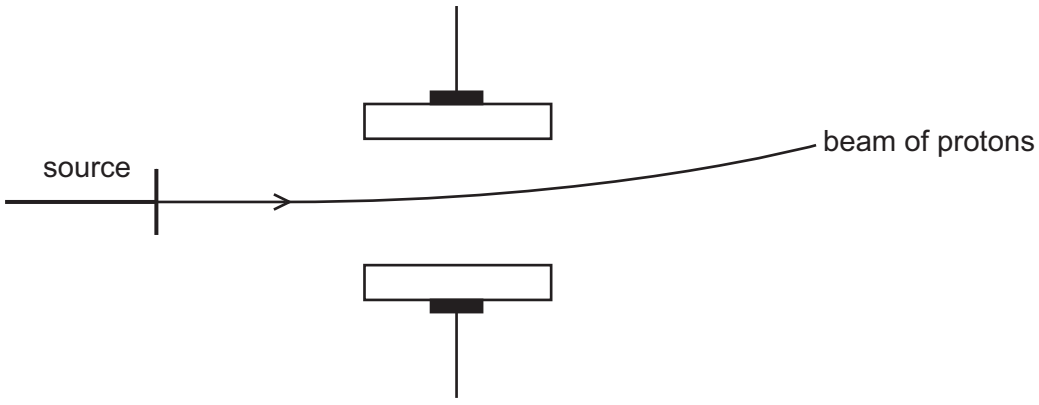

Fig. 2.1

[3]

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(d) (i) State what is observed when dilute hydrochloric acid is added to separate samples of barium oxide and barium carbonate.

barium oxide .....

barium carbonate .....

[2]

(ii) Write an equation for the reaction of strontium, Sr, with an excess of cold water.

..... [1]

(iii) State the variation in solubility of the Group 2 sulfates down the group.

..... [1]

[Total: 17]

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3 The halogens chlorine, bromine and iodine show trends in chemical and physical properties down the group.

Table 3.1 shows some properties of chlorine, bromine and iodine.

Table 3.1

property	chlorine	bromine	iodine
colour and state at room temperature	green gas		
bond energy / kJ mol^{-1}	242	193	151
electronegativity	3.0	2.8	2.5
formula of sodium halide	NaCl	NaBr	NaI

(a) (i) Complete Table 3.1. [1]

(ii) The bond energy values in Table 3.1 refer to the X—X bond where X is the halogen.

Explain the trend in the bond strength of the X—X bond in the halogens.

.....

.....

..... [2]

(b) Explain, with the use of an equation, how chlorine, Cl_2, is used in water purification. State the role of the active species produced.

.....

.....

..... [2]

(c) The sodium halides in Table 3.1 also show trends in chemical properties.

(i) Identify the sodium halide that reacts with concentrated H_2SO_4 to form H_2S.

..... [1]

(ii) Identify the sodium halide that **only** undergoes a Brønsted–Lowry acid–base reaction with concentrated H_2SO_4.

..... [1]

(iii) A student adds a few drops of $AgNO_3$(aq) to a solution of NaBr(aq). State what is observed.

.....

..... [1]

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(d) Iodine monobromide, IBr, is a dark red solid that melts near room temperature.

IBr reacts with propene. The mechanism for this reaction is the same as the mechanism for that of HBr with propene.

(i) Identify **all** the intermolecular forces that exist between molecules of IBr.

.....

..... [1]

(ii) Name the mechanism involved in the reaction of IBr with propene.

..... [1]

(iii) The reaction of IBr with propene forms two structural isomers.

Draw the **two** structural isomers shown by these molecules.

[2]

(iv) Identify the type of structural isomerism shown by the molecules in **(d)(iii)**.

..... [1]

(v) Explain why the two structural isomers do **not** form in equal amounts.

.....

.....

..... [2]

[Total: 15]

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4 Fig. 4.1 shows compounds **J** to **M**, each of which contains four carbon atoms.

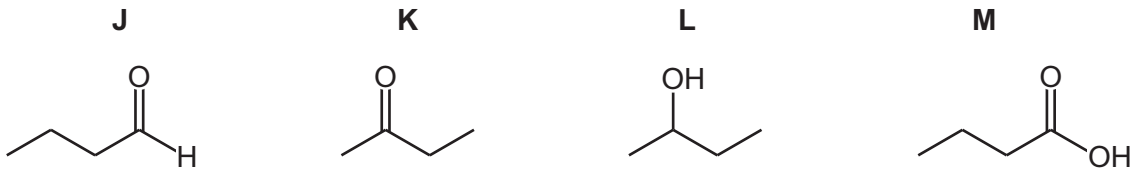

Fig. 4.1

(a) Table 4.1 gives details of tests on **J** to **M**. In each test, only **two** compounds give a positive result.

Complete Table 4.1.

Table 4.1

reagent	observation of positive result	compounds that give a positive result
acidified $K_2Cr_2O_7$(aq)		**J** and **L**
alkaline I_2(aq)	yellow precipitate	
	orange precipitate	**J** and **K**
Na(s)		

[5]

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(b) **K** reacts with HCN in the presence of a KCN catalyst, forming **N**.

(i) Complete Fig. 4.2 to show the mechanism for this reaction.

Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.



Fig. 4.2

[4]

(ii) Identify the class of compound of which **N** is a member.

..... [1]

(iii) **N** has a chiral centre.

Explain what is meant by a chiral centre.

.....

.....

..... [1]

[Total: 11]

Important values, constants and standards

molar gas constant	$R = 8.31\,\text{J K}^{-1}\,\text{mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^{4}\,\text{C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23}\,\text{mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\,\text{C}$
molar volume of gas	$V_m = 22.4\,\text{dm}^3\,\text{mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,\text{dm}^3\,\text{mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,\text{mol}^2\,\text{dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,\text{kJ kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J g}^{-1}\,\text{K}^{-1}$)

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The Periodic Table of Elements

Group																	
1	2											13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0											5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	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 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	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 –

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