Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Monday 12 May 2025

Morning (Time: 1 hour 30 minutes)

Paper reference **WCH12/01**

Chemistry

International Advanced Subsidiary/Advanced Level
UNIT 2: Energetics, Group Chemistry, Halogenoalkanes and Alcohols

You must have:
Scientific calculator, Data Booklet

Total Marks

Instructions:

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*

Information:

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- In the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice:

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶

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Pearson

SECTION A

Answer ALL the questions in this section.

You should aim to spend no more than 20 minutes on this section.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1: 25 cm^3 of sodium hydroxide solution, of concentration 2.00 mol dm^{-3}, was added to 30 cm^3 of ethanoic acid solution, of concentration 1.00 mol dm^{-3}, in a polystyrene cup. The mixture was stirred, causing the temperature to increase by 6.5 °C.

(a) What is the expression for the enthalpy change of neutralisation of sodium hydroxide and ethanoic acid, in J mol^{-1}?

[Assume: the specific heat capacity of the mixture = 4.18 J g^{-1} $°C^{-1}$
the density of the mixture = 1.00 g cm^{-3}]

(1)

☒ **A** $-(25 \times 4.18 \times 6.5) \div 0.05$

☒ **B** $-(30 \times 4.18 \times 6.5) \div 0.03$

☒ **C** $-(55 \times 4.18 \times 6.5) \div 0.05$

☒ **D** $-(55 \times 4.18 \times 6.5) \div 0.03$

(b) The measurement uncertainty in the thermometer used in the experiment is ±0.5 °C for each reading.

What is the percentage uncertainty in the temperature change of 6.5 °C?

(1)

☒ **A** 3.8%

☒ **B** 7.7%

☒ **C** 15.4%

☒ **D** 30.8%

(Total for Question 1 = 2 marks)

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2: (a) Methane burns to produce carbon dioxide and water vapour.

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) \qquad \Delta H = -810\,kJ\,mol^{-1}$$

Some bond enthalpy data are shown.

Bond	Bond enthalpy / kJ mol^{-1}
C — H	413
O = O	498
O — H	464

What is the mean bond enthalpy for the C = O bond, in kJ mol^{-1}?

(1)

☒ **A** 552

☒ **B** 801

☒ **C** 1016

☒ **D** 1265

(b) A data book value for the standard enthalpy change of combustion of methane is –890 kJ mol^{-1}.

What is the experimental value for the enthalpy change of vaporisation of water in kJ mol^{-1}?

$$H_2O(l) \rightarrow H_2O(g)$$

(1)

☒ **A** –40

☒ **B** +40

☒ **C** –80

☒ **D** +80

(Total for Question 2 = 2 marks)

3: Which amine, with molecular formula C_3H_9N, has the **lowest** boiling temperature?

☒ **A** $(CH_3)_3N$

☒ **B** $CH_3CH_2NHCH_3$

☒ **C** $CH_3CH_2CH_2NH_2$

☒ **D** $CH_3CH(NH_2)CH_3$

(Total for Question 3 = 1 mark)

4: An aqueous solution of potassium chloride is added to a solution of iodine in hexane and shaken. After a time, two layers are formed.

What is the colour of each layer?

	Upper layer	Lower layer
☒ **A**	purple	yellow
☒ **B**	yellow	purple
☒ **C**	purple	colourless
☒ **D**	colourless	purple

(Total for Question 4 = 1 mark)

5: Which is the correct order of **increasing** oxidation number of nitrogen in NO, NO_3^- and NH_3?

☒ **A** NH_3 NO NO_3^-

☒ **B** NH_3 NO_3^- NO

☒ **C** NO NH_3 NO_3^-

☒ **D** NO_3^- NH_3 NO

(Total for Question 5 = 1 mark)

6: The most common sources of iodine contain the iodate ion IO_3^-.
Iodate ions react with iodide ions in acidic conditions as shown.

$$5I^- + IO_3^- + 6H^+ \rightarrow 3I_2 + 3H_2O$$

The forward reaction is best described as

☒ **A** disproportionation

☒ **B** neutralisation

☒ **C** oxidation

☒ **D** redox

(Total for Question 6 = 1 mark)

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7: Which electron movement causes the yellow colour produced in a sodium chloride flame test?

- ☒ **A** addition of an electron to a sodium ion
- ☒ **B** an electron moving from a 3p to a 3s orbital
- ☒ **C** an electron moving from a 3s to a 3p orbital
- ☒ **D** removal of an electron from a sodium atom

(Total for Question 7 = 1 mark)

8: 20 g of an impure sample of calcium carbonate is heated and decomposes completely.
3.6 dm^3 of carbon dioxide is produced at room temperature and pressure (r.t.p.).

What is the percentage purity of the sample?
Assume that the impurities do not produce carbon dioxide when heated.

[M_r $CaCO_3$ = 100 molar volume of a gas = 24 dm^3 mol^{-1} at r.t.p.]

- ☒ **A** 15%
- ☒ **B** 20%
- ☒ **C** 25%
- ☒ **D** 75%

(Total for Question 8 = 1 mark)

9: In an experiment to measure the rate of reaction, a sample of magnesium ribbon, of mass 0.24 g, was added to 25 cm^3 sulfuric acid, of concentration 1.00 mol dm^{-3}.

In a second experiment, a sample of magnesium **powder**, of mass 0.24 g, was added to 50 cm^3 sulfuric acid of the same concentration.

What are the expected differences in observations in the second experiment?

	Rate of reaction	Total volume of hydrogen produced
☒ **A**	no change	no change
☒ **B**	no change	increases
☒ **C**	increases	no change
☒ **D**	increases	increases

(Total for Question 9 = 1 mark)

10: Which change increases the proportion of particles in a reaction that have sufficient energy to react?

- ☒ **A** an increase in reaction temperature
- ☒ **B** a decrease in reaction temperature
- ☒ **C** an increase in reactant concentration
- ☒ **D** a decrease in reactant concentration

(Total for Question 10 = 1 mark)

11: In the production of sulfuric acid, sulfur(IV) oxide reacts with oxygen to form sulfur(VI) oxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

In a closed system, the mixture is allowed to reach equilibrium.

(a) Which of the following statements must be correct?

(1)

- ☒ **A** the reactions stop
- ☒ **B** the sum of the masses of sulfur(IV) oxide and oxygen is equal to the mass of sulfur(VI) oxide
- ☒ **C** the rate of formation of sulfur(VI) oxide is equal to the rate of its decomposition
- ☒ **D** the concentration of sulfur(IV) oxide is equal to the concentration of sulfur(VI) oxide

(b) How does the use of a catalyst affect the equilibrium?

(1)

- ☒ **A** only the rate of the forward reaction increases
- ☒ **B** the position of equilibrium moves to the right
- ☒ **C** the position of equilibrium moves to the left
- ☒ **D** there is no effect on the position of equilibrium

(Total for Question 11 = 2 marks)

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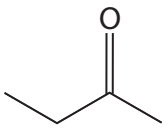
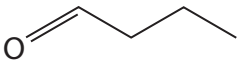
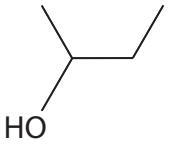
12: This question is about organic compounds containing four carbon atoms.



butanone



butanal



butan-2-ol

methylpropan-2-ol

(a) Which compound has peaks in its mass spectrum at *m/z* 74 and 45?

(1)

- ☒ **A** butanone
- ☒ **B** butanal
- ☒ **C** butan-2-ol
- ☒ **D** methylpropan-2-ol

(b) Which compound can be oxidised to form a ketone?

(1)

- ☒ **A** butanone
- ☒ **B** butanal
- ☒ **C** butan-2-ol
- ☒ **D** methylpropan-2-ol

(c) Which compound forms a red precipitate when warmed with Fehling's solution?

(1)

- ☒ **A** butanone
- ☒ **B** butanal
- ☒ **C** butan-2-ol
- ☒ **D** methylpropan-2-ol

(Total for Question 12 = 3 marks)

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13: Halogenoalkanes, R—X, react when warmed with aqueous silver nitrate in the presence of ethanol.
The rates of reaction of 1-chlorobutane, 1-bromobutane and 1-iodobutane were compared.

(a) The rate was fastest for 1-iodobutane and slowest for 1-chlorobutane.

Which is the **best** explanation for this result?

(1)

- ☒ **A** the bond strength of the hydrogen halide molecule decreases going down the group
- ☒ **B** the carbon-halogen bond polarity decreases going down the group
- ☒ **C** the first ionisation energy of the halogen decreases going down the group
- ☒ **D** the carbon-halogen bond strength decreases going down the group

(b) What is observed when 1-bromobutane is warmed with aqueous silver nitrate in the presence of ethanol?

(1)

- ☒ **A** an orange solution
- ☒ **B** a cream precipitate soluble in dilute aqueous ammonia
- ☒ **C** a cream precipitate insoluble in dilute aqueous ammonia
- ☒ **D** a yellow precipitate insoluble in dilute aqueous ammonia

(c) What is the mechanism of these hydrolysis reactions to form alcohols?

(1)

- ☒ **A** electrophilic addition
- ☒ **B** elimination
- ☒ **C** free radical substitution
- ☒ **D** nucleophilic substitution

(Total for Question 13 = 3 marks)

TOTAL FOR SECTION A = 20 MARKS

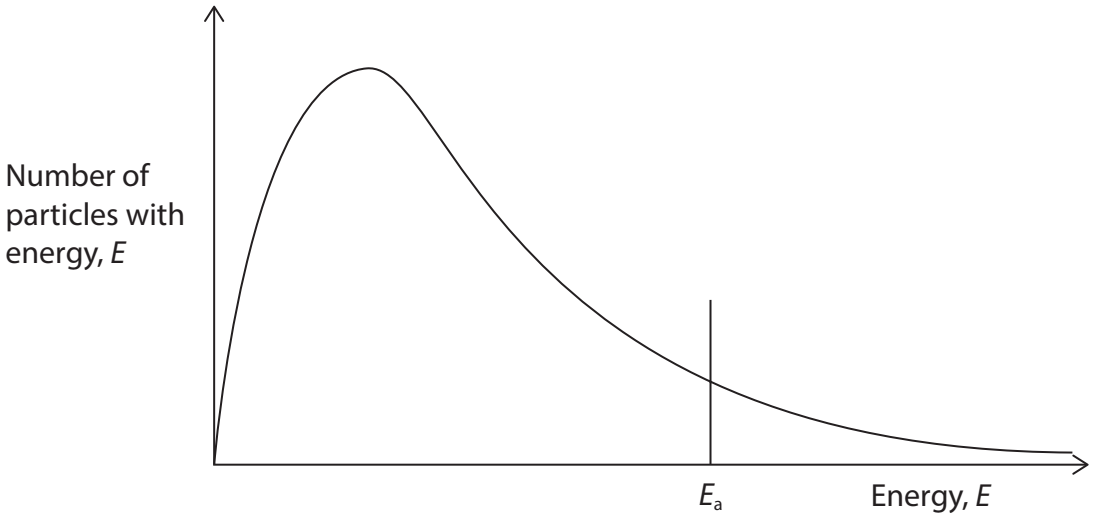
SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

14: This question is about nitrogen, hydrogen and their compounds.

(a) Ammonia is produced in the Haber process.
Nitrogen and hydrogen react at a pressure of 200 atmospheres and a temperature of 725 K, using an iron catalyst.

Explain how a catalyst increases the rate of a chemical reaction, using the Maxwell–Boltzmann distribution shown, and the collision theory.



(3)

(b) Storing and transporting hydrogen can be difficult due to its low energy density.

This has led to the use of various hydrides which contain a high proportion of hydrogen and are easier to liquefy and transport.

(i) Explain the differences in the boiling temperatures of the Group 5 hydrides shown.
Detailed descriptions of the intermolecular forces are not required.

Hydride	Boiling temperature / K
NH_3	240
PH_3	186
AsH_3	212
SbH_3	256

(4)

(ii) Hydrogen has been proposed as an alternative fuel to petrol.
Explain why hydrogen is a more environmentally friendly fuel than alkanes.

(3)

(c) Ethylamine may be prepared from the reaction between ammonia and bromoethane.

(i) State the conditions for this reaction.

(2)

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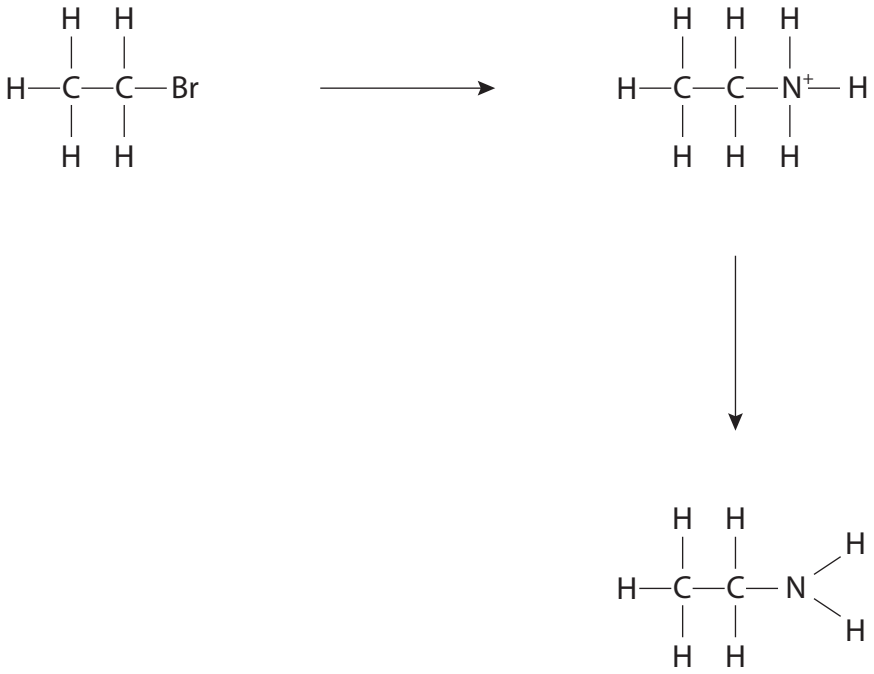
(ii) Complete the mechanism for this reaction.
Include curly arrows, and relevant dipoles and lone pairs.

(3)



(iii) Further substitution of the ethylamine molecule may occur if the halogenoalkane is in excess.
State **two** features of the ethylamine molecule that make this possible.

(2)

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(Total for Question 14 = 17 marks)

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15: This question is about the reactions of some elements in Group 7.

(a) When chlorine water is added to a solution of potassium bromide, a pale brown colour is seen.

Write an ionic equation for this reaction.
State symbols are not required.

(1)

(b) Chlorine is used to treat drinking water.

$$Cl_2(g) + H_2O(l) \rightleftharpoons HClO(aq) + HCl(aq)$$

By considering oxidation numbers, show that this equation represents a disproportionation reaction.

(2)

(c) Concentrated sulfuric acid, H_2SO_4, reacts with solid potassium halides. Some observations are shown in the table.

Halide	Observations
Potassium chloride	Misty fumes
Potassium bromide	Misty fumes and brown vapour
Potassium iodide	Misty fumes and purple vapour

(i) The equation for the reaction of concentrated sulfuric acid with potassium chloride is shown.

$$H_2SO_4 + KCl \rightarrow HCl + KHSO_4$$

State why this is **not** a redox reaction.

(1)

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(ii) The half-equation for the oxidation of iodide ions is shown.

$$2I^- \rightarrow I_2 + 2e^-$$

The half-equation for the reduction of concentrated sulfuric acid to hydrogen sulfide is shown.

$$8H^+ + H_2SO_4 + 8e^- \rightarrow H_2S + 4H_2O$$

Deduce the ionic equation for the reaction between iodide ions and concentrated sulfuric acid by combining these two half-equations.

(1)

(iii) Explain the difference in the reaction of concentrated sulfuric acid with chloride ions and with iodide ions.

(2)

(Total for Question 15 = 7 marks)

16: This question is about secondary alcohols.

(a) Give a chemical test, including the result, to show that alcohols contain an OH group.

(2)

.....

.....

.....

(b) A sample of cyclohexanol contains 7.13 g of carbon, 1.19 g of hydrogen and 1.58 g of oxygen.
Show that this data is consistent with the empirical formula $C_6H_{12}O$.

(2)

(c) Cyclohexanol can be converted to cyclohexanone.

(i) Name the reagents and conditions for this conversion.

(2)

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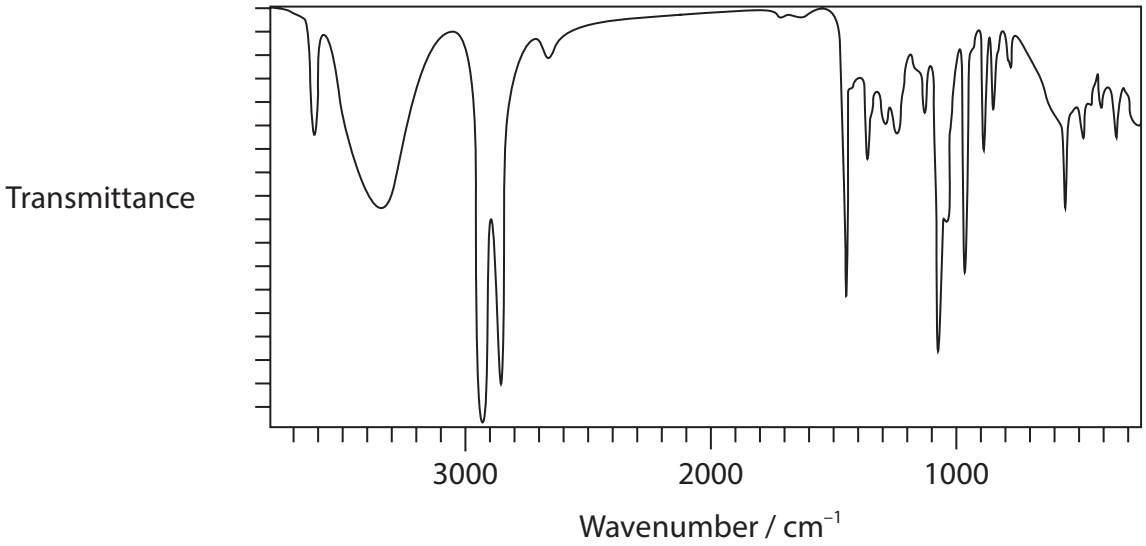
(ii) The infrared spectrum of cyclohexanol is shown.



Describe **two** differences, other than the fingerprint region, that would be expected in the infrared spectrum of cyclohexanone.

(2)

(iii) Give a reason why cyclohexanol and cyclohexanone can be separated by fractional distillation but not by simple distillation.

(1)

*(d) Discuss the reactions between sodium hydroxide and 2-chlorobutane.

The hydroxide ion acts in **two** different ways depending on the reaction conditions.

Include the structures of **four** possible products, the reaction conditions needed and the roles of the hydroxide ion.

Detailed mechanisms are not required.

(6)

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(Total for Question 16 = 15 marks)

TOTAL FOR SECTION B = 39 MARKS

SECTION C

Answer ALL the questions. Write your answers in the spaces provided.

17: Magnesium carbonate has been studied recently as a potential material for the removal of carbon dioxide from the atmosphere.

(a) The value of n in a sample of a hydrated magnesium carbonate, $MgCO_3 \cdot nH_2O$, can be determined by the reaction with hydrochloric acid.
The equation for the reaction is shown.

$$MgCO_3 \cdot nH_2O(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + CO_2(g) + (n+1)H_2O(l)$$

Procedure Step **1** Add 0.0600 mol of hydrochloric acid (an excess) to a 2.35 g sample of the hydrated magnesium carbonate.

Step **2** When the reaction is complete, transfer the resulting solution to a 250 cm^3 volumetric flask, make up to the mark with deionised water, and mix thoroughly.

Step **3** Titrate 25.0 cm^3 portions of the solution with sodium hydroxide solution of concentration 0.0960 mol dm^{-3}.

Data The mean titre volume = 27.15 cm^3

Determine the value of n in the hydrated salt.

(7)

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(b) The enthalpy change for the thermal decomposition of anhydrous magnesium carbonate, $\Delta_r H$, was measured indirectly using the enthalpy changes for the two reactions shown and applying Hess's Law.

Reaction **1**

$MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$ $\Delta_r H_1$

Reaction **2**

$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$ $\Delta_r H_2 = +3.58\,kJ\,mol^{-1}$

An experiment was carried out to measure the enthalpy change of reaction, $\Delta_r H_1$, for Reaction **1**.

1.92 g of magnesium oxide was added, with stirring, to 40.0 cm^3 dilute hydrochloric acid (an excess) in an insulated container. The temperature rise was 30.8 °C.

(i) Calculate $\Delta_r H_1$ for Reaction **1**. Include a sign and units in your answer.

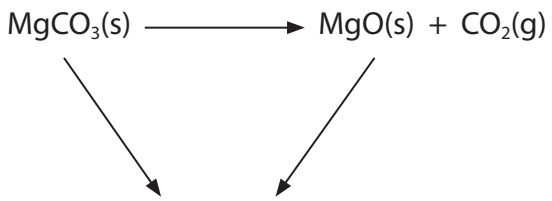
[Assume the specific heat capacity of the solution = 4.18 $J\,g^{-1}\,°C^{-1}$
the density of the solution = 1.00 $g\,cm^{-3}$]

(3)

(ii) The enthalpy change of decomposition, $\Delta_r H$, of magnesium carbonate can be found using a Hess cycle.
Calculate the enthalpy change of decomposition by using a completed Hess cycle, your answer to (b)(i) and the enthalpy change of reaction for Reaction **2**.

Give your answer to an appropriate number of significant figures.

(3)



(iii) Give a reason why it is not possible to measure the enthalpy change for the decomposition directly.

(1)

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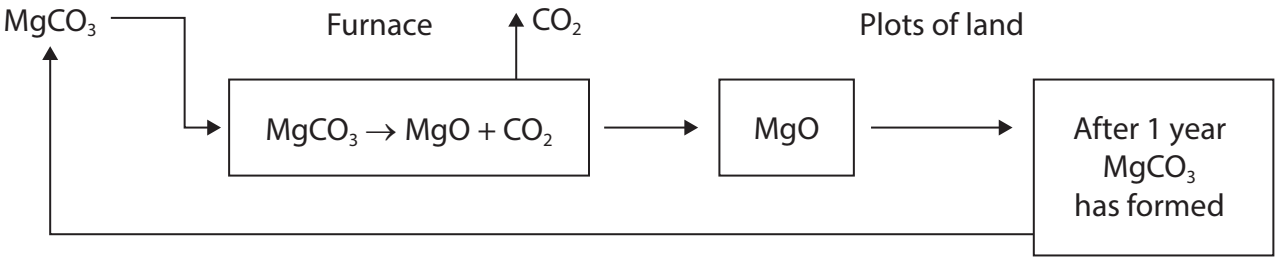
(c) The steps involved in using magnesium carbonate ore in a process to capture carbon dioxide from the air are shown.



- the magnesium carbonate ore is heated in a furnace and decomposes and the carbon dioxide produced is stored
- the magnesium oxide produced is transported to plots of land where it is spread to a depth of 0.1 m and reacts with carbon dioxide over a year
- the magnesium carbonate formed is then returned to the furnace and the process repeated.

Heating the furnace to decompose the magnesium carbonate accounts for most of the energy requirements of the process.

(i) Explain, with reference to the thermal stability of the Group 2 carbonates, why the use of calcium carbonate rather than magnesium carbonate would increase the cost of the process.

(3)

(ii) Methanol can be produced from the captured carbon dioxide by reaction with hydrogen using a copper catalyst.
The equation for the reaction is shown.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g) \qquad \Delta H = -49.5\ kJ\ mol^{-1}$$

Explain why the conditions for the industrial production of methanol are a pressure of 50 atmospheres and a temperature of 250 °C.

(4)

(Total for Question 17 = 21 marks)

TOTAL FOR SECTION C = 21 MARKS
TOTAL FOR PAPER = 80 MARKS

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The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
							1.0 H hydrogen 1										(18) 4.0 He helium 2
(1)	(2)		Key									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4		relative atomic mass atomic symbol name atomic (proton) number									10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series

* Actinide series

140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103