Please check the examination details below before entering your candidate information

| Candidate surname | Other names |
|---|---|
| | |

Centre Number | Candidate Number

# Pearson Edexcel International Advanced Level

**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, ruler

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

*Turn over* ▶

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P 7 1 8 7 6 A 0 1 2 8

Pearson

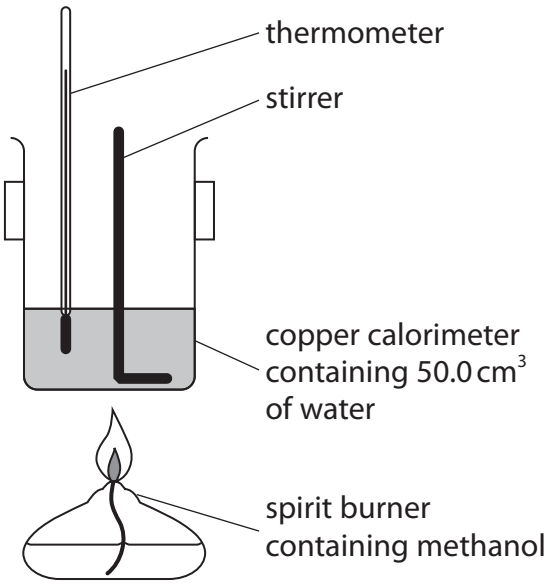
## SECTION A

**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** A student measures the enthalpy change of combustion, $\Delta_c H$, of methanol, $CH_3OH$, using the apparatus shown.




After burning 0.20 g of methanol, the temperature of the water increases by 16.0 °C.

(a) 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 16.0 °C?

**(1)**

☒ **A** 1.6%

☒ **B** 3.1%

☒ **C** 6.3%

☒ **D** 12.5%

(b) The student repeats the experiment but burns 0.30 g of methanol and uses 75.0 $cm^3$ of water in the copper calorimeter.

What is the expected temperature change in this repeat experiment?

**(1)**

- ☒ **A** 7.1 °C
- ☒ **B** 10.7 °C
- ☒ **C** 16.0 °C
- ☒ **D** 36.0 °C

(c) The student's calculated enthalpy change of combustion of methanol is **more** exothermic than a data book value.

What is a possible reason for this?

**(1)**

- ☒ **A** heat loss to the surroundings
- ☒ **B** incomplete combustion of methanol
- ☒ **C** evaporation of methanol from the wick of the spirit burner
- ☒ **D** use of the molar mass of ethanol, $C_2H_5OH$, in the calculation

**(Total for Question 1 = 3 marks)**

**2** Which equation represents the standard enthalpy change of atomisation, $\Delta_{at}H^{\ominus}$, of bromine?

- ☒ **A** $\frac{1}{2}Br_2(l) \rightarrow Br(g)$
- ☒ **B** $\frac{1}{2}Br_2(g) \rightarrow Br(g)$
- ☒ **C** $Br_2(l) \rightarrow 2Br(g)$
- ☒ **D** $Br_2(g) \rightarrow 2Br(g)$

**(Total for Question 2 = 1 mark)**

**Use this space for any rough working. Anything you write in this space will gain no credit.**

**3** The enthalpy change of reaction, $\Delta_r H$, for the equation shown can be calculated using bond enthalpy data.

$$\tfrac{1}{2}H_2(g) + \tfrac{1}{2}Cl_2(g) \rightarrow HCl(g)$$

| Bond | Bond enthalpy / kJ mol$^{-1}$ |
|---|---|
| H—H | 436 |
| Cl—Cl | 242 |
| H—Cl | 431 |

The expression that should be used in the calculation is

☒ **A** $(0.5 \times 436 + 0.5 \times 242) - 431$

☒ **B** $(2 \times 431) - (436 + 242)$

☒ **C** $431 - (0.5 \times 436 + 0.5 \times 242)$

☒ **D** $(436 + 242) - (2 \times 431)$

**(Total for Question 3 = 1 mark)**

**4** Which compound has London forces as the **only** intermolecular force?

☒ **A** HF

☒ **B** $OF_2$

☒ **C** $PF_3$

☒ **D** $CF_4$

**(Total for Question 4 = 1 mark)**

**Use this space for any rough working. Anything you write in this space will gain no credit.**

**5** Which compound has intermolecular hydrogen bonding?

- ☒ **A** $(CH_3)_3N$
- ☒ **B** $(CH_3)_3CF$
- ☒ **C** $(CH_3)_3COH$
- ☒ **D** $(CH_3)_3CCHO$

**(Total for Question 5 = 1 mark)**

**6** Which sequence shows the hydrogen halides in order of **decreasing** boiling temperature?

- ☒ **A** HF > HCl > HBr > HI
- ☒ **B** HF > HI > HBr > HCl
- ☒ **C** HI > HF > HCl > HBr
- ☒ **D** HI > HBr > HCl > HF

**(Total for Question 6 = 1 mark)**

**7** Which ion contains vanadium with an oxidation number of **+4**?

- ☒ **A** $VO^{2+}$
- ☒ **B** $VO_2^+$
- ☒ **C** $VO_3^-$
- ☒ **D** $VO_4^{3-}$

**(Total for Question 7 = 1 mark)**

**8** What is the formula of potassium manganate(VI)?

- ☒ **A** $KMnO_4$
- ☒ **B** $K_2MnO_4$
- ☒ **C** $K_3MnO_4$
- ☒ **D** $K_6Mn_2O_6$

**(Total for Question 8 = 1 mark)**

**Use this space for any rough working. Anything you write in this space will gain no credit.**

**9** Compound **Q** produces

- a red colour in a flame test
- a white precipitate when aqueous potassium sulfate is added to a solution of the compound.

What is compound **Q**?

☒ **A** LiCl

☒ **B** $NaNO_3$

☒ **C** $Sr(NO_3)_2$

☒ **D** $BaCl_2$

**(Total for Question 9 = 1 mark)**

**10** Which reaction produces more than one product?

☒ **A** $Mg + O_2 \rightarrow$

☒ **B** $Ca + Cl_2 \rightarrow$

☒ **C** $Sr + H_2O \rightarrow$

☒ **D** $BaO + H_2O \rightarrow$

**(Total for Question 10 = 1 mark)**

**11** Which equation shows a redox reaction that would **not** be expected to occur, based on the trend in reactivity of the halogens?

☒ **A** $I_2(aq) + 2At^-(aq) \rightarrow At_2(aq) + 2I^-(aq)$

☒ **B** $2Br^-(aq) + Cl_2(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$

☒ **C** $Cl_2(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2Cl^-(aq)$

☒ **D** $2F^-(aq) + At_2(aq) \rightarrow 2At^-(aq) + F_2(aq)$

**(Total for Question 11 = 1 mark)**

**Use this space for any rough working. Anything you write in this space will gain no credit.**

**12** A fixed amount of concentrated $H_2SO_4$ is reacted separately with an excess of four solid potassium halides.

In which reaction would the greatest number of moles of halide be oxidised?

- ☒ **A** $2KF(s) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2HF(g)$
- ☒ **B** $KCl(s) + H_2SO_4(aq) \rightarrow KHSO_4(aq) + HCl(g)$
- ☒ **C** $2KBr(s) + 3H_2SO_4(aq) \rightarrow 2KHSO_4(aq) + Br_2(l) + SO_2(g) + 2H_2O(l)$
- ☒ **D** $8KI(s) + 9H_2SO_4(aq) \rightarrow 8KHSO_4(aq) + 4I_2(s) + H_2S(g) + 4H_2O(l)$

**(Total for Question 12 = 1 mark)**

**13** Silver nitrate in aqueous ethanol is added separately to four halogenoalkanes.

Which would form a silver halide precipitate in the **shortest** time?

- ☒ **A** $(CH_3)_3CI$
- ☒ **B** $(CH_3)_3CCl$
- ☒ **C** $CH_3CH_2CH_2CH_2I$
- ☒ **D** $CH_3CH_2CH_2CH_2Cl$

**(Total for Question 13 = 1 mark)**

**14** $CH_3CH_2CHBrCH_2CH_2CH_3$ is heated with ethanolic potassium hydroxide.

How many **alkene** products are possible?

- ☒ **A** one
- ☒ **B** two
- ☒ **C** three
- ☒ **D** four

**(Total for Question 14 = 1 mark)**

**15** Which compound is **least** likely to have a prominent peak at $m/z = 43$ in its mass spectrum?

- ☒ **A** $CH_3COCH_2CH_3$
- ☒ **B** $CH_3CH_2NHCH_3$
- ☒ **C** $CH_3CH(CH_3)_2$
- ☒ **D** $CH_3CH_2CH_2CH_3$

**(Total for Question 15 = 1 mark)**

**16** Which compound has peaks at 3415 $cm^{-1}$ **and** 2250 $cm^{-1}$ in its infrared spectrum?
Refer to the Data Booklet.

☒ **A** $H_2NCH_2CH_2C{\equiv}N$

☒ **B** $CH_3CH_2CH_2COOH$

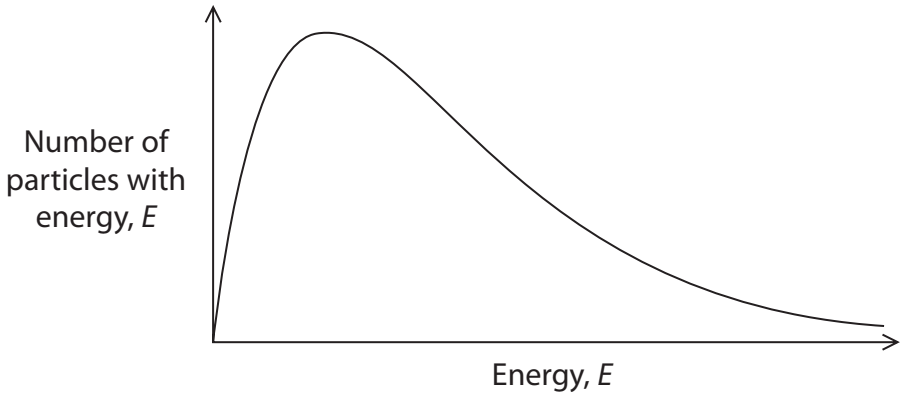
☒ **C** $ClCH_2CH_2C{\equiv}CH$

☒ **D** $HOCH_2CH_2CH{=}CH_2$

**(Total for Question 16 = 1 mark)**

**Use this space for any rough working. Anything you write in this space will gain no credit.**

**17** The distribution of molecular energies for a sample of gas in a sealed container is shown.




(a) Why does the distribution of energies start at the origin, (0,0)?

**(1)**

☒ **A** some molecules have no energy

☒ **B** all molecules possess some energy

☒ **C** the temperature is 0 K

☒ **D** some molecules do not have enough energy to react

(b) Some of the gas is removed and then the container is resealed and the gas is cooled.

How does the new distribution of molecular energies compare to the original sample?

**(1)**

| | Area under the curve | Position of peak |
|---|---|---|
| ☒ **A** | does not change | shifts to the left |
| ☒ **B** | decreases | shifts to the left |
| ☒ **C** | does not change | shifts to the right |
| ☒ **D** | decreases | shifts to the right |

**(Total for Question 17 = 2 marks)**

**TOTAL FOR SECTION A = 20 MARKS**

## SECTION B

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

**18** Calcium hypochlorite, $Ca(ClO)_2$, is used for water treatment in swimming pools. It is produced in the reaction between $Ca(OH)_2$ and $Cl_2$.

$$2Ca(OH)_2(aq) + 2Cl_2(g) \rightarrow Ca(ClO)_2(aq) + CaCl_2(aq) + 2H_2O(l)$$

(a) State the type of reaction occurring in the production of $Ca(ClO)_2$. Justify your answer using oxidation numbers.

**(3)**

(b) Calculate the percentage atom economy by mass for the production of $Ca(ClO)_2$ in this reaction.

**(2)**

(c) A swimming pool has the dimensions 50 m × 25 m × 2.0 m.
The water in this swimming pool has a $Ca(ClO)_2$ concentration of 4.2 mg $dm^{-3}$.

(i) Calculate the mass, **in kg**, of $Ca(ClO)_2$ required to treat the water needed to completely fill this swimming pool.

**(3)**

(ii) Calculate the volume of $Cl_2$, at room temperature and pressure, needed to make the mass of $Ca(ClO)_2$ calculated in (c)(i).

**(3)**

**(Total for Question 18 = 11 marks)**

**19** This question is about alcohols with the molecular formula $C_6H_{14}O$.

(a) Draw the **skeletal** formula of each of the three **tertiary** alcohols with the formula $C_6H_{14}O$.

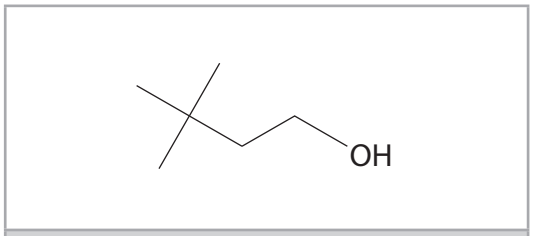
**(3)**

tertiary alcohol 1

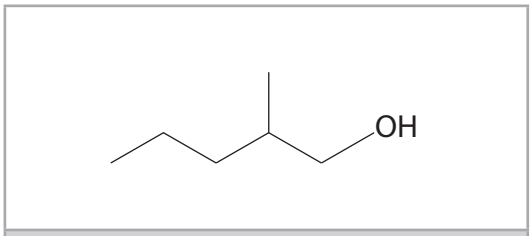
tertiary alcohol 2

tertiary alcohol 3

(b) Two primary $C_6H_{14}O$ alcohols, **A** and **B**, are shown.




alcohol **A**




alcohol **B**

(i) Give the IUPAC name of alcohol **A**.

**(1)**

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(ii) Explain why alcohol **B** has a higher boiling temperature than alcohol **A**.

**(2)**

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(iii) Explain why alcohol **B** is completely soluble in ethanol but only slightly soluble in water.
A detailed description of the forces involved is **not** required.

**(3)**

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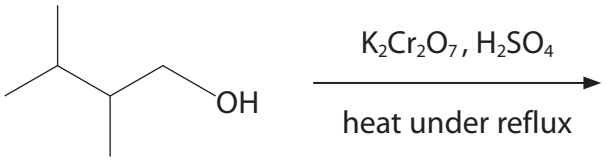
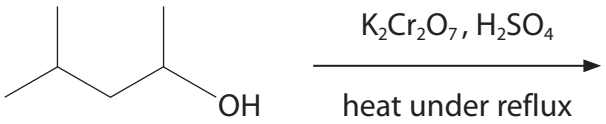
(c) Give the structure of the **organic** product of each reaction shown.

**(3)**

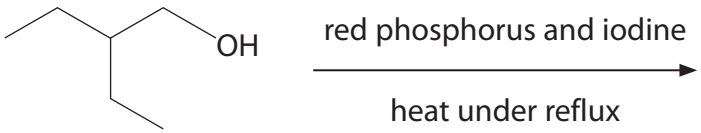
Reaction **1**




Reaction **2**



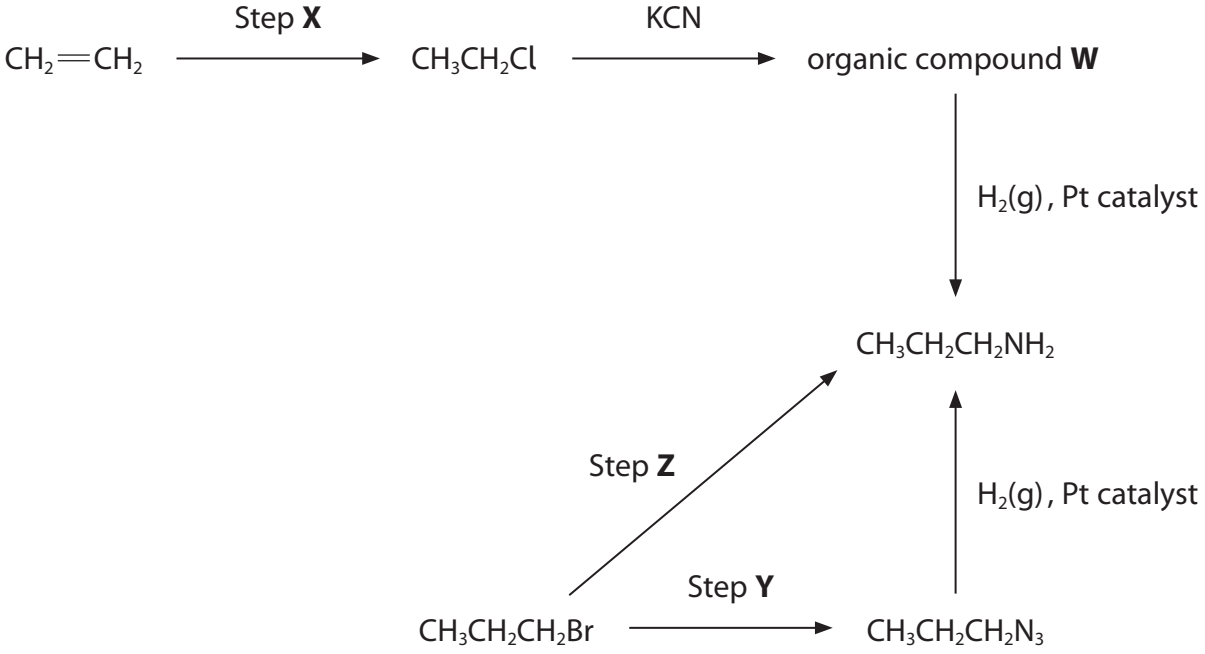

Reaction **3**




**(Total for Question 19 = 12 marks)**

**20** This question is about the synthesis of propylamine, $CH_3CH_2CH_2NH_2$.

Three routes for the synthesis of $CH_3CH_2CH_2NH_2$ are shown.




(a) Identify, by name or formula, the reagent used in Step **X**.

**(1)**

.....

(b) Give the structure of organic compound **W**.

**(1)**

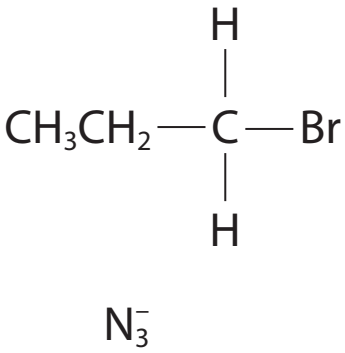
(c) The reagent used in Step **Y** is potassium azide, $KN_3$.
This is a source of the azide ion, $N_3^-$, which acts as a nucleophile.

(i) Complete a possible dot-and-cross diagram for $N_3^-$.
Show outer electrons only.

**(2)**


(ii) Complete the mechanism for Step **Y**.
Include curly arrows, and any relevant lone pairs and dipoles.

**(3)**



(d) Step **Z** is carried out by reacting ammonia with 1-bromopropane.

(i) Give the conditions for this reaction.

**(2)**

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(ii) Suggest why the yield of $CH_3CH_2CH_2NH_2$ obtained using Step **Z** is low.

**(1)**

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**(Total for Question 20 = 10 marks)**

***21** Discuss some aspects of the thermal stability of the anhydrous nitrates of the elements in Groups 1 and 2 of the Periodic Table.

In your answer you should

- explain the trend in thermal stability of the **Group 2** nitrates
- describe any differences in the products of thermal decomposition of the **Group 1** nitrates
- give equations for the thermal decomposition of sodium nitrate and of magnesium nitrate.

**(6)**

**(Total for Question 21 = 6 marks)**

**TOTAL FOR SECTION B = 39 MARKS**

## SECTION C

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

**22** Ammonium nitrate, $NH_4NO_3$, is used in the manufacture of fertilisers and explosives.
It is produced on a large scale using only methane, water and air.
The process has four stages.

(a) The first two reactions in Stage **1** involve the production of hydrogen.

At temperature $T_1$, methane reacts with excess steam to give hydrogen.

$$CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g) \qquad \Delta H = +206\,kJ\,mol^{-1}$$

At a different temperature, $T_2$, the carbon monoxide reacts with more steam.

$$CO(g) + H_2O(g) \rightleftharpoons H_2(g) + CO_2(g) \qquad \Delta H = -42\,kJ\,mol^{-1}$$

(i) Give the reason why excess steam is used in the first reaction.

**(1)**

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(ii) Predict which of $T_1$ and $T_2$ is the **higher** temperature.
Justify your answer.

**(1)**

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(iii) Derive the **overall** equation for the production of $H_2$ in Stage **1**.
State symbols are not required.

**(1)**

(b) The third reaction in Stage **1** involves the removal of carbon dioxide, using an aqueous solution of N-methyldiethanolamine, $CH_3N(CH_2CH_2OH)_2$.

$$CO_2(g) + H_2O(l) + 2CH_3N(CH_2CH_2OH)_2(aq) \rightleftharpoons (CH_3NH(CH_2CH_2OH)_2)_2CO_3(aq)$$

(i) Suggest **one** reason why $CO_2$ is removed.

**(1)**

(ii) Name the type of reaction occurring.

**(1)**

(iii) Draw the **displayed** formula of N-methyldiethanolamine, $CH_3N(CH_2CH_2OH)_2$.

**(1)**

(c) In Stage **2**, the hydrogen from Stage **1** reacts with nitrogen (from the air) to produce ammonia. The conditions for this reaction are:

- a temperature of 700 K
- a pressure in the range 100–200 atm
- an iron catalyst

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

Give **one** advantage and **one** disadvantage of using a pressure of 200 atm, compared to a pressure of 100 atm, in Stage **2**.

**(2)**

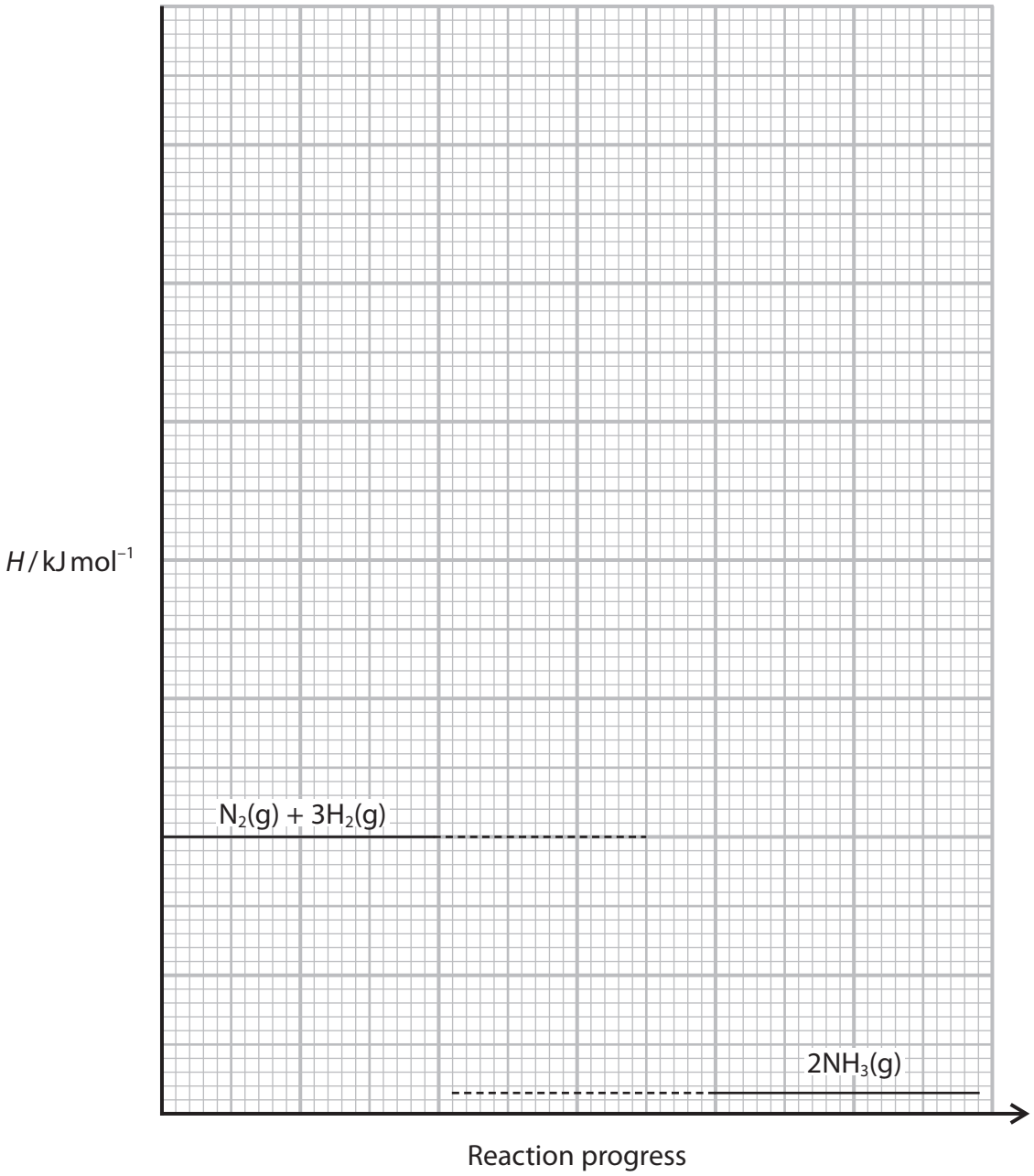
(d) The reaction in Stage **2** has an activation energy, $E_{cat} = +70\,kJ\,mol^{-1}$.

The **uncatalysed** reaction between $N_2$ and $H_2$ has an activation energy, $E_a = +290\,kJ\,mol^{-1}$.

(i) Complete the profile for the catalysed and uncatalysed reactions.
Label the activation energies and the enthalpy change of reaction, $\Delta H$.

Your diagram **must** match the scale shown for the production of $NH_3$.

**(3)**




(ii) Suggest why the use of the catalyst makes Stage **2** more sustainable.

**(1)**

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(e) In Stage **3**, nitrogen monoxide, NO, is produced in the reaction between $NH_3$ (from Stage **2**) and $O_2$ (from the air). The conditions used are a temperature of 1100 K in the presence of a platinum-rhodium catalyst.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -905\ kJ\ mol^{-1}$$

(i) Give **one** reason why a high temperature is needed in this reaction.

**(1)**

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(ii) Suggest why only a small amount of energy is used to maintain the temperature at 1100 K.

**(1)**

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(f) The NO from the first reaction in Stage **3** is cooled and then converted to nitrogen dioxide, $NO_2$, by reaction with more $O_2$.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$

Nitric acid, $HNO_3(aq)$, is produced by the addition of water.

$$3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g)$$

Explain how adding water in the second reaction affects the yield of $NO_2$ in the first reaction.

**(2)**

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(g) In Stage **4**, a solution of $NH_4NO_3$ is produced by reacting $NH_3$ (from Stage **2**) with $HNO_3$ (from Stage **3**).

$$NH_3(g) + HNO_3(aq) \rightarrow NH_4NO_3(aq)$$

Data

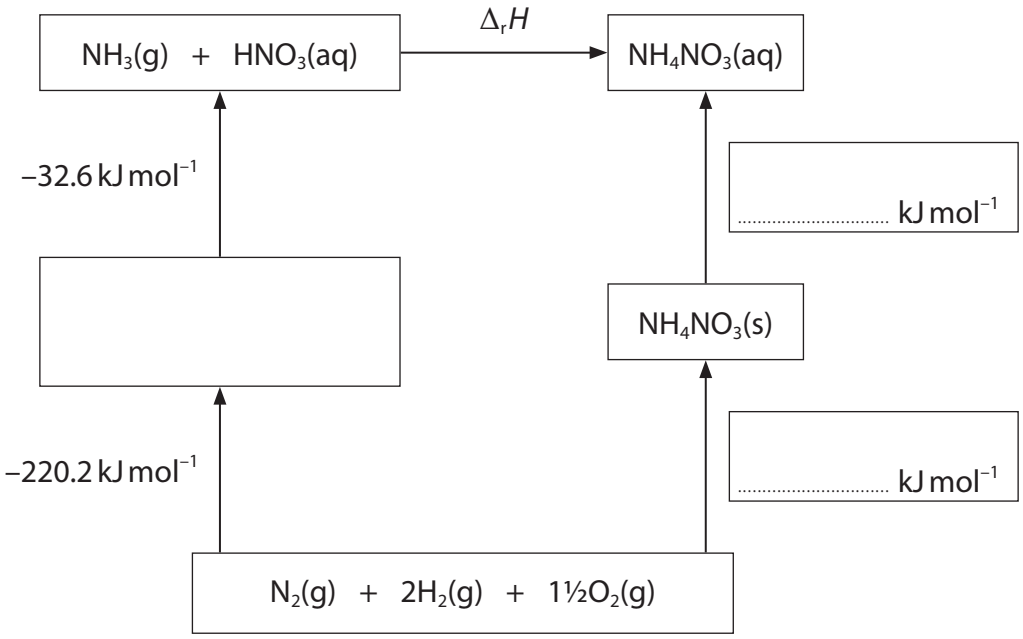
| Species | $NH_3(g)$ | $HNO_3(l)$ | $NH_4NO_3(s)$ |
|---|---|---|---|
| $\Delta_f H^{\ominus}$ / kJ mol$^{-1}$ | –46.1 | –174.1 | –365.6 |

| Equation | $\Delta H$ / kJ mol$^{-1}$ |
|---|---|
| $HNO_3(l) + aq \rightarrow HNO_3(aq)$ | –32.6 |
| $NH_4NO_3(s) + aq \rightarrow NH_4NO_3(aq)$ | +25.6 |

(i) Complete the enthalpy cycle.

**(2)**

**Enthalpy cycle**




(ii) Calculate the enthalpy change, $\Delta_r H$, in kJ mol$^{-1}$, for the reaction of $NH_3(g)$ with $HNO_3(aq)$.

**(1)**

(h) Suggest **two** reasons why it is more profitable to carry out all four stages at the **same** site, instead of using different sites for each stage in the industrial production of ammonium nitrate.

**(2)**

**(Total for Question 22 = 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<br>atomic symbol<br>name<br>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

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| * Lanthanide 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 |
| * Actinide series | 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 |