Oxford Cambridge and RSA

Tuesday 17 May 2022 – Morning

AS Level Chemistry A

H032/01 Breadth in chemistry

Time allowed: 1 hour 30 minutes

You must have:
- the Data Sheet for Chemistry A

You can use:
- a scientific or graphical calculator
- an HB pencil

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name StemUp Model Solution

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- This document has **24** pages.

ADVICE
- Read each question carefully before you start your answer.

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SECTION A

You should spend a maximum of 25 minutes on this section.

Answer **all** the questions.

Write your answer to each question in the box provided.

1 Which substance has a giant covalent lattice structure in its solid state?

A potassium

B silicon

C sodium chloride

D water

Your answer B **[1]**

2 What is the meaning of the term electronegativity?

A The ability of an atom to attract the electrons in a covalent bond.

B The ability of an atom to gain an electron.

C The electrostatic attraction between a negative ion and a positive ion.

D The size of the charge on a negative ion.

Your answer A **[1]**

3 Which compound is an alkali?

A CH_3COOH

B CH_3OH

C HNO_3

D NH_3

Your answer D **[1]**

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4 What is the number of paired orbitals in a sulfur atom?

A 4

B 6

C 7

D 8

Your answer C **[1]**

5 Which element has the lowest melting point?

A S

B P

C C*l*

D Ar

Your answer D **[1]**

6 The first four ionisation energies of a Period 3 element **X** are shown in the table.

Ionisation energy / kJ mol^{-1}			
1st	**2nd**	**3rd**	**4th**
738	1451	7733	10 541

Element **X** is reacted with chlorine.

What is the formula of the chloride formed?

A **X**C*l*

B **X**Cl_2

C **X**Cl_3

D **X**Cl_4

Your answer B **[1]**

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7 A sample of lead(II) sulfate (M = 303.3 g mol^{-1}) is decomposed by heat, as shown in the equation below.

$2PbSO_4(s) \rightarrow 2PbSO_3(s) + O_2(g)$

The reaction forms 2.40 g of $O_2(g)$.

What is the mass of lead(II) sulfate that has been heated? Assume a 100% yield.

A 22.7 g

B 30.3 g

C 45.5 g

D 60.7 g

Your answer C **[1]**

8 Which volume of 18.0 mol dm^{-3} hydrochloric acid should be diluted to 250.0 cm^3 to prepare a 0.450 mol dm^{-3} solution of hydrochloric acid?

A 4.50 cm^3

B 6.25 cm^3

C 10.0 cm^3

D 32.4 cm^3

Your answer B **[1]**

9 What is the number of **ions** in 4.00 mol of magnesium chloride, $MgCl_2$?

A 1.81×10^{24}

B 2.41×10^{24}

C 4.82×10^{24}

D 7.22×10^{24}

Your answer D **[1]**

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10 What is the correct explanation for the trend in the boiling points of chlorine, bromine, and iodine down the group?

A Bond enthalpy increases.

B Chemical reactivity decreases.

C Electronegativity decreases.

D London forces increase.

Your answer D **[1]**

11 Combustion of hydrazine, N_2H_4, produces NO_2 and H_2O as in the equation below.

$N_2H_4(l) + 3O_2(g) \rightarrow 2NO_2(g) + 2H_2O(l)$

The table shows standard enthalpy changes of formation, $\Delta_f H^\ominus$.

Substance	$\Delta_f H^\ominus$ **/ kJ mol^{-1}**
$N_2H_4(l)$	+50.6
$O_2(g)$	0
$NO_2(g)$	+33.2
$H_2O(l)$	–285.8

What is the enthalpy change of combustion, in kJ mol^{-1}, for hydrazine, $N_2H_4(l)$?

A –555.8

B –303.2

C +303.2

D +555.8

Your answer A **[1]**

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12 Which prediction can be made using le Chatelier's principle?

A The effect of a catalyst on the reaction rate.

B The effect of a catalyst on the equilibrium position.

C The effect of temperature on the reaction rate.

D The effect of concentration on the equilibrium position.

Your answer D **[1]**

13 Four equilibrium reactions are set up.

The concentration of each gas in the equilibrium mixtures is 0.1 mol dm^{-3}.

Which equilibrium has a numerical K_c value of 0.01?

A $CH_4(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 4H_2(g)$

B $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

C $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

D $2NO_2(g) \rightleftharpoons N_2O_4(g)$

Your answer A **[1]**

14 What is the number of σ-bonds in the molecule below?

A 1

B 3

C 7

D 9

Your answer D **[1]**

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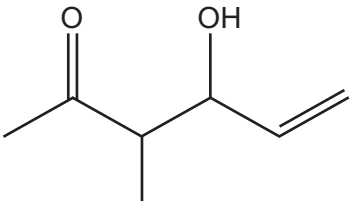
15 What is the number of hydrogen atoms in **one** molecule of the compound below?



A 8

B 10

C 12

D 14

Your answer C **[1]**

16 Complete combustion of an alkane forms 30 cm^3 of carbon dioxide and 40 cm^3 of water vapour, under the same conditions of temperature and pressure.

Which alkane has undergone complete combustion?

A butane

B ethane

C heptane

D propane

Your answer D **[1]**

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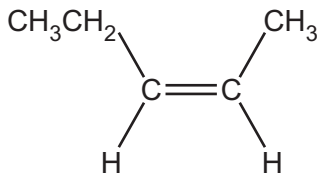
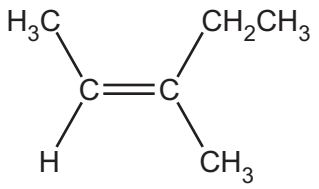
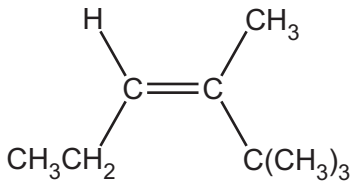
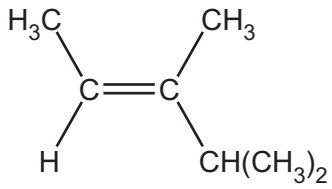
17 Which alkene is an *E* stereoisomer?

A	
B	
C	
D	

Your answer D **[1]**

18 When heated with NaOH(aq), 1-chlorobutane is hydrolysed at a slower rate than 1-bromobutane.

Which statement explains the different rates?

A The C–Br bond enthalpy is greater than the C–C*l* bond enthalpy.

B The C–Br bond enthalpy is less than the C–C*l* bond enthalpy.

C The C–Br bond is less polar than the C–C*l* bond.

D The C–Br bond is more polar than the C–C*l* bond.

Your answer B **[1]**

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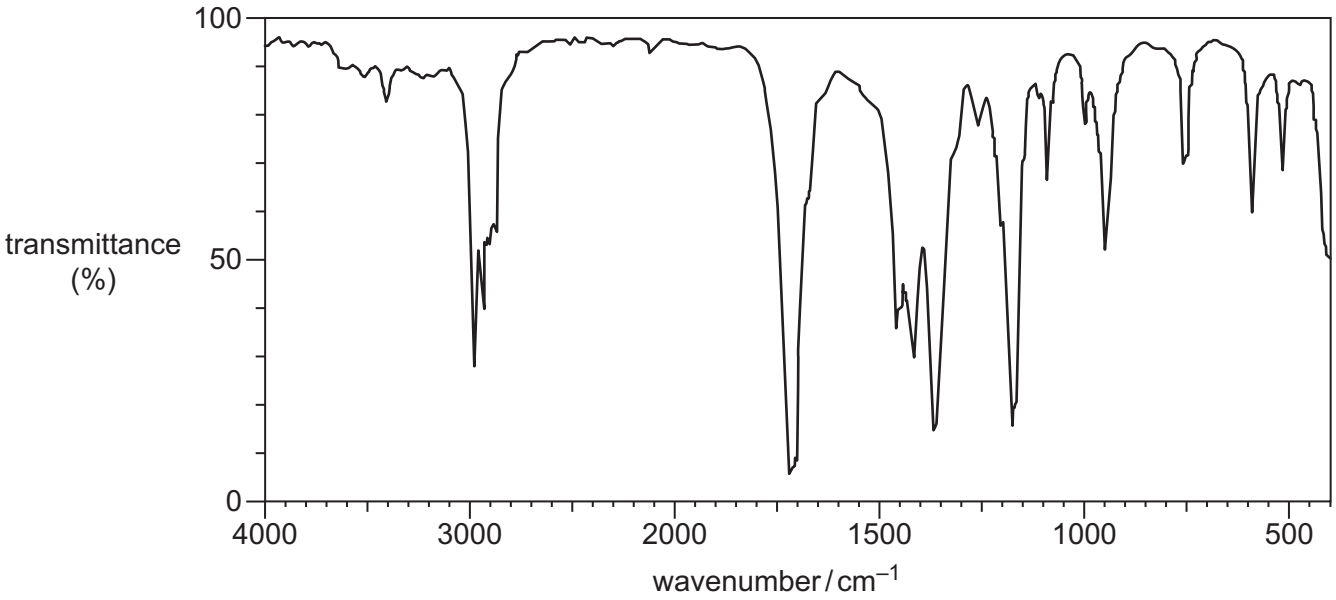
19 Which organic compound could have produced the infrared spectrum below?



A $CH_3COCH_2CH_3$

B $CH_3CH_2CHOHCH_3$

C $CH_3COCH_2CH_2OH$

D CH_3CH_2COOH

Your answer A **[1]**

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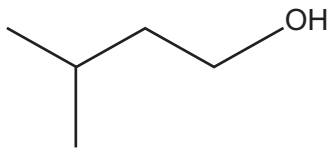
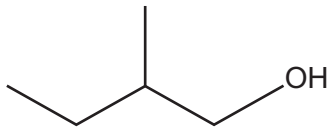
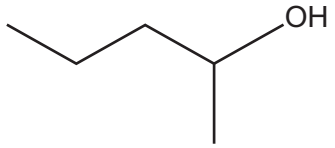
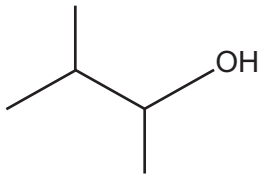
20 Which alcohol is likely to have fragment ions at m/z = 15, 29 **and** 43 in its mass spectrum?

A	
B	
C	
D	

Your answer C **[1]**

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SECTION B

Answer **all** the questions.

21 The alkene, $(CH_3)_3CCH{=}CH_2$, is used to make some perfumes.

(a) **(i)** What is the systematic name for $(CH_3)_3CCH{=}CH_2$?

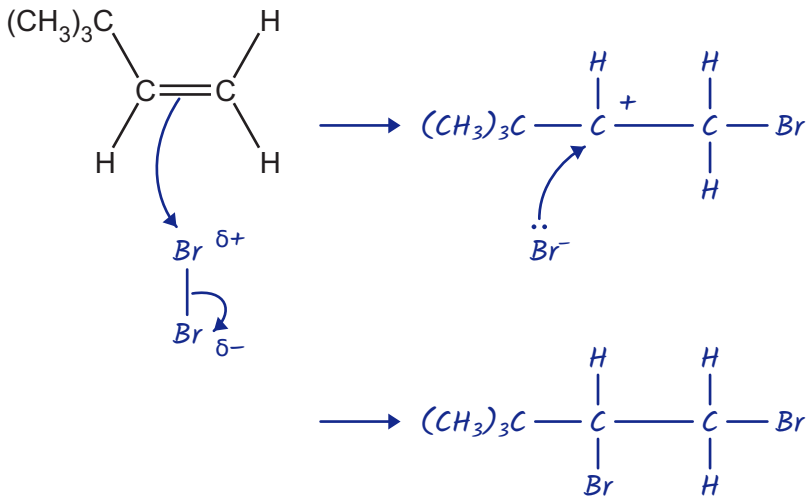
3,3-dimethylbut-1-ene ..... **[1]**

(ii) $(CH_3)_3CCH{=}CH_2$ decolourises bromine.

Outline the reaction mechanism for the reaction of $(CH_3)_3CCH{=}CH_2$ and bromine.

The structure of $(CH_3)_3CCH{=}CH_2$ has been provided.

Include curly arrows and relevant dipoles, the structure of the product and the name of the mechanism.



name of mechanism ..electrophilic addition ..... **[5]**

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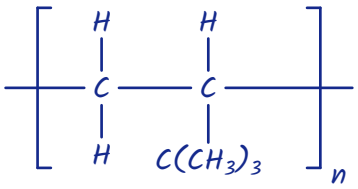
(b) The alkene $(CH_3)_3CCH{=}CH_2$ can be polymerised to form a polymer.

(i) Draw **one** repeat unit for this polymer.



[1]

(ii) State **one** advantage and **one** disadvantage of using combustion as a method for the disposal of a polymer after it has exceeded its useful life.

Advantage energy is released, which can be used to generate electricity (and less polymer goes to landfill)

Disadvantage CO_2 is produced, a greenhouse gas that contributes to global warming (climate change)

[1]

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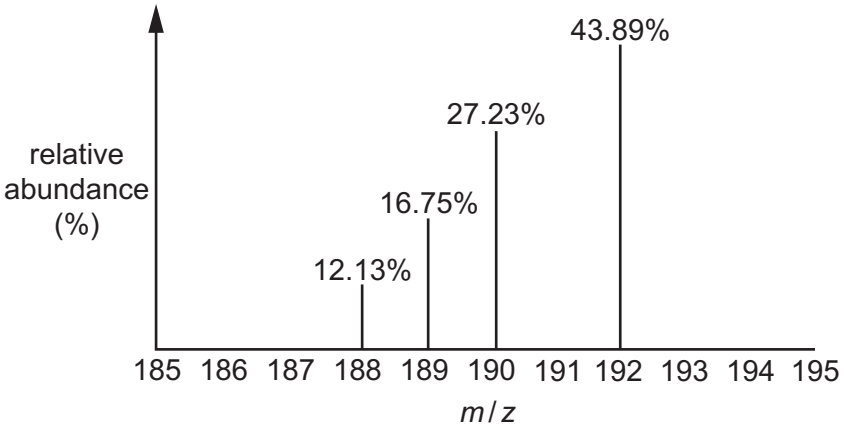
22 This question is about atomic structure and formulae.

(a) The relative atomic mass of a sample of osmium can be determined from its mass spectrum, shown below.



Calculate the relative atomic mass of osmium in the sample.

Give your answer to **two** decimal places.

$A_r = [(188 \times 12.13) + (189 \times 16.75) + (190 \times 27.23) + (192 \times 43.89)] \div 100$

$= 19046.77 \div 100$

$= 190.4677$

relative atomic mass = ...190.47..... **[2]**

(b) Complete the table for an atom and an ion of **two** different elements.

Element	Mass number	Protons	Neutrons	Electron configuration	Charge
.....Ni.....	.....62.....	28	34	..$1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$.....	0
.....P.....	33	.....15.....	.....18.....	$1s^2 2s^2 2p^6 3s^2 3p^6$	3–

[2]

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(c) Substance **A** is a hydrated salt with the following percentage composition by mass:

Zn, 21.99%; H, 4.04%; N, 9.41%; O, 64.56%.

- Determine the empirical formula of **A**.
- Write the formula of **A** showing the water of crystallisation.

Zn : H : N : O

21.99 ÷ 65.4 : 4.04 ÷ 1.0 : 9.41 ÷ 14.0 : 64.56 ÷ 16.0

= 0.336 : 4.04 : 0.672 : 4.04

÷ 0.336: 1 : 12 : 2 : 12

empirical formula: .....$ZnH_{12}N_2O_{12}$.....

formula showing water of crystallisation: .....$Zn(NO_3)_2 \cdot 6H_2O$.....

[3]

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23 This question is about different types of bonding.

(a) Ionic compounds have ionic bonding and exist in a giant ionic lattice structure.

(i) What is meant by **ionic bonding**?

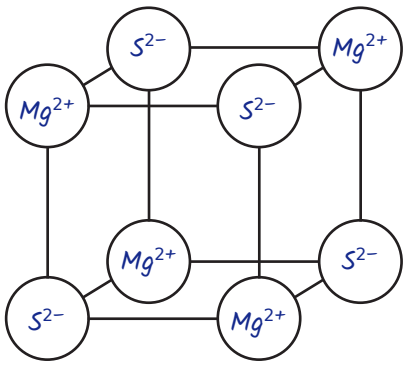
Electrostatic attraction between oppositely charged ions (positive and negative ions).

[1]

(ii) Magnesium reacts with sulfur to form a compound which has a giant ionic lattice structure.

The diagram shows ions as circles in part of the lattice.

Complete the diagram by showing the symbols of the ions, including charges.



[2]

(b) 'Oxyanions' are ions containing oxygen combined with atoms of other elements. Roman numerals are used to show the oxidation state of the element in the oxyanion.

Complete the table below for three oxyanions.
One row has been completed as an example.

Name of oxyanion	Ionic charge	Formula of oxyanion
Bromate(III)	1–	BrO_2^-
Sulfate(VI)	2–	SO_4^{2-}
Phosphate(V)	3–	PO_4^{3-}

[2]

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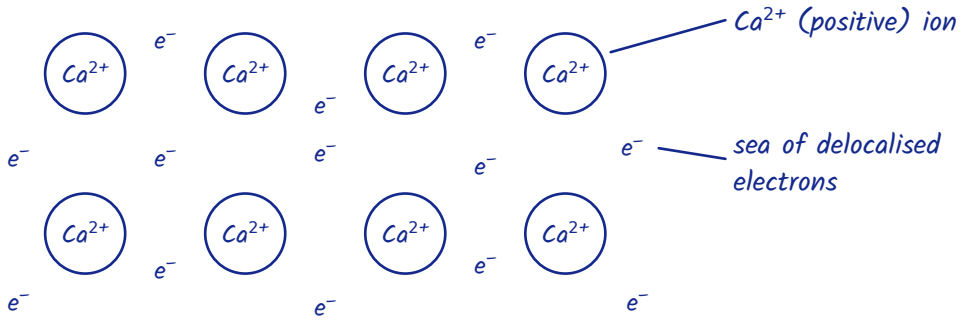
(c) Describe the structure and bonding and electrical conductivity of calcium in the solid state. You may wish to include a labelled diagram in your answer.



Calcium has a giant metallic lattice structure with metallic bonding.

Metallic bonding is the strong electrostatic attraction between the positive Ca^{2+} ions (cations) and the sea of delocalised electrons.

Calcium conducts electricity in the solid state because the delocalised electrons can move (flow) through the structure when a voltage is applied.

..... **[4]**

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24 This question is about halogens and practical tests.

(a) Chlorine gas reacts with dilute sodium hydroxide, NaOH(aq).

This is a disproportionation reaction. One of the products has the formula NaC*l*O.

(i) What is meant by the term **disproportionation**?

Oxidation and reduction of the same element in the same reaction.

[1]

(ii) Construct the equation for the reaction of chlorine with dilute sodium hydroxide.

Use your equation to explain that disproportionation has taken place.

Equation $Cl_2 + 2NaOH \rightarrow NaClO + NaCl + H_2O$

Explanation Chlorine is oxidised from 0 in Cl_2 to +1 in NaClO.

Chlorine is also reduced from 0 in Cl_2 to −1 in NaCl, so chlorine is both oxidised and reduced.

[3]

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(b) A student is supplied with aqueous solutions of ionic compounds **B** and **C**.

Compound **B** is a chloride, bromide or iodide of a Group 1 element.
Compound **C** is a chloride, bromide or iodide of a Group 2 element.

The molar masses of **B** and **C** are both in the range 100–115 g mol^{-1}.

Use this information and test-tube tests to show how the student could identify the halide present in **B** and **C** and the formulae of **B** and **C**.

Explain your reasoning.

In your answer, include observations, colours and equations.

Add aqueous silver nitrate, $AgNO_3(aq)$, (acidified with dilute nitric acid) to separate samples of B and C and look at the colour of the precipitate.

A chloride gives a white precipitate, a bromide gives a cream precipitate and an iodide gives a yellow precipitate: $Ag^+(aq) + X^-(aq) \rightarrow AgX(s)$, e.g. $Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$ and $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$.

B gives a cream precipitate, so B is a bromide, MBr.

$A_r(M)$ = 100 to 115 minus 79.9 (one Br) = 20 to 35, so the Group 1 metal is sodium (23.0): B is NaBr, M = 102.9 g mol^{-1}.

C gives a white precipitate, so C is a chloride, MCl_2.

$A_r(M)$ = 100 to 115 minus 71.0 (2 × 35.5 for two Cl) = 29 to 44, so the Group 2 metal is calcium (40.1): C is $CaCl_2$, M = 111.1 g mol^{-1}.

[5]

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25 This question is about enthalpy changes and reaction rates.

(a) Aqueous barium hydroxide, $Ba(OH)_2(aq)$, reacts with dilute nitric acid, $HNO_3(aq)$, as in **Equation 25.1**.

$Ba(OH)_2(aq) + 2HNO_3(aq) \rightarrow Ba(NO_3)_2(aq) + 2H_2O(l)$ **Equation 25.1**

A student carries out an experiment to determine the enthalpy change of this reaction, $\Delta_r H$.

The student measures out:

- 25.0 cm^3 of 2.00 mol dm^{-3} $Ba(OH)_2(aq)$ and
- 50.0 cm^3 of 2.00 mol dm^{-3} $HNO_3(aq)$.
  The temperature of each solution is the same.

The student mixes both solutions in a polystyrene cup, stirs the mixture and records the maximum temperature.

Temperature readings

Initial temperature	= 20.5 °C
Maximum temperature	= 39.0 °C

(i) Calculate $\Delta_r H$, in kJ mol^{-1}, for the reaction shown in **Equation 25.1**.

Give your answer to **3** significant figures.

Assume that the density and specific heat capacity, *c*, of the solutions are the same as for water.

energy released, $q = mc\Delta T = 75.0 \times 4.18 \times (39.0 - 20.5)$

$= 75.0 \times 4.18 \times 18.5 = 5799.75\ J = 5.79975\ kJ$

$n(Ba(OH)_2) = 2.00 \times 25.0 \div 1000 = 0.0500\ mol$

$n(HNO_3) = 2.00 \times 50.0 \div 1000 = 0.100\ mol$ (= 2 × 0.0500, so all of the $Ba(OH)_2$ and HNO_3 react as in Equation 25.1)

$\Delta_r H = -5.79975 \div 0.0500 = -115.995\ kJ\ mol^{-1}$

$= -116\ kJ\ mol^{-1}$ (3 s.f.)

$\Delta_r H$ = ...−116..... kJ mol^{-1} **[4]**

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(ii) The student looked back at **Equation 25.1** and noticed that the reaction was a neutralisation.
The student concluded that $\Delta_r H$ is the enthalpy change of neutralisation.

Explain why the student's conclusion is **incorrect** and determine the correct value for the enthalpy change of neutralisation.

The enthalpy change of neutralisation is the enthalpy change for the formation of 1 mol of H_2O, but Equation 25.1 forms 2 mol of H_2O.

$\Delta_{neut}H = -116 \div 2 = -58.0$ kJ mol^{-1}

enthalpy change of neutralisation = ...−58.0.... kJ mol^{-1} **[2]**

(b) The Boltzmann distribution model can be used by chemists to explain how the rate of a reaction is affected by temperature.

Fig. 25.1 shows the Boltzmann distribution for a gas at room temperature.

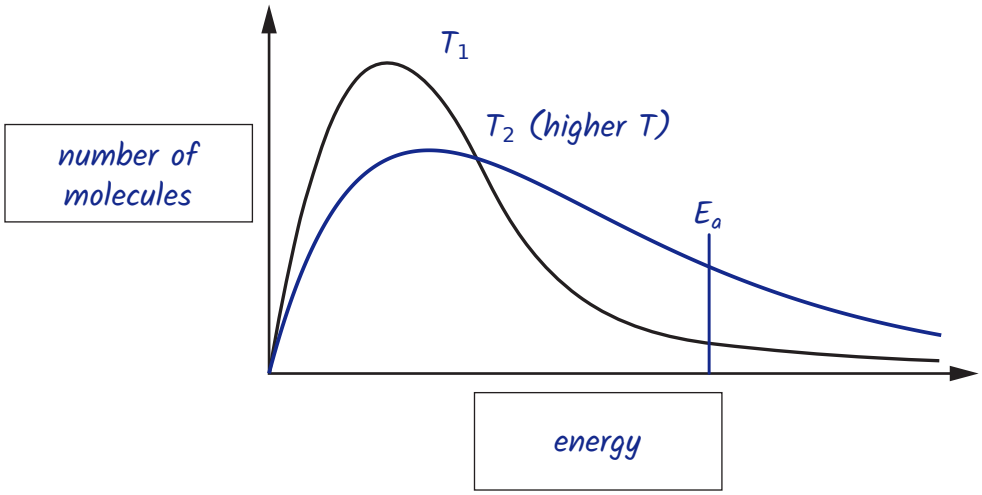

Fig. 25.1

Label the axes on **Fig. 25.1** and add a second curve to show the Boltzmann distribution of the gas at a higher temperature.

Explain why the Boltzmann distribution shows that the rate of a reaction is affected by temperature.

At the higher temperature, more molecules have energy greater than or equal to the activation energy, E_a (a greater area under the curve to the right of E_a), so a greater proportion of collisions are successful and the rate increases. **[3]**

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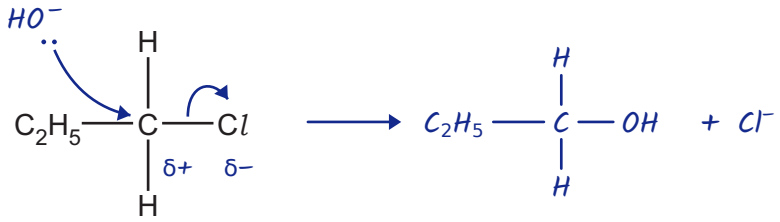
26 This question is about haloalkanes.

(a) 1-Chloropropane, $C_2H_5CH_2Cl$, can be hydrolysed with aqueous sodium hydroxide, NaOH.

Outline the mechanism for this reaction.

The structure of 1-chloropropane has been provided.

Show curly arrows, relevant dipoles and product(s).



[3]

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(b) A bromoalkane **D** is a liquid at room temperature and pressure but can easily be vaporised.

When vaporised, 0.330 g of **D** produces 74.0 cm^3 of gas at 1.01×10^5 Pa and 100 °C.

Determine the molar mass and molecular formula of bromoalkane **D**.

$pV = nRT$, so $n = pV \div RT$

$V = 74.0\ cm^3 = 74.0 \times 10^{-6}\ m^3$; $T = 100 + 273 = 373\ K$

$n = (1.01 \times 10^5 \times 74.0 \times 10^{-6}) \div (8.314 \times 373)$

$= 2.41 \times 10^{-3}$ mol

$M = m \div n = 0.330 \div 2.41 \times 10^{-3} = 136.9\ g\ mol^{-1}$

bromoalkane $C_nH_{2n+1}Br$: $12.0n + 1.0(2n + 1) + 79.9 = 136.9$

$14.0n = 56.0$, so $n = 4$

C_4H_9Br: $M = 48.0 + 9.0 + 79.9 = 136.9\ g\ mol^{-1}$

molar mass = ...136.9..... g mol^{-1}

molecular formula = ...C_4H_9Br.....

[5]

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

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