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 13 May 2024

Morning (Time: 1 hour 30 minutes)

Paper reference **WCH12/01R**

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 8 3 9 2 A 0 1 3 2

Pearson

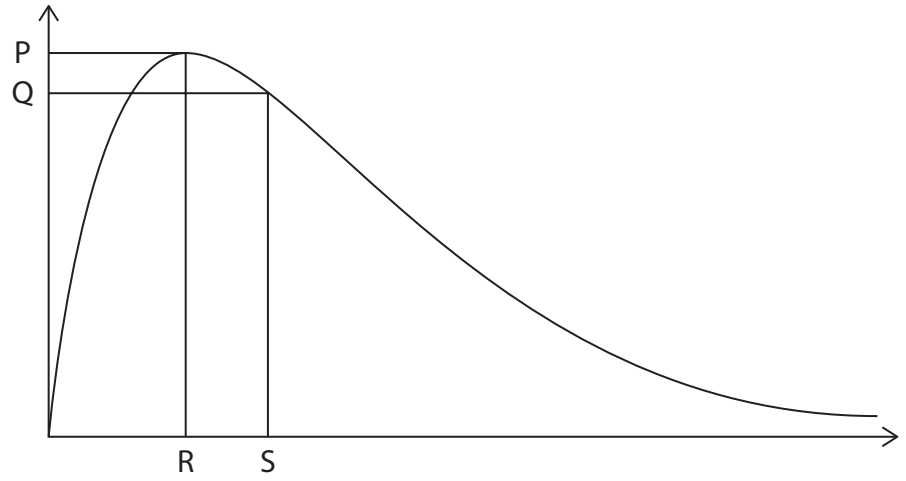
SECTION A

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 Maxwell-Boltzmann distribution of molecular energies is shown.



(a) Which letter represents the mean energy of the molecules?

(1)

☒ **A** letter P

☒ **B** letter Q

☒ **C** letter R

☒ **D** letter S

(b) What happens to the curve when the temperature is **decreased**?

(1)

☒ **A** the peak becomes higher and further to the right

☒ **B** the peak becomes higher and further to the left

☒ **C** the peak becomes lower and further to the right

☒ **D** the peak becomes lower and further to the left

(Total for Question 1 = 2 marks)

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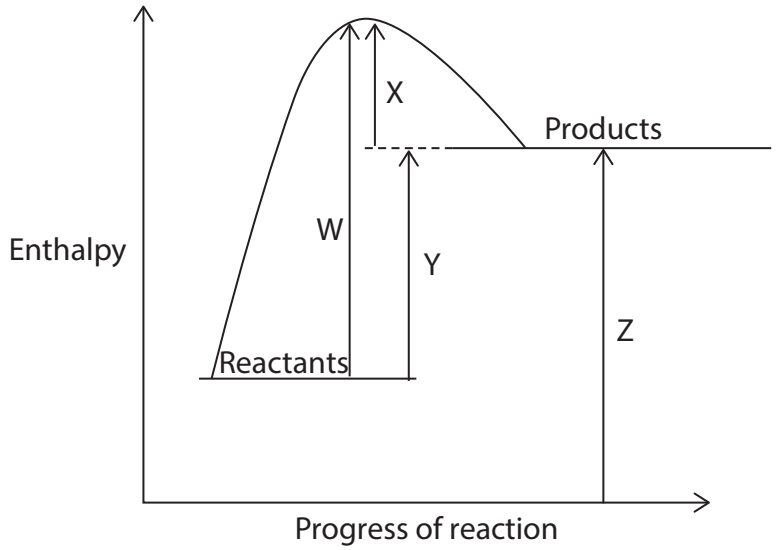
2 The reaction profile for a reaction is shown.



Which arrow represents the activation energy of the forward reaction?

- ☒ **A** letter W
- ☒ **B** letter X
- ☒ **C** letter Y
- ☒ **D** letter Z

(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 reaction between calcium carbonate and hydrochloric acid is investigated.

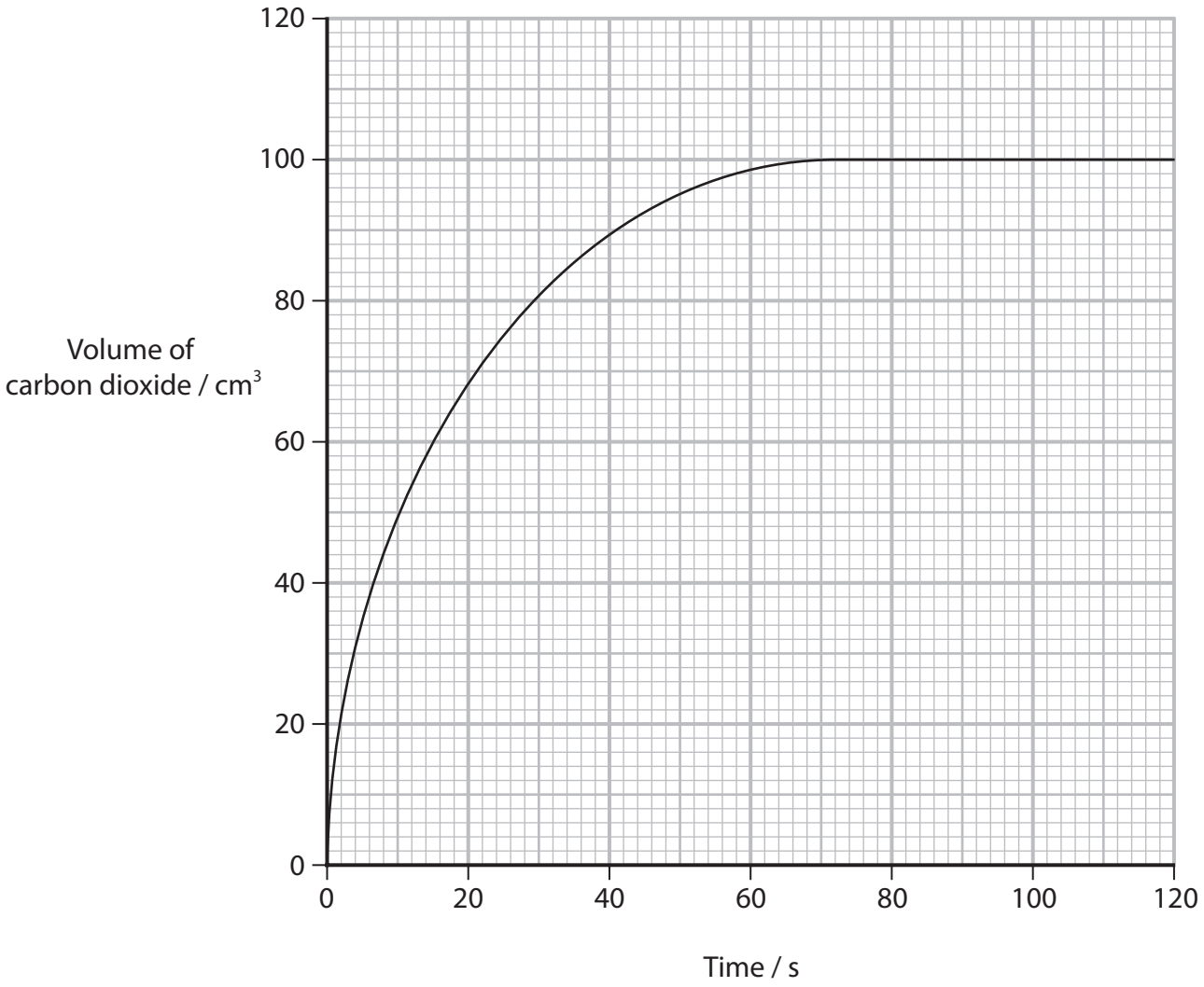
$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

(a) Which change in property will **not** affect the rate of this reaction?

(1)

- ☒ **A** concentration of hydrochloric acid
- ☒ **B** particle size of calcium carbonate
- ☒ **C** pressure of the system
- ☒ **D** temperature of hydrochloric acid

(b) The graph shows the results of one of the experiments.



What is the **approximate** rate of reaction in $cm^3 s^{-1}$ at 20 seconds?

(1)

- ☒ **A** 0.67
- ☒ **B** 0.70
- ☒ **C** 1.50
- ☒ **D** 3.50

(Total for Question 3 = 2 marks)

4 Nitrogen reacts with hydrogen to form ammonia.

$$\tfrac{1}{2}N_2(g) + 1\tfrac{1}{2}H_2(g) \rightleftharpoons NH_3(g) \qquad \Delta_f H = -46\,kJ\,mol^{-1}$$

Bond	Bond enthalpy / kJ mol^{-1}
H—H	436
N≡N	945

What is the bond enthalpy, in kJ mol^{-1}, of the N—H bond?

☒ **A** 360

☒ **B** 391

☒ **C** 548

☒ **D** 1173

(Total for Question 4 = 1 mark)

5 A gas cylinder contains 2.5 kg of butane.

How many molecules of butane are in the cylinder?

[Molar mass of butane = 58.0 g mol^{-1} Avogadro constant, $L = 6.02 \times 10^{23}$ mol^{-1}]

☒ **A** 1.40×10^{22}

☒ **B** 2.59×10^{22}

☒ **C** 1.40×10^{25}

☒ **D** 2.59×10^{25}

(Total for Question 5 = 1 mark)

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

6 In an experiment to calculate the enthalpy change of neutralisation, $\Delta_{neut}H$, 25 cm^3 of 0.1 mol dm^{-3} hydrochloric acid, HCl, was reacted with 25 cm^3 of 0.1 mol dm^{-3} sodium hydroxide solution. The increase in temperature, ΔT, was recorded.

[Assume the density of the solutions = 1.00 g cm^{-3}

Specific heat capacity of solutions = 4.2 J g^{-1} $°C^{-1}$]

(a) Which is the correct expression to calculate the enthalpy change of neutralisation for this reaction, in J mol^{-1}?

(1)

☒ **A** $\frac{\Delta T \times 4.2 \times 50}{5.0 \times 10^{-3}}$

☒ **B** $\frac{\Delta T \times 4.2 \times 25}{2.5 \times 10^{-3}}$

☒ **C** $\frac{-\Delta T \times 4.2 \times 50}{5.0 \times 10^{-3}}$

☒ **D** $\frac{-\Delta T \times 4.2 \times 50}{2.5 \times 10^{-3}}$

(b) The table below shows the measurement uncertainty of some laboratory apparatus.

Apparatus	Measurement uncertainty on each reading / cm^3
burette	+/– 0.05
25 cm^3 measuring cylinder	+/– 0.5
25 cm^3 volumetric flask	+/– 0.1
25 cm^3 pipette	+/– 0.06

Which piece of apparatus would measure 25 cm^3 of hydrochloric acid with the **lowest** percentage uncertainty?

(1)

☒ **A** burette

☒ **B** measuring cylinder

☒ **C** volumetric flask

☒ **D** pipette

(Total for Question 6 = 2 marks)

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7 Which equation shows the reaction that occurs when the standard enthalpy change of atomisation of iodine is measured?

- ☒ **A** $I_2(s) \rightarrow 2I(g)$
- ☒ **B** $\frac{1}{2}I_2(s) \rightarrow I(g)$
- ☒ **C** $I_2(g) \rightarrow 2I(g)$
- ☒ **D** $\frac{1}{2}I_2(g) \rightarrow I(g)$

(Total for Question 7 = 1 mark)

8 Which statement about the elements in Group 7 is **not correct**?

- ☒ **A** they all exist as diatomic molecules
- ☒ **B** electronegativity decreases down the group
- ☒ **C** reactivity increases up the group
- ☒ **D** they all show variable oxidation states in their compounds

(Total for Question 8 = 1 mark)

9 What are the only products formed when chlorine reacts with **cold** aqueous sodium hydroxide?

- ☒ **A** sodium chloride, sodium chlorate(I) and water
- ☒ **B** sodium chloride, sodium chlorate(V) and water
- ☒ **C** sodium chlorate(I) and water
- ☒ **D** sodium chloride and sodium chlorate(I)

(Total for Question 9 = 1 mark)

10 Which statement about the reaction between concentrated sulfuric acid and potassium bromide is correct?

- ☒ **A** bromide ions are reduced
- ☒ **B** hydrogen bromide and hydrogen sulfide are formed
- ☒ **C** sulfuric acid acts as an oxidising agent
- ☒ **D** bromine and hydrogen sulfide are formed

(Total for Question 10 = 1 mark)

11 Which statement is correct about the solubilities of Group 2 compounds as the group is descended?

- ☒ **A** the solubility of the hydroxides and sulfates increases for both
- ☒ **B** the solubility of the hydroxides and sulfates decreases for both
- ☒ **C** the solubility of the hydroxides increases and the solubility of the sulfates decreases
- ☒ **D** the solubility of the hydroxides decreases and the solubility of the sulfates increases

(Total for Question 11 = 1 mark)

12 Which nitrate does **not** produce brown fumes when heated?

- ☒ **A** $LiNO_3$
- ☒ **B** KNO_3
- ☒ **C** $Ca(NO_3)_2$
- ☒ **D** $Ba(NO_3)_2$

(Total for Question 12 = 1 mark)

13 Compound **X** gives a red flame test and a solution of **X** produces a white precipitate when added to nitric acid and silver nitrate solution.

Which could be compound **X**?

- ☒ **A** LiCl
- ☒ **B** NaCl
- ☒ **C** NaBr
- ☒ **D** RbBr

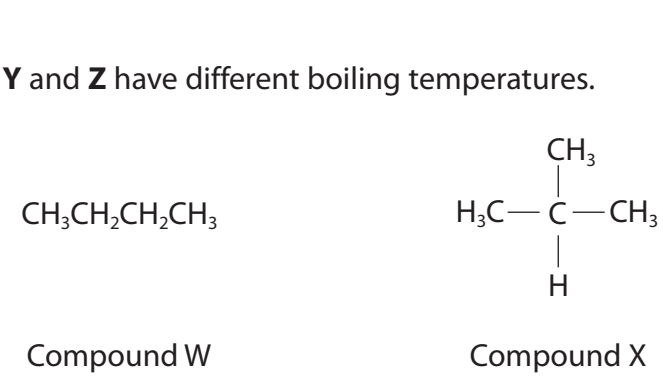
(Total for Question 13 = 1 mark)

14 Which species contains an element with an oxidation number of +4?

- ☒ **A** CrO_4^{2-}
- ☒ **B** MnO_4^{2-}
- ☒ **C** H_2SO_4
- ☒ **D** Na_2CO_3

(Total for Question 14 = 1 mark)

15 The compounds **W**, **X**, **Y** and **Z** have different boiling temperatures.



Compound W Compound X

Compound Y Compound Z

Which is the correct order of **increasing** boiling temperature?

- ☒ **A** X < W < Z < Y
- ☒ **B** X < Z < W < Y
- ☒ **C** W < X < Y < Z
- ☒ **D** X < W < Y < Z

(Total for Question 15 = 1 mark)

16 How many **structural** isomers are there with the molecular formula C_3H_6BrI?

- ☒ **A** 4
- ☒ **B** 5
- ☒ **C** 6
- ☒ **D** 7

(Total for Question 16 = 1 mark)

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

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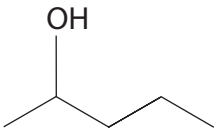
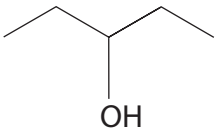
17 Which alcohol can be oxidised to a carboxylic acid by acidified potassium dichromate(VI)?

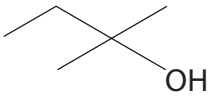
☒ **A**



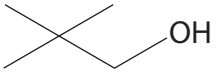
☒ **B**



☒ **C**



☒ **D**



(Total for Question 17 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

Answer ALL the questions in this section.

Write your answers in the spaces provided.

18 This question is about Group 2 carbonates.

Group 2 carbonates decompose on heating to form the corresponding metal oxide and carbon dioxide. The general equation is shown.

$$MCO_3(s) \rightarrow MO(s) + CO_2(g)$$

(a) A sample of magnesium carbonate was heated for 4 minutes.
The mass of the sample decreased from 4.17 g to 2.35 g.

Calculate the percentage of magnesium carbonate that has decomposed.

[Molar mass of magnesium carbonate = 84.3 g mol^{-1}]

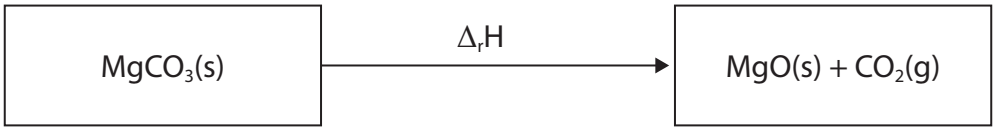
(3)

(b) The enthalpy change, $\Delta_r H$, for the thermal decomposition of magnesium carbonate, $MgCO_3$, can be calculated using the data in the table.

Substance	Enthalpy change of formation / kJ mol^{-1}
$MgCO_3$	–1095.8
MgO	–601.7
CO_2	–393.5

(i) Complete the Hess cycle with two arrows and correct species and state symbols in the box.

(2)



(ii) Calculate the enthalpy change for the thermal decomposition of magnesium carbonate, $\Delta_r H$. Include a sign and units in your answer.

(2)

(c) Explain how the enthalpy change for the thermal decomposition of calcium carbonate, $CaCO_3$, compares to that for magnesium carbonate in (b)(ii).

(3)

(Total for Question 18 = 10 marks)

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19 This question is about ozone, O_3.

Ozone is formed by the action of ultraviolet radiation on oxygen molecules.

$$3O_2(g) \rightleftharpoons 2O_3(g) \qquad \Delta_r H = +143\,kJ\,mol^{-1}$$

Ozone is a pale blue gas and oxygen gas is colourless.

A mixture of oxygen and ozone was placed in a sealed container and left to reach equilibrium.

(a) (i) Explain what you would **see** on heating the mixture.

(2)

(ii) Explain what you would **see** on increasing the pressure.

(2)

(b) Ozone can be used in the treatment of drinking water. As well as killing bacteria and viruses, ozone also removes other dissolved impurities such as hydrogen sulfide, H_2S. Hydrogen sulfide reacts with ozone to produce sulfuric acid.

$$4O_3(g) + H_2S(aq) \rightarrow H_2SO_4(aq) + 4O_2(g)$$

State the role of the ozone in this redox reaction.
Justify your answer using oxidation numbers.

(3)

(c) Ozone can also be used in the treatment of water in swimming pools.
A swimming pool has a volume of 375 000 dm^3 and contains 15 g of ozone.

Calculate the concentration of ozone in the pool in parts per million (ppm).

[Assume the density of water in the swimming pool = 1.00 g cm^{-3}]

(2)

(Total for Question 19 = 9 marks)

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20 An organic compound, acetoin, is one of the compounds that gives butter its characteristic flavour.

(a) Acetoin contains 54.5 % by mass of carbon and 9.1 % by mass of hydrogen. The remainder is oxygen.

(i) Calculate the empirical formula of acetoin.
You must show all your working.

(3)

(ii) The molar mass of acetoin is 88.0 g mol^{-1}.

Use this information to calculate the molecular formula of acetoin.

(1)

(b) Acetoin contains **two** functional groups.

(i) Some chemical tests were carried out on acetoin. These tests identify **one** of the two functional groups.

Acetoin produced steamy fumes when reacted with PCl_5.

Acetoin did **not** react with sodium hydrogencarbonate solution.

Acetoin turned hot acidified potassium dichromate(VI) solution from orange to green.

State what can be deduced from each of these three tests and hence identify this functional group.

(3)

.....

.....

.....

.....

.....

.....

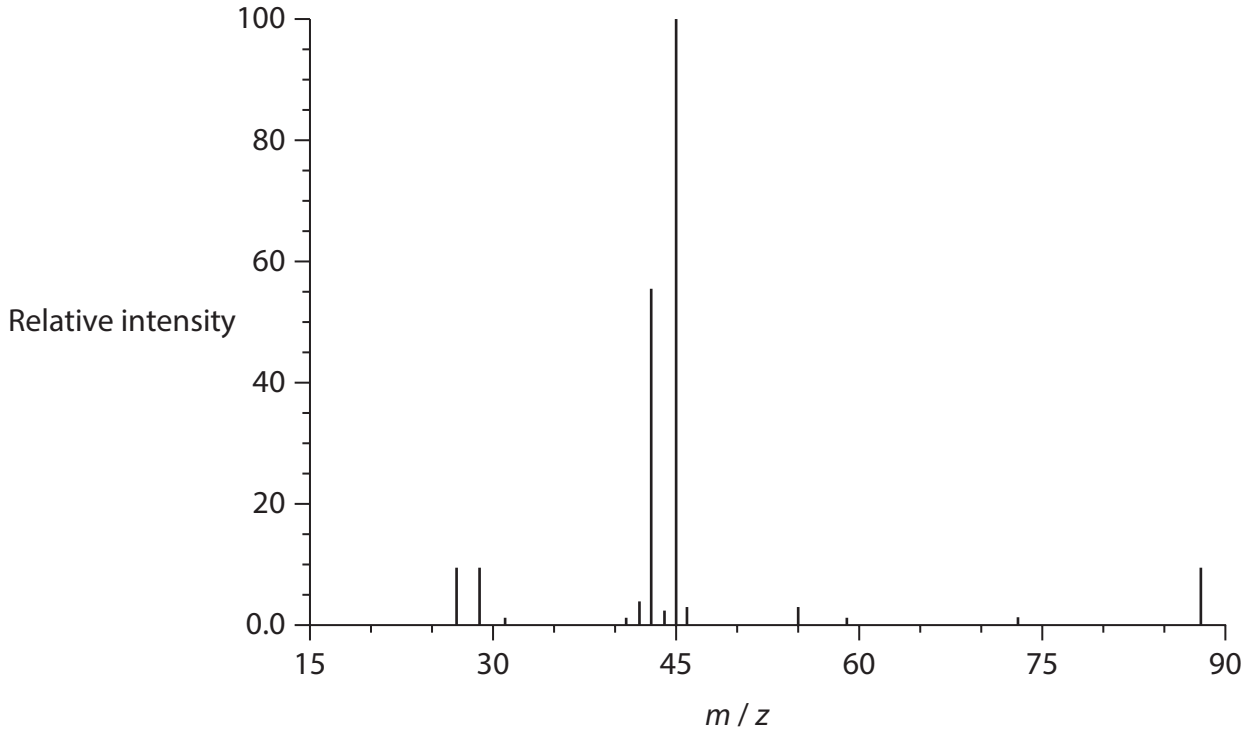
(ii) Acetoin also contains the carbonyl group C═O, in the form of a ketone **not** an aldehyde.

Use page 5 of your Data Booklet to show how infrared spectra data could be used to prove that acetoin contains a ketone not an aldehyde.
Complete the table.

(3)

	Bond	Wavenumber range / cm^{-1}
Absorption present in acetoin but not in an aldehyde		
One absorption present in an aldehyde but not in acetoin		
Another absorption present in an aldehyde but not in acetoin		

(iii) Part of the mass spectrum of acetoin is shown.



Determine a possible structure of acetoin using your answer to part (b)(i), the information given in (b)(ii) and the mass spectrum.

In your answer, identify the two ions responsible for the two peaks of highest intensity.

(3)

(Total for Question 20 = 13 marks)

21 This question is about halogenoalkanes.

(a) Complete the table by giving the **displayed** formula and name of each halogenoalkane.

(3)

	A straight chain primary chloroalkane with the molecular formula C_4H_9Cl	A tertiary iodoalkane with the molecular formula C_4H_9I
Displayed formula		
Name		

(b) The two halogenoalkanes in part (a) react with aqueous potassium hydroxide to produce alcohols.

Give **two** reasons why the rate of reaction of the iodoalkane is faster than that of the chloroalkane.

(2)

Reason 1 .....

.....

.....

Reason 2 .....

.....

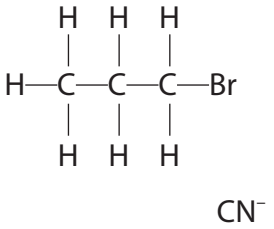
.....

(c) Halogenoalkanes react with cyanide ions, CN^-, in alcoholic solution to form nitriles. The cyanide ions act as nucleophiles.

Complete the mechanism for the formation of butanenitrile, $CH_3CH_2CH_2CN$.

Include curly arrows, and relevant lone pairs and dipoles.

(3)



(Total for Question 21 = 8 marks)

TOTAL FOR SECTION B = 40 MARKS

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SECTION C

Answer ALL the questions in this section.

Write your answers in the spaces provided.

22 Ammonia, ammonium nitrate and urea are nitrogen-based fertilisers.
The nitrogen in the fertiliser is taken up by the roots of plants and promotes growth.

Ammonia, NH_3, is manufactured by the reaction between nitrogen and hydrogen.
The nitrogen is obtained from the air.

Hydrogen can be obtained by two methods.

Method 1

The hydrogen is usually obtained by reacting methane gas with steam.

$$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$$

Method 2

Hydrogen can also be obtained using solar power to split water into hydrogen and oxygen.

$$2H_2O \rightarrow O_2 + 2H_2$$

(a) Evaluate which of these two methods used to obtain hydrogen is more sustainable.

(3)

(b) Ammonia can be used directly as a fertiliser or converted to other compounds such as ammonium nitrate and urea.

Name of fertiliser	ammonia	ammonium nitrate	urea
Formula	NH_3	NH_4NO_3	NH_2CONH_2
% nitrogen by mass	82.4		46.7

(i) Complete the table by calculating the percentage by mass of nitrogen in ammonium nitrate.

(1)

(ii) Give **one** advantage and **one** disadvantage of applying ammonia directly into the soil as a fertiliser.
Use information in the table and your knowledge of ammonia.

(2)

Advantage

.....

.....

Disadvantage

.....

.....

(c) Ammonium nitrate, NH_4NO_3, can be made by reacting ammonia with nitric acid.

(i) Give the equation for this reaction. State symbols are not required.

(1)

(ii) Name the type of reaction occurring.

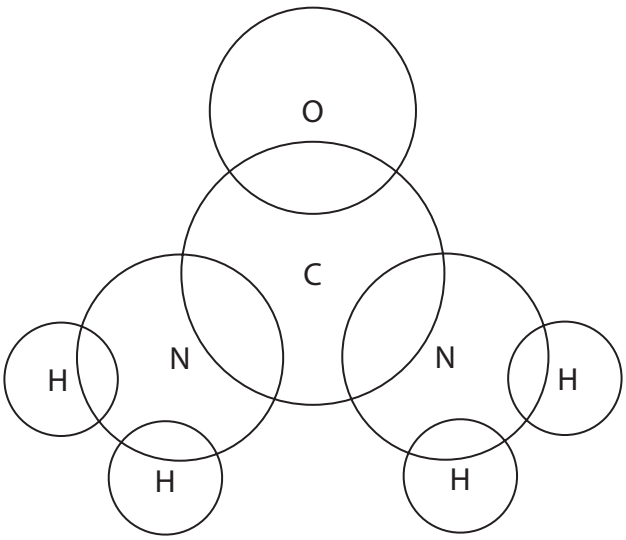
(1)

.....

(d) Urea, NH_2CONH_2, can also be made from ammonia.

Complete the dot-and-cross diagram for the urea molecule.

(2)



*(e) Both urea and ammonium nitrate are soluble in water.

Discuss the differences in the interactions of water molecules with both urea and ammonium nitrate.

Include **three** diagrams showing these interactions.

(6)

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(f) A field needs 160 kg of N per hectare to be applied using urea fertiliser.
The field size is 500 m × 640 m.

[1 hectare (ha) = 10 000 m^2, molar mass of urea = 60 g mol^{-1}]

Urea contains 46.7 % N by mass.

Calculate the mass of urea, in tonnes, that needs to be applied to the field.

Give your answer to an appropriate number of significant figures.

(4)

(Total for Question 22 = 20 marks)

TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 80 MARKS

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The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8) (18)
							1.0 H hydrogen 1										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

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

* Lanthanide series

* Actinide series