Oxford Cambridge and RSA

Tuesday 16 May 2023 – Morning

AS Level Chemistry B (Salters)

H033/01 Foundations of chemistry

Time allowed: 1 hour 30 minutes

You must have:
- the Data Sheet for Chemistry B

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.

Write your answer to each question in the box provided.

1 What is the outer electron configuration of tellurium, Te?

A $4p^6$

B $4s^2 4p^4$

C $5p^6$

D $5s^2 5p^4$

Your answer D **[1]**

2 Which of the following exists as cis/trans isomers?

A $(CH_3)_2CCHCH_3$

B $CH_3CHCHCH_3$

C $CH_3CH_2CH_2CH_3$

D $CH_2C(CH_3)_2$

Your answer B **[1]**

3 Which of these properties of chlorine is a benefit to humankind?

A It is a bleach.

B It is a gas.

C It is toxic to humans.

D It is pale green.

Your answer A **[1]**

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4 A solid substance has a high melting point and does not conduct electricity.

Which type of structure does this substance have?

A Ionic lattice

B Metallic lattice

C Simple molecular

D Structure resembling graphite

Your answer A **[1]**

5 A student looks up the concentrations of two gases in a sample.

The concentration of gas Y is given as 0.0001% and the concentration of gas Z is given as 1 ppm.

What is correct about the gases in the sample?

A Gases Y and Z are present in equal concentrations.

B It is impossible to tell the relative concentrations as the volume and pressure are not given.

C There is more gas Y than gas Z.

D There is more gas Z than gas Y.

Your answer A **[1]**

6 Which of the following is an elimination reaction?

A $CH_3COOCH_3 + NaOH \rightarrow CH_3COONa + CH_3OH$

B $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$

C $C_6H_5OH + (CH_3CO)_2O \rightarrow C_6H_5OCOCH_3 + CH_3COOH$

D $C_2H_5OH \rightarrow C_2H_4 + H_2O$

Your answer D **[1]**

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7 What is correct about a cracking reaction?

A An alkane can be broken into an alkane and two alkenes.

B An alkane can be converted into two smaller alkanes and an alkene.

C Matter is destroyed in the reaction.

D Unsaturated molecules are converted to saturated molecules.

Your answer A **[1]**

8 The Earth and the Sun both emit electromagnetic radiation.

Which statement is correct?

A The Earth emits infrared radiation.

B The Earth emits mainly ultraviolet radiation.

C The Sun emits no infrared radiation.

D The Sun emits only visible radiation.

Your answer A **[1]**

9 A sample of a gas has a volume of 0.60 m^3 under a pressure of 200 kPa and at 300 K.

How many moles of molecules are in this sample of gas?

A 0.021

B 0.048

C 21

D 48

Your answer D **[1]**

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10 Methane reacts with steam to form hydrogen:

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

What is the atom economy of this reaction for the formation of hydrogen?

A 4.3%

B 15%

C 24%

D 80%

Your answer B **[1]**

11 Chlorine is made by electrolysing sea water.

The following reaction occurs at the anode.

$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

Which statement is correct?

A Chloride ions are reduced.

B Electrons flow through the solution from the anode to the cathode.

C Sodium forms at the cathode.

D Some of the chlorine formed dissolves in the sea water.

Your answer D **[1]**

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12 A liquid is insoluble in water. It is purified from an aqueous solution in which it has been prepared.

One stage in the purification is allowing the liquid to stand over anhydrous sodium sulfate.

Which statement is correct?

A In this stage, no other anhydrous salt can be used.

B The next stage involves the use of a separating funnel.

C This stage is done before a final distillation.

D This stage is done to remove acidic impurities.

Your answer C **[1]**

13 Aluminium melts at 933 K and silicon melts at 1683 K.

Which of the following is a reason that silicon has a higher melting point than aluminium?

A Aluminium has an ionic structure, silicon has a simple molecular structure.

B Non-metals have higher melting points than metals.

C The bonds in the silicon lattice are stronger than the bonds in the aluminium lattice.

D There is a trend of increasing melting point across Period 3.

Your answer C **[1]**

14 The calcium ion is Ca^{2+}. The phosphate ion is PO_4^{3-}.

What is the formula of calcium phosphate?

A $CaPO_4$

B $Ca_2(PO_4)_3$

C Ca_3PO_4

D $Ca_3(PO_4)_2$

Your answer D **[1]**

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15 Which of the following represents the wavelength of radiation in terms of its energy, ΔE, the Planck constant, h, and the speed of light, c?

A $ch/\Delta E$

B $\Delta E/hc$

C $c\Delta E/h$

D $h\Delta E/c$

Your answer A **[1]**

16 Which of the following is correct?

A Infrared radiation has a longer wavelength than ultraviolet.

B Ultraviolet radiation has a lower frequency than infrared.

C Visible radiation has a higher frequency than ultraviolet.

D Visible radiation has a longer wavelength than infrared.

Your answer A **[1]**

17 What is the Avogadro constant, N_A, the number of?

A Atoms in one mole of carbon dioxide.

B Carbon atoms in one mole of C_2H_5OH.

C Sodium ions in one mole of $NaCl$.

D Molecules in one mole of magnesium.

Your answer C **[1]**

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18 How many π and σ bonds are there in one molecule of 2-methylpropene?

	π bonds	σ bonds
A	1	10
B	1	11
C	2	3
D	2	10

Your answer B **[1]**

19 The table shows some homologous series and the molecular formulae of compounds that may be members of those series.

Which row is correct?

	Homologous series	**Molecular formula of one member of the series**
A	acid anhydride	$C_4H_6O_3$
B	aldehyde	C_4H_7O
C	carboxylic acid	$C_4H_{10}O_2$
D	ester	$C_4H_8O_3$

Your answer A **[1]**

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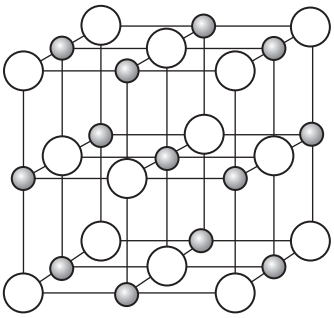
20 The model shown below represents part of a lattice of sodium chloride.



Which statement is correct about the model shown?

A Each line represents a shared pair of electrons.

B There are unequal numbers of sodium and chloride ions.

C The model represents a molecule of sodium chloride.

D The white circles are sodium ions.

Your answer B **[1]**

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Section B

21 Some students investigate plaster of Paris, hydrated calcium sulfate.
This is used for setting fractured bones as it sets into a hard mass when soaked in water.

Groups of students heat samples of plaster of Paris to constant mass to drive off the water of crystallisation.

Their results are shown in **Table 21.1** below.

Table 21.1

Group	Mass of plaster of Paris heated / g	Mass left after heating to constant mass / g
A	5.45	5.11
B	7.09	6.65
C	3.49	3.27
D	4.05	3.80
E	6.59	5.48

(a) **(i)** Explain the meaning of heating to constant mass.

Heat, cool and reweigh the sample, then keep repeating the heating and reweighing until there is no further change in mass. **[1]**

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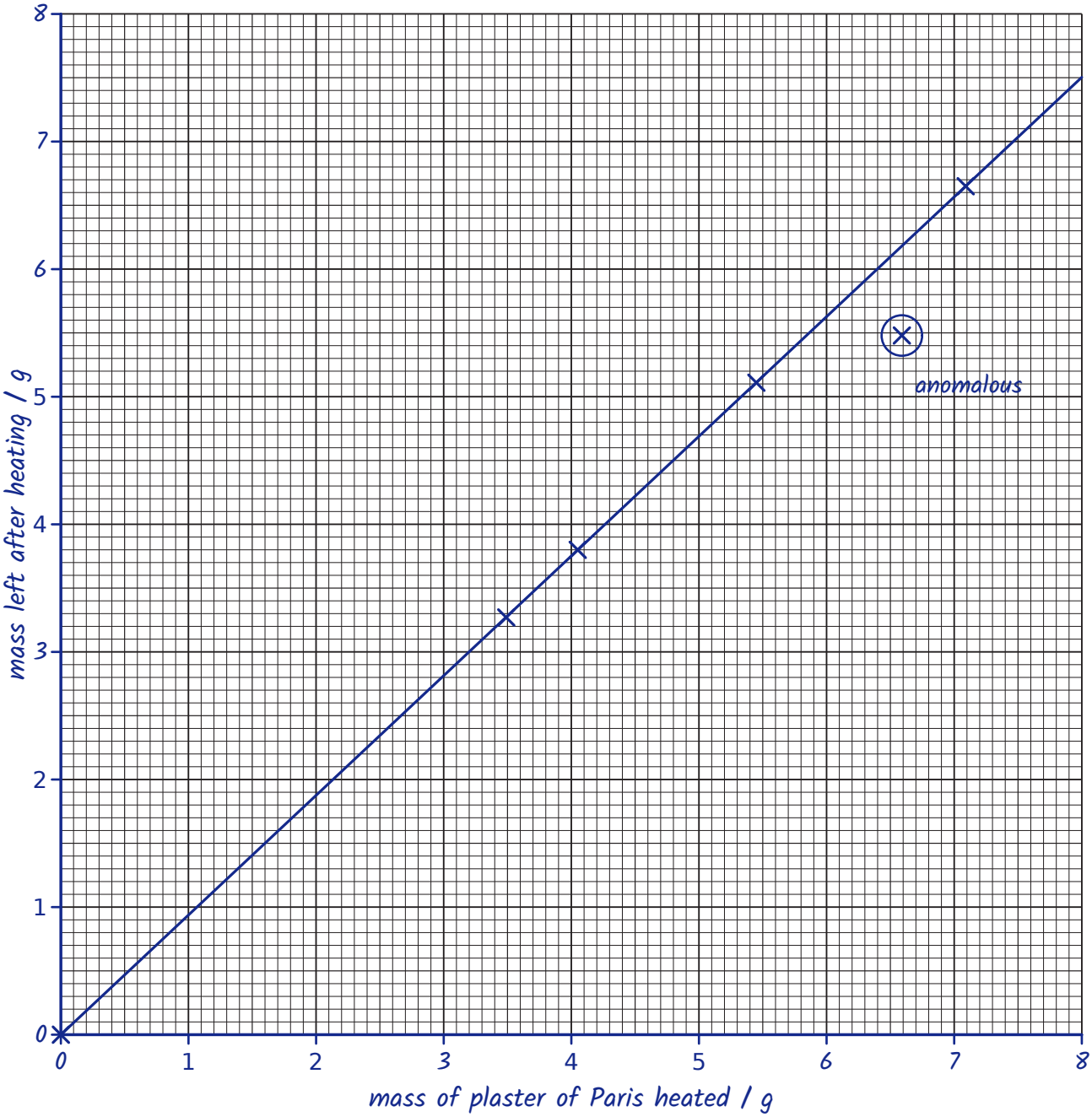
(ii) On the grid below, plot a graph of the results in **Table 21.1**. Include the origin. Draw the line of best fit.



[3]

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(iii) Plaster of Paris has the formula $CaSO_4 \cdot xH_2O$.

Calculate the value of *x* in this formula.

Give your answer to **1** significant figure.

$M_r(CaSO_4) = 40.1 + 32.1 + 4(16.0) = 136.2$

Group B: $n(CaSO_4) = 6.65 / 136.2 = 4.88 \times 10^{-2}$ mol

$n(H_2O) = (7.09 - 6.65) / 18.0 = 0.44 / 18.0 = 2.44 \times 10^{-2}$ mol

$x = n(H_2O) / n(CaSO_4) = 2.44 \times 10^{-2} / 4.88 \times 10^{-2}$

$= 0.50 = 0.5$ (1 s.f.)

x = ...0.5..... **[3]**

(b) The students do a flame test on plaster of Paris, hydrated calcium sulfate.

What colour would they see?

brick red..... **[1]**

(c) Why do chemists often compare the chemistry of magnesium and calcium?

Refer to electronic configurations in your answer.

Magnesium and calcium are both in Group 2 of the periodic table.

Both have two electrons in their outer s sub-shell (outer configuration s^2:

Mg $3s^2$, Ca $4s^2$), so they react in similar ways. **[2]**

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(d) The abundance of isotopes in a sample of calcium are shown in **Table 21.2**.

Table 21.2

Isotope	Abundance / %
^{40}Ca	96.968
^{42}Ca	0.652
^{44}Ca	2.190
^{48}Ca	0.190

(i) Give the mass number of the isotope that has 22 neutrons in its nucleus.

..42..... **[1]**

(ii) Use the data in **Table 21.2** to calculate a value for the relative atomic mass of this calcium sample.

Give your answer to **2** decimal places.

A_r = [(40 × 96.968) + (42 × 0.652) + (44 × 2.190)

+ (48 × 0.190)] / 100

= 4011.584 / 100 = 40.11584

relative atomic mass = ...40.12..... **[2]**

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22 The Antarctic ozone holes of 2020 and 2021 were some of the largest on record, in spite of an overall downwards trend. This was because of unusually cold conditions in the Antarctic in those years.

Chlorine radicals in the stratosphere form other radicals that react together on the cold surface of polar clouds. Chlorine molecules are one of the products.

When the clouds warm up, the chlorine molecules are split by ultraviolet radiation. This causes a sudden release of chlorine radicals.

(a) **(i)** Draw a mechanism (including 'half curly arrows') to show how a chlorine molecule is split to produce chlorine radicals.

[1]

(ii) Name the **type** of bond fission occurring in **part (i)**.

homolytic fission ..... **[1]**

(b) Chlorine radicals react in the stratosphere as shown in **equations 22.1, 22.2 and 22.3**.

$Cl + O_3 \rightarrow ClO + O_2$ **Equation 22.1**

$ClO + O \rightarrow Cl + O_2$ **Equation 22.2**

$Cl + Cl \rightarrow Cl_2$ **Equation 22.3**

(i) Identify a **termination** reaction from **Equation 22.1**, **Equation 22.2** and **Equation 22.3**.

Explain your answer.

Equation 22.3 .....

Explanation two (chlorine) radicals combine to form a molecule (a non-radical), so radicals are removed and the chain reaction stops. .....

..... **[1]**

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(ii) A student says:

- The reactions shown in **Equation 22.1** and **Equation 22.2** work together to cause the breakdown of ozone by the equation shown below:

  $2O_3 \rightarrow 3O_2$

- This does not break down much ozone, as there are so few chlorine atoms in the stratosphere and any present are rapidly removed by the reaction in **Equation 22.3**.

Comment on these statements.

The first statement is partly right: equations 22.1 and 22.2 do together cause the breakdown of ozone, but the overall equation is wrong. Adding them and cancelling Cl and ClO gives $O_3 + O \rightarrow 2O_2$, not $2O_3 \rightarrow 3O_2$.

The Cl radical is regenerated in equation 22.2, so it is not used up: it acts as a catalyst. So one chlorine atom can break down many (thousands of) ozone molecules even though there are few of them.

The second statement is wrong: equation 22.3 is slow, because there are so few chlorine radicals and they are so widely spaced that two rarely meet. Also Cl_2 is split by UV again to regenerate Cl radicals. **[5]**

(c) Haloalkanes are the source of the original chlorine radicals in the stratosphere.

CH_3Cl is present in the stratosphere, having been released by natural processes.

(i) Give the systematic name for CH_3Cl.

chloromethane **[1]**

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(ii) CH_3Cl has a higher boiling point than CH_4. This is because CH_3Cl has permanent dipole-permanent dipole bonding whereas CH_4 does not.

Explain why CH_3Cl has a permanent dipole.

Chlorine is more electronegative than carbon, so the C–Cl bond is polar ($C^{\delta+}–Cl^{\delta-}$). The molecule is asymmetric, so the dipoles do not cancel: one side is slightly negative and the other slightly positive. **[2]**

(d) When CH_3Cl is bubbled through a warm solution of silver ions in aqueous ethanol, a precipitate forms slowly.

Write an **ionic** equation for the formation of the precipitate.

Include state symbols.

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

[2]

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23 Cyanogen, N≡C–C≡N, is a gas which gives a very hot flame when it burns.

$N{\equiv}C{-}C{\equiv}N(g) + O_2(g) \rightarrow 2CO(g) + N_2(g)$ $\Delta_r H = -529\,kJ\,mol^{-1}$ **Equation 23.1**

Table 23.1 gives some bond enthalpy data.

Table 23.1

Bond	Enthalpy / kJ mol^{-1}	Bond	Enthalpy / kJ mol^{-1}
C–C (average)	+347	O=O	+498
C≡O (in CO)	+1077	C=O (in CO_2)	+805
N≡N	+945		

(a) The bond enthalpy for C–C in **Table 23.1** is described as an **average** bond enthalpy.

Explain the meaning of average in this context.

It is the mean of the C–C bond enthalpies measured in many different compounds (molecules), as the value varies slightly. **[1]**

(b) Use **Equation 23.1** and data from **Table 23.1** to calculate the bond enthalpy of C≡N in cyanogen.

Broken: 2(C≡N) + (C–C) + (O=O) = 2(C≡N) + 347 + 498

Made: (N≡N) + 2(C≡O) = 945 + 2(1077) = 3099

$\Delta_r H$ = broken − made: −529 = 2(C≡N) + 845 − 3099

2(C≡N) = 3099 − 845 − 529 = 1725

C≡N = 1725 / 2 = 862.5 kJ mol^{-1}

bond enthalpy = +863 kJ mol^{-1} **[3]**

(c) **(i)** Explain why the bond enthalpies in **Table 23.1** are all endothermic.

Energy has to be taken in (supplied) to break a bond, to overcome the attraction between the bonding pair of electrons and the two nuclei. Bond enthalpies are for breaking bonds, so they are all positive. **[2]**

(ii) Use the information in **Table 23.1** to compare the **relative bond lengths** in CO and CO_2.

C≡O in CO has a larger bond enthalpy than C=O in CO_2, so the C≡O bond in CO is shorter than the C=O bond in CO_2. **[1]**

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(d) **Equation 23.1** is repeated below:

$N{\equiv}C{-}C{\equiv}N(g) + O_2(g) \rightarrow 2CO(g) + N_2(g)$ $\Delta_r H = -529\,kJ\,mol^{-1}$ **Equation 23.1**

Scientists do two experiments using a steady flow of cyanogen gas.

Experiment 1

They collect the cyanogen from the flow in a measuring cylinder over water for 5.0 minutes.

They collect $2.4 \times 10^2\,cm^3$ at RTP.

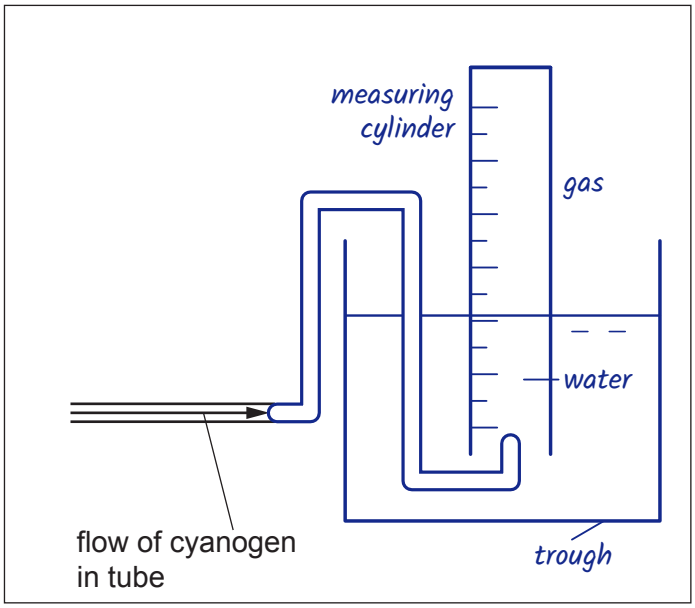
Experiment 2

They ignite the flow of cyanogen and use it to heat $110\,cm^3$ of water for 5.0 minutes.

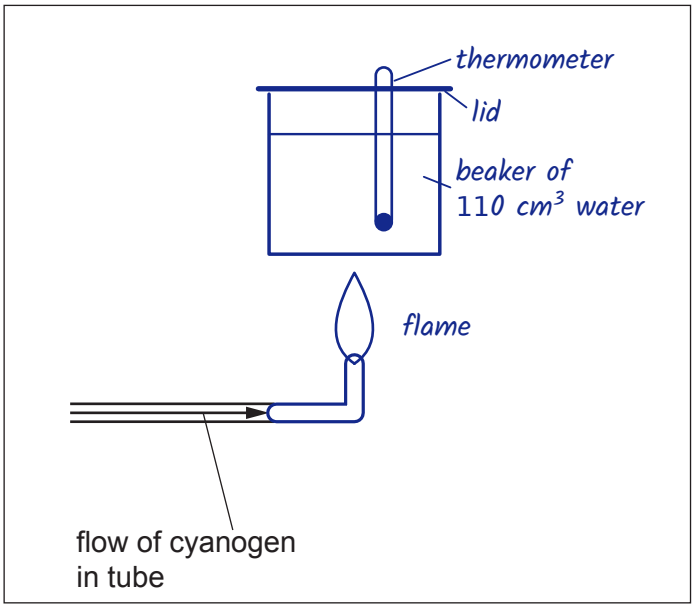
They measure the increase in temperature of the water.

(i) Complete labelled diagrams of simple apparatus that could be used for **Experiment 1** and **Experiment 2**.

Experiment 1



Experiment 2



[3]

(ii) Describe **one** improvement that could have been made to **Experiment 2** to improve the accuracy of the result.

Insulate (lag) the beaker of water, to reduce heat loss to the surroundings. **[1]**

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(iii) Calculate the maximum possible temperature rise of the water.

Use the scientists' result and measurements from **part (d)** and **Equation 23.1**.

Give your answer to an **appropriate** number of significant figures.

n(cyanogen) = 240 / 24 000 = 0.0100 mol

energy released = 0.0100 × 529 = 5.29 kJ = 5290 J

q = mcΔT, so ΔT = q / mc (m = 110 g of water)

ΔT = 5290 / (110 × 4.18) = 11.5 °C

= 12 °C (2 s.f., as the data are given to 2 s.f.)

maximum possible temperature rise = ...12..... °C **[4]**

(e) Cyanogen is toxic.

Name another toxic compound in **Equation 23.1**.

..carbon monoxide..... **[1]**

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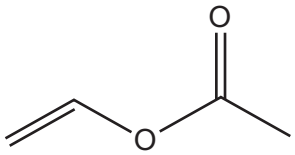
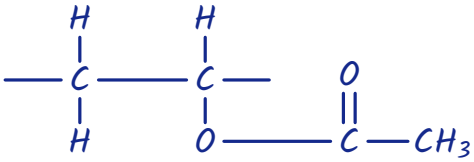
24 Polyvinyl acetate, PVAc, is a polymer used as a wood glue.

PVAc is made from the monomer vinyl acetate.



Vinyl acetate

(a) Give the **full structural** formula of a repeating unit of PVAc.



[1]

(b) PVAc acts as a glue because of the intermolecular bonds it forms.

Name the **strongest** type of intermolecular bond between chains of PVAc.

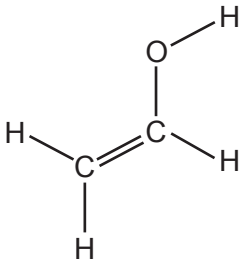
permanent dipole-permanent dipole bonds ..... **[1]**

(c) A student carries out a simple test to show that the liquid vinyl acetate is unsaturated.

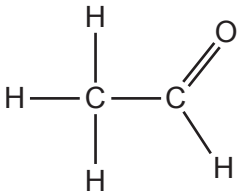
Give details of the test and its result.

Add bromine water and shake: it is decolourised (turns from orange to colourless). ..... **[1]**

(d) Polyvinyl alcohol is another useful polymer. However, the monomer, vinyl alcohol, is unstable and forms its isomer ethanal.



Vinyl alcohol



Ethanal

Name the functional group in ethanal.

aldehyde (carbonyl) group ..... **[1]**

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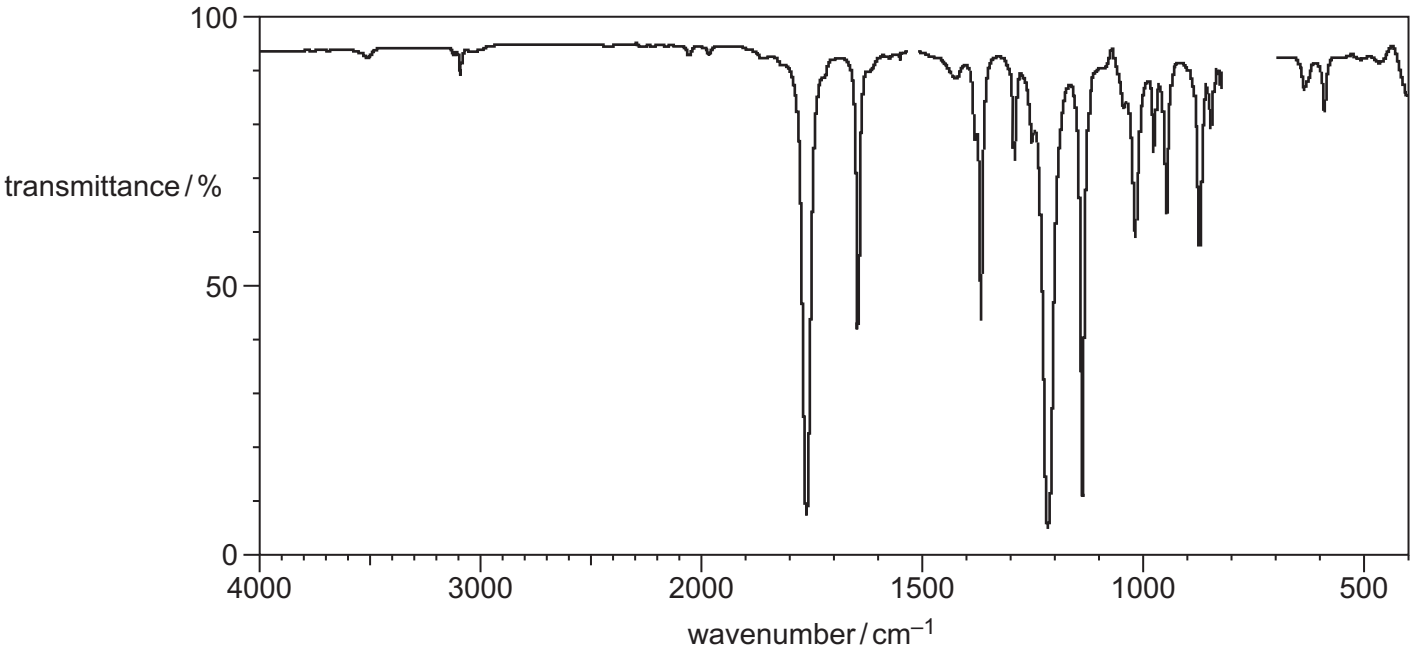
(e) The IR spectrum of a compound is shown below.



The compound is **one** of:

- ethanal
- polyvinyl acetate
- polyvinyl alcohol
- vinyl acetate

Identify the compound and give your reasons in terms of wavenumbers and the related bonds.

The compound is vinyl acetate.

Peak at about 1650 cm^{-1}: C=C (alkene), so the compound is unsaturated and is not one of the polymers.

Strong peak at about 1760 cm^{-1}: C=O (ester).

Strong peaks at about 1220 and 1140 cm^{-1} (within 1000 to 1300): C–O, so it is not ethanal.

No broad peak at 3200 to 3600 cm^{-1}, so there is no O–H (not polyvinyl alcohol). **[4]**

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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