OCR
Oxford Cambridge and RSA

Tuesday 23 May 2023 – Morning

AS Level Chemistry A

H032/02 Depth 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

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H032/02

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

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

First name(s) _____

Last name _____

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 **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **16** pages.

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

1 This question is about titanium (atomic number 22) and its compounds.

(a) Titanium exists as a mixture of five isotopes.

A chemist analyses a sample of titanium using mass spectrometry.

The results are shown in the table below.

Isotope	Abundance (%)
^{46}Ti	8.30
^{47}Ti	7.40
^{48}Ti	73.70
^{49}Ti	5.40
^{50}Ti	5.20

(i) Calculate the relative atomic mass of titanium in the sample.

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

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

(ii) Complete the electron configuration of a titanium atom.

$1s^2$ ..... **[1]**

(iii) Complete the table to show the number of protons, neutrons and electrons in a $^{48}Ti^{2+}$ ion.

	Protons	Neutrons	Electrons
$^{48}Ti^{2+}$ ion			

[1]

(b) An ore of titanium contains impure TiO_2.

Titanium is manufactured from TiO_2 in a two-stage process.

Stage 1 $TiO_2 + 2C + 2Cl_2 \rightarrow TiCl_4 + 2CO$ **Reaction 1.1**

Stage 2 $TiCl_4 + 4Na \rightarrow Ti + 4NaCl$ **Reaction 1.2**

(i) The common name for TiO_2 is titanium dioxide.

What is the systematic name of TiO_2?

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

(ii) In **Reaction 1.2**, the percentage yield of titanium from $TiCl_4$ is 72.0%.

Calculate the minimum mass, in kg, of sodium that is needed to produce 1.00 kg of titanium.

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

mass of sodium = ... kg **[4]**

(iii) **Reaction 1.2** produces a mixture of titanium and sodium chloride.

Suggest how titanium could be separated from this mixture at room temperature.

Explain your answer.

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..... **[2]**

2 This question is about some elements in Period 3 and compounds they form.

(a) A student adds a small piece of calcium to a beaker containing an excess of water.

(i) Construct the equation for the reaction and predict **one** observation that the student would make.

Equation .....

Observation .....

.....

[2]

(ii) Suggest **one** difference that the student would observe in the reaction of barium with water compared to the reaction of calcium with water.

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

(b) A student has a 5.00 g mixture of sodium chloride, NaCl(s), and barium nitrate, $Ba(NO_3)_2$(s).

The student also has a solution of sodium sulfate, Na_2SO_4(aq).

The student uses the method below to determine the percentage by mass of NaCl(s) in the mixture.

Step 1 Dissolve the 5.00 g mixture in distilled water.

Step 2 Add an excess of Na_2SO_4(aq) to the solution. A precipitate of barium sulfate forms.

Step 3 Filter off the precipitate, wash with water, and dry.

Step 4 Weigh the dried precipitate.

The molar mass of barium sulfate is 233.4 g mol^{-1}.

(i) Write an equation for the formation of barium sulfate in **step 2**.

Include state symbols.

..... **[2]**

(ii) The student obtains 3.28 g of precipitate.

Calculate the percentage by mass of NaCl(s) in the 5.00 g mixture.

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

percentage by mass of NaCl(s) = ... % **[4]**

(iii) The student changes the method in **2(b)**.

In **step 2**, the student adds an excess of silver nitrate solution, $AgNO_3$(aq), instead of Na_2SO_4(aq).

Explain whether this change would allow the student to determine the percentage by mass of NaCl(s) in the mixture.

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..... **[2]**

(c) The table below shows melting points and electrical conductivities of some elements in Period 3 and compounds they form.

Substance	**Magnesium sulfide, MgS**	**Aluminium, Al**	**Silicon, Si**	**Phosphorus trichloride, PCl_3**
Melting point / °C	2000	660	1414	–94
Electrical conductivity		Good	Poor	
Type of lattice structure	Giant	....	....	....

(i) Complete the table above to show the type of lattice structure of each substance. **[4]**

(ii) Explain the following:

- MgS has a higher melting point than PCl_3.
- Al has a greater electrical conductivity than Si.

Melting points .....

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Conductivities .....

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[4]

3 This question is about halogens and halogen compounds.

(a)* Seawater contains very small quantities of dissolved iodide ions.

The concentration of potassium iodide, KI, in seawater is $0.150\,g\,dm^{-3}$.

Iodine can be extracted by bubbling chlorine gas through seawater.

Explain why chlorine is more reactive than iodine and determine the volume, in dm^3, of seawater that is needed to manufacture 1.00 tonne of iodine, I_2. **[6]**

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Additional answer space if required.

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(b) Chlorine reacts with calcium hydroxide to form $Ca(OCl)_2$, which is the active ingredient in bleaching powder.

$2Cl_2 + 2Ca(OH)_2 \rightarrow CaCl_2 + Ca(OCl)_2 + 2H_2O$

This is a disproportionation reaction.

State what is meant by **disproportionation** and use oxidation numbers to show that disproportionation has taken place.

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..... **[3]**

(c) A student is studying the hydrolysis of haloalkanes.

The equation for the alkaline hydrolysis of 2-bromopropane, $CH_3CHBrCH_3$, is shown below.

$CH_3CHBrCH_3 + OH^- \rightarrow CH_3CHOHCH_3 + Br^-$

Use the curly arrow model to outline the mechanism for the alkaline hydrolysis of 2-bromopropane.

Show relevant dipoles and lone pairs, and name the mechanism.

name of mechanism ..... **[3]**

(d) The student sets up an experiment to compare the rates of hydrolysis of 2-bromopropane and 2-iodopropane.

The student uses the method below.

Step 1 Place two test tubes, both containing aqueous silver nitrate and ethanol, in a water bath at 60 °C.

Step 2 Add five drops of 2-bromopropane to one test tube and five drops of 2-iodopropane to the other test tube.

Step 3 Record the time taken for a precipitate to appear in each test tube.

(i) Complete the table below to show the formula and colour of each precipitate formed.

Haloalkane	Formula of precipitate	Colour of precipitate
2-bromopropane		
2-iodopropane		

[2]

(ii) Predict which precipitate would form first and explain the difference in the rates of hydrolysis of 2-bromopropane and 2-iodopropane.

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

4 This question is about the enthalpy change of combustion of alcohols.

(a) Explain the term **enthalpy change of combustion**.

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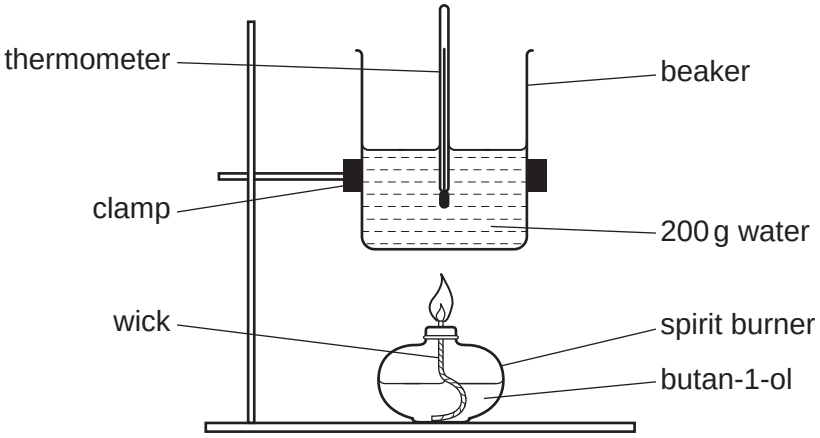
..... **[2]**

(b) A student carries out an experiment to determine the enthalpy change of combustion, $\Delta_c H$, of butan-1-ol, $CH_3CH_2CH_2CH_2OH$.

The student sets up the apparatus as shown below.



The student's results are shown in the table below.

Initial temperature of water / °C	18.5
Final temperature of water / °C	49.5
Mass of burner before heating / g	212.38
Mass of burner after heating / g	211.07

(i) The thermometer had an uncertainty of ± 0.25 °C in each temperature reading.

Calculate the percentage uncertainty in the temperature change.

percentage uncertainty = ... % **[1]**

(ii)* Use the student's results to determine $\Delta_c H$ of butan-1-ol in $kJ\,mol^{-1}$.

Explain why this value of $\Delta_c H$ is different from the data book value and suggest how the experimental design could be modified to improve the accuracy of the $\Delta_c H$ value obtained. **[6]**

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Additional answer space if required.

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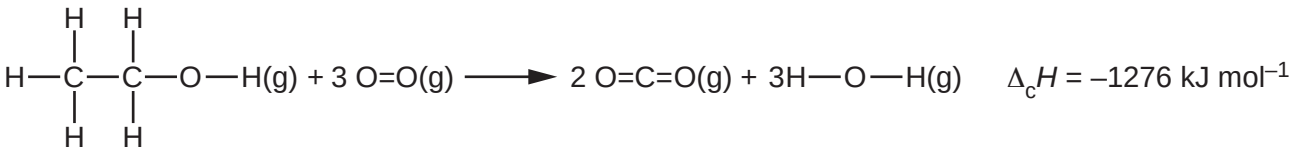
(iii) Another student carries out the experiment in **4(b)** using 150 g of water in the beaker instead of 200 g.

Calculate the mass of butan-1-ol that would produce the same temperature rise as in the experiment in **4(b)**.

Assume the same heat losses.

mass of butan-1-ol = ... g **[1]**

(c) The enthalpy change of combustion of ethanol, $\Delta_c H$, in the gaseous state can be calculated using average bond enthalpies.



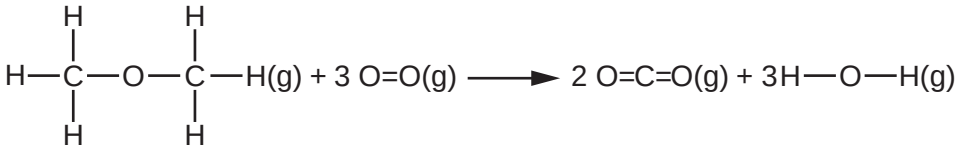
(i) Use this value of $\Delta_c H$ and the average bond enthalpies below to calculate the average bond enthalpy of C=O.

Bond	Average bond enthalpy / kJ mol^{-1}
C–H	+413
C–C	+347
C–O	+358
O–H	+464
O=O	+498

C=O bond enthalpy = ...kJ mol^{-1} **[4]**

(ii) Methoxymethane, CH_3OCH_3, is an isomer of ethanol.

On combustion, methoxymethane, in the gaseous state, produces carbon dioxide and steam.



$\Delta_c H$ for methoxymethane is more negative than $\Delta_c H$ for ethanol.

Explain why the $\Delta_c H$ values are different, in terms of the bonds broken and the bonds formed.

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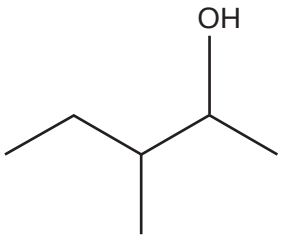
..... **[2]**

5 This question is about alkenes.

(a) A mixture of alkenes is produced when water is eliminated from alcohol **A**.



Alcohol A

(i) What is the systematic name of alcohol **A**?

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

(ii) Alcohol **A** is refluxed with an acid catalyst.

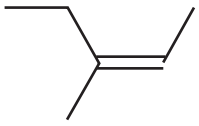
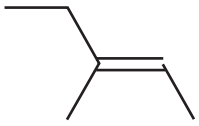
- A mixture of alkene isomers **B**, **C** and **D** is formed.
- Alkenes **B** and **C** show *E*/*Z* isomerism but alkene **D** does not.

Construct the equation for the formation of alkene **D** from alcohol **A**.

Show the structure of the organic product.

[2]

(iii) The skeletal formulae of alkenes **B** and **C** are shown below.

	Alkene B	**Alkene C**
Skeletal formula		
Isomer	*Z*	*E*

Use the Cahn-Ingold-Prelog priority rules to explain why alkene **B** is the *Z* isomer.

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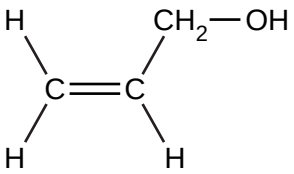
(b) A chemistry company is developing water-soluble polymers.

The chemists decide to use compound **E**, shown below, as the monomer.



Compound E

(i) Draw a section of the polymer formed, showing **two** repeat units, and suggest why this polymer is likely to be soluble in water.

Section of polymer (**two** repeat units)

Reason for solubility in water .....

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[2]

(ii) Outline **two** ways that waste hydrocarbon polymers can be processed usefully, rather than being disposed of in landfill sites.

1 .....

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2 .....

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[2]

END OF QUESTION PAPER

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).