OCR
Oxford Cambridge and RSA

Monday 18 October 2021 – Morning

A Level Chemistry A

H432/03 Unified 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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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 **20** pages.

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

Answer **all** the questions.

1 These short questions are from different areas of chemistry.

(a) A flask contains 110 g CO_2 and 120 g O_2 at a pressure of 50.0 atm.

What is the partial pressure of the CO_2?

partial pressure of CO_2 = ... atm **[2]**

(b) Pure PCl_5 is placed in a sealed container which is heated to 200 °C.

An equilibrium is set up: $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

Under these conditions:
- $K_c = 8.00 \times 10^{-3}$ mol dm^{-3}
- equilibrium concentration of $PCl_5 = 0.0500$ mol dm^{-3}.

Calculate the concentrations of PCl_3 and Cl_2 at equilibrium.

concentration of PCl_3 = ... mol dm^{-3}

concentration of Cl_2 = ... mol dm^{-3}
[2]

(c) The electronegativities of H, C, N and F, and the boiling points of methane, ammonia and hydrogen fluoride are shown below.

Electronegativity	H: 2.1	C: 2.5	N: 3.0	F: 4.0

Compound	CH_4	NH_3	HF
Boiling point/ºC	–161.5	–33.3	19.5

Explain the difference in the boiling points of CH_4, NH_3 and HF.

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

(d) Compound **A** has the following percentage composition by mass:

Ca, 81.10%; N, 18.90%.

A student reacts compound **A** with water to form alkaline gas **B** and alkali **C**.

Identify **A**, **B** and **C** and write the equation for the reaction of compound **A** with water.

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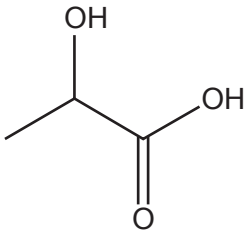
..... **[4]**

(e) The structure of lactic acid is shown below.



lactic acid

Complete and balance the equations for two reactions of lactic acid.

Reaction with sodium carbonate

$CH_3CH(OH)COOH$ + ... → .....

Reaction with aluminium

$CH_3CH(OH)COOH$ + ... → .....

[4]

(f) The ester, methyl ethanoate, can be synthesised by reacting a haloalkane with a carboxylate ion.

The mechanism is nucleophilic substitution.

Outline the mechanism for this reaction.

[3]

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2 Europium (A_r = 152.0) reacts with dilute aqueous acid in a redox reaction, forming a solution and hydrogen gas.

A student proposed three possible ionic equations for this reaction, forming europium ions with different charges:

Equation 1 $2Eu(s) + 2H^+(aq) \rightarrow 2Eu^+(aq) + H_2(g)$

Equation 2 $Eu(s) + 2H^+(aq) \rightarrow Eu^{2+}(aq) + H_2(g)$

Equation 3 $2Eu(s) + 6H^+(aq) \rightarrow 2Eu^{3+}(aq) + 3H_2(g)$

The student plans to carry out an investigation to determine which equation is correct.
Hydrochloric acid is used as the source of $H^+(aq)$ ions.

The student's method is outlined below.

Step 1 Using a 3 decimal place balance, weigh a suitable container for the reaction.
Add **about** 1 g of europium to the container and reweigh.

Step 2 Set up apparatus for gas collection.
Add an excess of dilute hydrochloric acid to the europium.

Step 3 Measure the volume of gas produced.

Results

Mass of container	= 32.795 g
Mass of container + europium	= 33.783 g
Volume of gas collected	= 152 cm^3

(a) Draw a labelled diagram of suitable apparatus for this investigation.

[2]

(b) Analyse the student's results to conclude which of **Equation 1** or **2** or **3**, is supported by the experimental results.

Assume that the conditions in the laboratory are 'room temperature and pressure' (RTP).

correct equation (**1**, **2**, or **3**) = ... **[3]**

(c) The student repeats the experiment but adds concentrated hydrochloric acid instead of dilute hydrochloric acid. The apparatus gets hot during the reaction.

Predict how the hot apparatus would change the student's results and the conclusion in **(b)**.

Explain your answer.

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

(d) The student modifies their method as outlined below:

- 1.52 g (0.01 mol) of europium is reacted with an excess of dilute hydrochloric acid.
- An excess of aqueous sodium hydroxide is added to the reaction mixture.
- A precipitate forms which is collected, dried and weighed.

Explain how the mass of precipitate formed would allow the student to conclude which of **Equation 1** or **2** or **3** is correct.

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

3 This question is about carboxylic acids.

Compound **D** is a *cis* stereoisomer of an unsaturated organic acid with the general formula $C_nH_{2n-1}COOH$.

A student plans to analyse acid **D** by carrying out a titration.

(a) A student first prepares 250.0 cm^3 of a standard solution of 0.150 $mol\,dm^{-3}$ $Ba(OH)_2$ for the titration.

The student is provided with solid $Ba(OH)_2$ and usual laboratory apparatus and equipment.

Describe how the student would prepare the standard solution, giving full details of quantities, apparatus and method.

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..... **[5]**

(b) The student prepares a 100.0 cm^3 solution containing 3.215 g of acid **D**.

The student titrates 25.0 cm^3 samples of the solution of **D** with 0.150 mol dm^{-3} $Ba(OH)_2(aq)$ in the burette.

1 mol $Ba(OH)_2$ reacts with 2 mol of **D**.

The mean titre of $Ba(OH)_2(aq)$ is 23.50 cm^3.

Analyse the titration results to determine **two** possible structures for the *cis* stereoisomer of organic acid **D**.

Structures of 2 possible *cis* stereoisomers of acid D

[7]

4 Pent-1-ene and iodine react as shown in the equation below.

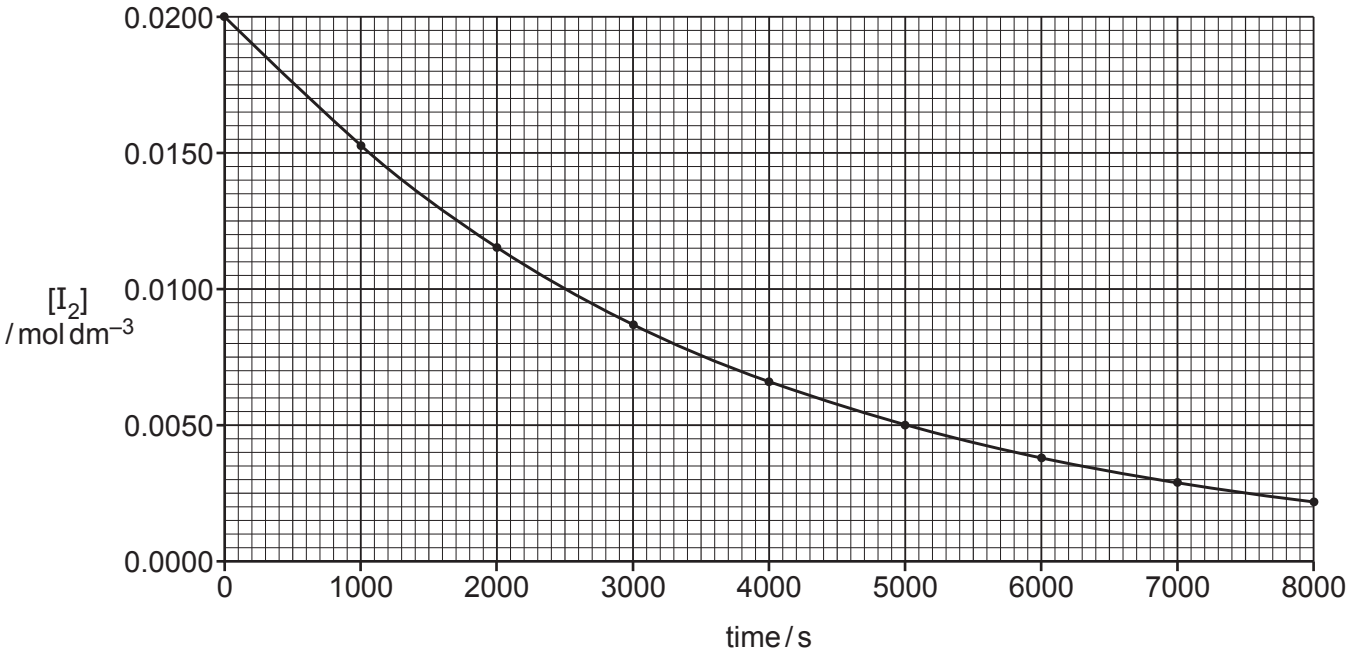
$CH_3CH_2CH_2CH{=}CH_2 + I_2 \longrightarrow CH_3CH_2CH_2CHICH_2I$

A student investigates the rate of this reaction by monitoring the concentration of iodine over time. The initial concentrations are shown in the table.

	Concentration / mol dm^{-3}
I_2	0.0200
$CH_3CH_2CH_2CH{=}CH_2$	2.0000

In this investigation, the order with respect to pent-1-ene can be assumed to be zero.

The student plots the graph below from the experimental results.



(a) Why can the order with respect to pent-1-ene be assumed to be zero in this investigation?

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

(b)* The student's experimental procedure shows that the reaction is first order with respect to iodine.

Show that this statement is true and determine the initial rate of reaction and rate constant.

Assume that the reaction is zero order with respect to pent-1-ene. Show your working on the graph on page 10 and the lines below as appropriate. **[6]**

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(c) Further experiments provide evidence that the reaction is first order with respect to **both** $CH_3CH_2CH_2CH=CH_2$ **AND** I_2.

(i) Write equations to suggest a two-step mechanism for the reaction.

Slow

Fast

[2]

(ii) Suggest how the investigation could be modified to show that the reaction is first order with respect to pent-1-ene.

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

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5 This question is about nitrogen and its compounds.

(a) Sodium azide, NaN_3, has been used in car airbags.

The airbag inflates when the NaN_3 decomposes to form nitrogen gas:

$2NaN_3(s) \longrightarrow 2Na(s) + 3N_2(g)$

(i) This is a redox reaction.

Write half-equations for the reduction and oxidation processes that take place.

Reduction .....

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

(ii) A 16.0 dm^3 airbag is inflated at 17.0 °C.
The pressure in the inflated airbag is 1.20×10^5 Pa.

Calculate the mass of NaN_3 that has decomposed.

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

mass of NaN_3 = ... g **[5]**

(b) Hydrazoic acid, HN_3, is a weak acid ($K_a = 2.51 \times 10^{-5}\,mol\,dm^{-3}$).

(i) Calculate the pH of $0.125\,mol\,dm^{-3}$ hydrazoic acid.

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

pH = ... **[2]**

(ii) When added to water, hydrazoic acid forms an equilibrium mixture containing conjugate acid–base pairs.

Complete the equation for this equilibrium and label the conjugate acid–base pairs as: **A1**, **B1** and **A2**, **B2**.

Equation HN_3 + ... $\rightleftharpoons$ ..... + ...

Acid-base pairs ....

[2]

(iii) In the Schmidt reaction, hydrazoic acid, HN_3, reacts with carboxylic acids to form primary amines.

For example, HN_3 reacts with RCOOH to form RNH_2 and two gases that are found in the atmosphere.

Write the equation for the reaction of HN_3 with 2-methylbutanoic acid.

Show structures for organic compounds.

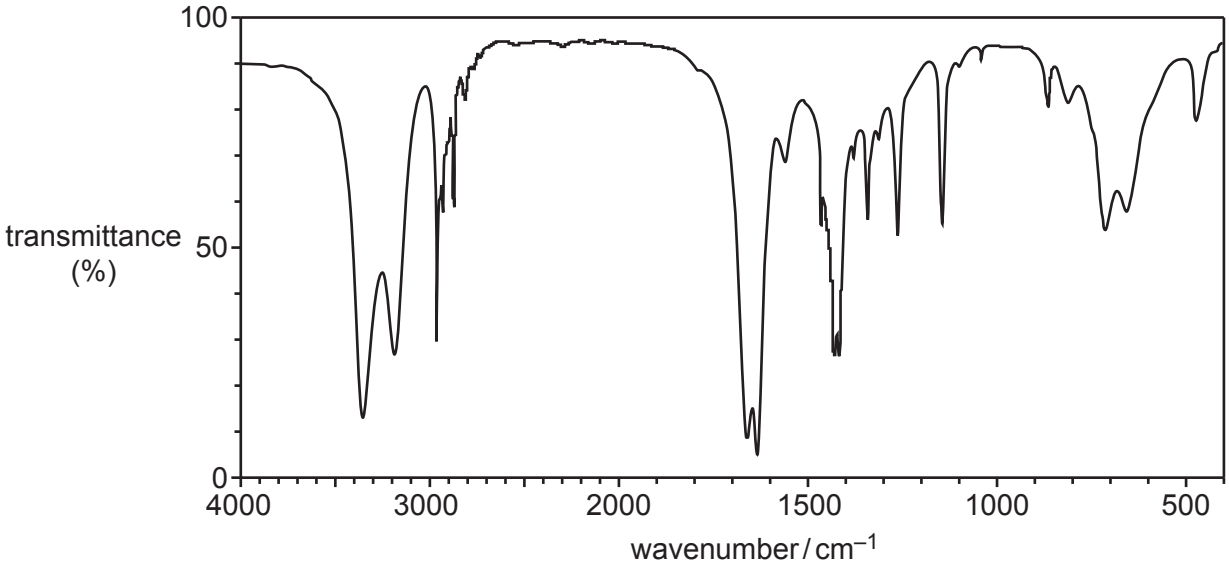
[3]

(c)* This question is about two reactions of ammonia.

Reaction 1
Excess ammonia is reacted with 4.77 g of copper(II) oxide. The reaction produces 3.81 g of solid **E**, liquid **F** and 0.560 g of gas **G**, which has a volume of 480 cm^3 at RTP.

Reaction 2
Ammonia reacts with compound **H** to form compound **I**, C_2H_5NO, and chloride salt **J**.

The IR spectrum of **I** is shown below.



Identify **E**, **F**, **G**, **H**, **I** and **J**, and write equations for the **two** reactions.

Show your reasoning. **[6]**

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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).