



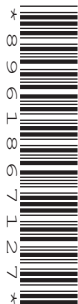
Oxford Cambridge and RSA

**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



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

Centre number

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Candidate number

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First name(s)

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Last name

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**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<sub>2</sub> and 120 g O<sub>2</sub> at a pressure of 50.0 atm.

What is the partial pressure of the CO<sub>2</sub>?

partial pressure of CO<sub>2</sub> = ..... atm **[2]**

**(b)** Pure PCl<sub>5</sub> is placed in a sealed container which is heated to 200°C.

An equilibrium is set up:  $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$

Under these conditions:

- $K_c = 8.00 \times 10^{-3} \text{ mol dm}^{-3}$
- equilibrium concentration of PCl<sub>5</sub> = 0.0500 mol dm<sup>-3</sup>.

Calculate the concentrations of PCl<sub>3</sub> and Cl<sub>2</sub> at equilibrium.

concentration of PCl<sub>3</sub> = ..... mol dm<sup>-3</sup>

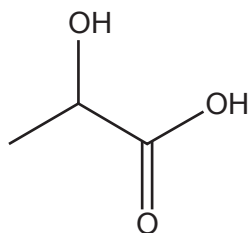
concentration of Cl<sub>2</sub> = ..... mol dm<sup>-3</sup>  
**[2]**

|                         |                 |                 |      |
|-------------------------|-----------------|-----------------|------|
| <b>Compound</b>         | CH <sub>4</sub> | NH <sub>3</sub> | HF   |
| <b>Boiling point/°C</b> | −161.5          | −33.3           | 19.5 |

[3]

[4]

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



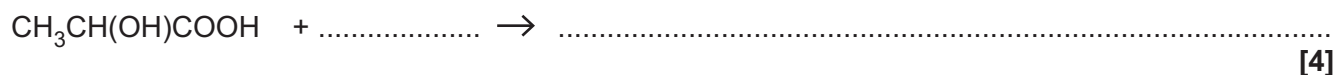
**lactic acid**

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

**Reaction with sodium carbonate**



**Reaction with aluminium**



**[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.

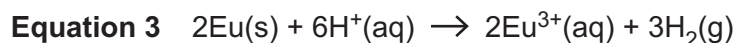
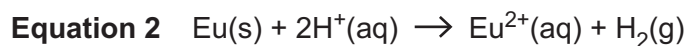
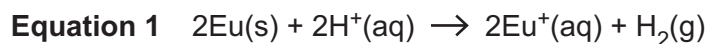
**[3]**

**5**  
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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:



The student plans to carry out an investigation to determine which equation is correct. Hydrochloric acid is used as the source of  $\text{H}^+(\text{aq})$  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 <sup>3</sup> |

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

- (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.

.....  
.....  
.....  
..... [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.

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

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

- The student is provided with solid  $\text{Ba}(\text{OH})_2$  and usual laboratory apparatus and equipment.

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

..... [5]

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

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

$1\text{ mol Ba}(\text{OH})_2$  reacts with  $2\text{ mol}$  of **D**.

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

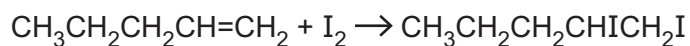
Analyse the titration results to determine **two** possible structures for the *cis* stereoisomer of organic acid **D**.

**Structures of 2 possible *cis* stereoisomers of acid D**

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[7]

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

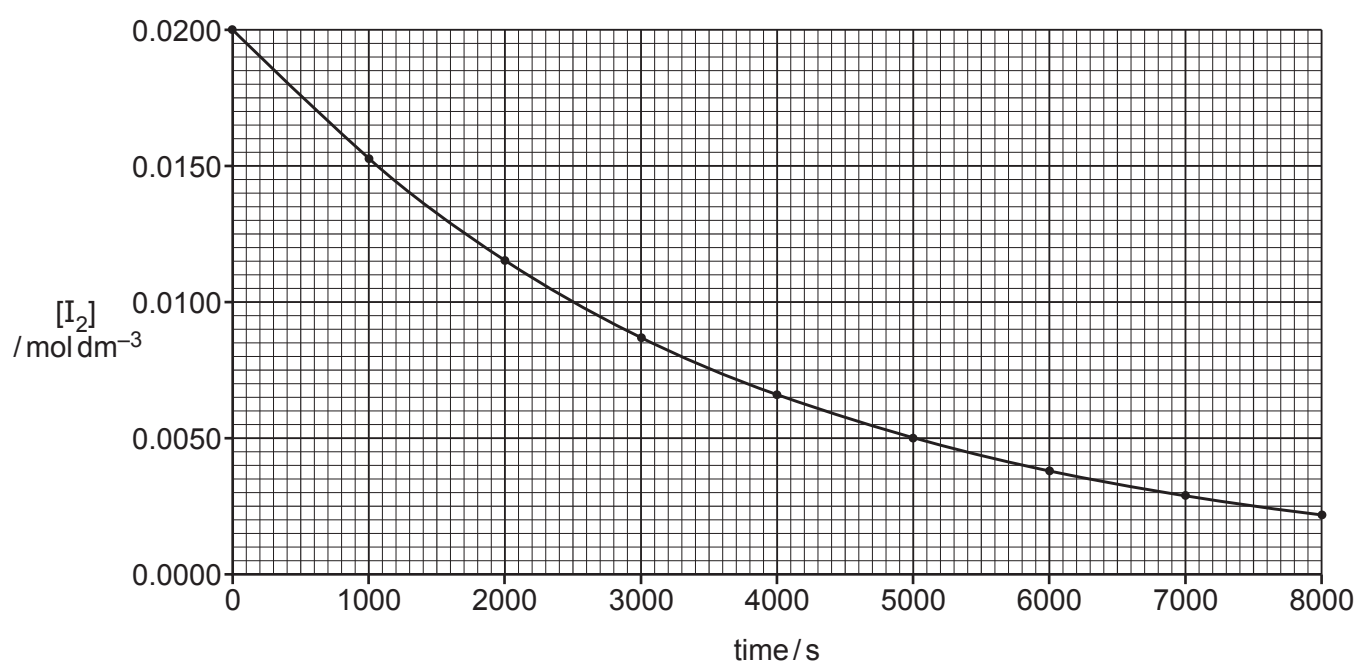


A student investigates the rate of this reaction by monitoring the concentration of iodine over time. The initial concentrations are shown in the table.

|                                                          | Concentration / $\text{mol dm}^{-3}$ |
|----------------------------------------------------------|--------------------------------------|
| $\text{I}_2$                                             | 0.0200                               |
| $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2$ | 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?

.....  
 .....  
 ..... [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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Additional answer space if required.

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- (c) Further experiments provide evidence that the reaction is first order with respect to **both**  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2$  **AND**  $\text{I}_2$ .

- (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.

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

**13**  
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5 This question is about nitrogen and its compounds.

(a) Sodium azide,  $\text{NaN}_3$ , has been used in car airbags.

The airbag inflates when the  $\text{NaN}_3$  decomposes to form nitrogen gas:



(i) This is a redox reaction.

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

Reduction .....

Oxidation ..... [2]

(ii) A  $16.0 \text{ dm}^3$  airbag is inflated at  $17.0^\circ\text{C}$ .  
The pressure in the inflated airbag is  $1.20 \times 10^5 \text{ Pa}$ .

Calculate the mass of  $\text{NaN}_3$  that has decomposed.

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

mass of  $\text{NaN}_3$  = ..... g [5]

(b) Hydrazoic acid,  $\text{HN}_3$ , is a weak acid ( $K_a = 2.51 \times 10^{-5} \text{ mol dm}^{-3}$ ).

(i) Calculate the pH of  $0.125 \text{ mol dm}^{-3}$  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**.

|                        |               |   |       |                      |       |   |       |
|------------------------|---------------|---|-------|----------------------|-------|---|-------|
| <b>Equation</b>        | $\text{HN}_3$ | + | ..... | $\rightleftharpoons$ | ..... | + | ..... |
| <b>Acid-base pairs</b> | .....         |   | ..... |                      | ..... |   | ..... |

[2]

(iii) In the Schmidt reaction, hydrazoic acid,  $\text{HN}_3$ , reacts with carboxylic acids to form primary amines.

For example,  $\text{HN}_3$  reacts with  $\text{RCOOH}$  to form  $\text{RNH}_2$  and two gases that are found in the atmosphere.

Write the equation for the reaction of  $\text{HN}_3$  with 2-methylbutanoic acid.

Show structures for organic compounds.

[3]

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

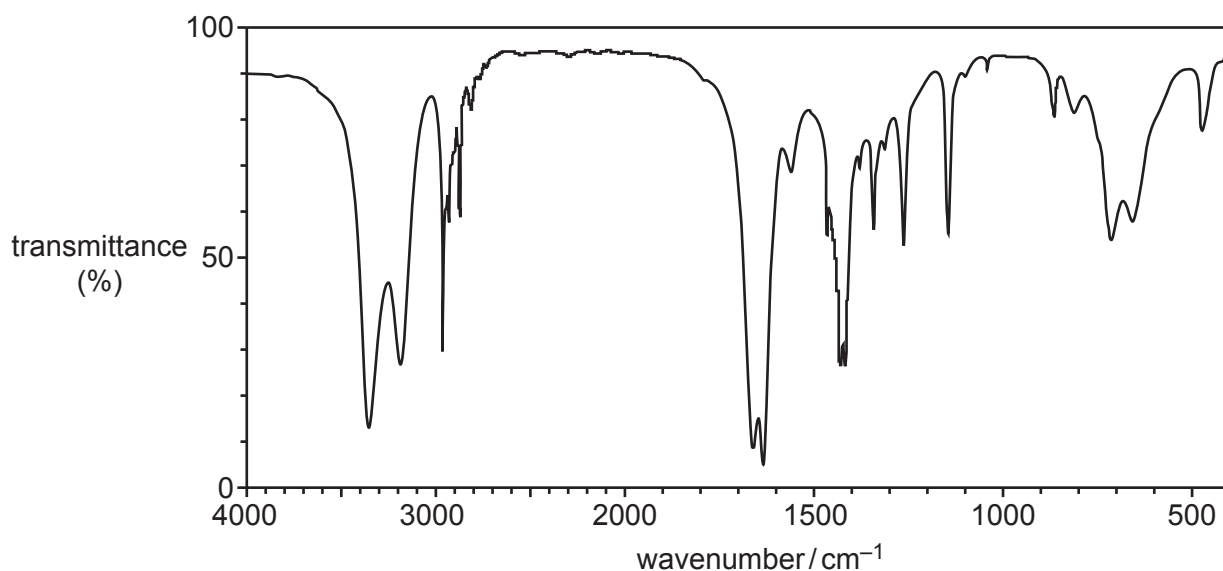
### Reaction 1

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<sup>3</sup> at RTP.

### Reaction 2

Ammonia reacts with compound **H** to form compound **I**, C<sub>2</sub>H<sub>5</sub>NO, 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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