OCR
Oxford Cambridge and RSA

Tuesday 12 October 2021 – 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.

Answer **all** the questions.

1 This question is about compounds of sulfur.

(a) Potassium sulfide, K_2S, shows ionic bonding.

(i) Explain what is meant by **ionic bonding**.

.....

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

(ii) Draw a 'dot-and-cross' diagram to show the bonding in K_2S.

Show outer electrons only.

[2]

(b) Sulfur difluoride, SF_2, shows covalent bonding.

Draw a 'dot-and-cross' diagram to show the bonding in SF_2.

Show outer electrons only.

[2]

(c) At room temperature, K_2S is a solid, but SF_2 is a gas.

Use ideas about structure and bonding to explain this difference.

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

(d) Sulfur hexafluoride, SF_6, is used in medical ultrasound imaging because SF_6 is unreactive.

(i) State the shape of, and F—S—F bond angle in, an SF_6 molecule.

Shape .....

Bond angle .....

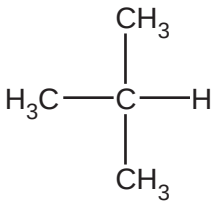
[2]

(ii) Suggest why SF_6 is unreactive.

.....

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

2 Alkane **A**, shown below, reacts with bromine in a radical substitution reaction.



Alkane A

(a) What is meant by a **radical**?

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

(b) Name the type of bond breaking that occurs in a radical substitution reaction.

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

(c) In this reaction with bromine, monosubstitution of alkane **A** forms a mixture of organic products.

Show the structures of **two** monosubstituted organic products that are formed.

[2]

(d) With excess bromine, further substitution takes place.

Write an equation for the reaction of alkane **A** with excess bromine to produce 1,3-dibromo-2-methylpropane.

Use structures for the organic compounds.

[2]

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3 Glutaric acid is used in the production of polymers.

The formula of glutaric acid can be represented as $HOOC(CH_2)_nCOOH$, where *n* is a whole number.

A student carries out a titration to find the value of *n*.

1. The student dissolves 2.891 g of glutaric acid in water and makes up the solution to 250.0 cm^3 in a volumetric flask.
2. The student transfers 25.0 cm^3 of this solution into a conical flask.
3. The student titrates the solution with 0.240 mol dm^{-3} NaOH(aq) in the burette.

Equation:
$HOOC(CH_2)_nCOOH(aq) + 2NaOH(aq) \rightarrow NaOOC(CH_2)_nCOONa(aq) + 2H_2O(l)$

The student uses phenolphthalein as the indicator.
Phenolphthalein is colourless in acid and pink in alkali.

(a) State the colour change observed at the end point of the titration.

Colour from ..... to ..... **[1]**

(b) The student carries out a trial titration followed by three further titrations, **1**, **2** and **3**.

The results are shown in the table below.

Titration	**Trial**	**1**	**2**	**3**
Final reading / cm^3	18.70	36.55	18.30	36.60
Initial reading / cm^3	0.20	18.50	0.10	18.30
Titre / cm^3				

(i) Complete the table to show the titre in each titration. **[1]**

(ii) Why does the student carry out a trial titration?

.....

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

(iii) Calculate the mean titre of NaOH(aq) that the student should use for analysing the results.

mean titre = ... cm^3 **[1]**

(iv) In the titration, the uncertainty in each burette reading is ± 0.05 cm^3.

Calculate the percentage uncertainty in the titre for **Titration 1**.

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

(c) Calculate the value of *n* in $HOOC(CH_2)_nCOOH$.

Give your answer to the nearest whole number.

n = ... **[5]**

(d) A 25.0 cm^3 pipette was used to measure out the 25.0 cm^3 of glutaric acid solution for each titration.

Before use, one student washed the pipette out with water instead of the glutaric acid solution.

State the effect of this mistake on the titre.

Explain your answer.

Effect .....

Explanation .....

.....

.....

[2]

4 A student carries out an investigation to find the enthalpy change for the decomposition of magnesium carbonate, ΔH_1 (**Reaction 1**).

Reaction 1 $MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$ ΔH_1

This enthalpy change cannot be found directly. It can be determined indirectly from the enthalpy changes for the reactions below, which can be found by experiment.

Reaction 2 $MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$ ΔH_2

Reaction 3 $MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$ ΔH_3

The enthalpy cycle is shown in **Fig. 4.1**.

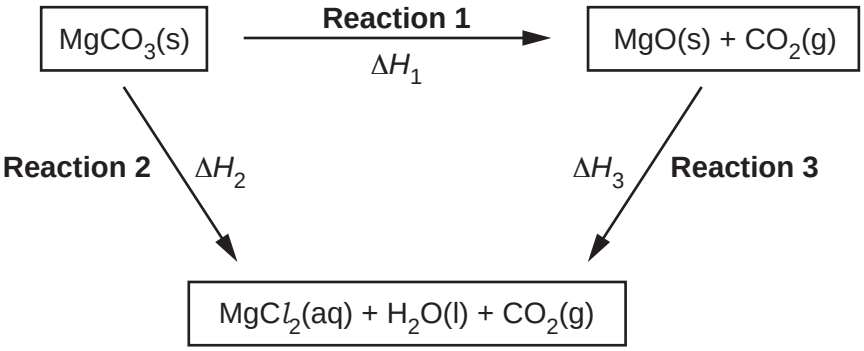

Fig. 4.1

Determination of ΔH_2 for Reaction 2

Student's method

- Weigh a 250 cm^3 polystyrene cup.
- Add about 100 cm^3 of 2.00 mol dm^{-3} hydrochloric acid (an excess) to the polystyrene cup and record the initial temperature of the $HCl(aq)$.
- Add 4.215 g $MgCO_3$, stir the mixture, and record the final temperature.
- Weigh the polystyrene cup containing the final solution.

Results

Mass of polystyrene cup / g	21.415
Mass of polystyrene cup + final solution / g	124.425
Initial temperature of $HCl(aq)$ / °C	20.40
Final temperature of solution / °C	25.40

Determination of ΔH_3 for Reaction 3

The student uses the same method as for **Reaction 2** but with MgO in place of $MgCO_3$.

The student calculates ΔH_3 for **Reaction 3** as –136.1 kJ mol^{-1}.

(a)* Use the student's results to calculate ΔH_2 for **Reaction 2** and determine the enthalpy change ΔH_1, in $kJ\,mol^{-1}$, for the decomposition of magnesium carbonate (**Reaction 1**), using the energy cycle in **Fig. 4.1**.

Assume the specific heat capacity, *c*, of the reaction mixture is the same as for water.

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Additional answer space if required.

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..... **[6]**

5 Methanol, CH_3OH, is manufactured by the reaction of carbon monoxide, CO, with hydrogen, H_2.

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91\,kJ\,mol^{-1}$

(a) Write the expression for the equilibrium constant, K_c, for this equilibrium.

[1]

(b) A chemist mixes CO and H_2 in a container.
The mixture is heated to 200 °C and left to reach equilibrium.

The equilibrium concentrations of CO and H_2 are shown in the table.

Compound	**Equilibrium concentration / mol dm^{-3}**
CO(g)	0.57
$H_2(g)$	0.40

The numerical value of K_c for this equilibrium is 15.4.

(i) Calculate the equilibrium concentration of $CH_3OH(g)$.

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

(ii) What does the numerical value of K_c tell you about the position of equilibrium?

.....

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

(c) The industrial manufacture of methanol has used a copper-based catalyst.

Chemists have recently developed a new method for making methanol that uses a nickel-gallium catalyst. This allows methanol to be produced at a lower temperature than the old method.

Suggest **two** reasons why using a lower temperature is beneficial to the environment.

1 .....

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2 .....

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[2]

(d) Nickel and gallium are in period 4 of the periodic table.

(i) Which block in the periodic table does nickel belong to?

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

(ii) Complete the electron configuration of gallium.

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

(e) Element **A** is in period 3 of the periodic table (Na-Ar).

The first six ionisation energies (I.E.) of element **A** are shown below.

1st I.E. / kJ mol^{-1}	2nd I.E. / kJ mol^{-1}	3rd I.E. / kJ mol^{-1}	4th I.E. / kJ mol^{-1}	5th I.E. / kJ mol^{-1}	6th I.E. / kJ mol^{-1}
789	1577	3232	4356	16091	19785

Identify element **A**.

Explain your answer.

Element **A** = ...

Explanation .....

.....

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

6 A student investigates the rate of reaction between strontium and water.

$Sr(s) + 2H_2O(l) \rightarrow Sr(OH)_2(aq) + H_2(g)$

The student's method is shown below.

- Pour 100 cm^3 of water into a conical flask.
- Add 0.26 g of strontium and quickly connect a 100 cm^3 gas syringe.
- Measure the volume of gas produced every 10 seconds until all the strontium has reacted.

The student plots a graph of volume of gas produced against time as shown in **Fig. 6.1**.

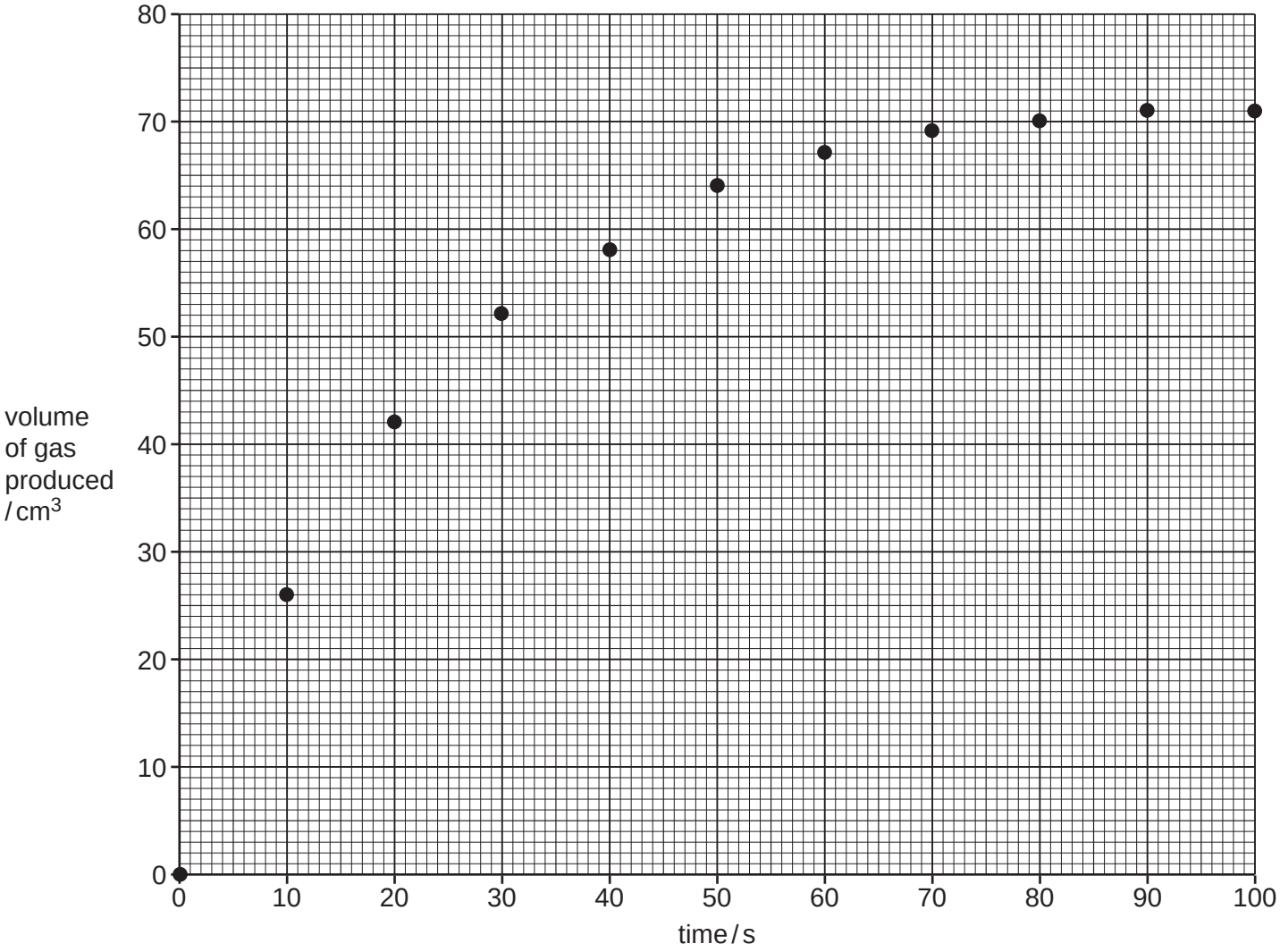

Fig. 6.1

(a) Draw a best fit curve on **Fig. 6.1**.
Use the graph to determine the rate of reaction, in $cm^3 s^{-1}$, at 50 s.

Show your working below and on the graph.

rate at 50 s ..... $cm^3 s^{-1}$ **[3]**

(b) A second student suggests that the experiment could be improved by measuring the loss in mass in the conical flask over time.

The student places a conical flask containing 100 cm^3 of water on a 2 decimal place balance, and then adds 0.26 g of strontium.

The mass is recorded every 10 seconds.

Suggest **one** advantage and **one** disadvantage of using this method compared to the gas collection method.

Advantage: .....

.....

Disadvantage: .....

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

(c) A third student repeats the original experiment using the same amount, in moles, of barium as strontium.

(i) Calculate the mass of barium that the student uses.

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

mass of barium = ... g **[2]**

(ii) The student observes that the rate of reaction for barium is different from the rate of reaction with strontium.

On **Fig. 6.1** sketch the graph the student would obtain using barium instead of strontium. **[2]**

(iii) Describe and explain the difference in reactivity of barium and strontium with water.

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

7 2-Chloro-2-methylpropane, $(CH_3)_3CCl$, is an organic liquid with a boiling point of 50 °C.

A student prepares $(CH_3)_3CCl$ by reacting 2-methylpropan-2-ol, $(CH_3)_3COH$, with concentrated hydrochloric acid.

(a) Write a balanced equation for this reaction.

Use skeletal formulae for organic compounds.

[2]

(b)* The student's method for the preparation is outlined below.

- Add 10.0 cm^3 (7.70 g) of $(CH_3)_3COH$ and 30 cm^3 concentrated hydrochloric acid (an excess) to a round-bottom flask. Stopper the flask.
- Shake the flask until the mixture separates into two layers.

Densities: $(CH_3)_3CCl$: 0.85 g cm^{-3}; concentrated HCl: 1.18 g cm^{-3}

After purification, the percentage yield of $(CH_3)_3CCl$ is 76%.

Explain how the student could obtain a pure, dry sample of $(CH_3)_3CCl$ from the mixture in the flask and calculate the mass of pure $(CH_3)_3CCl$ that would be expected from this preparation.

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Additional answer space if required.

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..... **[6]**

(c) Compounds **A** and **B** are structural isomers of $(CH_3)_3COH$.

(i) Compound **A** is a secondary alcohol.

What is the systematic name of compound **A**?

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

(ii) Compound **B** is a branched primary alcohol.

Compound **B** is refluxed with acidified potassium dichromate(VI) as an oxidising agent.

Write the equation for the reaction that takes place.

Use structures for organic compounds and [O] for the oxidising agent.

[3]

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).