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**Chemistry**  
**Standard level**  
**Paper 2**

9 May 2024

**Zone A** morning | **Zone B** morning | **Zone C** morning

Candidate session number

1 hour 15 minutes

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**Instructions to candidates**

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.



Answer **all** questions. Answers must be written within the answer boxes provided.

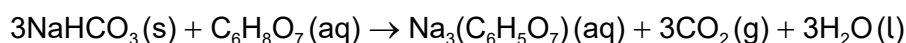
1. A powder has the following percentage composition by mass:

30.0 % sucrose,  $C_{12}H_{22}O_{11}$

45.0 % citric acid,  $C_6H_8O_7$

25.0 % sodium hydrogencarbonate,  $NaHCO_3$

In the presence of water, the powder effervesces as the citric acid reacts with the sodium hydrogencarbonate:



- (a) (i) Determine the limiting reactant when 1.00 g of this powder reacts.

[3]

$$m_{C_6H_8O_7} = 1.00 \times 0.45 = 0.45 \text{ g}$$

$$n_{C_6H_8O_7} = \frac{0.45}{192.14} = 2.34 \cdot 10^{-3} \text{ mol}$$

$$n_{NaHCO_3} = \frac{0.25}{84.01} = 2.98 \cdot 10^{-3} \text{ mol}$$

$$\frac{2.98 \cdot 10^{-3}}{3} < 2.34 \cdot 10^{-3}; \text{ Therefore } NaHCO_3 \text{ is the limiting reactant.}$$

- (ii) Determine the volume, in  $\text{dm}^3$  at SATP, of carbon dioxide released in the reaction in (a)(i). Use sections 1 and 2 of the data booklet.

[2]

$$101.395 \text{ kPa} = (2.98 \cdot 10^{-3}) R (298.15)$$

$$V = 0.073 \text{ dm}^3$$

(This question continues on the following page)



(Question 1 continued)

- (iii) Calculate the percentage yield obtained by a student who collected  $0.043 \text{ dm}^3$  of carbon dioxide from  $1.00 \text{ g}$  of the powder.

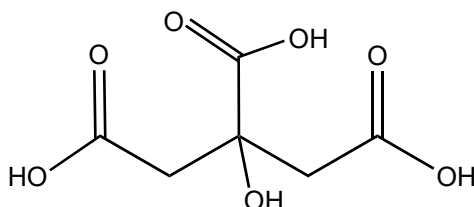
If you did not obtain an answer to (a)(ii), use  $0.068 \text{ dm}^3$ , but this is not the correct value.

[1]

$$\frac{0.043}{0.073} \times 100 = 58.4\%$$

- (b) (i) State the number of acidic hydrogens in the citric acid molecule shown.

[1]



.....

- (ii) Deduce the structural formula of the conjugate base of citric acid.

[1]

- (iii) Predict, giving a reason, the strength of citric acid.

[1]

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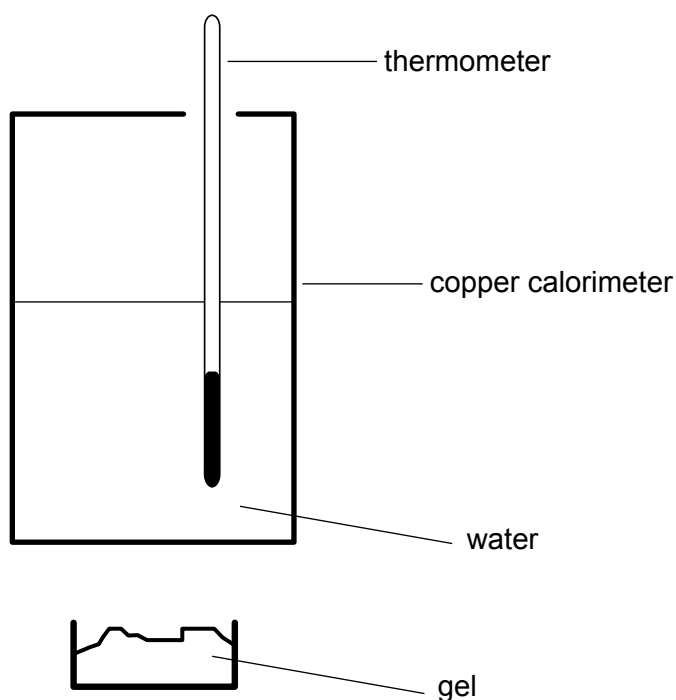
- (c) Calculate the pH of a solution with a hydrogen ion concentration,  $[\text{H}^+] = 0.0025 \text{ mol dm}^{-3}$ .

[1]

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 .....



2. A student investigated the use of hand sanitising gel containing propan-1-ol as a camping fuel.



Mass of water / g $\pm 0.02$ g	400.00
Initial temperature of water / $^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$	19.0
Final temperature of water / $^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$	40.0
Initial mass of gel / g $\pm 0.01$ g	20.00
Final mass of gel / g $\pm 0.01$ g	18.20

- (a) (i) Calculate the heat energy absorbed by the water, in J. Use sections 1 and 2 of the data booklet.

[1]

$$Q = 400 \pm 0.02 \cdot 4.18 \cdot 21 \pm 1$$

$$Q = 35112 \text{ J}$$

- (ii) Calculate the percentage uncertainty of your answer in (a)(i).

[2]

(This question continues on the following page)



**(Question 2 continued)**

- (iii) Suggest a way to reduce the random uncertainty of the answer. [1]

.....

.....

- (b) (i) Calculate the enthalpy of combustion of propan-1-ol, in  $\text{kJ mol}^{-1}$ , stating **one** assumption.

If you did not obtain an answer to (a)(i), use 30 000 J, though this is not the correct value. [3]

Calculation: .....

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Assumption: .....

- (ii) Calculate the percentage error, using section 13 of the data booklet. [1]

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- (iii) Suggest the main source of error, and a way to reduce it. [1]

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**(This question continues on the following page)**



**(Question 2 continued)**

(c) Ethanol and propan-1-ol are members of a homologous series.

(i) State the names of the class of compound and the functional group of this series. [2]

Class: .....  
Functional group: .....

(ii) State the strongest intermolecular force present in ethanol and propan-1-ol. [1]

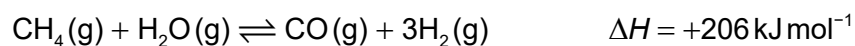
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(iii) Predict an intermolecular force which would be stronger in the next member of the homologous series, butan-1-ol. [1]

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3. Hydrogen is manufactured from methane by a process called steam reforming:



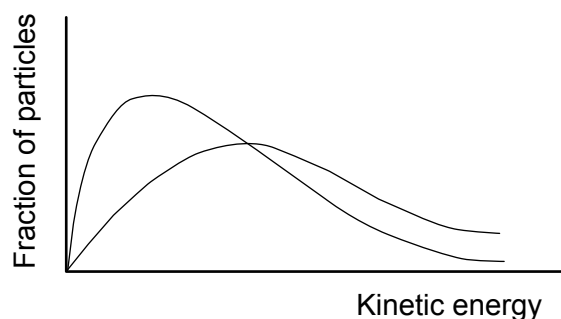
- (a) Deduce the equilibrium constant,  $K_c$ , expression for the reaction. [1]

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 .....

- (b) Predict, with a reason, the effect of increasing the temperature on the position of equilibrium. [1]

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- (c) Explain why the reaction rate increases with temperature, adding annotations to the following Maxwell–Boltzmann graph to assist your explanation. [3]



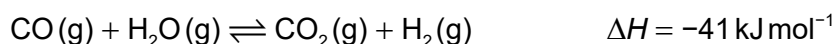
Explanation: .....  
 .....  
 .....  
 .....

- (d) Annotate this Maxwell–Boltzmann distribution graph in (c) to show the effect of a catalyst. [1]





4. The water-gas shift reaction is another way to manufacture hydrogen.



- (a) (i) State the oxidation state of carbon in carbon monoxide and carbon dioxide. [1]

carbon monoxide: .....  
carbon dioxide: .....

- (ii) Identify the oxidising and reducing agents, and the species oxidised and reduced, in the forward reaction. [2]

	CO(g)	H <sub>2</sub> O(g)
oxidising or reducing agent?		
species oxidised or reduced?		

- (b) (i) Draw the Lewis structure of carbon dioxide. [1]

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- (ii) Annotate the Lewis structure in (b)(i) to show the polarity of the bonds by adding the symbols  $\delta+$  and  $\delta-$  as appropriate. [1]

- (iii) Explain the molecular geometry and polarity of the carbon dioxide molecule. [2]

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**(Question 4 continued)**

- (iv) Outline why the increase in carbon dioxide concentration in the atmosphere is of international concern.

[2]

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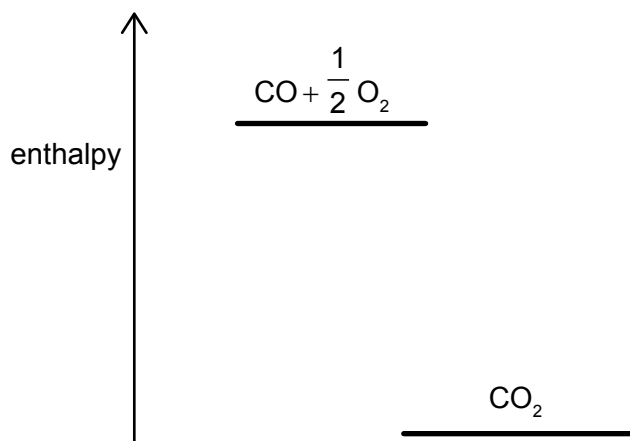
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- (v) Explain, referring to the enthalpy profile shown, whether carbon monoxide is more or less stable than carbon dioxide.

[1]



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5. (a) State the electron configuration of sulfur, S. [1]

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- (b) State a physical property of sulfur which supports its classification as a non-metal element. [1]

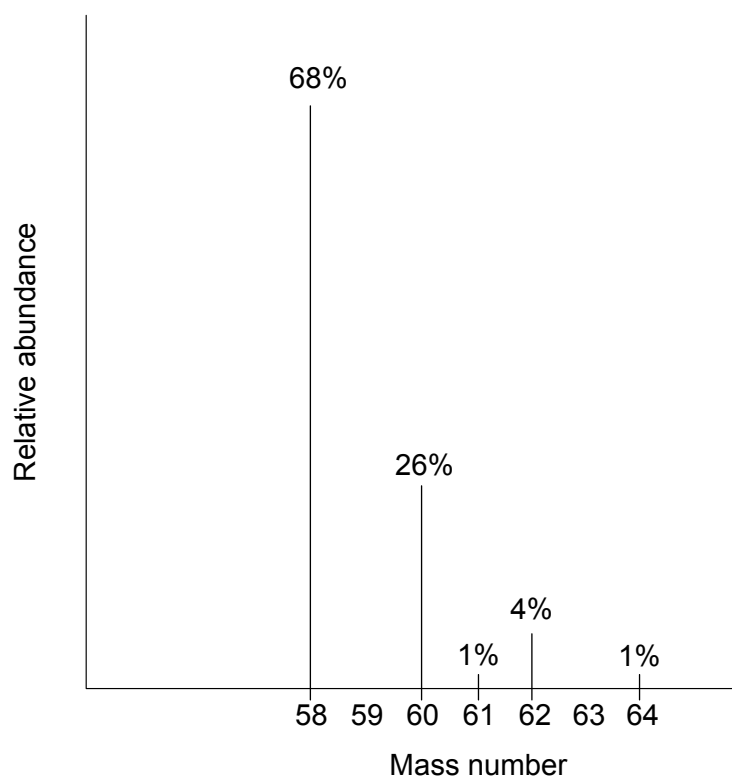
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- (c) Suggest a balanced equation for the reaction of an oxide of sulfur with water. [1]

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6. (a) Determine the relative atomic mass of nickel from the mass spectrum shown. [1]



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- (b) (i) Deduce the nuclear symbol,  ${}^A_Z\text{X}$ , for an ion of nickel-58 with 26 electrons. [1]

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**(Question 6 continued)**

(ii) Draw arrows to represent electrons in the orbital diagram for this ion.

[1]

4s

3d

(iii) Explain how the ions are held together in nickel chloride, and why it only conducts electricity when molten.

[2]

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.....

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7. (a) Compare the length and strength of the C–C bonds in benzene and cyclohexene, referring to sections 10 and 11 of the data booklet.

[1]

Bond length: .....

.....

Bond strength: .....

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- (b) Explain why the structure of benzene favours substitution and not addition reactions.

[2]

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16EP15



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