Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

9 May 2024

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

Candidate session number

1 hour 15 minutes

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]**.

2224 – 6205

14 pages

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:

$3NaHCO_3(s) + C_6H_8O_7(aq) \rightarrow Na_3(C_6H_5O_7)(aq) + 3CO_2(g) + 3H_2O(l)$

(a) (i) Determine the limiting reactant when 1.00 g of this powder reacts. [3]

$m_{C_6H_8O_7} = 1 \times 0.45 = 0.45\,g$

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

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

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

(ii) Determine the volume, in dm^3 at SATP, of carbon dioxide released in the reaction in (a)(i). Use sections 1 and 2 of the data booklet. [2]

$101.325\,V = (2.98 \times 10^{-3})R(298.15)$

$V = 0.0732\,dm^3$

(This question continues on the following page)

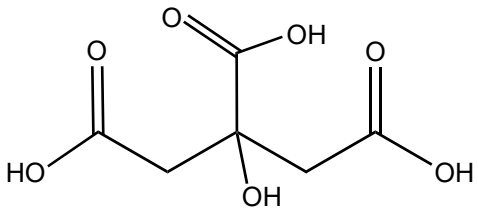
(Question 1 continued)

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

If you did not obtain an answer to (a)(ii), use 0.068 dm^3, but this is not the correct value. [1]

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

(b) (i) State the number of acidic hydrogens in the citric acid molecule shown. [1]

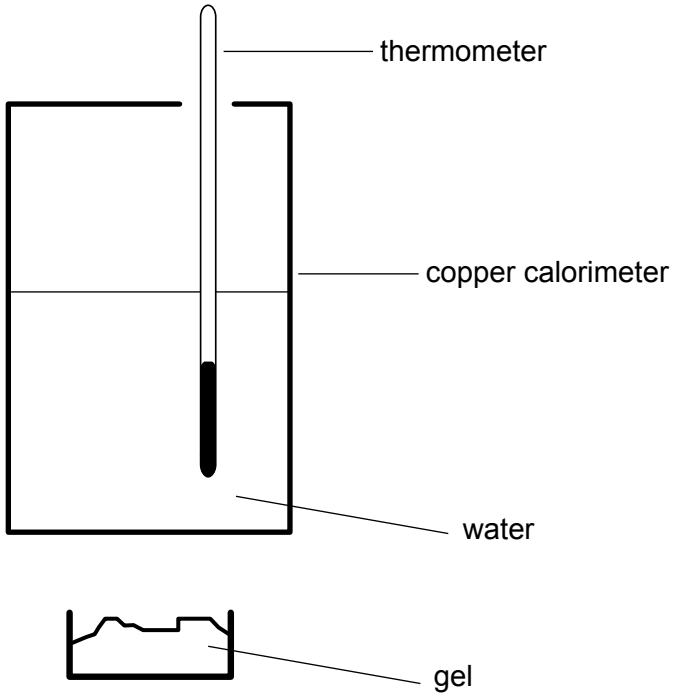


(ii) Deduce the structural formula of the conjugate base of citric acid. [1]

(iii) Predict, giving a reason, the strength of citric acid. [1]

(c) Calculate the pH of a solution with a hydrogen ion concentration, $[H^+] = 0.0025\,mol\,dm^{-3}$. [1]

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



Mass of water / g ± 0.02 g	400.00
Initial temperature of water / °C ± 0.5 °C	19.0
Final temperature of water / °C ± 0.5 °C	40.0
Initial mass of gel / g ± 0.01 g	20.00
Final mass of gel / g ± 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]

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

$Q = 35112\ J$

(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]

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(b) (i) Calculate the enthalpy of combustion of propan-1-ol, in $kJ\,mol^{-1}$, 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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(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:

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206\,kJ\,mol^{-1}$

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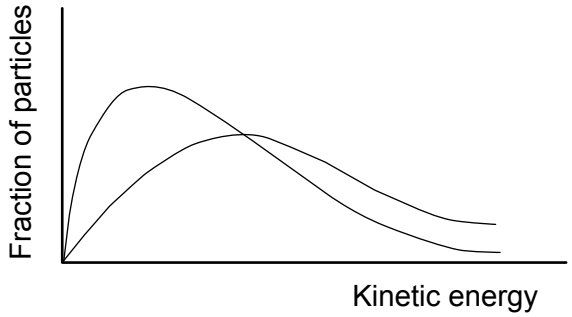
(c) Explain why the reaction rate increases with temperature, adding annotations to the following Maxwell–Boltzmann graph to assist your explanation. [3]



Explanation: . . . . . .

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(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.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g) \qquad \Delta H = -41\,kJ\,mol^{-1}$$

(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_2O (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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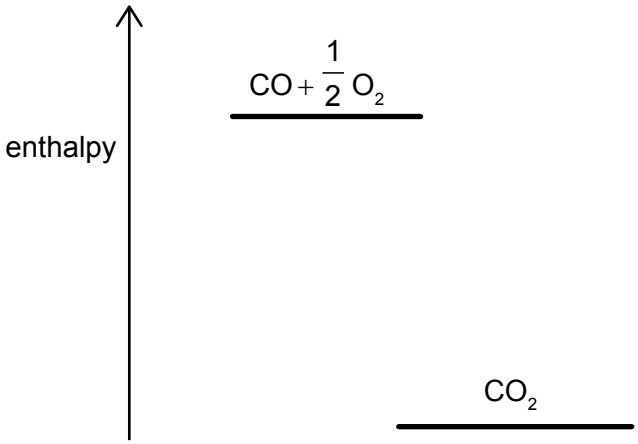
(v) Explain, referring to the enthalpy profile shown, whether carbon monoxide is more or less stable than carbon dioxide. [1]



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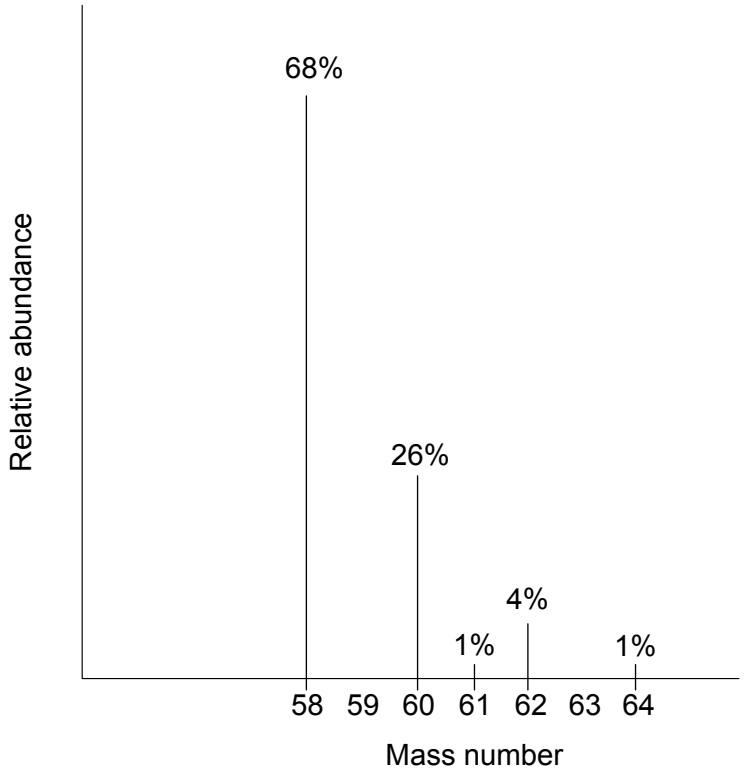
6. (a) Determine the relative atomic mass of nickel from the mass spectrum shown. [1]



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

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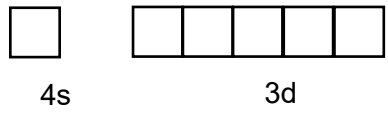
(Question 6 continued)

(ii) Draw arrows to represent electrons in the orbital diagram for this ion. [1]



(iii) Explain how the ions are held together in nickel chloride, and why it only conducts electricity when molten. [2]

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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: . . . . . .

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Bond strength: . . . . . .

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(b) Explain why the structure of benzene favours substitution and not addition reactions. [2]

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