Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

3 November 2025

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

Candidate session number

1 hour 30 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]**.

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

1. Nitrogen monoxide, NO (g), is produced in internal combustion and jet engines.

(a) Outline a reason why NO is a pollutant. [1]

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(b) Calculate the amount, in moles, of NO in $1.0 \times 10^{-3}\,m^3$ of engine exhaust gas which contains 0.10 % NO by volume at 200 °C and 1.0×10^5 Pa.

Use sections 1 and 2 of the data booklet. [3]

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(c) In an exhaust pipe catalytic converter, NO reacts with carbon monoxide, CO.

$$NO(g) + CO(g) \rightarrow CO_2(g) + \frac{1}{2} N_2(g)$$

Deduce which element is reduced in this process, indicating the initial and final oxidation states. [1]

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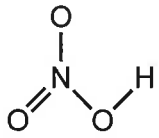
Element	Initial oxidation state	Final oxidation state

2. Nitric acid, HNO_3, is a strong acid.

(a) (i) Annotate the structure of nitric acid to indicate the coordination bond. [1]



(ii) Write an equation for the reaction of excess nitric acid with sodium carbonate. [1]

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(b) (i) Draw the Lewis formula of the nitrate ion. [1]

(ii) Write the formula of nickel(II) nitrate. [1]

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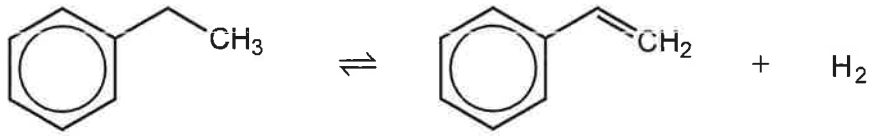
3. Phenylethene (styrene) is produced from ethylbenzene in a gas-phase equilibrium.



Ethylbenzene, $C_8H_{10}(g)$ $\rightleftharpoons$ Styrene, $C_8H_8(g)$ + Hydrogen, $H_2(g)$

(a) (i) Calculate the mass, in g, of styrene produced from 1.0 kg of ethylbenzene if the yield of the reaction is 90 %. [2]

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(ii) Calculate the atom economy of the reaction. [1]

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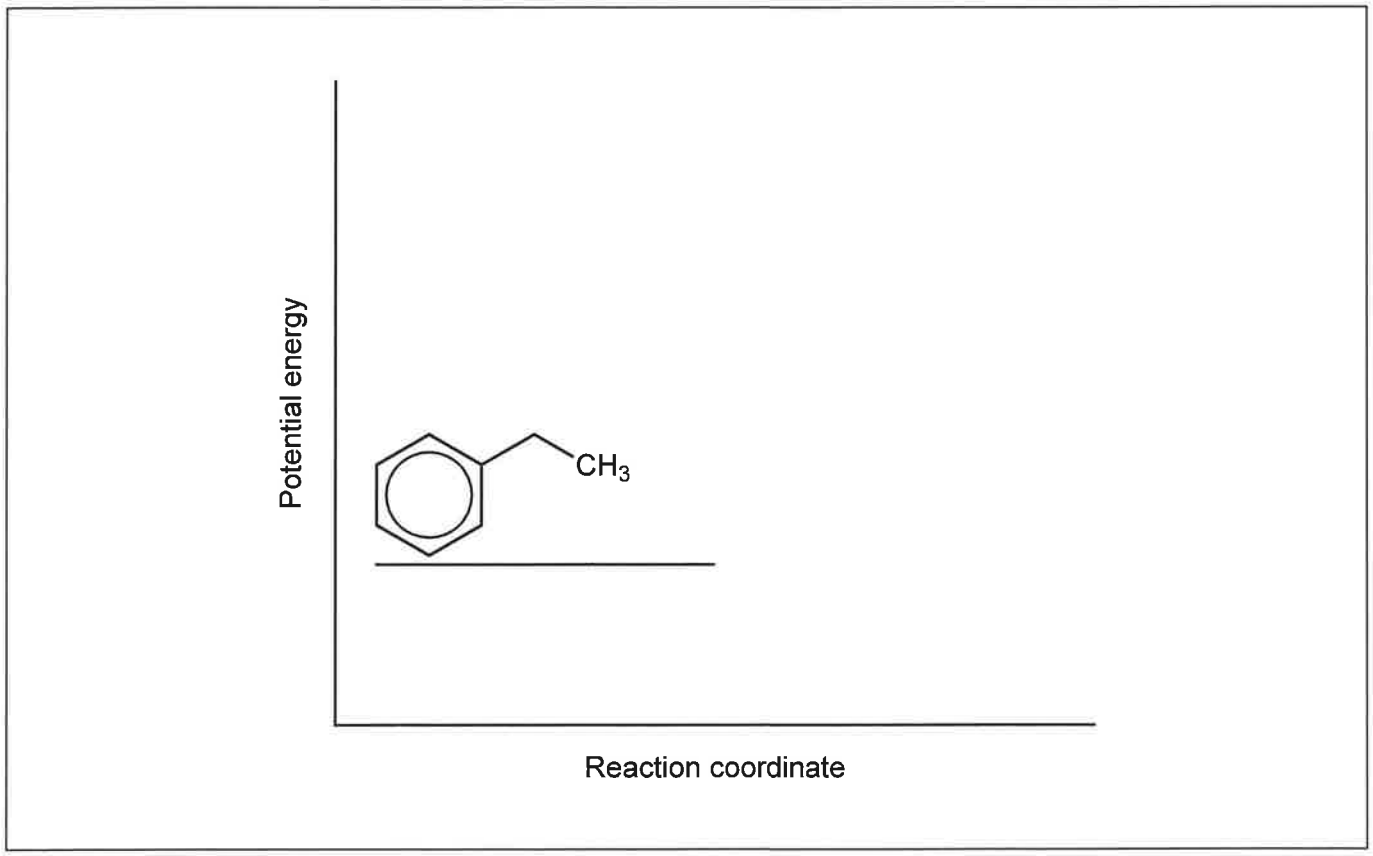
(Question 3 continued)

(b) The forward reaction is endothermic, uses iron(III) oxide as a catalyst, and takes place at 900 K.

Sketch the energy profile for the reaction, both with and without the catalyst, labelling ΔH and the activation energies. [3]



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(Question 3 continued)

(c) (i) Sketch the Maxwell–Boltzmann distribution curve for 298 K on the same axes as the 900 K curve. [1]

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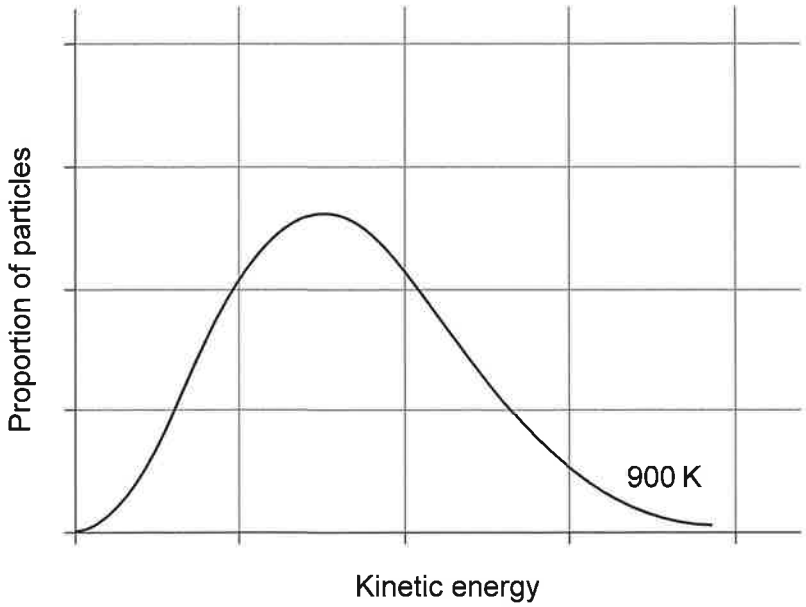

(ii) Annotate the graph to show the activation energy, E_a. [1]

(iii) Explain why reducing the temperature decreases the rate of reaction, referring to the graph in your explanation. [2]

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(Question 3 continued)

(iv) Suggest, with a reason, the effect of increasing the pressure on the position of equilibrium. [1]

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(v) Outline the effect of decreasing temperature on the position of equilibrium. [1]

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(d) (i) Complete the diagram to show the repeating unit of polystyrene. [2]

(ii) State the type of polymerization that occurs. [1]

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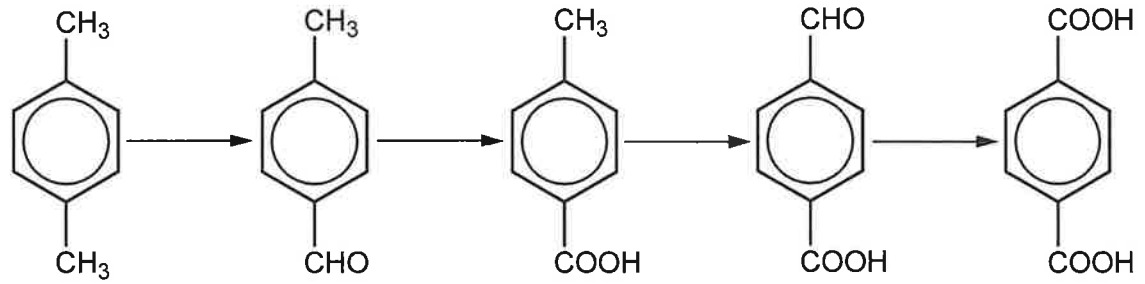
(Question 3 continued)

(e) Another compound used to make polymers, benzene-1,4-dicarboxylic acid, can be produced by a series of reactions.



Reactant A | Reactant B | Reactant C | Reactant D | Benzene-1, 4-dicarboxylic acid

(i) Deduce the relationship between reactant A and ethylbenzene. [1]

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(ii) State the structural formula, functional group name and homologous series of the CHO functional group. [2]

Structural formula drawing	Functional group name	Homologous series name
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	. . . . .	. . . . .
	. . . . .	. . . . .

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(iii) Suggest the conditions required and the role of the reagent $KMnO_4$ used to convert intermediate B into intermediate C. [2]

Conditions: . . . . . .

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Role of $KMnO_4$: . . . . . .

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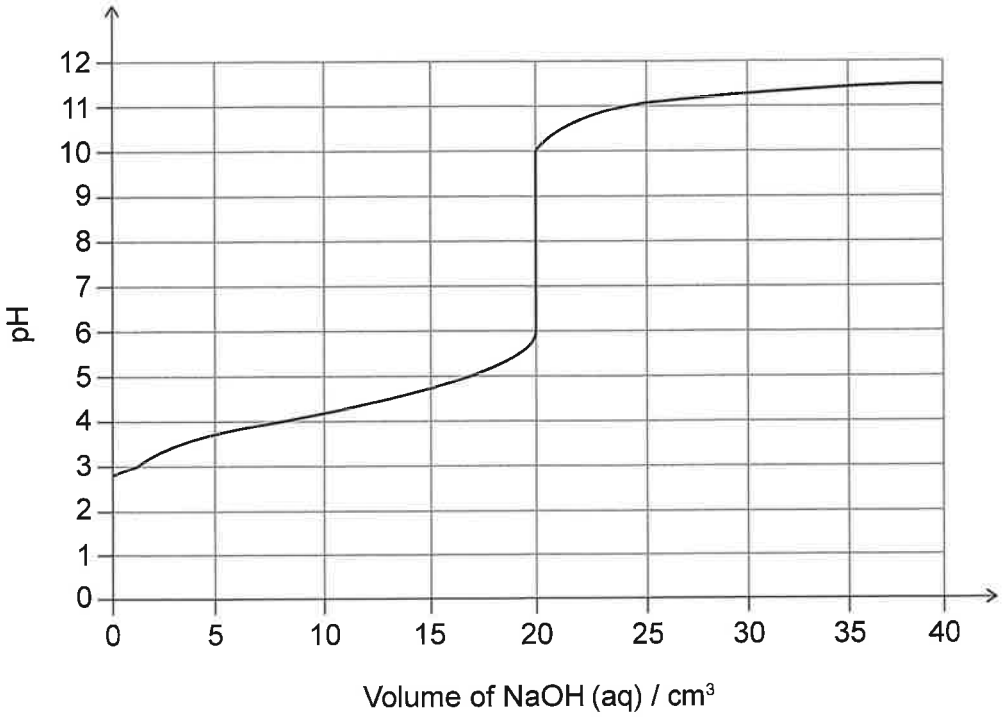
(Question 3 continued)

(f) Benzoic acid is a weak acid. The graph shows how the pH changes during the titration of a 10.0 cm^3 aqueous solution of benzoic acid with aqueous sodium hydroxide.



(i) Deduce the equilibrium constant expression, K, for the ionization of benzoic acid (C_6H_5COOH). [1]

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(ii) State the volume of sodium hydroxide added at the equivalence point. [1]

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(iii) Calculate the concentration of the benzoic acid solution, in mol dm^{-3}, given that the sodium hydroxide concentration was 0.010 mol dm^{-3}. [1]

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4. Bromoethane can react with aqueous hydroxide ions to produce ethanol.

$$H_3CCH_2Br(l) + OH^-(aq) \rightarrow H_3CCH_2OH(aq) + Br^-(aq)$$

(a) State the type of reaction. [1]

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(b) Sketch the mechanism of the reaction, showing structural formulas and using curly arrows to represent the movement of electron pairs. [3]

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(c) Determine the standard enthalpy change of the reaction, in $kJ\,mol^{-1}$. Use section 12 of the data booklet. Ignore interactions between ions and the solvent. [2]

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5. A sample of bromine has the following composition by mass:

^{79}Br: 50.75 %

^{81}Br: 49.25 %

(a) Contrast the atomic structures of the isotopes. [1]

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(b) Calculate the relative atomic mass of bromine from the sample, giving your answer to two decimal places. [2]

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(Question 5 continued)

(c) (i) Deduce the condensed electron configuration of bromine. [1]

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(ii) Describe the bonding in a molecule of bromine in terms of valence electrons. [1]

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(iii) Explain why bromine is a liquid at STP, whereas chlorine is a gas and iodine is a solid. [2]

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(iv) Deduce the equation, and the colour change observed, for the reaction of dilute bromine water with aqueous iodide solution. [2]

Equation: . . . . . .

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Colour change: . . . . . .

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(v) Outline why bromine does not react with an aqueous chloride solution. [1]

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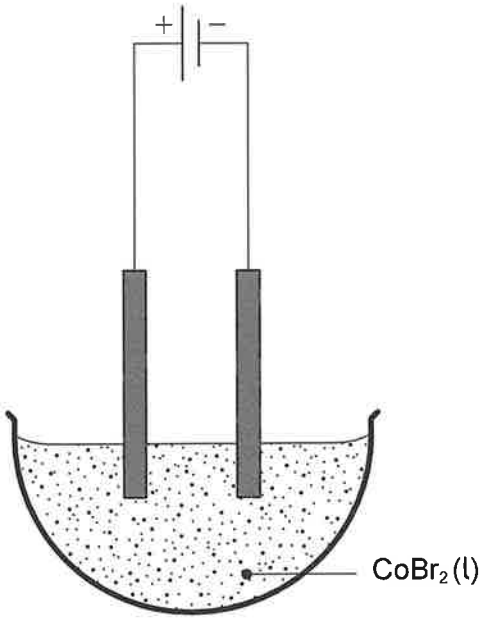
(Question 5 continued)

(vi) Deduce the products of the electrolysis of molten cobalt(II) bromide, $CoBr_2(l)$. [2]



Product at anode: .....

Product at cathode: .....

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