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Chemistry

Standard level

Paper 2

3 November 2025

Zone A morning | Zone B morning | Zone C morning

Candidate session number

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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]**.



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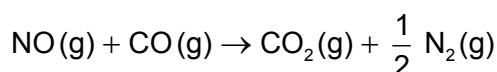
(b) Calculate the amount, in moles, of NO in $1.0 \times 10^{-3} \text{ m}^3$ of engine exhaust gas which contains 0.10% NO by volume at 200 °C and $1.0 \times 10^5 \text{ Pa}$.

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.



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

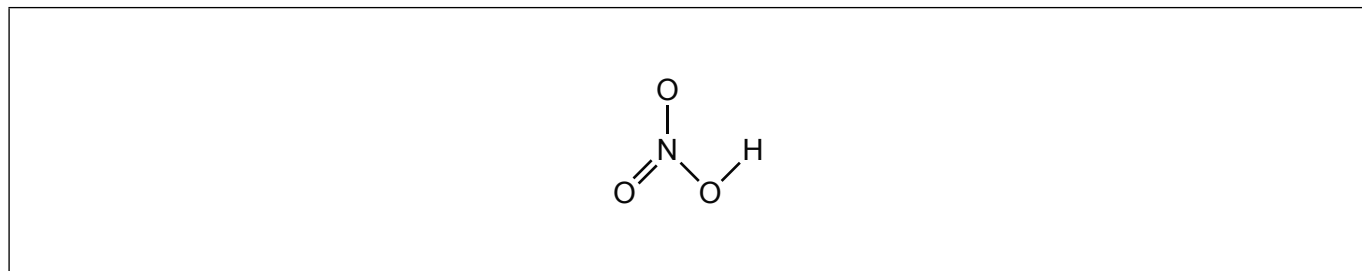
[1]

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]

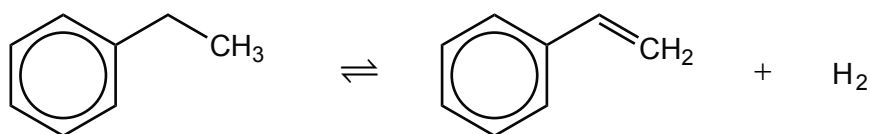
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(ii) Write the formula of nickel(II) nitrate. [1]

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



(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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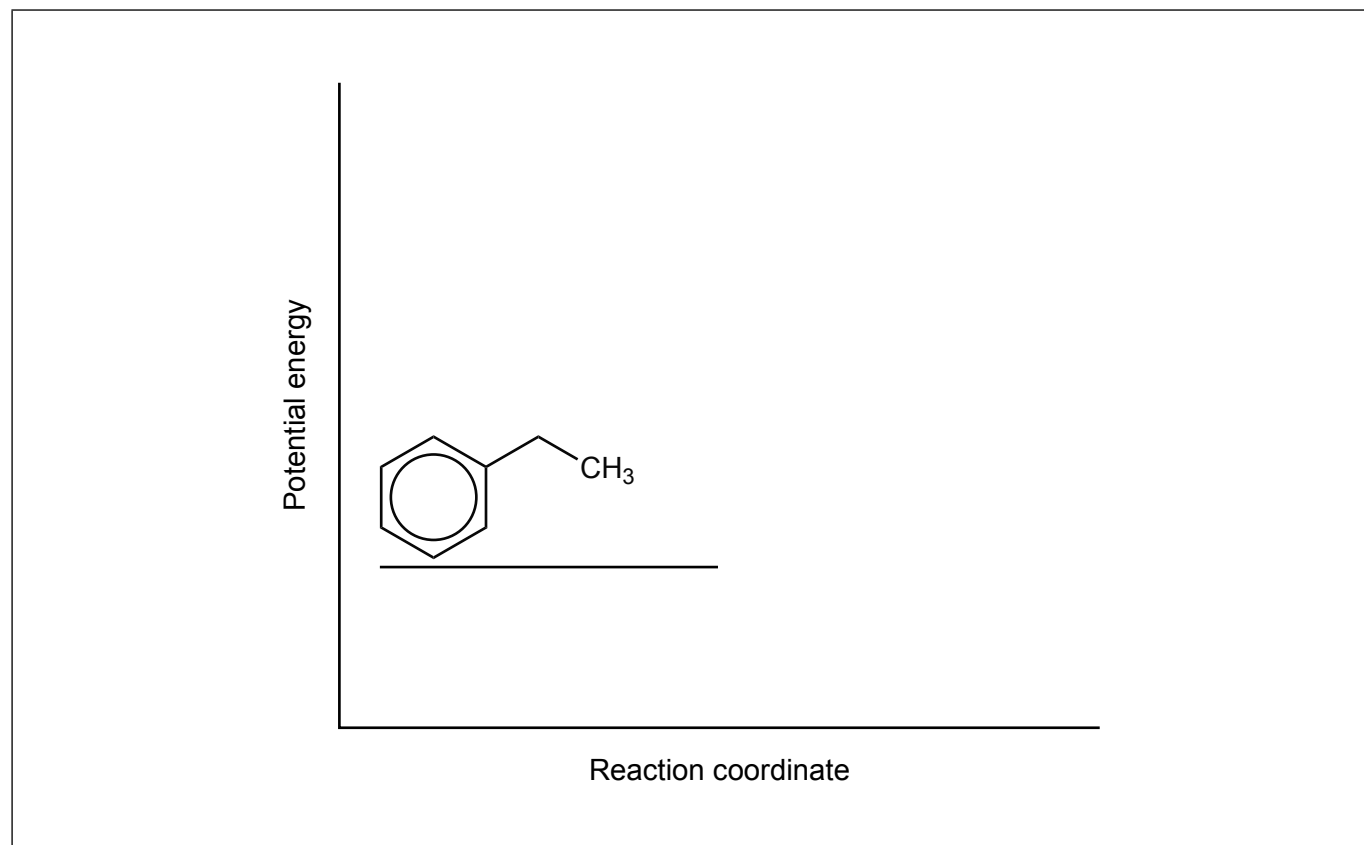


(Question 3 continued)

- (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]

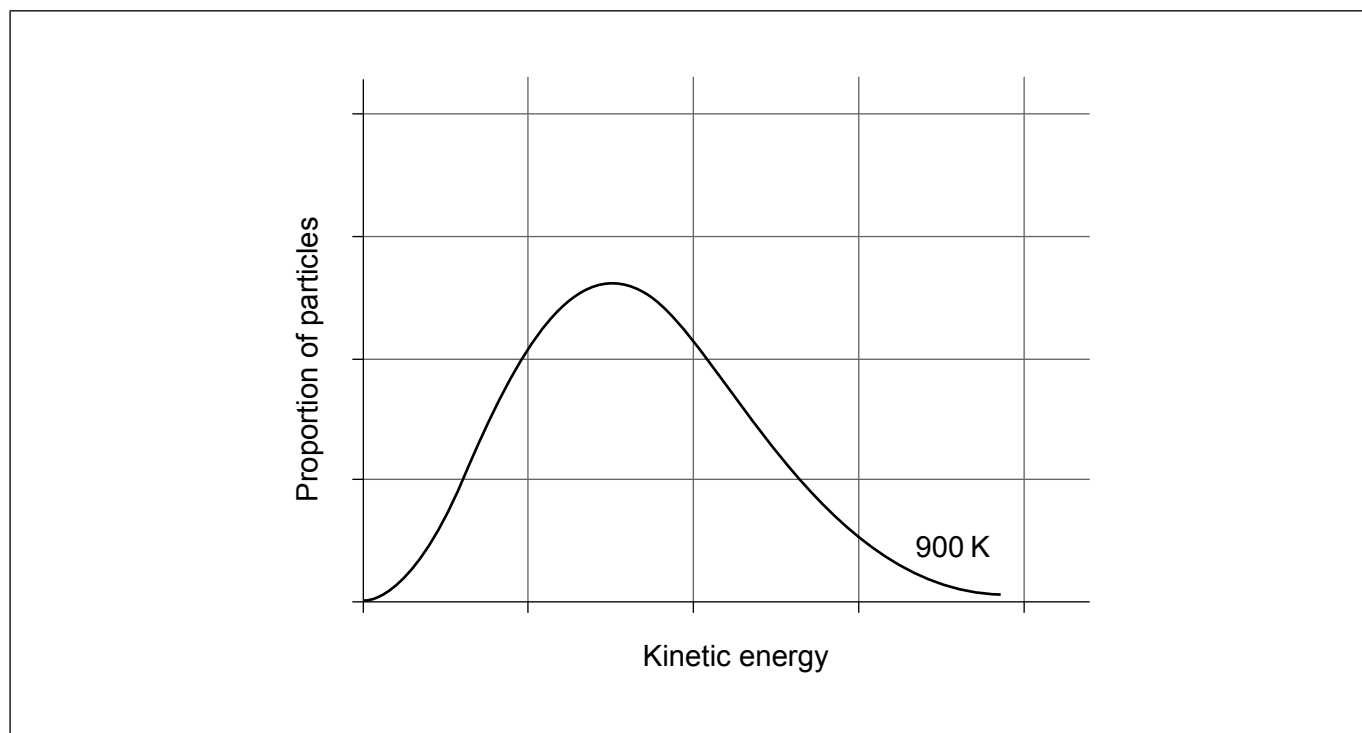


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(Question 3 continued)

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



- (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)

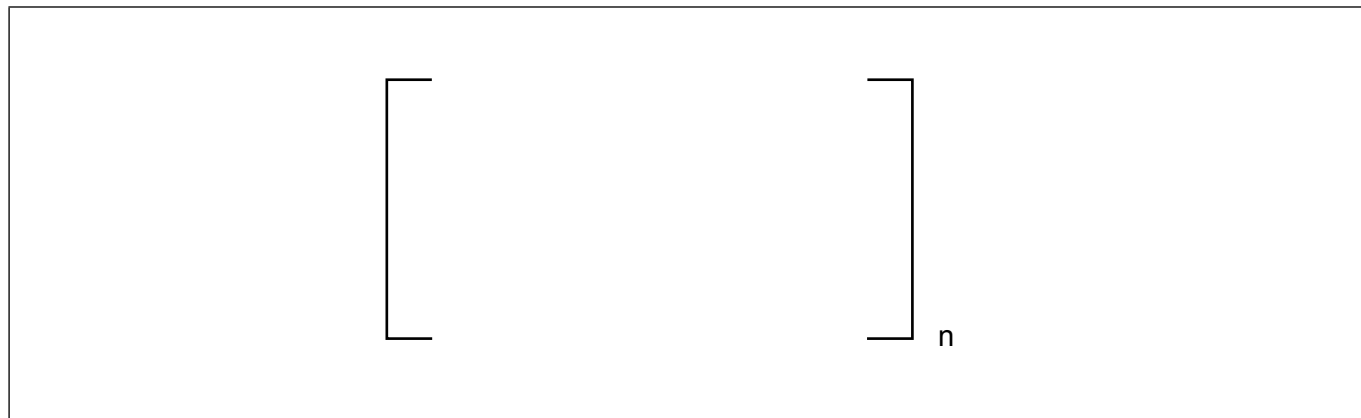
(iv) Suggest, with a reason, the effect of increasing the pressure on the position of equilibrium. [1]

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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]

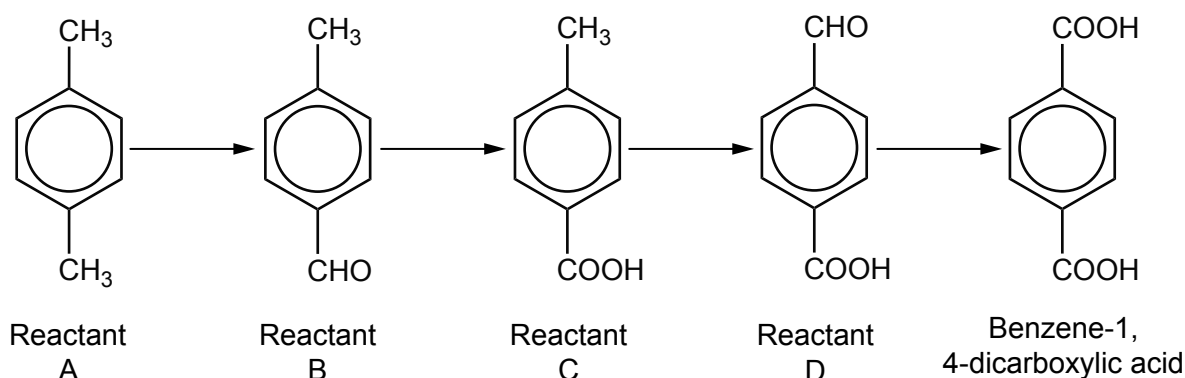
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(Question 3 continued)

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



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

.....

- (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

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

Conditions:

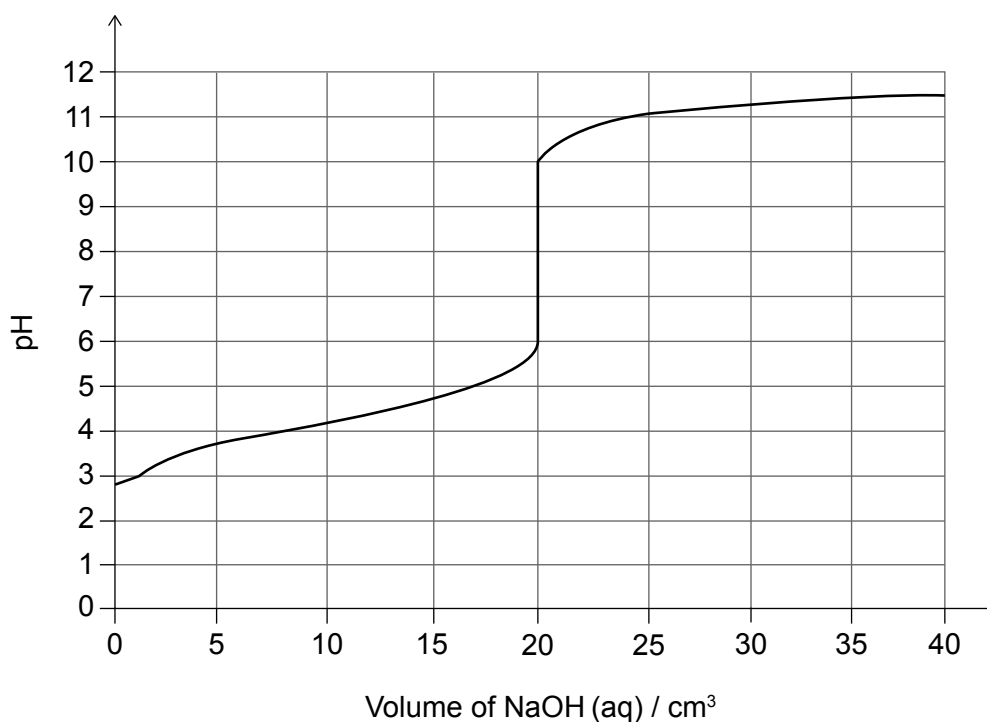
 Role of KMnO_4 :

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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 cm³ 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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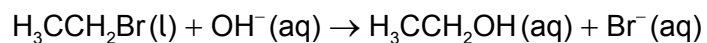
- (iii) Calculate the concentration of the benzoic acid solution, in mol dm⁻³, given that the sodium hydroxide concentration was 0.010 mol dm⁻³.

[1]

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



(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]

(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:

Colour change:

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

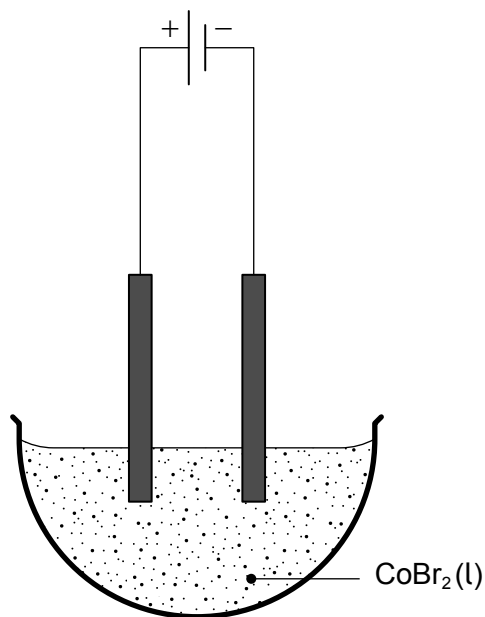
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(Question 5 continued)

(vi) Deduce the products of the electrolysis of molten cobalt(II) bromide, $\text{CoBr}_2(\text{l})$. [2]



Product at anode:

Product at cathode:



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