Chemistry
Standard level
Paper 2

19 May 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]**.

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

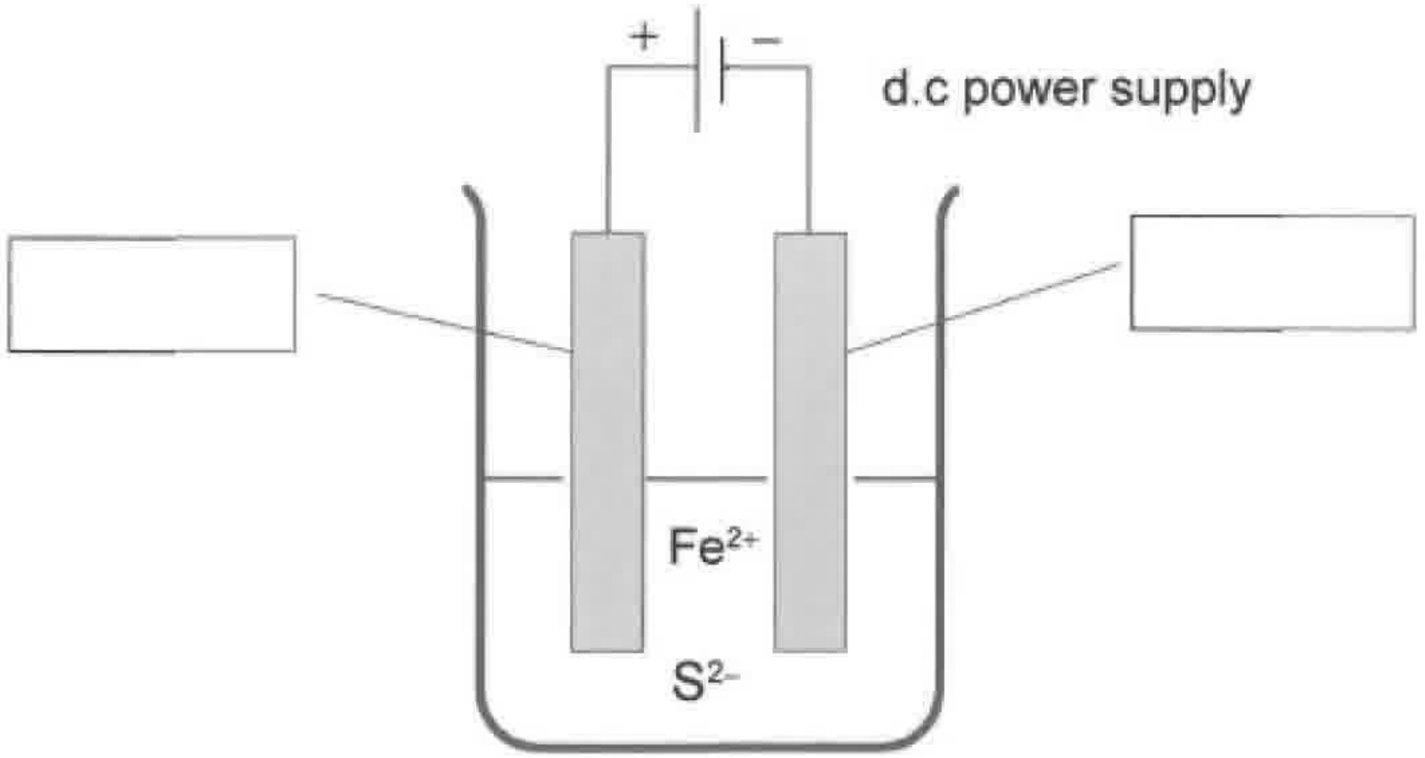
1. Iron(II) sulfide can be produced by heating powdered iron and sulfur together.

(a) Describe the difference between an element and a compound. [2]

(b) Outline why solid iron(II) sulfide is a polar covalent compound. Use sections 9 and 17 of the data booklet. [1]

(c) A student hypothesised that iron(II) sulfide is ionic and therefore can be converted back to iron and sulfur by electrolysis of the molten salt, using inert electrodes.

(i) Annotate the electrolytic cell with the terms anode and cathode, and show the direction of ion movement. [2]



(Question 1 continued)

(ii) Write half-equations for the reaction occurring at each electrode. [2]

Negative electrode: .....

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Positive electrode: .....

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(iii) Contrast **one** physical property of iron and iron(II) sulfide. [1]

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2. Cobalt ions form coloured compounds.

(a) Deduce the electron configuration of the Co^{2+} ion. [1]

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(b) An equilibrium is established when hydrated cobalt ions are mixed with concentrated hydrochloric acid.

$$Co^{2+}(aq) + 4Cl^{-}(aq) \rightleftharpoons CoCl_4^{2-}(aq)$$

Pink Blue

(i) State the equilibrium constant expression, *K*, for this equilibrium. [1]

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(i) State the equilibrium constant expression, K, for this equilibrium. [1]

(ii) Predict the effect on the value of K and the equilibrium position when solid sodium chloride, NaCl(s), is added to the mixture at constant temperature. [1]

(This question continues on the following page)

(Question 2 continued)

(iii) Heating an equilibrium mixture that is initially pink changes the colour to purplish-blue. Deduce, giving a reason, whether the formation of $CoCl_4^{2-}(aq)$ is an exothermic or endothermic process. [1]

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(iv) Sketch an energy profile for this equilibrium, labelling reactants, products, activation energy, E_a, and enthalpy change for the forward reaction, ΔH. [3]

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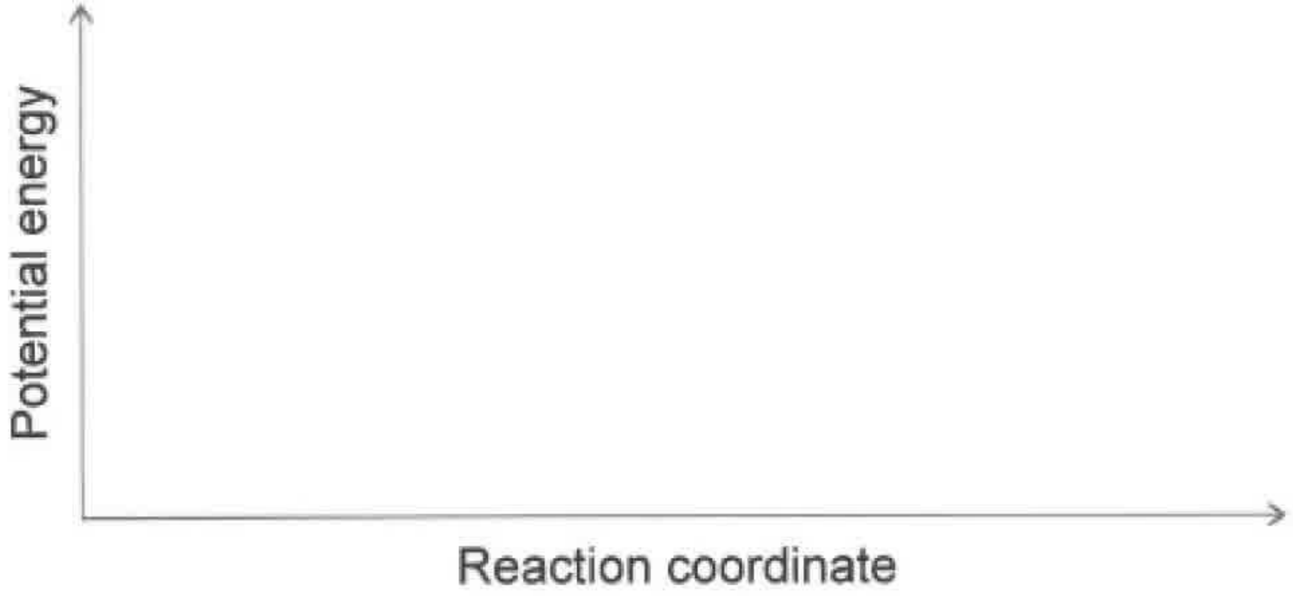

3. 3.162 g of calcium carbonate, $CaCO_3(s)$, is reacted with 20.0 cm^3 of 4.00 mol dm^{-3} hydrochloric acid, HCl(aq).

(a) Write an equation for the reaction, including state symbols. [2]

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(b) Deduce which reactant is limiting. Use sections 1, 4 and 7 of the data booklet. [2]

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(c) Calculate the volume, in dm^3 at STP, of the gas produced. Use section 2 of the data booklet. [1]

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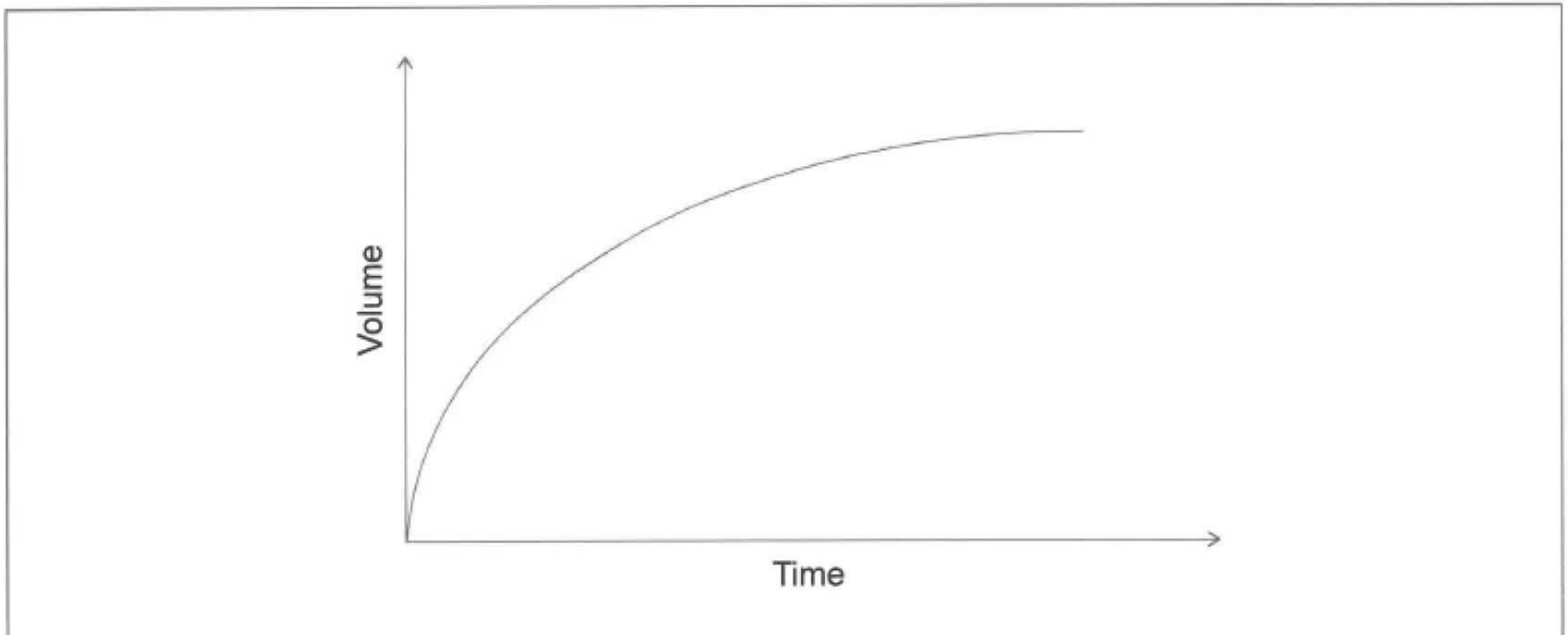
(This question continues on the following page)

(Question 3 continued)

(d) The rate of this reaction can be experimentally determined by measuring the volume of gas produced as time progresses.

Sketch another curve for the reaction taking place with the acid at a higher temperature and all other conditions unchanged. [1]



4. The rate of reaction between solutions of iron(III) nitrate and sodium thiosulfate can be measured using the time it takes for the colour to change.

(a) The first step in the reaction produces an unstable dark violet ion.

$$Fe^{3+}(aq) + 2S_2O_3^{2-}(aq) \rightarrow Fe(S_2O_3)_2^{-}(aq)$$

(i) $CoCl_2(s)$ is used as a catalyst. Explain how the catalyst increases the reaction rate. [2]

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(ii) The reaction continues until the violet colour disappears. The thiosulfate ion, $S_2O_3^{2-}$, is oxidized to SO_2, and Fe^{3+} is reduced to Fe^{2+}.
Deduce the oxidation half-equation, and the overall redox equation for this second step of the reaction. [2]

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Oxidation half-equation: .....

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Overall redox equation: .....

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(b) Iron(III) nitrate is a compound that involves both ionic and covalent bonding.

(i) Describe the two types of bonding. [2]

Ionic bonding: .....

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Covalent bonding: .....

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(Question 4 continued)

(ii) Deduce a Lewis formula of the nitrate ion. [1]

(iii) State the molecular geometry of the nitrate ion. [1]

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5. An unknown organic compound contains only carbon, hydrogen and oxygen.

(a) 4.32 g of the compound was combusted completely in oxygen and produced 9.49 g of CO_2 and 5.18 g of H_2O.
Determine the empirical formula of the compound, using sections 1 and 7 of the data booklet. [3]

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(b) The same organic compound was vaporized completely at a controlled temperature and pressure.

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(i) 0.108 g of the vaporized compound was found to have a volume of 55.7 cm^3 at 100 °C and a pressure of 1.00×10^5 Pa.
Calculate the amount, in moles, of the compound. Use sections 1, 2 and 4 of the data booklet. [2]

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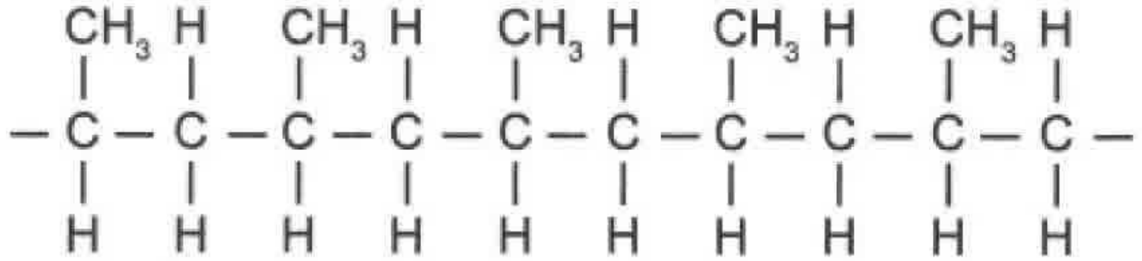
(ii) Determine the molar mass of the organic compound, using section 1 of the data booklet.
If you did not get an answer to (i), use $n = 0.00220$ mol, although this is not the correct value. [1]

6. Organic compounds have many industrial applications.

(a) A section of an addition polymer is shown.



(i) Deduce the structure of the monomer that forms this polymer. [1]

(i) Deduce the structure of the monomer that forms this polymer. [1]

(ii) Describe **one** chemical property that makes this type of polymer a useful material. [1]

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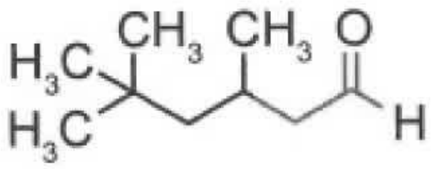
(Question 6 continued)

(b) The following organic compound, ***X***, is used as a flavouring agent.



(i) State the name of the functional group present in ***X***. [1]

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(ii) Deduce the systematic name of ***X*** using IUPAC nomenclature. [1]

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(iii) Draw an isomer of ***X*** which belongs to a different homologous series. [1]

(Question 6 continued)

(iv) Molecule ***X*** can undergo both oxidation and reduction.
Deduce the formulas of the organic products when ***X*** reacts separately with an oxidizing agent and with a reducing agent.
Use RCHO to represent ***X***. [2]

Product of reaction with oxidizing agent: .....

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Product of reaction with reducing agent: .....

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(c) An alkene such as ethene can be used as starting material for a range of compounds.

(i) Predict the product of the reaction between ethene and bromine. [1]

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(ii) Outline why unsaturated molecules, such as ethene, readily undergo this type of reaction. [1]

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(iii) State the general formula for the homologous series of alkenes. [1]

(iv) Explain, in terms of the intermolecular forces present, the trend in the boiling points of the first four alkenes. [2]

Alkene	Boiling point / K
ethene	169
propene	225
but-1-ene	267
pent-1-ene	303

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(d) Ethene reacts with steam to produce ethanol.

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$$C_2H_4(g) + H_2O(g) \rightarrow C_2H_5OH(g)$$

Calculate the enthalpy, in kJ, of the reaction using section 12 of the data booklet. [3]

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