Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

5 November 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]**.

8824 – 9544

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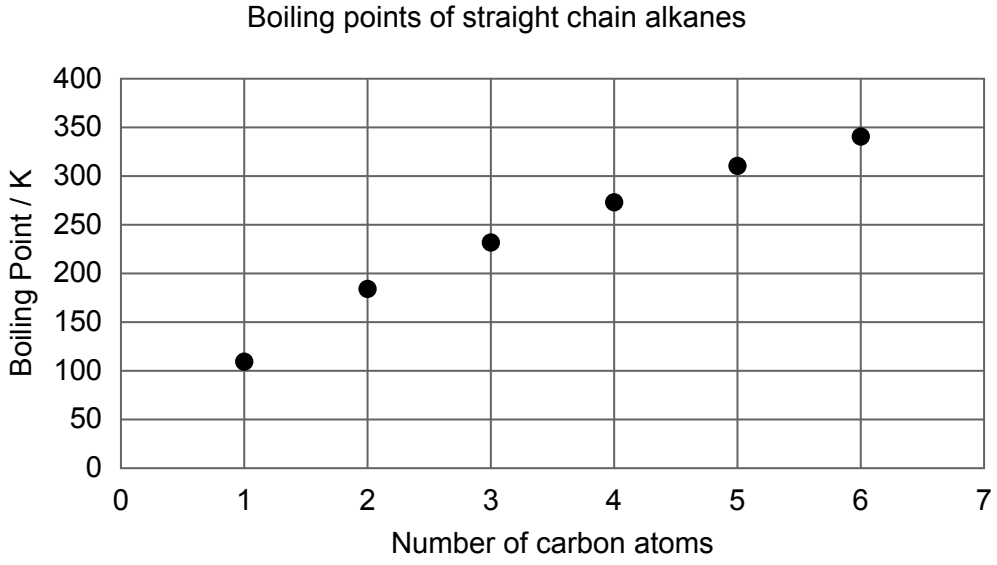
Answers written on this page
will not be marked.

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

1. Alkanes are commonly occurring organic compounds.

(a) The first four straight chain alkanes are gases at room temperature.



(i) Explain why the boiling point increases from methane to propane. [2]

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(ii) Explain why the volume occupied by a sample of propane increases sharply when the sample is heated up from 200 to 250 K at constant pressure. [2]

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(Question 1 continued)

(iii) Calculate the volume, in dm^3, occupied by 6.45 g of propane gas at 100 kPa and 15 °C. [2]

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(iv) Outline why the volume occupied by propane (g) at very high pressure is higher than the value calculated using PV = nRT. [2]

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(Question 1 continued)

(b) Ethane can be converted to chloroethane by reacting with chlorine gas, $Cl_2(g)$, in the presence of UV light.

(i) State the type of reaction and the name of the mechanism by which it occurs. [1]

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(ii) Explain the reaction mechanism by writing equations for each step. [4]

One initiation step: . . . . . .

Two propagation steps: . . . . . .

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One termination step: . . . . . .

(c) Chloroethane can be converted to ethanol. Identify the reagent and conditions necessary for this reaction to occur. [2]

Reagent: . . . . . .

Conditions: . . . . . .

2. Potassium, K, and potassium chloride, KCl, both form lattice structures in the solid state.

(a) Predict, with a reason, the electrical conductivity of K (s) and KCl (s). [2]

K (s): . . . . . .

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KCl (s): . . . . . .

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(b) An electrolytic cell is made using inert electrodes and molten potassium chloride, KCl (l). State the half equation for the reaction occurring at each electrode. [2]

Anode (positive electrode): . . . . . .

. . . . . .

Cathode (negative electrode): . . . . . .

. . . . . .

(c) State the number of each type of subatomic particle in the potassium ion, $^{41}_{19}K^{+}$. [1]

Protons: . . . . . .

Electrons: . . . . . .

Neutrons: . . . . . .

(This question continues on the following page)

(Question 2 continued)

(d) Potassium reacts with water to produce potassium hydroxide.

$2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$

(i) Calculate the enthalpy of reaction, in $kJ\,mol^{-1}$, when 1 mol of potassium reacts with water. Use section 12 of the data booklet. ΔH_f of $KOH(aq)$ is $-481.8\,kJ\,mol^{-1}$. [3]

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(ii) Describe the difference between the reactions of sodium and potassium with water. [1]

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(iii) Demonstrate, with an equation, the acid-base nature of $K_2O(s)$. [1]

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3. Sulfur trioxide is an important compound in industry.

(a) Sulfur trioxide has more than one possible Lewis (electron dot) structure.

(i) Sketch a Lewis (electron dot) structure for SO_3 which obeys the octet rule. [1]

(ii) Predict the length of each S to O bond in pm. Use section 10 of the data booklet. [1]

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(iii) State the molecular geometry and the O-S-O bond angle in SO_3. [2]

Molecular geometry: . . . . . .

Bond angle: . . . . . .

(b) Suggest why atmospheric $SO_3(g)$ is an environmental concern. [1]

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(Question 3 continued)

(c) State the name of a post-combustion method used to lower the quantity of $SO_3(g)$ released to the atmosphere. [1]

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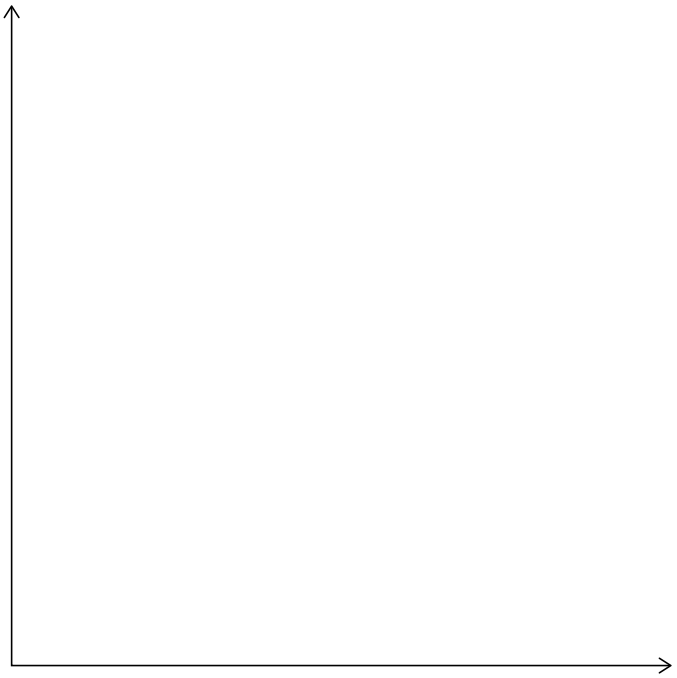
(d) $SO_3(g)$ is made using the contact process.

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H^{\ominus} < 0$

(i) Sketch a potential energy profile for this reaction on the axes provided. Label E_a and include labels on the axes. [3]



(ii) Explain why increasing the temperature increases the rate of reaction. [2]

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(Question 3 continued)

(iii) Vanadium pentoxide, V_2O_5, is used as a catalyst. Explain how a catalyst increases the rate of a reaction. [2]

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(iv) During the reaction, V_2O_5 changes to V_2O_4. Identify the oxidation states of vanadium in each compound. [1]

V_2O_5: . . . . . .

V_2O_4: . . . . . .

(v) State the equilibrium constant expression, K_c, for the production of SO_3. [1]

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

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

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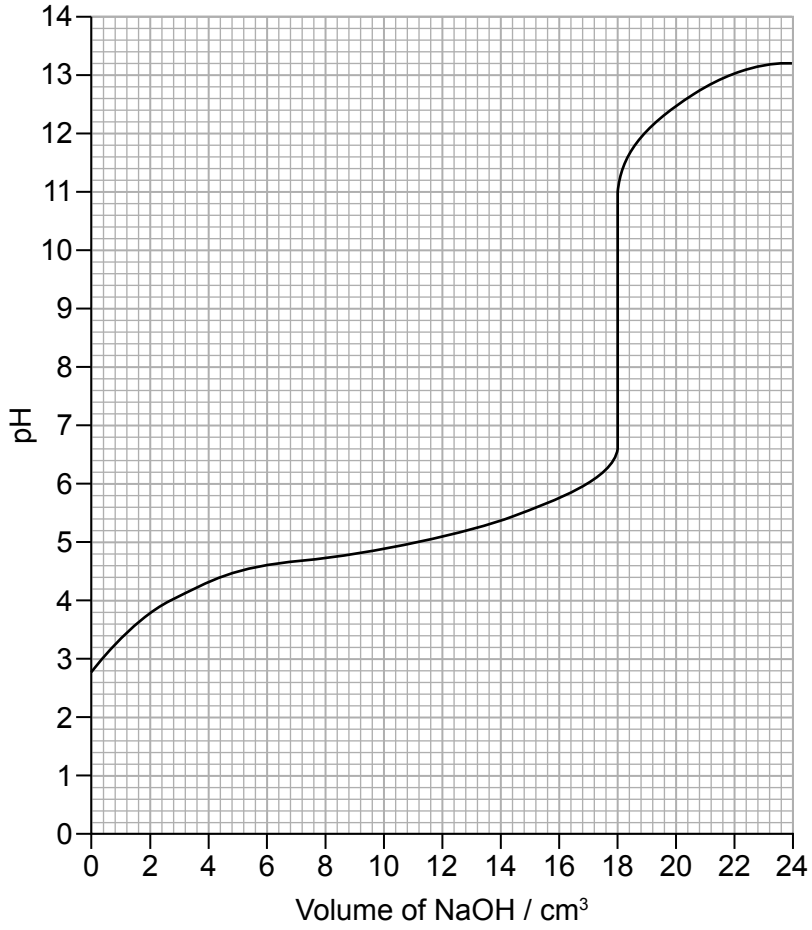
4. Propanoic acid is a weak acid.

(a) A 20.00 cm^3 sample of 0.150 mol dm^{-3} propanoic acid, $CH_3CH_2COOH(aq)$, was titrated with a solution of sodium hydroxide, NaOH(aq), giving the pH curve shown.



Determine the concentration, in mol dm^{-3}, of the NaOH(aq) used in the titration. [2]

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(b) Predict the number of signals and the ratio of areas under the signals in the ^1H NMR spectrum of propanoic acid, CH_3CH_2COOH. [2]

Number of signals: . . . . . .

Ratio of areas: . . . . . .

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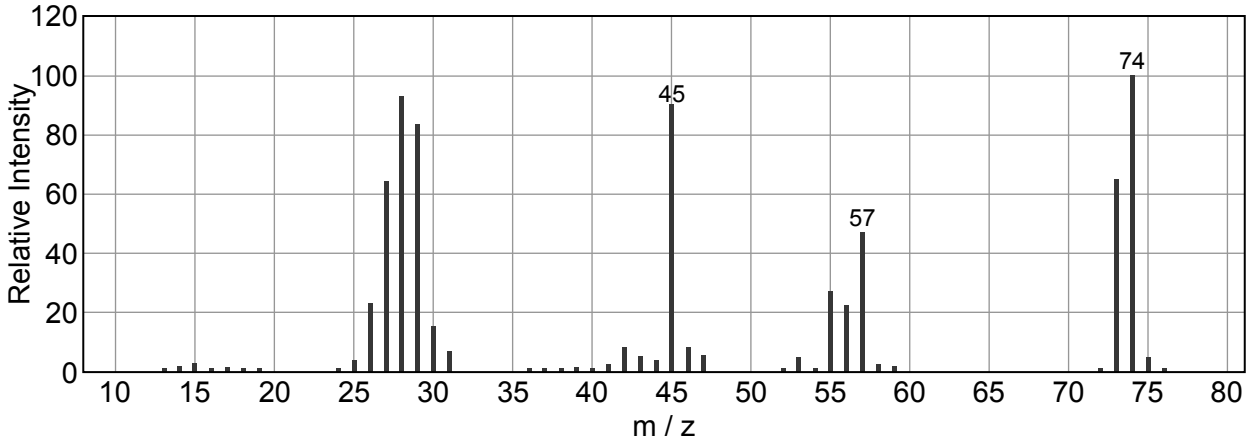
(Question 4 continued)

(c) The mass spectrum of propanoic acid is shown.



(i) The molar mass of propanoic acid is 74.09 g mol^{-1}. Suggest why there are two smaller peaks with higher m/z value than 74. [1]

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(ii) Identify the fragments with m/z 57 and 45. Use section 28 of the data booklet. [2]

m/z 57: . . . . . .

m/z 45: . . . . . .

(d) Outline how samples of propanoic acid and a strong acid of the same concentration can be distinguished from each other. [2]

Method: . . . . . .

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Observation: . . . . . .

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References:

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