



Chemistry
Standard level
Paper 2

Specimen paper

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]**.



Please **do not** write on this page.

Answers written on this page
will not be marked.



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

1. A monoprotic acid, HX, is found to have the following composition by mass:

C = 39.99 %

H = 6.73 %

O = 53.28 %

- (a) Determine the empirical formula of the compound HX.

[2]

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- (b) 25.00 cm³ of a solution, containing 1.51 g of HX is titrated with a 0.750 mol dm⁻³ solution of NaOH(aq). The HX(aq) solution is exactly neutralized by 22.30 cm³ of the NaOH(aq) solution. Determine the molar mass (*M*) of HX.

[2]

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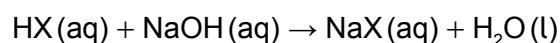
- (c) State the molecular formula of HX.

[1]

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- (d) HX reacts with aqueous sodium hydroxide according to the equation:



Identify a functional group present in HX.

[1]

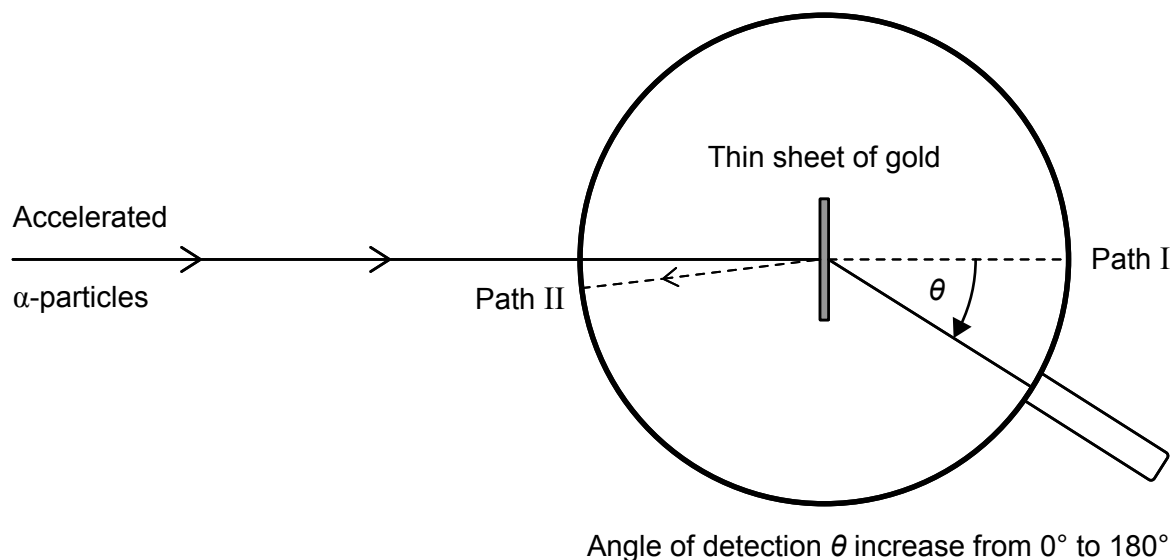
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2. Scientific models are used to explain the structure of matter.

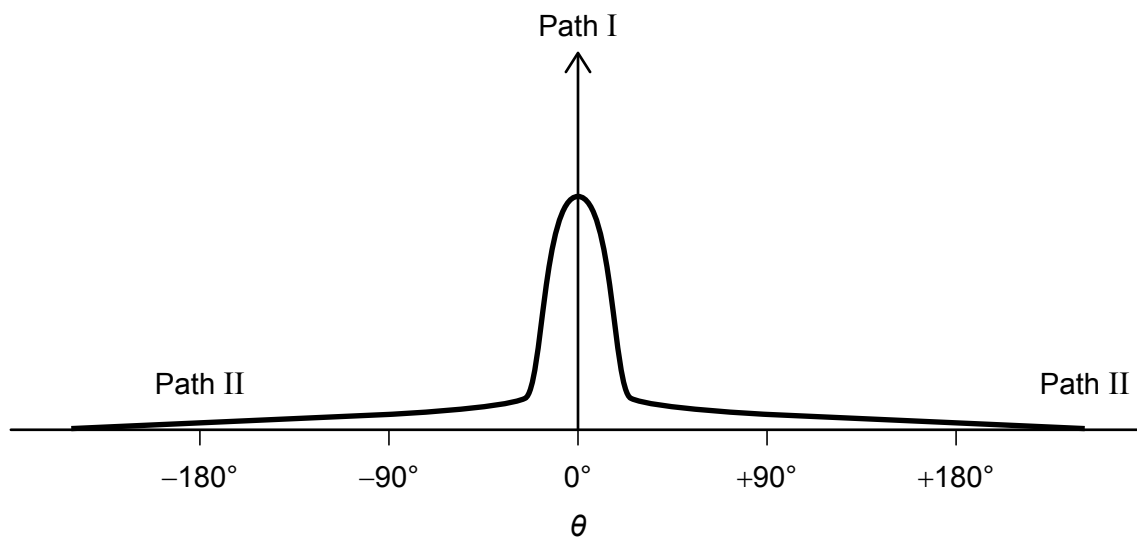
- (a) An α -particle is a helium-4 nucleus. In an experiment, α -particles are accelerated towards a thin sheet of gold and their resulting paths are detected, giving evidence of the positive charge of the nucleus.



The number of α -particles detected at different angles of deflection θ are shown.

Key:

— Number of α -particles detected



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(Question 2 continued)

- (i) State the nuclear charges of gold and helium. [1]

Gold:

Helium:

- (ii) Explain why some α -particles follow path II, rebounding from the gold sheet. [1]

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- (iii) Most of the α -particles follow path I and pass straight through undeflected ($\theta = 0^\circ$). Suggest a conclusion that can be made about the structure of the atom based on this evidence. [1]

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(Question 2 continued)

(b) Helium was first identified by analysing spectra of solar radiation.

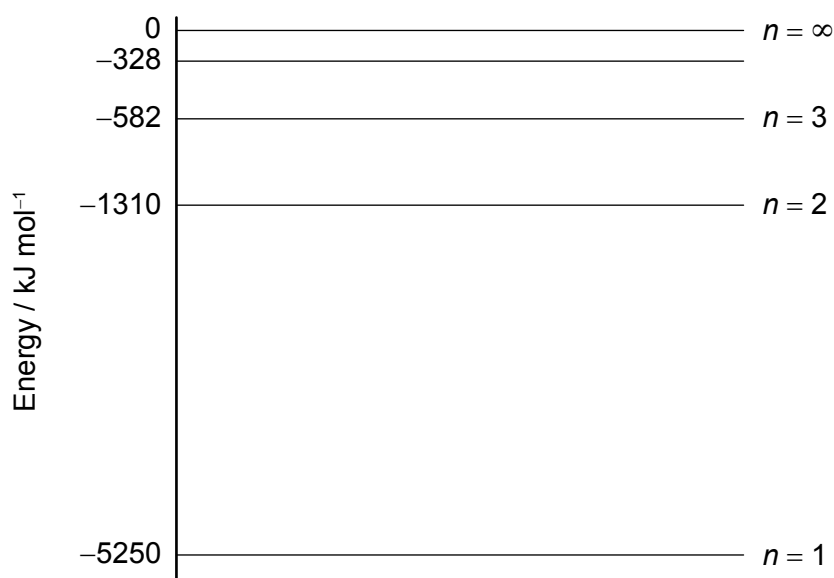
(i) Outline the appearance of the emission spectrum of helium.

[1]

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Emission spectra of one-electron systems can be explained using a model with the electron attracted to the nucleus by an electrostatic force.

This model predicts that the electron occupies discrete energy levels. Some energy levels for the He^+ ion are shown.



(ii) Explain how the frequencies observed in emission spectra support the idea of the electron occupying discrete energy levels.

[2]

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(This question continues on the following page)



(Question 2 continued)

The ionization energy of the He^+ ion is 5250 kJ mol^{-1} and the ionisation energy of hydrogen is 1312 kJ mol^{-1} .

- (iii) Suggest **two** reasons why the ionization energy of the hydrogen atom is significantly smaller than the ionization energy of the He^+ ion. [2]

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- (iv) Suggest why the model outlined in (b)(ii) can predict the emission spectrum of He^+ but not He. [1]

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- (c) Outline why models of the atom have evolved over time. [1]

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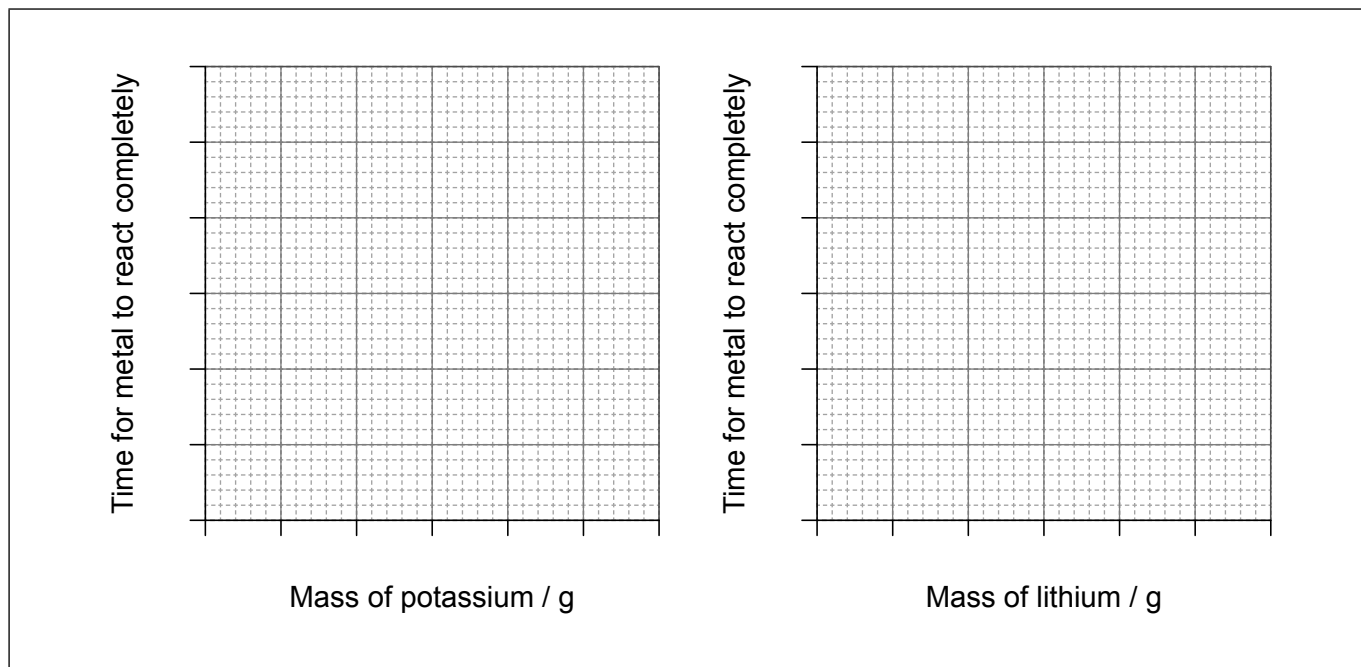
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3. In a simulation, equal masses of potassium and lithium are added to water and the time taken for the metals to fully react is recorded. Five different increasing masses of each metal are used, and the reaction is timed.

(a) Sketch the graphs on the axes to show the expected results of this experiment.

[2]



- (b) Suggest a reason why comparing the time for complete reaction of equal masses is not a valid measure of reactivity.

[1]

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- (c) Lithium carbide, Li_2C_2 , is one of many compounds of lithium and carbon. Determine the percentage covalent character and bonding type in this compound by using sections 9 and 17 of the data booklet.

[2]

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(Question 3 continued)

(d) Draw the Lewis formula of the anion in the salt Li_2C_2 .

[2]



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will not be marked.



4. Heptadecane, $C_{17}H_{36}$, can be extracted from crude oil or cactus plants.

(a) Write an equation for the complete combustion of $C_{17}H_{36}$. [1]

(b) The enthalpy of combustion of $C_{17}H_{36}$ is $-11\,350\text{ kJ mol}^{-1}$.

(i) Calculate the maximum energy produced when 2.00 g of $C_{17}H_{36}$ is combusted. [2]

(ii) Determine the maximum temperature change when 500.0 cm^3 of water is heated by a 2.00 g sample of $C_{17}H_{36}$. [2]

(iii) Outline **two** assumptions made in the calculation in (b)(ii). [2]

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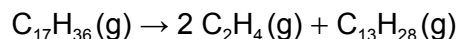


(Question 4 continued)

- (c) Explain why biofuels contribute less to climate change than fossil fuels. [1]

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- (d) Heptadecane can be broken down into smaller molecules. Consider the reaction:



Determine the standard enthalpy change, $\Delta H^\ominus$, for the reaction stated, using section 12 of the data booklet. [3]

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- (e) Ethene can be converted to ethanol in one reaction. State the equation for this reaction. [1]

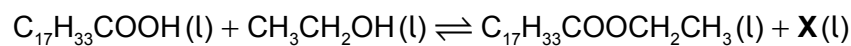
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(Question 4 continued)

- (f) Ethanol reacts with oleic acid to produce ethyl oleate.



- (i) Identify the side product **X**(l). [1]

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

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- (iii) Discuss why the atom economy of a reaction is an important consideration when evaluating the impact of a reaction in an industrial process. [2]

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5. Halogens are important reactants in the laboratory and in the environment.

- (a) (i) Write an equation for the homolytic fission of chlorine under UV light, showing the movement of electrons. [2]

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- (ii) Under different conditions, chlorine molecules can break down by heterolytic fission. Write an equation showing the movement of electrons. [1]

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- (iii) Identify, giving a reason, which one of the three species produced in (a)(i) and (a)(ii) is an electrophile. [1]

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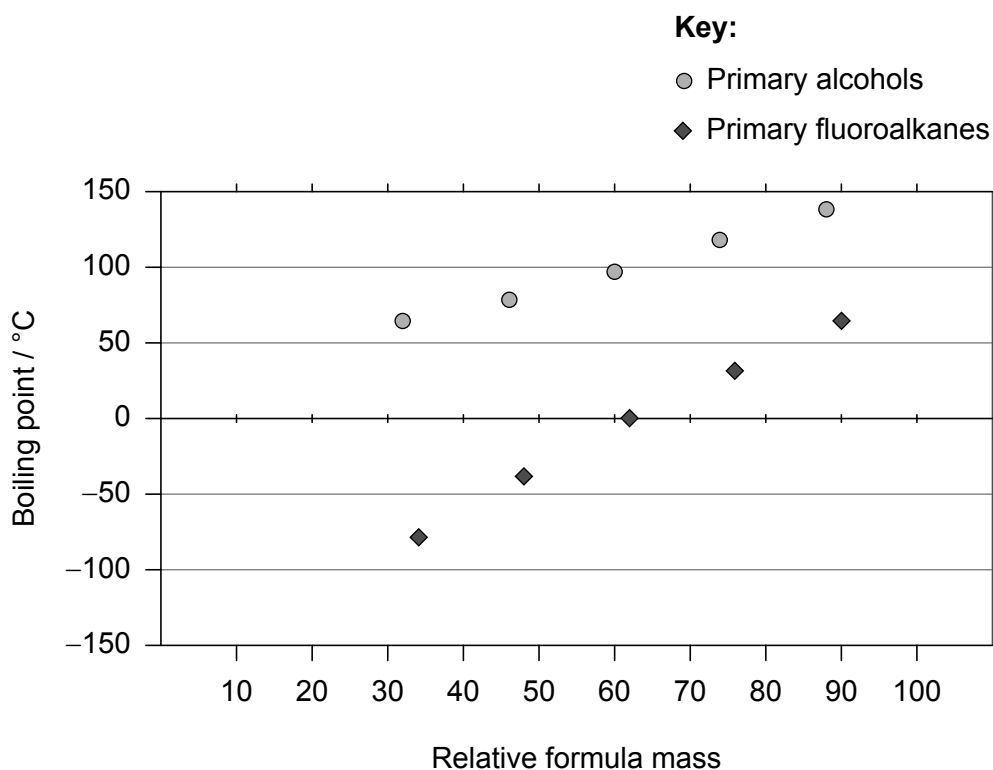
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(Question 5 continued)

- (b) The graph shows the boiling points of the first five straight-chain primary alcohols and fluoroalkanes.



- (i) Outline why the alcohols have higher boiling points than fluoroalkanes of similar relative formula mass.

[1]

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- (ii) Explain the general trend in the boiling points shown for the alcohols.

[2]

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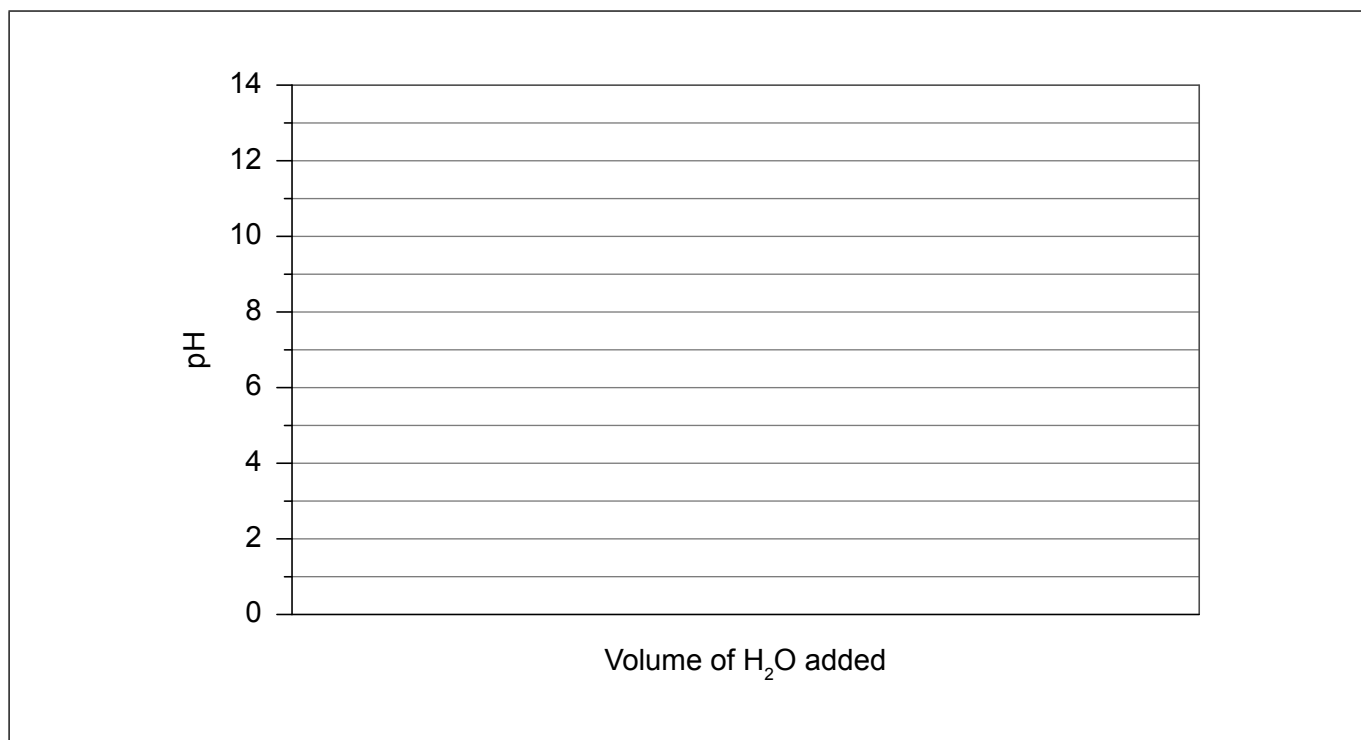


(Question 5 continued)

- (c) Hydrochloric acid is an important chemical reactant and industrial chemical.

A pH probe is placed in a small volume of 0.10 mol dm^{-3} solution of hydrochloric acid. The pH is recorded while a steady stream of distilled water is added to the acid at constant temperature.

- (i) On the axes, sketch the graph of pH against volume of water added. [3]



- (ii) The experiment is repeated using $0.010 \text{ mol dm}^{-3}$ NaOH (aq) at the same temperature. State the initial pH of the sodium hydroxide solution. [1]

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