Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Higher level
Paper 2

18 May 2026

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

Session number

2 hours 30 minutes

Instructions to students

- 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 **[90 marks]**.

2226 – 4224

26 pages

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

1. Hydrobromic acid, HBr (aq), and hydrochloric acid, HCl (aq), are strong acids and methanoic acid, HCOOH (aq), is a weak acid.

(a) $20.0\,cm^3$ of $0.250\,mol\,dm^{-3}$ HBr (aq) was titrated with potassium hydroxide solution, KOH (aq).

(i) Calculate the initial pH of the hydrobromic acid. Use section 1 of the data booklet. [1]

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(ii) Write the equation for the neutralization reaction between HBr (aq) and KOH (aq). [1]

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(iii) Calculate the amount, in mol, of KOH (aq) needed to neutralize the solution of HBr (aq). Use section 1 of the data booklet. [1]

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(iv) Calculate the volume of $0.220\,mol\,dm^{-3}$ KOH (aq) required for neutralization. Use section 1 of the data booklet. [1]

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(This question continues on the following page)

(Question 1 continued)

(v) Suggest one method, and the expected result, that could distinguish between unlabelled solutions of HBr(aq) and HCOOH(aq) of the same concentration. [2]

Method: . . . . . .

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Expected result: . . . . . .

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(vi) Deduce the formula and pK_b of the conjugate base of HCOOH. [2]

$$pK_a\ (HCOOH) = 3.75$$

Formula of conjugate base: . . . . . .

pK_b: . . . . . .

(This question continues on page 5)

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

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will not be marked.

(Question 1 continued)

(vii) Calculate the pH when 20.0 cm^3 of 0.250 mol dm^{-3} HCOOH (aq) has been neutralized by 22.0 cm^3 of KOH (aq) of a different concentration.

Assume that the volumes of dilute solutions are additive. [3]

$$K_b = \frac{[HCOOH][OH^-]}{[HCOO^-]} = 5.62 \times 10^{-11}$$

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(viii) Suggest a suitable indicator for this titration of HCOOH (aq) with KOH (aq). Use section 18 of the data booklet. [1]

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(ix) Explain, using equations, why colour of an indicator changes with pH.

Use HInd to represent the indicator. [3]

Equilibrium in HInd (aq) solution: . . . . . .

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Adding H^+: . . . . . .

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Adding OH^-: . . . . . .

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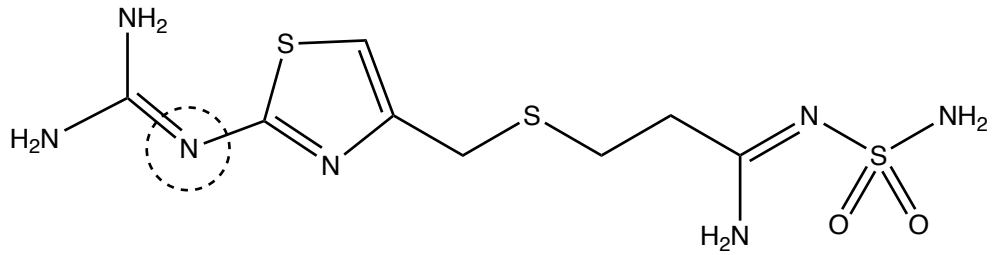
(Question 1 continued)

(b) Famotidine is a drug that reduces the production of stomach acid which contains HCl (aq).



$C_8H_{15}N_7O_2S_3$

$M_r = 337.51$

(i) Deduce the hybridization of the circled N atom. [1]

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(ii) Describe how sigma (σ) and pi (π) bonds form between S and O in famotidine. [2]

sigma (σ) bond: . . . . . .

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pi (π) bond: . . . . . .

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(This question continues on the following page)

(Question 1 continued)

(iii) Deduce the number of signals and their relative areas in the famotidine ^{1}H NMR spectrum. [2]

Number of signals: . . . . . .

Relative areas: . . . . . .

(iv) Calculate the percentage by mass of nitrogen in a molecule of famotidine. Use section 7 of the data booklet. [1]

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2. Iodine occurs naturally in seawater.

(a) Iodine crystals, $I_2(s)$, were placed in a sealed flask. Some of the solid turned into purple vapour as equilibrium was reached.

$$I_2(s) \rightleftharpoons I_2(g)$$

(i) State the name of the change from $I_2(s)$ to $I_2(g)$, and the type of force which is overcome. [2]

Change of state: . . . . . .

Type of force: . . . . . .

(ii) Explain why the purple vapour became darker as temperature increased. [2]

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(iii) Explain why the pressure in the flask increased as temperature increased. [2]

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(This question continues on the following page)

(Question 2 continued)

(iv) At equilibrium, 2.05×10^{-3} g of iodine was present as vapour in a 500 cm^3 flask at 25 °C.

Calculate the pressure, in kPa, in the flask due to the iodine vapour. [3]

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(b) An 'iodine clock' experiment involves two reactions occurring at the same time.

$$H_2O_2(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow I_2(aq) + 2H_2O(l) \quad \text{slow}$$

$$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq) \quad \text{fast}$$

When the $S_2O_3^{2-}$ has all reacted, excess I_2 reacts with starch indicator to produce a dark blue complex.

(i) Deduce the oxidation state of O in H_2O_2. [1]

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(ii) Write a redox half-equation for the conversion of $S_2O_3^{2-}$ to $S_4O_6^{2-}$. [1]

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(iii) Suggest one change that would decrease the time for the dark blue colour to appear. [1]

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(This question continues on page 11)

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will not be marked.

(Question 2 continued)

(c) Outline what is known about the electron configuration of an iodine atom from its position in the periodic table. [2]

Information from group number: . . . . . .

. . . . . .

Information from period number: . . . . . .

. . . . . .

3. Metals are widely used in industry.

(a) Aluminium is used by itself and in alloys.

(i) Describe the structure of aluminium and the forces holding the metal together. [2]

Structure: . . . . . .

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Forces: . . . . . .

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(ii) Explain why aluminium is malleable. [1]

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(iii) Explain why aluminium has a higher melting point than gallium. [2]

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(iv) State the electron configuration of gallium. [1]

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(This question continues on the following page)

(Question 3 continued)

(v) Outline why the first ionization energy of aluminium is lower than that of magnesium. [2]

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(b) An alloy of aluminium and lithium is used in aerospace applications.

(i) Suggest why the addition of lithium creates a material that is stronger and less flexible than aluminium alone. [2]

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(ii) Suggest why adding lithium to aluminium is a good choice for an aerospace alloy. [1]

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(Question 3 continued)

(c) Lithium is a reactive metal.

(i) Write an equation for the reaction between lithium and water, including state symbols. [2]

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(ii) Describe an **observation** from the reaction in (c)(i). [1]

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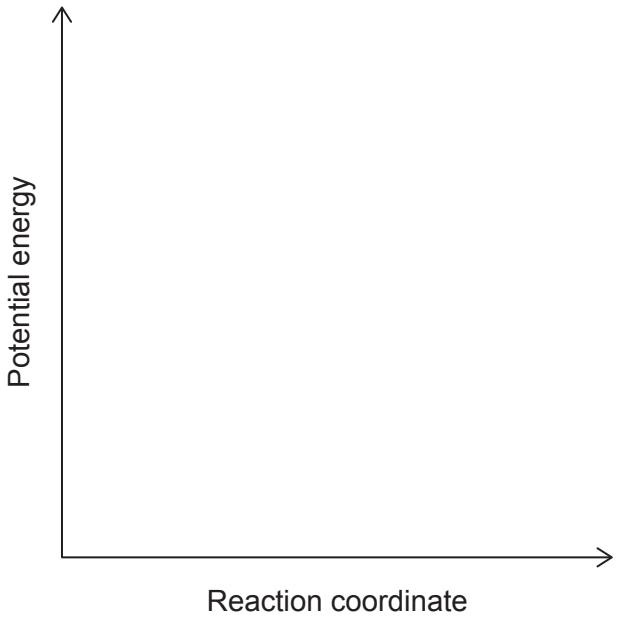
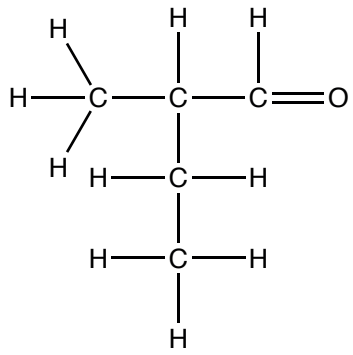
(iii) Sketch an energy profile for the reaction between lithium and water, showing activation energy, E_a and enthalpy change of reaction, ΔH. [2]



4. Organic compounds are the main constituents of living organisms.

(a) Compound **X** is found in plant and animal cells.



Compound **X**

(i) State the IUPAC name of compound **X**. [1]

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(ii) State the name of the C=O functional group in compound **X**. [1]

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(iii) Predict the H–C=O bond angle in compound **X**. [1]

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(iv) Predict the IR absorption range for the C=O bond in compound **X**. Use section 20 of the data booklet. [1]

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(This question continues on the following page)

(Question 4 continued)

(v) Sketch the full structural formula of the product formed from the reaction of compound **X** with a reducing agent. [1]

(This question continues on the following page)

(Question 4 continued)

(b) 1-Bromopropane is used as a solvent and a building block for organic molecules.

(i) Predict the organic product formed when 1-bromopropane reacts with hydroxide ions. [1]

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(ii) Deduce, with a reason, the reaction type in (b)(i). [1]

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(iii) Sketch the mechanism of the reaction between 1-bromopropane and hydroxide ions, using curly arrows to show the movement of electron pairs. [3]

(This question continues on the following page)

(Question 4 continued)

(c) Ethane reacts with chlorine gas in the presence of UV radiation to produce chlorinated hydrocarbons.

(i) Explain, using an equation, the homolytic fission of chlorine. [1]

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(ii) Explain, using two equations, the propagation steps for the reaction between ethane and chlorine. [2]

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(This question continues on the following page)

(Question 4 continued)

(d) Ethene can be reduced by hydrogen gas in the presence of a nickel catalyst at 150 °C.

Outline how the catalyst increases the reaction rate. [2]

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(e) Ethene reacts with hydrogen bromide at room temperature.

$$H_2C{=}CH_2(g) + HBr(g) \rightarrow CH_3CH_2Br(l) \qquad \Delta H^{\ominus} = -106\,kJ\,mol^{-1}$$

(i) Calculate the change in entropy, $\Delta S^{\ominus}$, for this reaction in $J\,K^{-1}\,mol^{-1}$. Use section 13 of the data booklet. [1]

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(ii) Explain the sign of the entropy change. [1]

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(Question 4 continued)

(iii) Calculate the change in Gibbs energy, $\Delta G^{\ominus}$, in $kJ\,mol^{-1}$, using sections 1 and 4 of the data booklet.

If you were unable to get an answer to (e)(i), use $\Delta S^{\ominus} = -200\,J\,K^{-1}\,mol^{-1}$, although this is not the correct value. [2]

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(iv) Explain why the formation of bromoethane becomes less spontaneous as temperature increases. [2]

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(v) Calculate the temperature, in *K*, above which the reaction becomes non-spontaneous. Use section 1 of the data booklet.

If you were unable to get an answer to (e)(i), use $\Delta S^{\ominus} = -200\,J\,K^{-1}\,mol^{-1}$, although this is not the correct value. [1]

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5. Nitrogen (II) oxide reacts with ozone in the stratosphere.

$$NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$$
$$NO_2(g) + O\bullet(g) \rightarrow NO(g) + O_2(g)$$

Species	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
NO	90.25
NO_2	33.18
O•	249.2
O_3	142.7

(a) Determine the enthalpy change, in kJ mol^{-1}, for the overall reaction. [2]

Overall reaction: . . . . . .

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$\Delta H_{reaction}$: . . . . . .

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(b) Calculate the enthalpy change, in kJ mol^{-1}, for the first reaction.

$$NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$$

Use section 12 of the data booklet and the information provided. [3]

Bond	Bond enthalpy / kJ mol^{-1}
Between N and O in NO molecule	632
Between N and O in NO_2 molecule	469
Between O and O in O_3 molecule	302

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6. The rate of reaction between methanoic acid and bromine solution can be monitored using a colorimeter.

Initial rates of reaction were determined using different initial concentrations of the reactants.

$[Br_2]$ / mol dm^{-3}	[HCOOH] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
2.4×10^{-3}	5.0×10^{-1}	1.1×10^{-5}
4.8×10^{-3}	5.0×10^{-1}	2.2×10^{-5}
4.8×10^{-3}	2.5×10^{-1}	1.1×10^{-5}

(a) Deduce the order of reaction with respect to each reactant and the rate equation. [2]

Order of reaction with respect to Br_2: . . . . . .

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Order of reaction with respect to HCOOH: . . . . . .

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Rate equation: . . . . . .

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(b) Calculate the value, including units, of the rate constant, *k*, using data from the table. [2]

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(Question 6 continued)

(c) Outline how the activation energy, E_a, can be determined.

Details of experimental procedure are not required. [3]

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7. Copper forms different coloured complex ions with a variety of ligands.

Complex ion	$[Cu(H_2O)_6]^{2+}$	$[Cu(NH_3)_4(H_2O)_2]^{2+}$	$[CuCl_4]^{2-}$
Colour	blue	dark blue	green

(a) Outline the type and formation of the bond between the copper ion and the ligand. [2]

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(b) Explain why the copper complexes are coloured. [3]

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