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 – 4230

23 pages

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. Binary ionic compounds contain metals and non-metals.

(a) (i) Explain, using electron configurations, how ions are formed by lithium and chlorine and how these ions form a compound. [3]

$$Li(s) + \frac{1}{2}Cl_2(g) \rightarrow LiCl(s)$$

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(ii) Explain why the element chromium, Cr, is an exception to the Aufbau principle using electron configurations. [2]

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(Question 1 continued)

(b) Lithium also forms compounds with polyatomic ions.

(i) 35.0 cm^3 of a 0.550 mol dm^{-3} lithium hydroxide, LiOH, solution is mixed with 35.0 cm^3 of 0.250 mol dm^{-3} of an iron(III) nitrate, $Fe(NO_3)_3$, solution.

Determine the limiting reactant and mass of iron(III) hydroxide, $Fe(OH)_3$, produced showing your working. Use sections 1 and 7 of the data booklet. [3]

$$3LiOH\,(aq) + Fe(NO_3)_3\,(aq) \rightarrow Fe(OH)_3\,(s) + 3LiNO_3\,(aq)$$

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(ii) Calculate the percentage yield of iron(III) hydroxide from part (b)(i) if 0.542 g of the product was collected.

If you did not obtain an answer in part (b)(i), use 0.763 g, although this is not the correct answer. [1]

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(This question continues on the following page)

(Question 1 continued)

(c) Some ionic compounds are the product of acid–base neutralization reactions.

(i) State the names of the acid and base that would produce ammonium chloride, NH_4Cl. [1]

Acid: . . . .

Base: . . . .

(ii) Estimate the pH value of an aqueous solution of ammonium chloride. [1]

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(iii) Ionic salts can be used as components of acid–base buffers.

Determine the pH of a buffer solution containing $0.350\,mol\,dm^{-3}$ ethanoic acid and $0.455\,mol\,dm^{-3}$ sodium ethanoate.

The pK_a of ethanoic acid is 4.76.

Use section 1 of the data booklet. [2]

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2. Nitrogen dioxide is a covalently bonded compound.

(a) (i) Nitrogen monoxide reacts with monatomic oxygen in the atmosphere.

Determine the enthalpy change, $\Delta H^{\ominus}$, in kJ mol^{-1}, for the reaction:

$$NO\,(g) + O\,(g) \rightarrow NO_2\,(g)$$

given these reactions and enthalpy values: [2]

$2O_3\,(g) \rightarrow 3O_2\,(g)$	$\Delta H^{\ominus} = -285.4\ \text{kJ mol}^{-1}$
$O_2\,(g) \rightarrow 2O\,(g)$	$\Delta H^{\ominus} = +498.0\ \text{kJ mol}^{-1}$
$NO\,(g) + O_3\,(g) \rightarrow NO_2\,(g) + O_2\,(g)$	$\Delta H^{\ominus} = -199.9\ \text{kJ mol}^{-1}$

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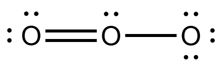
(ii) Suggest the value of the bond angle and molecular geometry of ozone based on the Lewis formula. [2]



Bond angle: . . . .

Molecular geometry: . . . .

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(Question 2 continued)

(iii) Calculate the volume, in dm^3, of 1.75 mol of ozone gas at 75.0 °C and 115 kPa.

Use sections 1 and 2 of the data booklet. [1]

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(iv) Explain **one** limitation of the ideal gas model. [1]

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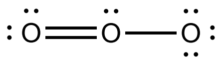
(v) Annotate the Lewis formula for ozone with formal charges. [1]



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(Question 2 continued)

(b) The decomposition of nitrogen dioxide, NO_2, is an equilibrium reaction.

$$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$$

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

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(ii) Explain, with a reason, how increasing the pressure at constant volume and temperature will affect the equilibrium position and the value of the equilibrium constant, K. [2]

Equilibrium position: . . . .

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Value of equilibrium constant: . . . .

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(iii) For a certain reaction, the value of the reaction quotient, Q, was found to be greater than the value of the equilibrium constant, K.

Explain the difference between Q and K and predict the direction of the spontaneous process for this reaction. [2]

	Explanation
Relationship of *Q* and *K*	. . . .
Direction of the spontaneous process with reason	. . . .

(This question continues on the following page)

(Question 2 continued)

(iv) Explain why increasing the temperature will increase the rate of the reaction. [2]

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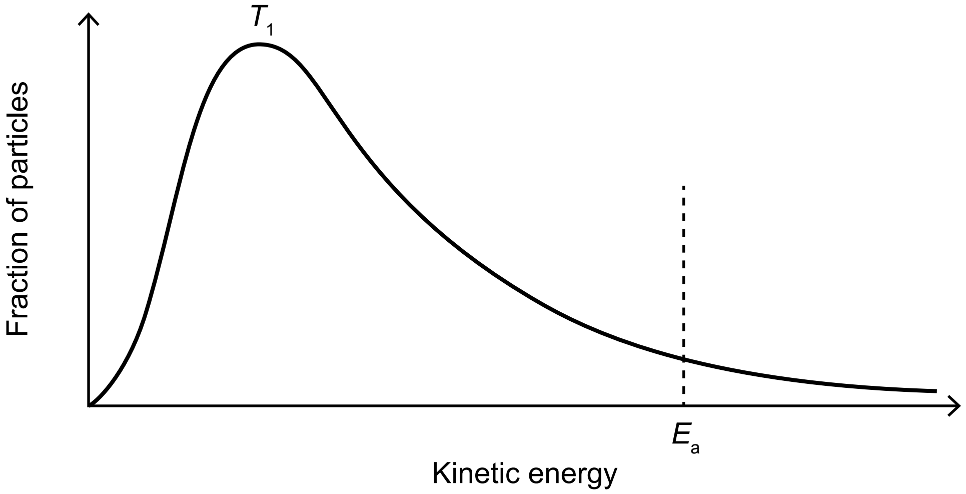
(v) Consider the Maxwell–Boltzmann energy distribution curve at temperature T_1.



Sketch a curve on the graph at a higher temperature and label it T_2. [1]

(vi) State the effect of an increase in temperature from T_1 to T_2 on the activation energy, E_a. [1]

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(Question 2 continued)

(c) The reverse reaction from part (b) produces nitrogen dioxide from nitrogen monoxide:

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

The rate equation was experimentally determined as $Rate = k[NO]^2[O_2]$.

(i) A student proposed the following mechanism and suggested that Step 1 was the rate-determining step.

Step 1: $NO(g) + NO(g) \rightarrow N_2O_2(g)$

Step 2: $N_2O_2(g) + O_2(g) \rightarrow 2NO_2(g)$

Evaluate the proposed mechanism and rate-determining step. [2]

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(ii) Calculate the value and units of the rate constant. [2]

[NO] / mol dm^{-3}	**[O_2] / mol dm^{-3}**	**Rate / mol dm^{-3} s^{-1}**
1.6×10^{-1}	2.4×10^{-1}	1.5×10^{-4}

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3. Iridium is a transition metal.

(a) Iridium has two stable abundant isotopes with an average atomic mass of 192.22 amu.

Isotope	**Atomic mass**	**Percent abundance**
Ir-191	190.96	. . . .
Ir-193	192.96	. . . .

(i) Determine the percent abundance of the isotopes showing your work. [2]

Ir-191: . . . .

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Ir-193: . . . .

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(ii) State the number of subatomic particles in $^{193}Ir^{4+}$. [1]

Subatomic particles	**Number**
Protons	. . . .
Neutrons	. . . .
Electrons	. . . .

(b) Sodium and aluminium are metals of the same period.

(i) Outline why the strength of the metallic bond increases from sodium, Na, to aluminium, Al. [2]

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(This question continues on the following page)

(Question 3 continued)

(ii) Write an equation for the reaction of sodium, Na, with water, including state symbols. [2]

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(iii) Outline why the electronegativity of sodium, Na, is greater than that of caesium, Cs. [1]

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(iv) The first ionization energy of Cs is $376\,kJ\,mol^{-1}$.

Determine the wavelength of convergence for one atom of caesium, in m, and the region it corresponds to in the electromagnetic spectrum.

Use sections 1, 2, and 5 of the data booklet. [3]

Wavelength: . . . .

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Region: . . . .

(This question continues on the following page)

(Question 3 continued)

(c) (i) Outline **one** reason why alloys are often harder than pure metals. [1]

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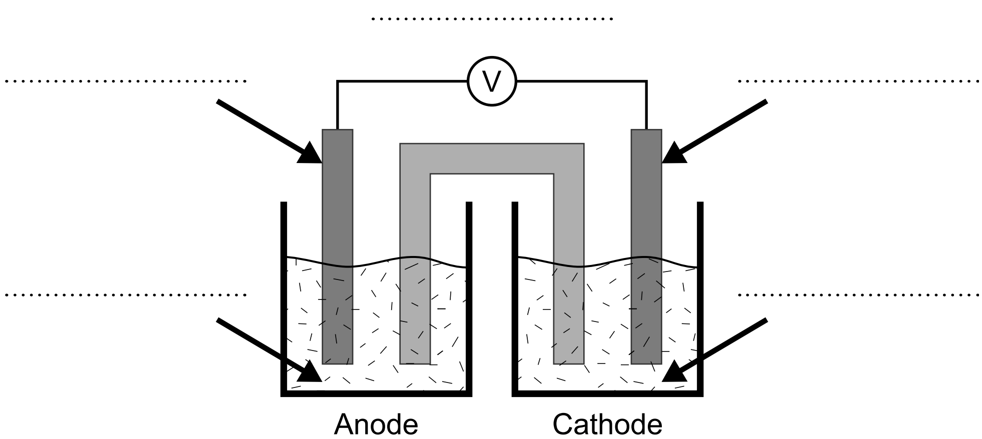
(ii) State **one** additional property, other than hardness, that could be modified by forming an alloy. [1]

Property: . . . .

(d) Metals can be used to design voltaic cells.

$$Sn(s) + Pb^{2+}(aq) \rightarrow Sn^{2+}(aq) + Pb(s)$$

(i) Annotate the diagram with the appropriate electrodes, electrolyte solutions, and direction of electron flow. [2]



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(Question 3 continued)

(ii) The redox reactions in some voltaic cells can be reversed.

Explain the process of recharging the voltaic cell in part (d)(i). [3]

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(e) The cobalt ion, Co^{3+}, forms a variety of coloured complexes.

(i) Outline, with a reason, why solutions containing $[Co(H_2O)_6]^{3+}$ ions have violet colour.

Use section 15 of the data booklet. [2]

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(ii) State the type of bond between the cobalt ion, Co^{3+}, and water, H_2O, in the complex, $[Co(H_2O)_6]^{3+}$. [1]

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4. Organic compounds can be produced by a variety of reactions.

(a) Reactions of halogenoalkanes with hydroxide ions are an example of nucleophilic substitution.

(i) Sketch the mechanism for the reaction of 1-bromobutane with aqueous sodium hydroxide.

Use curly arrows to show movement of electrons. [3]

(ii) State the name of the organic product in part (a)(i). [1]

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(b) Butane undergoes combustion.

$$CH_3CH_2CH_2CH_3(g) + 6\frac{1}{2}O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$$

(i) Calculate the standard enthalpy change of reaction, $\Delta H^\ominus$, in $kJ\,mol^{-1}$, for the combustion of butane.

Use section 13 of the data booklet. [2]

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(This question continues on the following page)

(Question 4 continued)

(ii) The standard entropy change, $\Delta S^{\ominus}$, for the combustion of butane is $-437.5\,J\,K^{-1}\,mol^{-1}$.

Determine the standard Gibbs energy change, $\Delta G^{\ominus}$, in $kJ\,mol^{-1}$ for the combustion of butane at 25 °C using the answer from part (b)(i).

Use sections 1 and 4 of the data booklet.

If you did not obtain an answer in part (b)(i), use $-2400\,kJ\,mol^{-1}$, although this is not the correct answer. [2]

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(iii) State the oxidation state for **carbon-1** in butane and carbon in carbon dioxide. [2]

Compound	**Oxidation state**
$\mathbf{C}H_3CH_2CH_2CH_3$	. . . .
CO_2	. . . .

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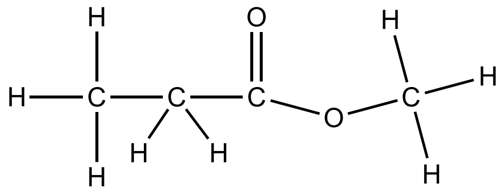
(Question 4 continued)

(c) (i) State the names of the organic compounds used to produce this ester. [2]



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(ii) State the name of the by-product of this reaction. [1]

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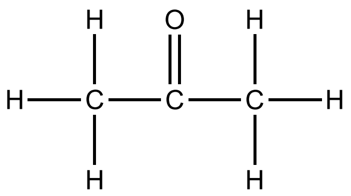
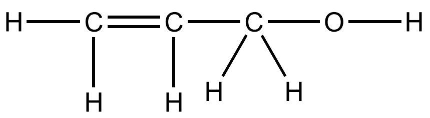
(Question 4 continued)

(iii) The following compounds have the same molar mass.



Propanone



Prop-2-en-1-ol

Explain, with reasons, why prop-2-en-1-ol has a higher boiling point than propanone. [2]

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(Question 4 continued)

(d) Methane, CH_4, reacts with chlorine, Cl_2, to produce chloromethane, CH_3Cl.

(i) Outline why light or heat are needed to start the reaction. [1]

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(ii) Deduce **two** propagation steps and **one** termination step for this mechanism. [3]

Propagation: . . . .

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Termination: . . . .

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(e) (i) Explain why but-2-ene, $CH_3CHCHCH_3$, has two stereoisomers but but-1-ene, $CH_2CHCH_2CH_3$, does not. [1]

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(ii) State the hybridization of the carbon atoms in but-2-ene. [1]

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(This question continues on the following page)

(Question 4 continued)

(iii) Predict the number of signals and relative areas under these signals for the ^{1}H NMR spectrum of but-2-ene. [2]

Number of signals: . . . .

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Relative areas: . . . .

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(iv) Sketch the mechanism for the reaction of hydrogen bromide, HBr, with but-1-ene, $CH_2CHCH_2CH_3$, showing the formation of the major product 2-bromobutane.

Use curly arrows to represent the movement of electrons. [3]

(v) Draw the two stereoisomers of 2-bromobutane using wedge-dash representations. [1]

(This question continues on the following page)

(Question 4 continued)

(vi) Outline how to distinguish between the two stereoisomers of 2-bromobutane. [2]

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(vii) Discuss why benzene, C_6H_6, does not react with HBr in a similar manner as but-1-ene. [2]

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(Question 4 continued)

(f) Organic compounds can also be used as fuel.

(i) Calculate the change in enthalpy for the combustion of methane using section 12 of the data booklet. [2]

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

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(ii) Enthalpy of combustion for methane could also be calculated using section 13 of the data booklet.

State, with a reason, the value of the standard enthalpy of formation, $\Delta H_f^{\ominus}$, for $O_2(g)$. [1]

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(iii) This is a reaction for the incomplete combustion of methane:

$$CH_4(g) + \frac{3}{2}O_2(g) \rightarrow CO(g) + 2H_2O(g)$$

$$\Delta H = -499\ \text{kJ mol}^{-1}$$

Suggest why the incomplete combustion of methane releases less energy than its complete combustion. [2]

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