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Chemistry Higher level Paper 2

18 May 2026

Zone A morning | Zone B morning | Zone C morning

Session number

2 hours 30 minutes

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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]**.



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

Answers written on this page
will not be marked.

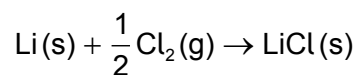


Answer **all** questions. Answers must be written within the answer boxes provided.

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]



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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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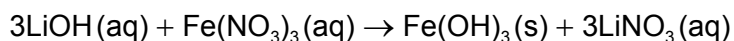
(Question 1 continued)

(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, $\text{Fe}(\text{NO}_3)_3$, solution.

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

[3]



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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 $0.350 \text{ mol dm}^{-3}$ ethanoic acid and $0.455 \text{ mol dm}^{-3}$ sodium ethanoate.

The $\text{p}K_{\text{a}}$ of ethanoic acid is 4.76.

Use section 1 of the data booklet.

[2]

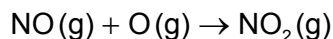
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2. Nitrogen dioxide is a covalently bonded compound.

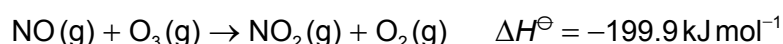
(a) (i) Nitrogen monoxide reacts with monatomic oxygen in the atmosphere.

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



given these reactions and enthalpy values:

[2]



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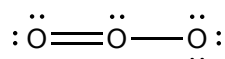
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(ii) Suggest the value of the bond angle and molecular geometry of ozone based on the Lewis formula.

[2]



Bond angle:

Molecular geometry:

(This question continues on the following page)



(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]

: $\ddot{\text{O}}=\ddot{\text{O}}-\ddot{\text{O}}:$

.....

(This question continues on the following page)



(Question 2 continued)

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



- (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:

 Value of equilibrium constant:

- (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]

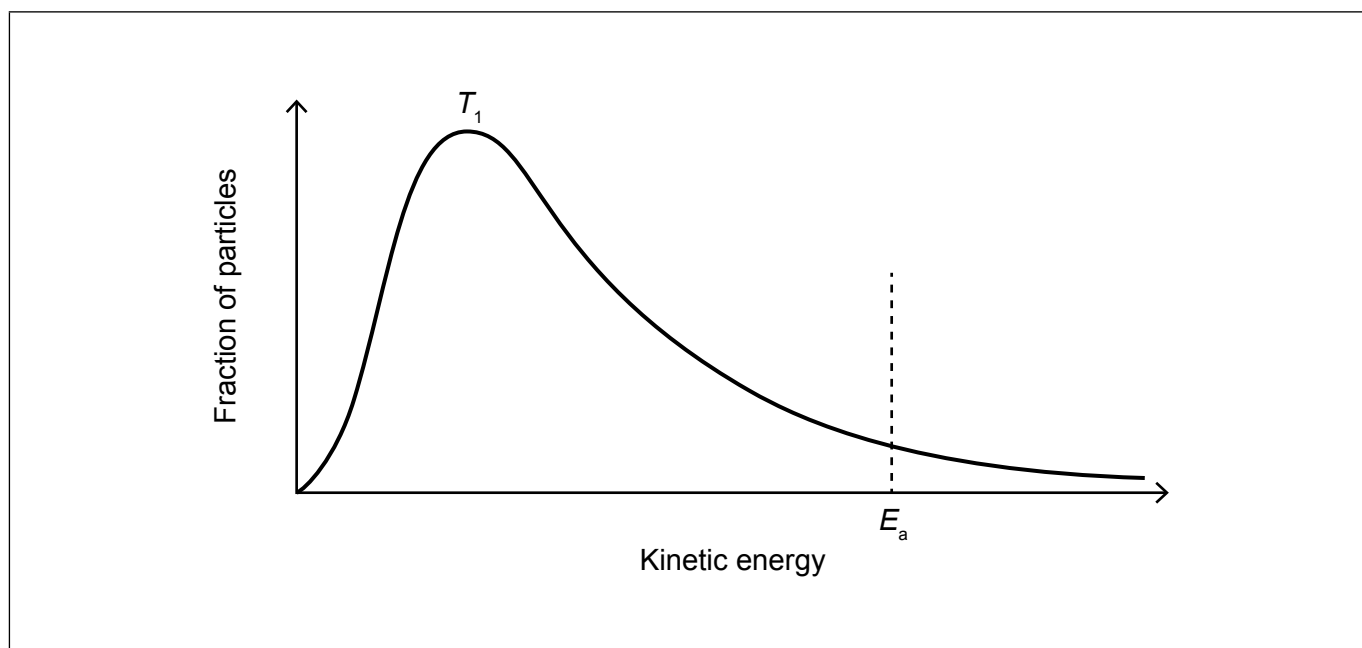
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- (v) Consider the Maxwell–Boltzmann energy distribution curve at temperature T_1 .



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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(This question continues on page 11)



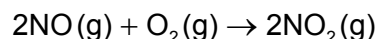
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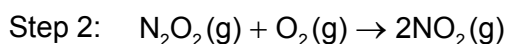
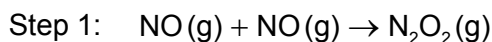
(Question 2 continued)

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



The rate equation was experimentally determined as $\text{Rate} = k[\text{NO}]^2[\text{O}_2]$.

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



Evaluate the proposed mechanism and rate-determining step.

[2]

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- (ii) Calculate the value and units of the rate constant.

[2]

$[\text{NO}] / \text{mol dm}^{-3}$	$[\text{O}_2] / \text{mol dm}^{-3}$	$\text{Rate} / \text{mol dm}^{-3} \text{s}^{-1}$
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:

 Ir-193:

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

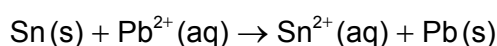
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- (ii) State **one** additional property, other than hardness, that could be modified by forming an alloy.

[1]

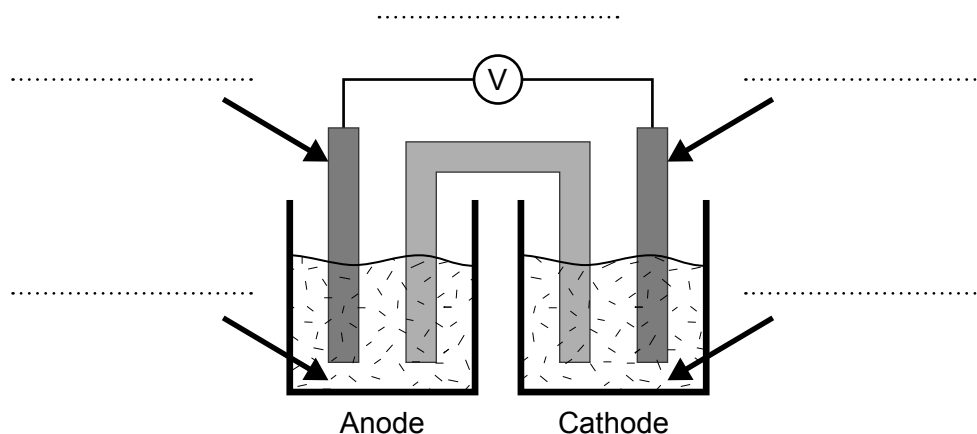
Property:

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



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

[2]



(This question continues on the following page)



(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 $[\text{Co}(\text{H}_2\text{O})_6]^{3+}$ 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, $[\text{Co}(\text{H}_2\text{O})_6]^{3+}$.

[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.

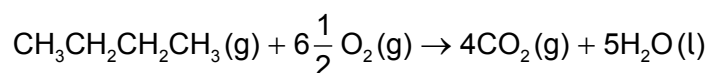
[3]

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

[1]

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(b) Butane undergoes combustion.



(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 $-437.5 \text{ J K}^{-1} \text{ mol}^{-1}$.

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 $-2400 \text{ kJ mol}^{-1}$, 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]

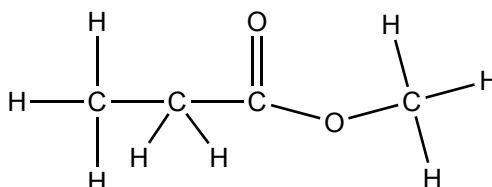
Compound	Oxidation state
$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$	
CO_2	

(This question continues on the following page)



(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]

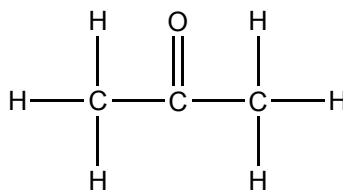
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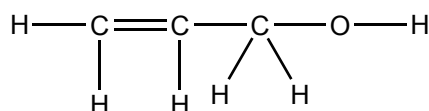


(Question 4 continued)

(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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(This question continues on the following page)



(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:

 Termination:

(e) (i) Explain why but-2-ene, $\text{CH}_3\text{CHCHCH}_3$, has two stereoisomers but but-1-ene, $\text{CH}_2\text{CHCH}_2\text{CH}_3$, 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 ^1H NMR spectrum of but-2-ene. [2]

Number of signals:

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Relative areas:

.....

- (iv) Sketch the mechanism for the reaction of hydrogen bromide, HBr, with but-1-ene, $\text{CH}_2\text{CHCH}_2\text{CH}_3$, 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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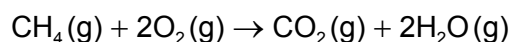
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(Question 4 continued)

(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]



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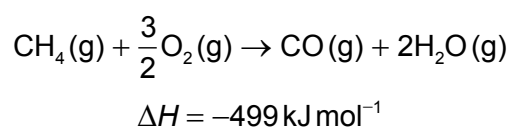
- (ii) Enthalpy of combustion for methane could also be calculated using section 13 of the data booklet.

State, with a reason, the value of the standard enthalpy of formation, $\Delta H_f^\ominus$, for $\text{O}_2(\text{g})$. [1]

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



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

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