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Chemistry
Standard level
Paper 2

9 May 2024

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

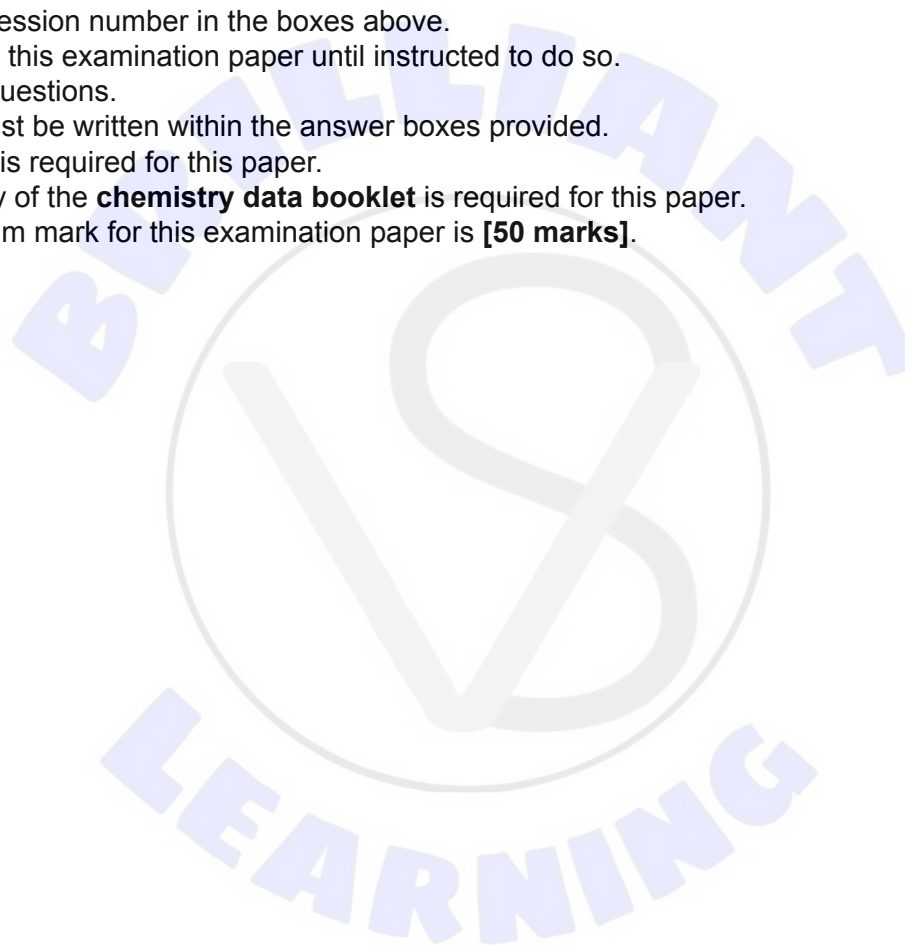
Candidate session number

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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]**.



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

1. An organic compound, **A**, has the following composition by mass when its only combustion products, carbon dioxide and water, are analysed.

C / %	H / %
71.93	12.10

- (a) Outline why this compound is **not** a hydrocarbon. [1]

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- (b) Determine the empirical formula of **A**. [2]

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- (c) A sample of the vapour of **A** at 200.0 °C and 1.00×10^5 Pa has a density of 2.544×10^3 g m⁻³. Determine the molar mass and the molecular formula of **A**. [2]

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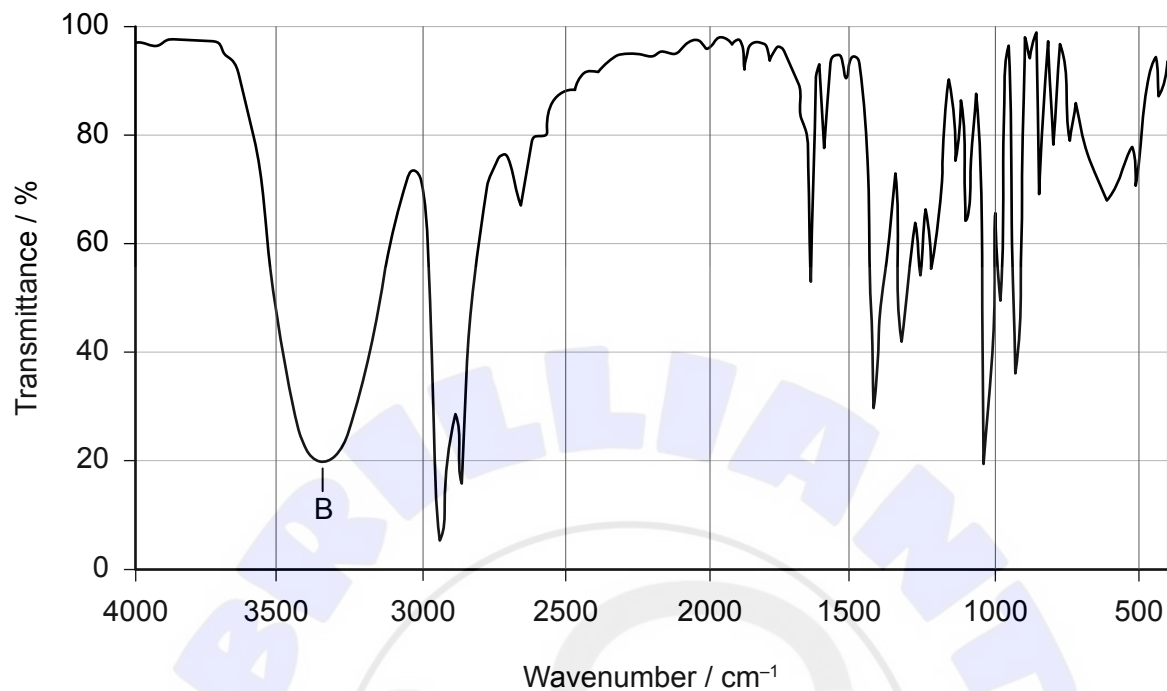
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(Question 1 continued)

(d) The infrared (IR) spectrum of **A** is shown below.



Identify the bond responsible for the absorption labelled **B** in the IR spectrum. Use section 26 of the data booklet.

[1]

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(e) **A** can be converted to compound **E**, which has a higher molecular mass, by heating it under reflux with acidified potassium dichromate(VI), $K_2Cr_2O_7$.

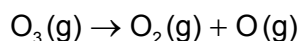
Identify **one** functional group present in **E**, based on this information only.

[1]

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.....



2. In the stratosphere, ozone is decomposed by ultraviolet radiation.



(a) State the full electron configuration of an oxygen atom and the number of unpaired electrons in that atom. [2]

Electron configuration:

Unpaired electrons:

(b) (i) Draw a Lewis (electron dot) structure for the ozone molecule. [1]

BRILLIANT LEARNING

(ii) Predict the shape and bond angle of the ozone molecule. [2]

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(c) Suggest a value, in pm, for the bond lengths in the ozone molecule and explain your answer. Use section 10 of the data booklet. [2]

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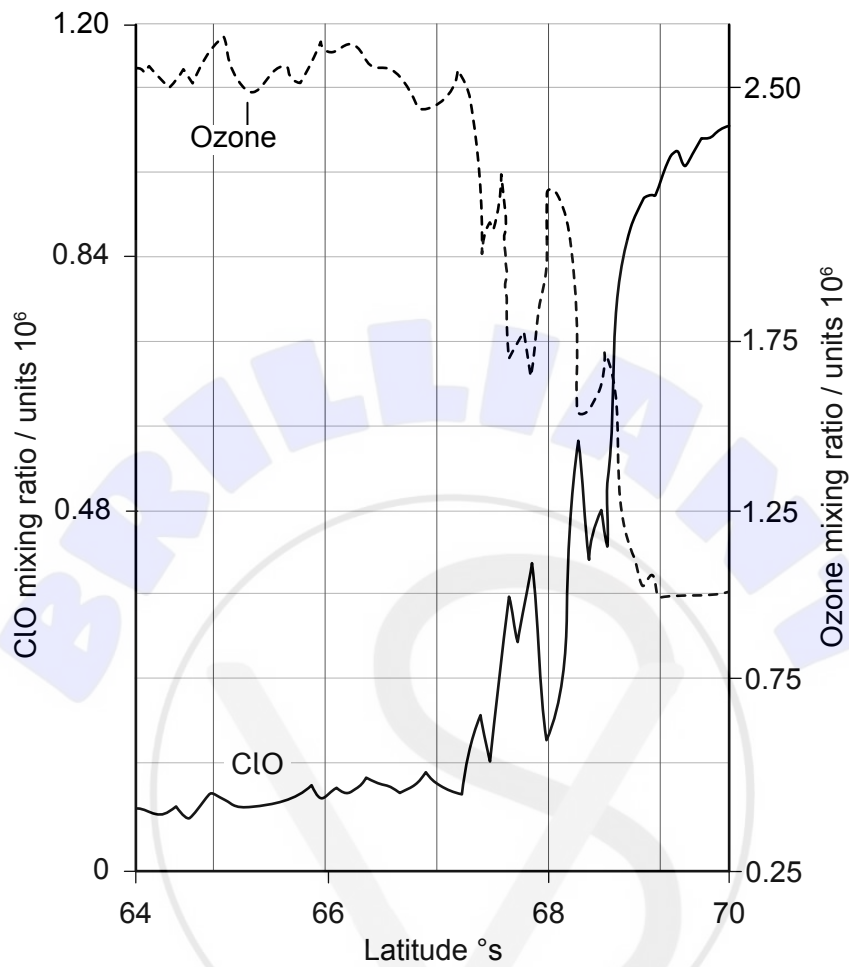
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(Question 2 continued)

- (d) The concentrations of ozone molecules and chlorine monoxide, ClO, free radicals were measured.



- (i) Outline the relationship between the concentrations of ozone and ClO, free radicals. [1]

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- (ii) Comment, based on this graph, on the conclusion that the hole in the ozone layer is caused by ClO free radicals. [2]

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3. The acid–base character of the oxides of elements depends on their position in the periodic table.

(a) (i) State **one** environmental problem caused by sulfur dioxide, SO_2 . [1]

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(ii) Write an equation to show how sulfur dioxide reacts in the atmosphere to produce a secondary pollutant. [1]

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(b) A solution was prepared by dissolving 0.100 mol of sodium oxide in distilled water and making the total volume up to 1.00 dm^3 .

(i) Write the equation for the reaction between sodium oxide and water. [1]

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(ii) Calculate the pH of the solution. [2]

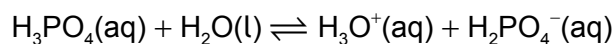
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(Question 3 continued)

(c) Phosphoric acid, H_3PO_4 , also reacts with water.



(i) State an expression for the equilibrium constant, K_c , for this equation. [1]

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(ii) State, with a reason, the effect of an increase in temperature on the position of this equilibrium, assuming $\Delta H^\ominus < 0$. [1]

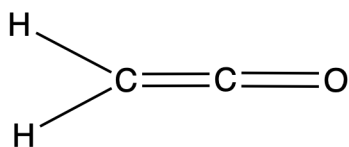
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(d) Outline why the ionic radius of the phosphide ion, P^{3-} , is greater than that of the sulfide ion, S^{2-} . [1]

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4. Ethenone, CH₂CO, is used in the synthesis of pharmaceutical compounds.



(a) Suggest why the compound is given this IUPAC name. [2]

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(b) Compare and contrast the intermolecular forces that result in ethenone being less volatile than carbon dioxide. [2]

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(c) Ethenone can be made by the thermal decomposition of propanone.



(i) Calculate the standard enthalpy change for this reaction.
Use ΔH_f^\ominus ethenone = $-87.2 \text{ kJ mol}^{-1}$ and section 12 of the data booklet. [2]

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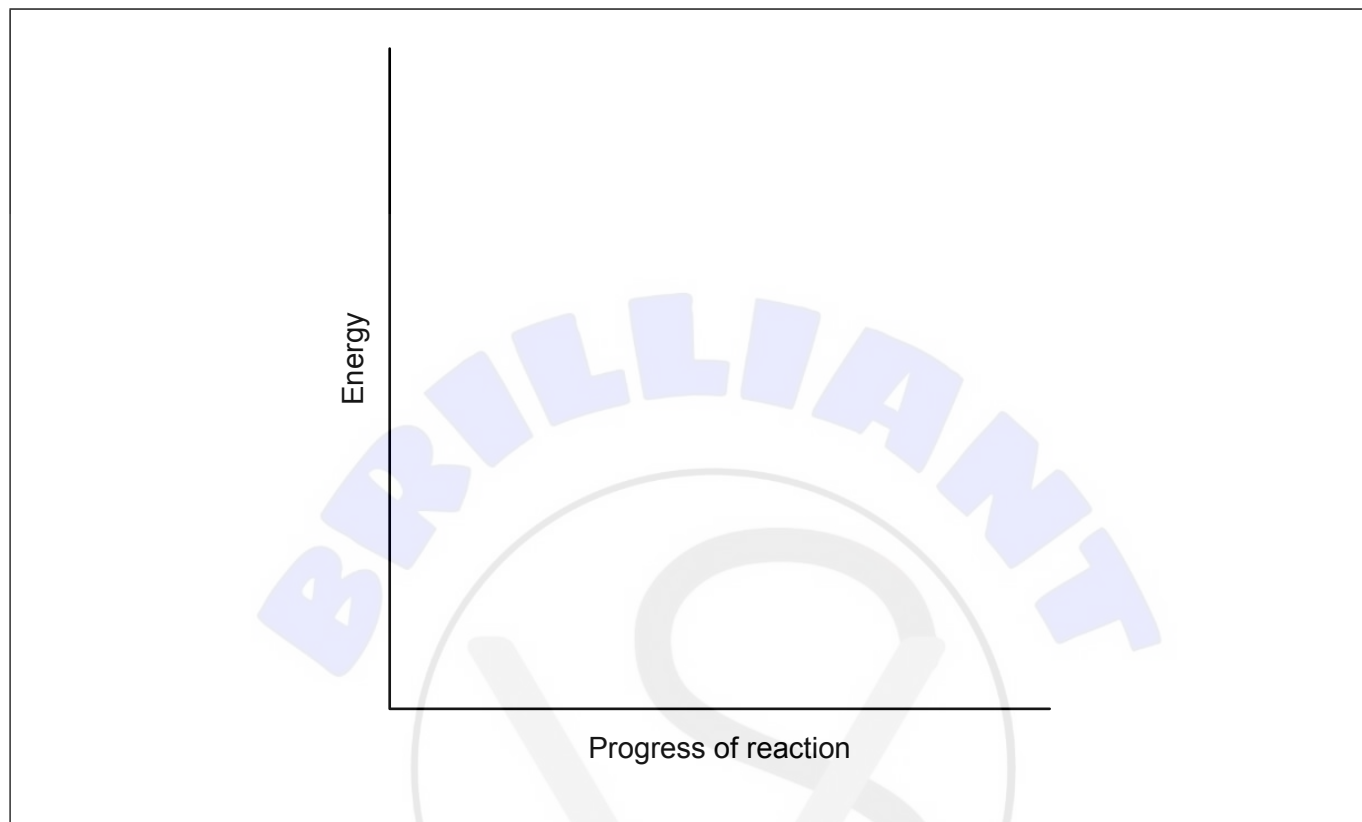
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(Question 4 continued)

- (ii) Sketch the potential energy diagram for the thermal decomposition of propanone from (c)(i). Use the axes given and indicate both the enthalpy of reaction and the activation energy. [2]



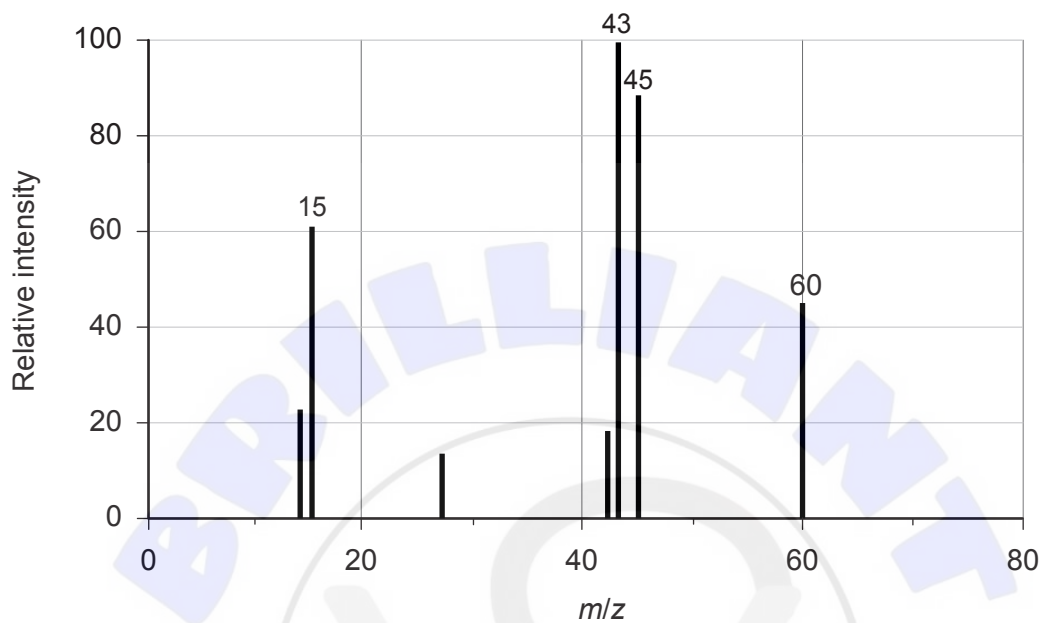
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(Question 4 continued)

- (d) Ethenone can be converted to compound **G**, which reacts slowly with metal oxides when in aqueous solution.

The mass spectrum of **G** is shown.



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Deduce the identity of **G**, giving **two** reasons based on the spectrum.

[3]

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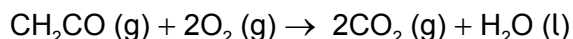
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(Question 4 continued)

- (e) 10.0 cm³ of ethenone is mixed with 100 cm³ of oxygen and burnt completely.



Determine the final volume of the gaseous mixture after the reaction mixture has returned to the original temperature and pressure.

[2]

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- (f) Calculations often assume that real gases behave like ideal gases.

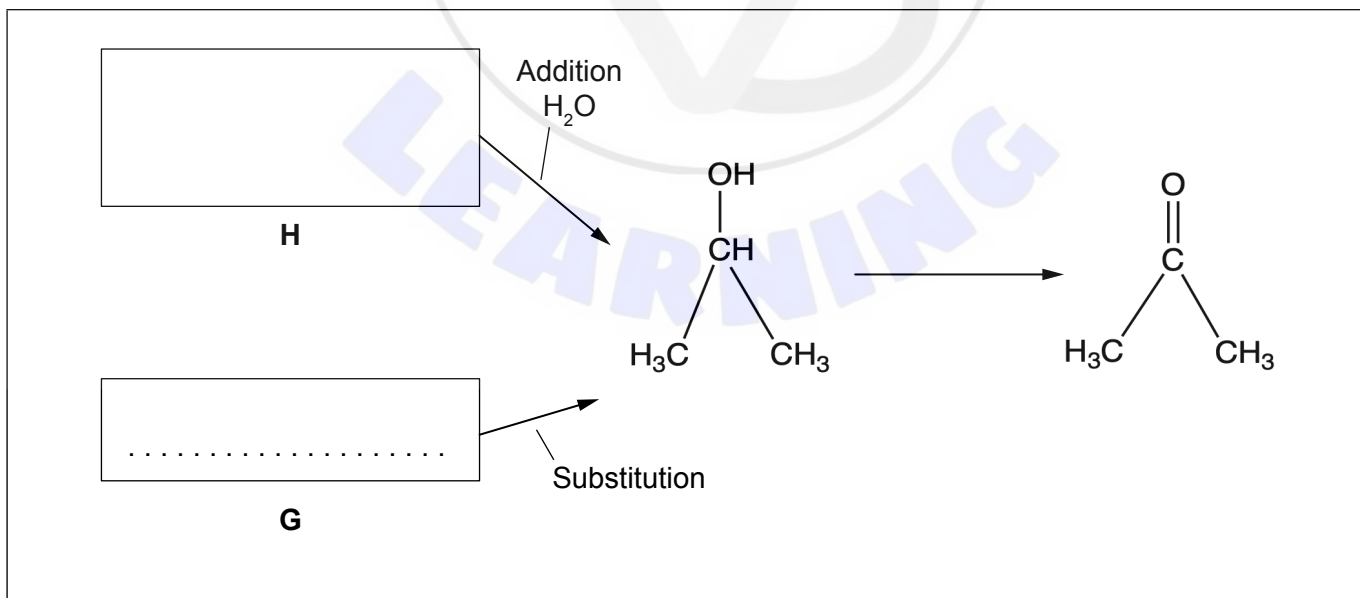
State **one** reason why gases such as carbon dioxide and ethenone become less ideal at higher pressures.

[1]

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- (g) Propanone can be synthesised by the oxidation of propan-2-ol. Propan-2-ol can be synthesised in **two** ways, from **H** by addition of water or from **G** by a substitution reaction.



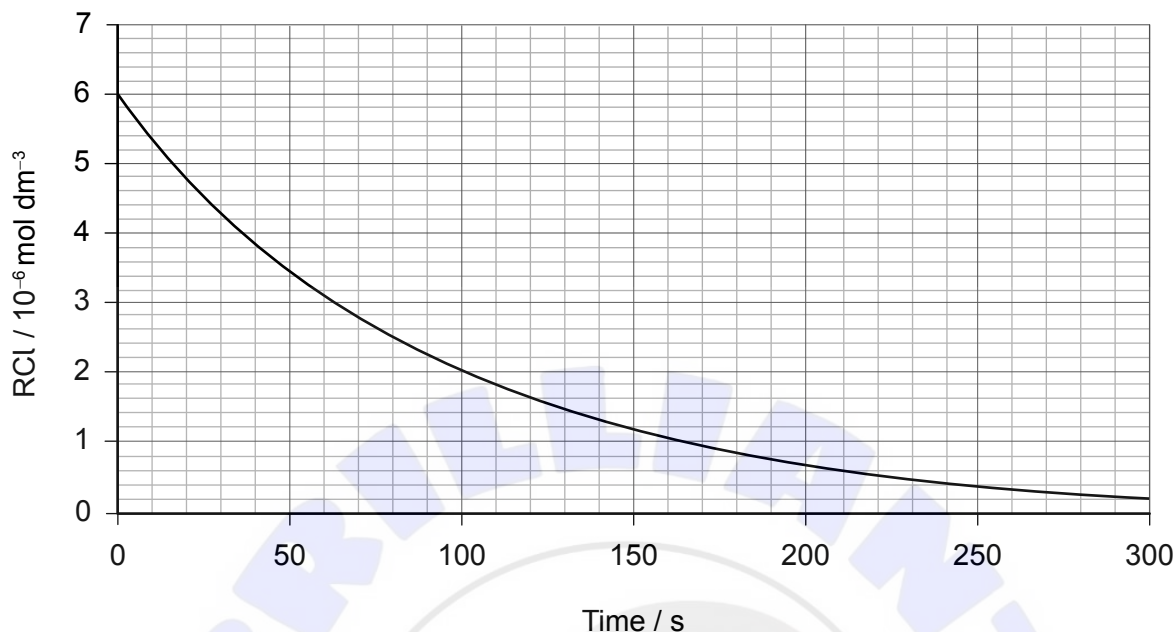
Draw the **structure** of **H** and state the **name** of **G**, applying IUPAC rules.

[2]



(Question 5 continued)

A graph of [RCl] versus time for experiment 3 is shown.



(i) Using the graph, determine the missing values from the table for **experiment 3**.

Justify your answer.

[3]

Initial [RCl]:
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Initial rate:
.....
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(ii) Outline, on a molecular level, why the rate decreases with time.

[1]

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6. Compounds are often identified as oxidizing and reducing agents.

(a) Write the half-equations for the formation of the products at the positive electrode (anode) and negative electrode (cathode) when molten sodium bromide is electrolysed. [2]

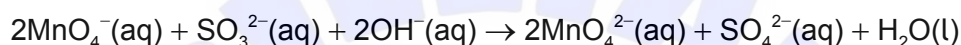
Positive electrode (anode):

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Negative electrode (cathode):

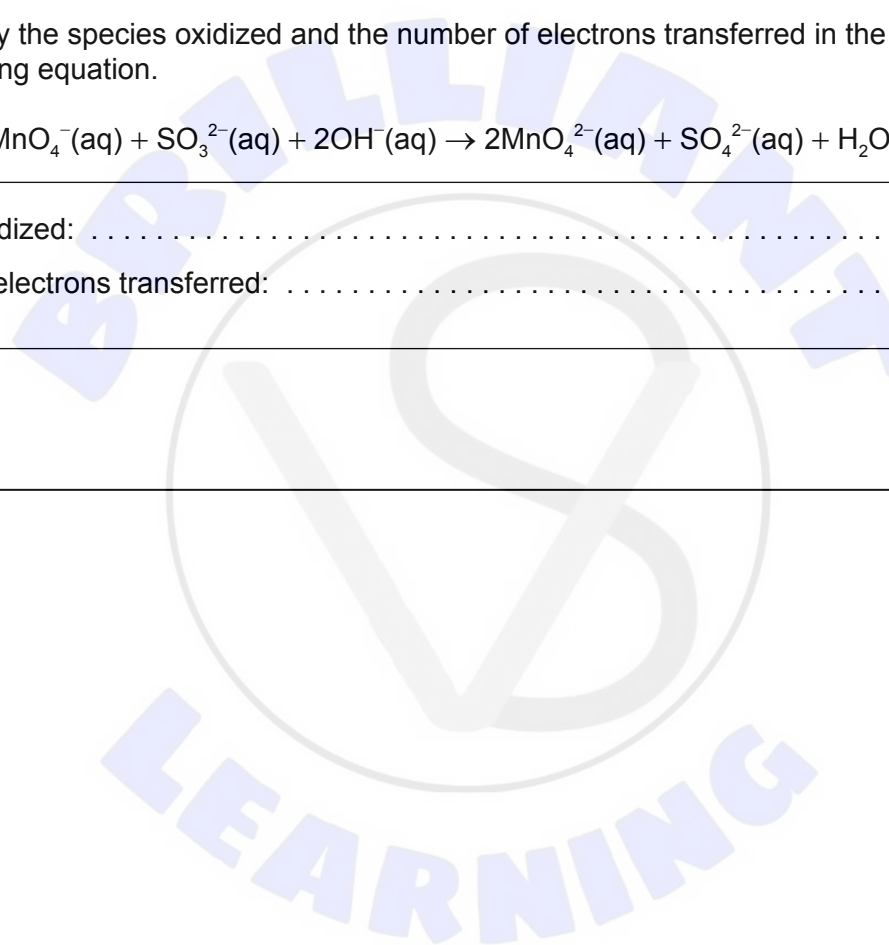
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(b) Identify the species oxidized and the number of electrons transferred in the following equation. [2]



Species oxidized:

Number of electrons transferred:





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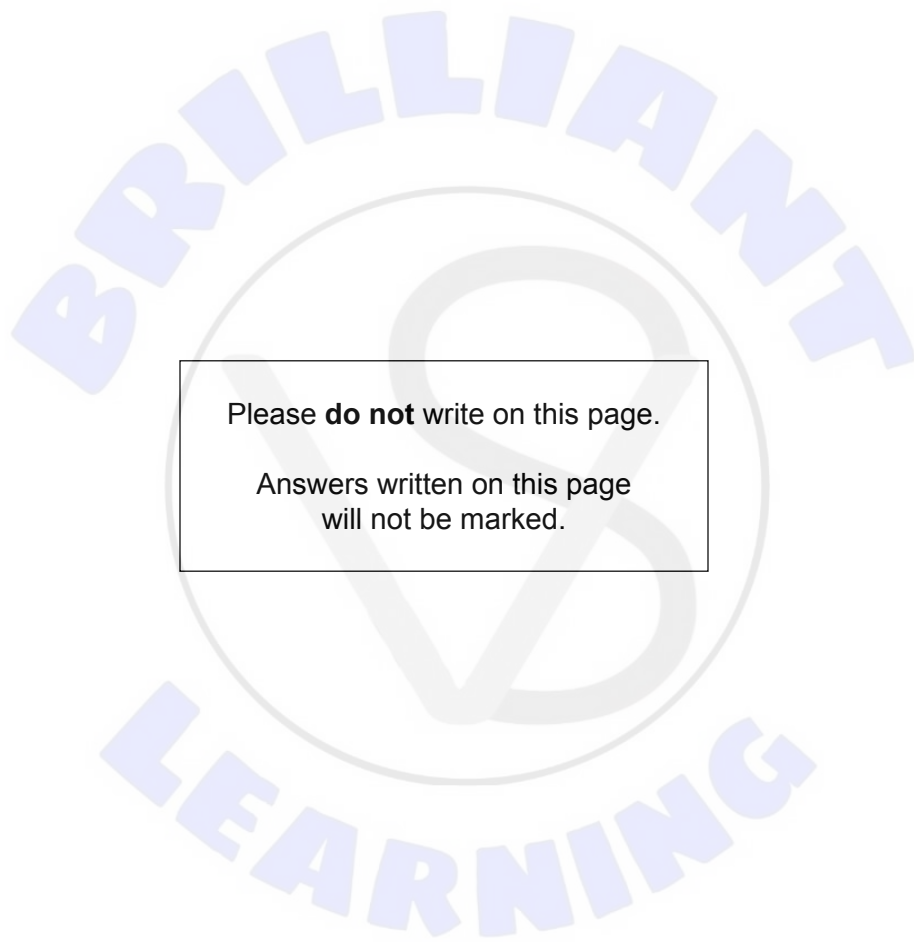
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References:

- 1.(d) Irina Doroshenko et al. Infrared Absorption Spectra of Monohydric Alcohols. Open access article distributed under the Creative Commons Attribution License <https://creativecommons.org/licenses/by/4.0/>. Image adapted.
- 2.(d) Rowland, F.S., 2006. Stratospheric ozone depletion. *Philos Trans R Soc Lond B Biol Sci* 361(1469), pp. 769–790. [e-journal] Available at: <https://pubmed.ncbi.nlm.nih.gov/16627294/> [Accessed 12 April 2023]. Source adapted.
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Answers written on this page
will not be marked.

