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**Chemistry**
Standard level
Paper 2

Wednesday 13 November 2019 (afternoon)

Candidate session number

1 hour 15 minutes

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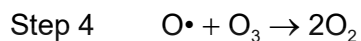
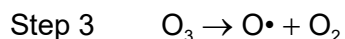
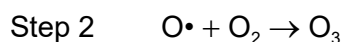
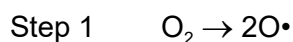
Instructions to candidates

- 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. The equations show steps in the formation and decomposition of ozone in the stratosphere, some of which absorb ultraviolet light.



- (a) Draw the Lewis structures of oxygen, O_2 , and ozone, O_3 .

[2]

BRILLIANT
LEARNING

- (b) Outline why both bonds in the ozone molecule are the same length and predict the bond length in the ozone molecule. Refer to section 10 of the data booklet.

[2]

Reason:

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Length:

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BRILLIANT
LEARNING

- (c) Distinguish ultraviolet light from visible light in terms of wavelength and energy.

[1]

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(This question continues on the following page)



(Question 1 continued)

- (d) Discuss how the different bond strengths between the oxygen atoms in O₂ and O₃ in the ozone layer affect radiation reaching the Earth's surface.

[2]

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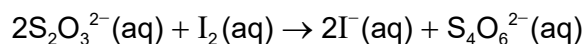
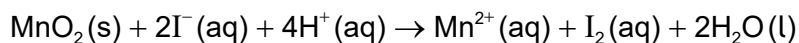
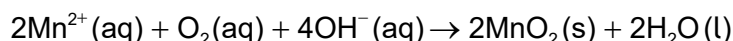
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2. The biochemical oxygen demand of a water sample can be determined by the following series of reactions. The final step is titration of the sample with sodium thiosulfate solution, $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$.



A student analysed two 300.0 cm^3 samples of water taken from the school pond: one immediately (day 0), and the other after leaving it sealed in a dark cupboard for five days (day 5). The following results were obtained for the titration of the samples with $0.0100\text{ mol dm}^{-3}\text{ Na}_2\text{S}_2\text{O}_3(\text{aq})$.

Sample	Titre / $\text{cm}^3 \pm 0.1\text{ cm}^3$
Day 0	25.8
Day 5	20.1

- (a) (i) Determine the mole ratio of $\text{S}_2\text{O}_3^{2-}$ to O_2 , using the balanced equations. [1]

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(This question continues on the following page)



(Question 2 continued)

- (ii) Calculate the number of moles of oxygen in the day 0 sample. [2]

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- (iii) The day 5 sample contained 5.03×10^{-5} moles of oxygen.
Determine the 5-day biochemical oxygen demand of the pond, in mg dm^{-3}
("parts per million", ppm). [2]

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- (b) (i) Calculate the percentage uncertainty of the day 5 titre. [1]

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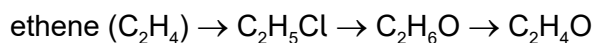
- (ii) Suggest a modification to the procedure that would make the results more reliable. [1]

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3. The following shows some compounds which can be made from ethene, C₂H₄.



(a) State the type of reaction which converts ethene into C₂H₅Cl. [1]

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(b) Write an equation for the reaction of C₂H₅Cl with aqueous sodium hydroxide to produce a C₂H₆O compound, showing structural formulas. [1]

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(c) (i) Write an equation for the complete combustion of the organic product in (b). [1]

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(ii) Determine the enthalpy of combustion of the organic product in (b), in kJ mol⁻¹, using data from section 11 of the data booklet. [3]

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(This question continues on the following page)



(Question 3 continued)

- (d) (i) State the reagents and conditions for the conversion of the compound C_2H_6O , produced in (b), into C_2H_4O . [2]

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- (ii) Explain why the compound C_2H_6O , produced in (b), has a higher boiling point than compound C_2H_4O , produced in d(i). [2]

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- (e) Ethene is often polymerized. Draw a section of the resulting polymer, showing two repeating units. [1]

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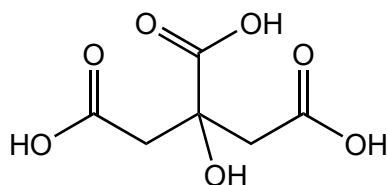


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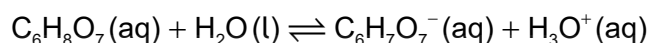
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4. A molecule of citric acid, $C_6H_8O_7$, is shown.



The equation for the first dissociation of citric acid in water is



(a) (i) Identify a conjugate acid–base pair in the equation. [1]

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(ii) The value of the equilibrium constant for the first dissociation at 298K is 5.01×10^{-4} . State, giving a reason, the strength of citric acid. [1]

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(iii) The dissociation of citric acid is an endothermic process. State the effect on the hydrogen ion concentration, $[H^+]$, and on the equilibrium constant, of increasing the temperature. [2]

Effect on $[H^+]$	Effect on equilibrium constant
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(b) Outline **one** laboratory method of distinguishing between solutions of citric acid and hydrochloric acid of equal concentration, stating the expected observations. [1]

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5. Copper forms two chlorides, copper(I) chloride and copper(II) chloride.

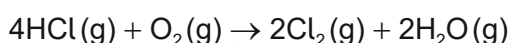
(a) (i) State the electron configuration of the Cu^+ ion.

[1]

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(ii) Copper(II) chloride is used as a catalyst in the production of chlorine from hydrogen chloride.



Calculate the standard enthalpy change, ΔH^\ominus , in kJ, for this reaction, using section 12 of the data booklet.

[2]

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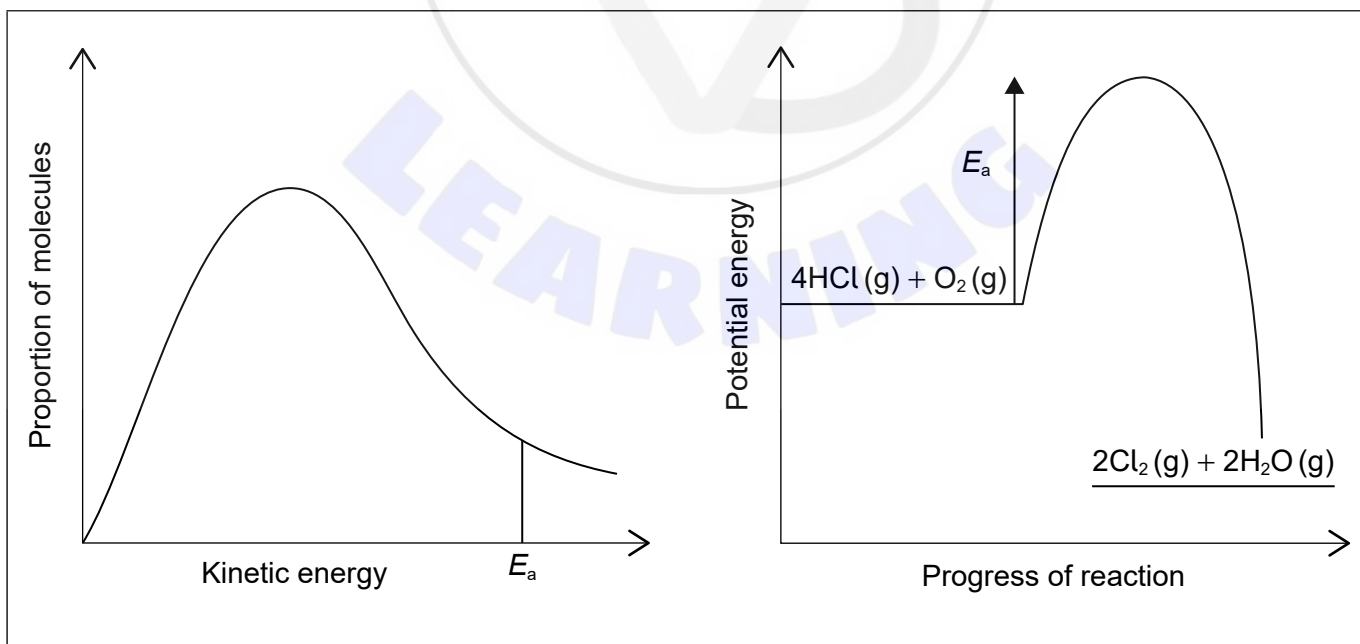
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(iii) The diagram shows the Maxwell–Boltzmann distribution and potential energy profile for the reaction without a catalyst.

Annotate both charts to show the activation energy for the catalysed reaction, using the label $E_{a(\text{cat})}$.

[2]



(This question continues on the following page)



(Question 5 continued)

(iv) Explain how the catalyst increases the rate of the reaction.

[2]

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(b) Solid copper(II) chloride absorbs moisture from the atmosphere to form a hydrate of formula $\text{CuCl}_2 \cdot x\text{H}_2\text{O}$.

A student heated a sample of hydrated copper(II) chloride, in order to determine the value of x . The following results were obtained:

Mass of crucible = 16.221 g

Initial mass of crucible and hydrated copper(II) chloride = 18.360 g

Final mass of crucible and anhydrous copper(II) chloride = 17.917 g

Determine the value of x .

[3]

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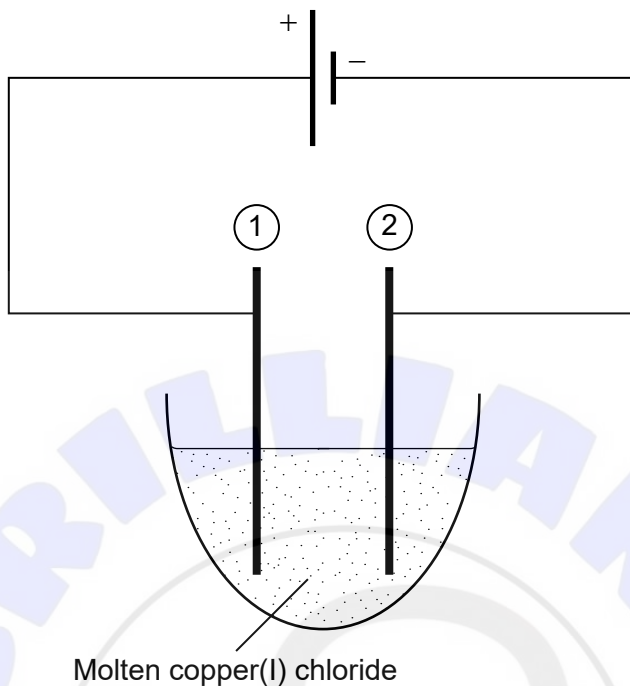
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(Question 5 continued)

(c) An electrolysis cell was assembled using graphite electrodes and connected as shown.



(i) State how current is conducted through the wires and through the electrolyte. [2]

Wires:

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Electrolyte:

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(ii) Write the half-equation for the formation of gas bubbles at electrode 1. [1]

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6. Automobile air bags inflate by a rapid decomposition reaction. One typical compound used is guanidinium nitrate, $C(NH_2)_3NO_3$, which decomposes very rapidly to form nitrogen, water vapour and carbon.

(a) (i) Deduce the equation for the decomposition of guanidinium nitrate. [1]

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(ii) Calculate the total number of moles of gas produced from the decomposition of 10.0g of guanidinium nitrate. [1]

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(iii) Calculate the pressure, in kPa, of this gas in a 10.0dm^3 air bag at 127°C , assuming no gas escapes. [1]

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(iv) Suggest why water vapour deviates significantly from ideal behaviour when the gases are cooled, while nitrogen does not. [2]

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(This question continues on the following page)



(Question 6 continued)

- (b) Another airbag reactant produces nitrogen gas and sodium.

Suggest, including an equation, why the products of this reactant present a safety hazard. [2]

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