Diploma Programme
Programme du diplôme
Programa del Diploma

# Chemistry
# Standard level
# Paper 2

Wednesday 13 November 2019 (afternoon)

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]**.



8819 – 6105

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.

Step 1 $O_2 \rightarrow 2O\bullet$

Step 2 $O\bullet + O_2 \rightarrow O_3$

Step 3 $O_3 \rightarrow O\bullet + O_2$

Step 4 $O\bullet + O_3 \rightarrow 2O_2$

(a) Draw the Lewis structures of oxygen, $O_2$, and ozone, $O_3$. [2]

(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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(c) Distinguish ultraviolet light from visible light in terms of wavelength and energy. [1]

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**(Question 1 continued)**

(d) Discuss how the different bond strengths between the oxygen atoms in $O_2$ and $O_3$ in the ozone layer affect radiation reaching the Earth's surface. [2]

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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, $Na_2S_2O_3(aq)$.

$$2Mn^{2+}(aq) + O_2(aq) + 4OH^-(aq) \rightarrow 2MnO_2(s) + 2H_2O(l)$$

$$MnO_2(s) + 2I^-(aq) + 4H^+(aq) \rightarrow Mn^{2+}(aq) + I_2(aq) + 2H_2O(l)$$

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

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 $mol\,dm^{-3}$ $Na_2S_2O_3(aq)$.

| **Sample** | **Titre / $cm^3$ $\pm$0.1 $cm^3$** |
|---|---|
| Day 0 | 25.8 |
| Day 5 | 20.1 |

(a) (i) Determine the mole ratio of $S_2O_3^{2-}$ to $O_2$, using the balanced equations. [1]

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**(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 $5.03 \times 10^{-5}$ 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, $C_2H_4$.

$$\text{ethene } (C_2H_4) \rightarrow C_2H_5Cl \rightarrow C_2H_6O \rightarrow C_2H_4O$$

(a) State the type of reaction which converts ethene into $C_2H_5Cl$. [1]

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(b) Write an equation for the reaction of $C_2H_5Cl$ with aqueous sodium hydroxide to produce a $C_2H_6O$ compound, showing structural formulas. [1]

(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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**(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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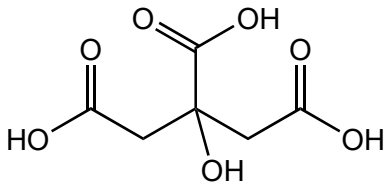
Answers written on this page
will not be marked.

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




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

$$C_6H_8O_7(aq) + H_2O(l) \rightleftharpoons C_6H_7O_7^-(aq) + H_3O^+(aq)$$

(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 298 K is $5.01 \times 10^{-4}$.

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.

$$4HCl(g) + O_2(g) \rightarrow 2Cl_2(g) + 2H_2O(g)$$

Calculate the standard enthalpy change, $\Delta H^{\ominus}$, in kJ, for this reaction, using section 12 of the data booklet. [2]

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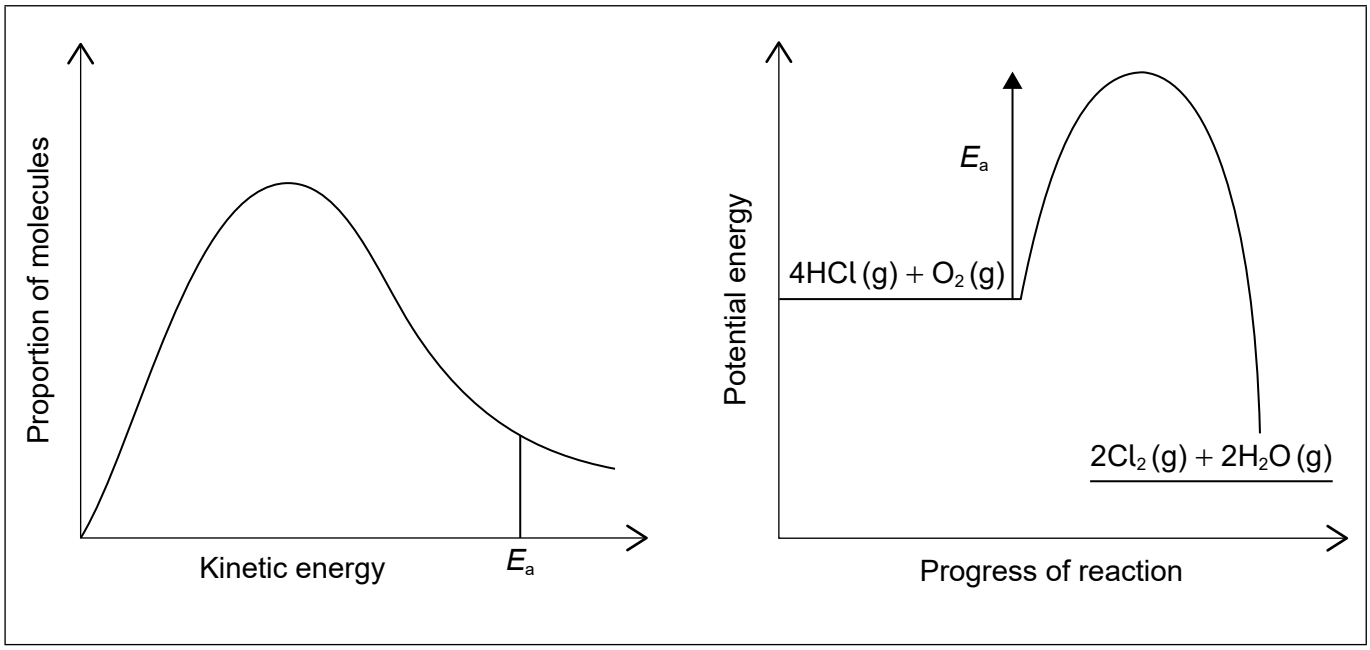
(iii) The diagram shows the Maxwell–Boltzmann distribution and potential energy profile for the reaction without a catalyst.

Annotate both charts to show the activation energy for the catalysed reaction, using the label $E_{a\,(cat)}$. [2]

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**(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 $CuCl_2 \bullet xH_2O$.

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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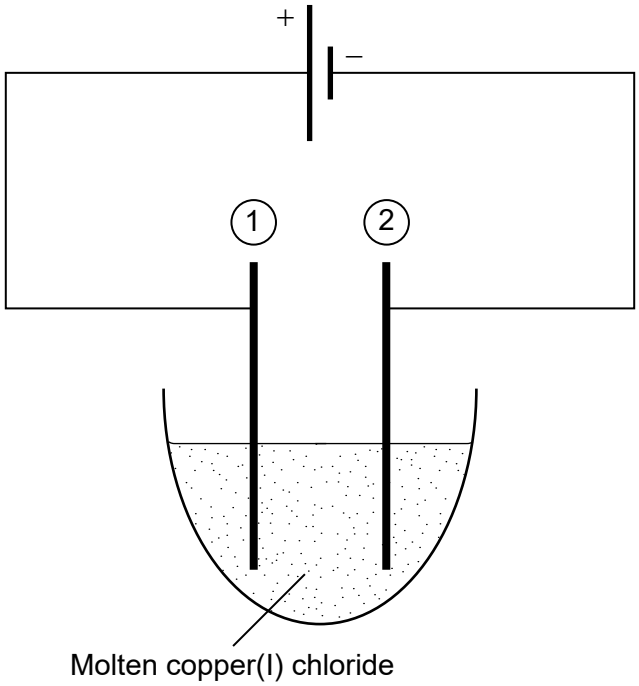
**(Question 5 continued)**

(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 10.0 g of guanidinium nitrate. [1]

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(iii) Calculate the pressure, in kPa, of this gas in a 10.0 $dm^3$ 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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**(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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