Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

Wednesday 13 November 2019 (afternoon)

1 hour 15 minutes

Candidate session number

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 5.03×10^{-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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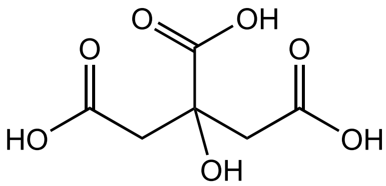
Answers written on this page
will not be marked.

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 5.01×10^{-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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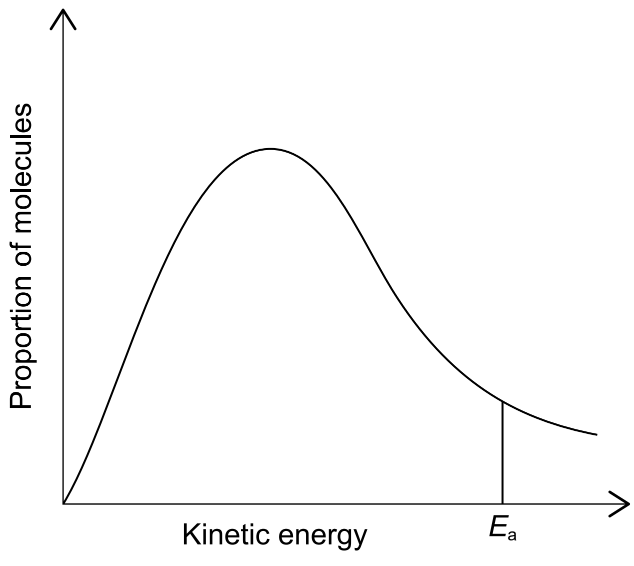
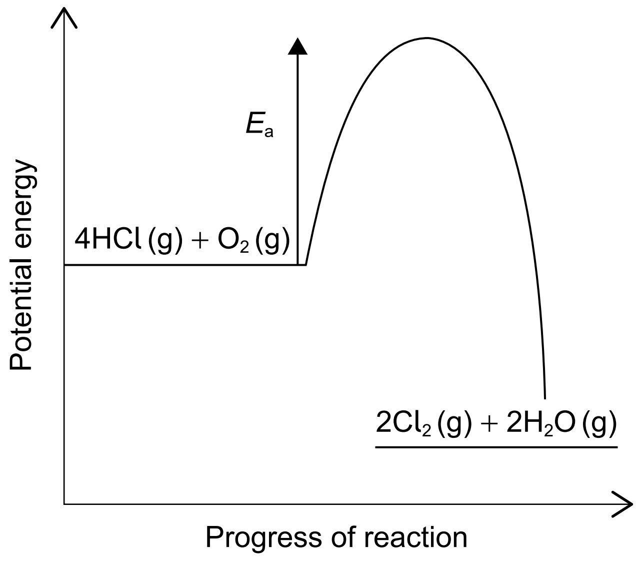
(iii) The diagram shows the Maxwell–Boltzmann distribution and potential energy profile for the reaction without a catalyst.

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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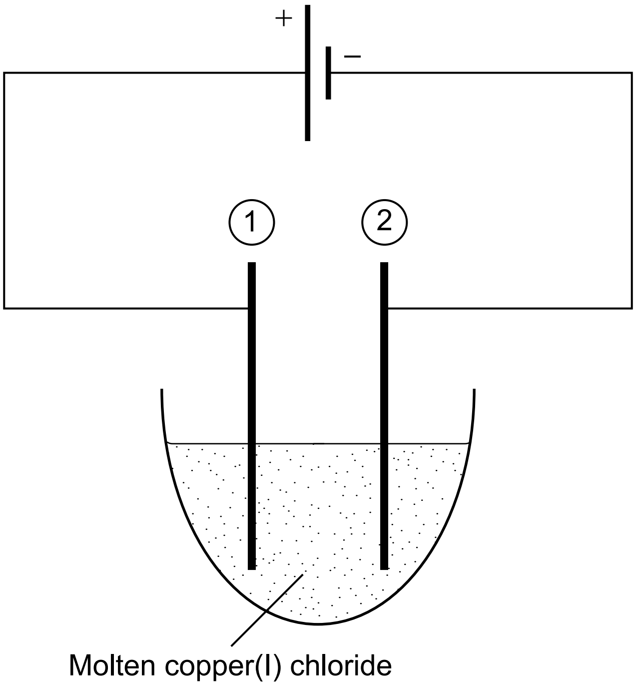
(Question 5 continued)

(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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