Diploma Programme
Programme du diplôme
Programa del Diploma

# Chemistry
# Standard level
# Paper 2

Monday 14 November 2016 (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.
- Write your answers in the 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]**.



8816 – 6105

Answer **all** questions. Write your answers in the boxes provided.

**1.** Ethane-1,2-diol, $HOCH_2CH_2OH$, has a wide variety of uses including the removal of ice from aircraft and heat transfer in a solar cell.

(a) Ethane-1,2-diol can be formed according to the following reaction.

$$2CO(g) + 3H_2(g) \rightleftharpoons HOCH_2CH_2OH(g)$$

(i) Deduce the equilibrium constant expression, $K_c$, for this reaction. [1]

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(ii) State how increasing the pressure of the reaction mixture at constant temperature will affect the position of equilibrium and the value of $K_c$. [2]

Position of equilibrium:

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$K_c$:

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(iii) Calculate the enthalpy change, $\Delta H^{\ominus}$, in kJ, for this reaction using section 11 of the data booklet. The bond enthalpy of the carbon–oxygen bond in CO(g) is $1077\,kJ\,mol^{-1}$. [3]

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**(This question continues on the following page)**

**(Question 1 continued)**

(iv) The enthalpy change, $\Delta H^{\ominus}$, for the following similar reaction is –233.8 kJ.

$$2CO(g) + 3H_2(g) \rightleftharpoons HOCH_2CH_2OH(l)$$

Deduce why this value differs from your answer to (a)(iii). [1]

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(b) Determine the average oxidation state of carbon in ethene and in ethane-1,2-diol. [2]

Ethene:

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Ethane-1,2-diol:

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(c) Explain why the boiling point of ethane-1,2-diol is significantly greater than that of ethene. [2]

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(d) Ethane-1,2-diol can be oxidized first to ethanedioic acid, $(COOH)_2$, and then to carbon dioxide and water. Suggest the reagents to oxidize ethane-1,2-diol. [1]

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**2.** The concentration of a solution of a weak acid, such as ethanedioic acid, can be determined by titration with a standard solution of sodium hydroxide, NaOH (aq).

(a) Distinguish between a weak acid and a strong acid. [1]

Weak acid:

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Strong acid:

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(b) Suggest why it is more convenient to express acidity using the pH scale instead of using the concentration of hydrogen ions. [1]

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(c) 5.00 g of an impure sample of hydrated ethanedioic acid, $(COOH)_2 \cdot 2H_2O$, was dissolved in water to make 1.00 $dm^3$ of solution. 25.0 $cm^3$ samples of this solution were titrated against a 0.100 mol $dm^{-3}$ solution of sodium hydroxide using a suitable indicator.

$$(COOH)_2(aq) + 2NaOH(aq) \rightarrow (COONa)_2(aq) + 2H_2O(l)$$

The mean value of the titre was 14.0 $cm^3$.

(i) Calculate the amount, in mol, of NaOH in 14.0 $cm^3$ of 0.100 mol $dm^{-3}$ solution. [1]

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**(Question 2 continued)**

(ii) Calculate the amount, in mol, of ethanedioic acid in each 25.0 $cm^3$ sample. [1]

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(iii) Determine the percentage purity of the hydrated ethanedioic acid sample. [3]

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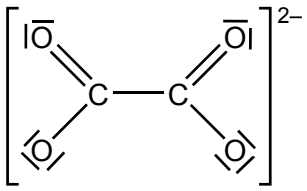
(d) The Lewis (electron dot) structure of the ethanedioate ion is shown below.



Outline why all the C–O bond lengths in the ethanedioate ion are the same length and suggest a value for them. Use section 10 of the data booklet. [2]

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will not be marked.

**3.** Sodium thiosulfate solution reacts with dilute hydrochloric acid to form a precipitate of sulfur at room temperature.

$$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow S(s) + SO_2(g) + 2NaCl(aq) + X$$

(a) Identify the formula and state symbol of X. [1]

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(b) Suggest why the experiment should be carried out in a fume hood or in a well-ventilated laboratory. [1]

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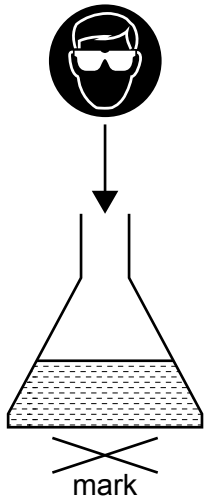
**(Question 3 continued)**

(c) The precipitate of sulfur makes the mixture cloudy, so a mark underneath the reaction mixture becomes invisible with time.




$10.0\,cm^3$ of $2.00\,mol\,dm^{-3}$ hydrochloric acid was added to a $50.0\,cm^3$ solution of sodium thiosulfate at temperature, $T_1$. Students measured the time taken for the mark to be no longer visible to the naked eye. The experiment was repeated at different concentrations of sodium thiosulfate.

| Experiment | $[Na_2S_2O_3(aq)]$ / mol dm$^{-3}$ | Time, t, for mark to disappear / s $\pm$ 1 s | $\frac{1}{t}$* / $10^{-3}$ s$^{-1}$ |
|---|---|---|---|
| 1 | 0.150 | 23 | 43.5 |
| 2 | 0.120 | 27 | 37.0 |
| 3 | 0.090 | 36 | 27.8 |
| 4 | 0.060 | 60 | 16.7 |
| 5 | 0.030 | 111 | 9.0 |

* The reciprocal of the time in seconds can be used as a measure of the rate of reaction.

[Source: Adapted from http://www.flinnsci.com/]

Show that the hydrochloric acid added to the flask in experiment 1 is in excess. [2]

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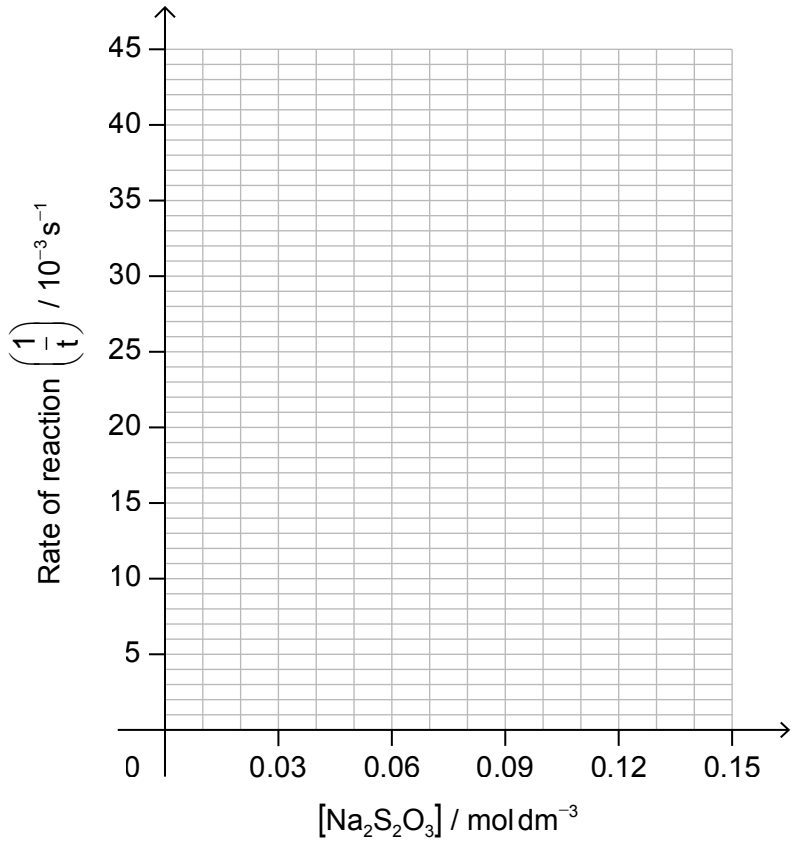
**(Question 3 continued)**

(d) Draw the best fit line of $\frac{1}{t}$ against concentration of sodium thiosulfate on the axes provided. [2]




(e) A student decided to carry out another experiment using 0.075 mol dm$^{-3}$ solution of sodium thiosulfate under the same conditions. Determine the time taken for the mark to be no longer visible. [2]

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**(Question 3 continued)**

(f) An additional experiment was carried out at a higher temperature, $T_2$.

(i) On the same axes, sketch Maxwell–Boltzmann energy distribution curves at the two temperatures $T_1$ and $T_2$, where $T_2 > T_1$. [2]

(ii) Explain why a higher temperature causes the rate of reaction to increase. [2]

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(g) Suggest one reason why the values of rates of reactions obtained at higher temperatures may be less accurate. [1]

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**4.** Magnesium is a group 2 metal which exists as a number of isotopes and forms many compounds.

(a) State the nuclear symbol notation, ${}^{A}_{Z}X$, for magnesium-26. [1]

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(b) Mass spectroscopic analysis of a sample of magnesium gave the following results:

| | **% abundance** |
|---|---|
| Mg-24 | 78.60 |
| Mg-25 | 10.11 |
| Mg-26 | 11.29 |

Calculate the relative atomic mass, $A_r$, of this sample of magnesium to two decimal places. [2]

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(c) Magnesium burns in air to form a white compound, magnesium oxide. Formulate an equation for the reaction of magnesium oxide with water. [1]

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**(Question 4 continued)**

(d) Describe the trend in acid-base properties of the oxides of period 3, sodium to chlorine. [2]

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(e) In addition to magnesium oxide, magnesium forms another compound when burned in air. Suggest the formula of this compound. [1]

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(f) Describe the structure and bonding in solid magnesium oxide. [2]

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(g) Magnesium chloride can be electrolysed.

Deduce the half-equations for the reactions at each electrode when **molten** magnesium chloride is electrolysed, showing the state symbols of the products. The melting points of magnesium and magnesium chloride are 922 K and 987 K respectively. [2]

Anode (positive electrode):

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Cathode (negative electrode):

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**5.** Propane and propene are members of different homologous series.

(a) Draw the full structural formulas of propane and propene. [1]

Propane:

Propene:

(b) Both propane and propene react with bromine.

(i) State an equation and the condition required for the reaction of 1 mol of propane with 1 mol of bromine. [2]

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(ii) State an equation for the reaction of 1 mol of propene with 1 mol of bromine. [1]

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**(Question 5 continued)**

(iii) State the type of each reaction with bromine. [1]

Propane:

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Propene:

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