Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

Friday 13 November 2015 (afternoon)

Candidate session number

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.
- Section A: answer all questions.
- Section B: answer one question.
- 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]**.

17 pages

8815 – 6105

Section A

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

1. A student used the technique of titration to determine the concentration of ascorbic acid ($C_6H_8O_6$) in a sample of orange juice. Excess potassium iodide, KI(aq), was added to acidified orange juice. The resulting solution was titrated with potassium iodate, KIO_3(aq), in the presence of starch as an indicator. The end-point of the titration was shown by a blue-black colour.

Step 1 $IO_3^-(aq) + 5I^-(aq) + 6H^+(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$

Iodine is only slightly soluble in water; but in the presence of excess iodide ions, I^-(aq), it forms the soluble tri-iodide ion, I_3^-(aq).

Step 2 $I_2(aq) + I^-(aq) \rightleftharpoons I_3^-(aq)$

Ascorbic acid reacts with tri-iodide ions as follows.

Step 3 $C_6H_8O_6(aq) + I_3^-(aq) \rightarrow C_6H_6O_6(aq) + 2H^+(aq) + 3I^-(aq)$

(a) (i) Deduce the changes in oxidation number of iodine in step 1. [2]

IO_3^- to I_2:

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I^- to I_2:

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(ii) Identify the oxidizing **and** reducing agents in step 1. [1]

Oxidizing agent:

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Reducing agent:

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(Question 1 continued)

(b) The concentration of KIO_3 used in the titration was 2.00×10^{-3} mol dm^{-3}.
The titration produced the following results.

	Titration 1	**Titration 2**	**Titration 3**
Final volume of KIO_3 ($\pm$ 0.05 cm^3)	7.10	14.40	21.60
Initial volume of KIO_3 ($\pm$ 0.05 cm^3)	0.00	7.10	14.40
Volume added of KIO_3 ($\pm$ 0.10 cm^3)	7.10	7.30	7.20
Mean volume added of KIO_3 ($\pm$ 0.10 cm^3)	7.20		

(i) Calculate the percentage uncertainty associated with the mean volume of KIO_3(aq). [1]

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(ii) The colour of orange juice interfered with the blue-black colour at the equivalence point. State the name of this type of error **and** suggest how this can be minimized. [2]

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(iii) Determine the amount, in mol, of KIO_3(aq), in the mean volume. [1]

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(Question 1 continued)

(c) Determine the amount, in mol, of ascorbic acid, $C_6H_8O_6\,(aq)$, in the sample of acidified orange juice. [2]

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(d) Calculate the mass, in g, of ascorbic acid, $C_6H_8O_6\,(aq)$, present in the sample of acidified orange juice. [1]

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2. (a) Draw the Lewis (electron dot) structures of oxygen, O_2, ozone, O_3, and hydrogen peroxide, H_2O_2. [3]

(b) Deduce, giving a reason, the relative lengths of the oxygen to oxygen bonds in oxygen and hydrogen peroxide. [1]

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(c) Predict, with a reason, the O–O–O bond angle in O_3. [2]

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3. Propane, $C_3H_8(g)$, undergoes complete combustion to form carbon dioxide, $CO_2(g)$, and water, $H_2O(g)$.

(a) State an equation for the complete combustion of propane, $C_3H_8(g)$. [1]

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(b) Calculate the standard enthalpy change for the reaction in part (a) using bond enthalpy values given in table 10 of the data booklet. [3]

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(c) Determine, using Hess's law, the enthalpy change, $\Delta H^{\ominus}$, in $kJ\,mol^{-1}$, for the complete combustion of propane by using the following data. [4]

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H^{\ominus} = -394\ kJ\,mol^{-1}$$

$$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g) \qquad \Delta H^{\ominus} = -242\ kJ\,mol^{-1}$$

$$3C(s) + 4H_2(g) \rightarrow C_3H_8(g) \qquad \Delta H^{\ominus} = -104\ kJ\,mol^{-1}$$

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(Question 3 continued)

(d) Suggest, with a reason, why the values obtained in parts (b) and (c) are different. [1]

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4. (a) (i) Define the term electronegativity. [1]

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(ii) Suggest why the noble gases are generally not assigned electronegativity values. [1]

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(b) Explain why the melting points of the group 1 metals (Li $\rightarrow$ Cs) decrease down the group whereas the melting points of the group 7 elements (F $\rightarrow$ I) increase down the group. [3]

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Section B

Answer **one** question. Write your answers in the boxes provided.

5. (a) The following reaction is used in industry to obtain hydrogen from natural gas by partial oxidation with steam.

$$CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g) \qquad \Delta H^{\ominus} = +206\,kJ$$

(i) Describe the effect, if any, of each of the following changes on the equilibrium amount of hydrogen, giving a reason in each case. [4]

Increasing the pressure, at constant temperature:

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Increasing the temperature, at constant pressure:

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(ii) Identify which of the changes in part (a) (i) will affect the value of K_c and whether the value will increase or decrease. [1]

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(iii) Discuss the effects of adding a solid catalyst to the mixture of methane and steam, at constant pressure and temperature. [3]

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(Question 5 continued)

(b) The equations of two acid-base reactions are given below.

Reaction **A** $H_2CO_3(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$

Reaction **B** $HCO_3^-(aq) + H_2O(l) \rightleftharpoons CO_3^{2-}(aq) + H_3O^+(aq)$

(i) Explain whether $HCO_3^-(aq)$ behaves as an acid or a base in each of the reactions **A** and **B**. [2]

Reaction **A**:

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Reaction **B**:

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(ii) Deduce **two** conjugate acid-base pairs from reactions **A** and **B**. [2]

	Acid	**Base**
Conjugate acid-base pair 1	. . . .	. . . .
Conjugate acid-base pair 2	. . . .	. . . .

(This question continues on the following page)

(Question 5 continued)

(c) Nitric acid, HNO_3, and nitrous acid, HNO_2, are described as strong and weak acids respectively.

(i) Distinguish between *strong* and *weak* acids. [1]

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(ii) A 1.00 g sample of solid magnesium carbonate, $MgCO_3$, is added to separate solutions of HNO_3 and HNO_2 of the same concentration and temperature. State **one** similarity and **one** difference in the observations made in these reactions. [2]

Similarity:

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Difference:

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(iii) A solution of HNO_3 has a pH of 1, while a solution of HNO_2 has a pH of 5. Determine the ratio of the hydrogen ion concentration in HNO_3:HNO_2. [1]

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(Question 5 continued)

(d) (i) State the acid-base character of the oxides of the period 3 elements Na to Ar. [2]

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(ii) State balanced equations to illustrate the acid-base character of sodium oxide and sulfur trioxide. [2]

Sodium oxide:

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Sulfur trioxide:

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6. (a) A purple solution of potassium manganate(VII), $KMnO_4$, reacts with ethanedioate ions according to the following equation.

$$2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) + 16H^+(aq) \rightarrow 10CO_2(g) + 2Mn^{2+}(aq) + 8H_2O(l)$$

(i) Outline an experimental procedure which may be used to measure the rate of this reaction. [3]

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(ii) Sketch a graph to show the results of the experimental procedure outlined in (a) (i). [2]

(iii) Outline how the rate of reaction at a particular time could be determined from the graph. [1]

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(Question 6 continued)

(iv) Discuss, in terms of collision theory, the effect of increasing temperature on the rate of this reaction. [3]

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(b) Consider the following spontaneous reactions.

$$Fe(s) + Ni^{2+}(aq) \rightarrow Fe^{2+}(aq) + Ni(s)$$

$$Zn(s) + Fe^{2+}(aq) \rightarrow Zn^{2+}(aq) + Fe(s)$$

$$Ni(s) + Pb^{2+}(aq) \rightarrow Ni^{2+}(aq) + Pb(s)$$

(i) Deduce the order of **increasing** reactivity of the metals based on the reactions above. [2]

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(ii) Identify the strongest oxidizing agent in the reactions above. [1]

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(Question 6 continued)

(c) Draw a diagram of an electrolytic cell for the electrolysis of molten nickel(II) bromide, $NiBr_2(l)$. Include the direction of the electron flow, the polarity of electrodes and the half-equations at each electrode. [4]

Negative electrode (cathode):

. . . .

Positive electrode (anode):

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(d) (i) In the operation of a mass spectrometer, the first stage is vaporization and the last is detection. State the names of the other three stages and outline what happens in each one. [3]

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(ii) Suggest why a very low pressure is maintained inside the mass spectrometer. [1]

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7. (a) A 0.842 g sample of a liquid halogenoalkane, RBr(l), was heated under reflux with 1.35×10^{-2} mol of aqueous sodium hydroxide, NaOH(aq). After cooling the mixture, the excess NaOH was titrated with hydrochloric acid, HCl(aq), and required 7.36×10^{-3} mol of the acid.

(i) State the equation for the substitution reaction of the halogenoalkane with sodium hydroxide. [1]

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(ii) Calculate the amount, in mol, of sodium hydroxide that reacted with the halogenoalkane. [1]

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(iii) Calculate the molar mass of the halogenoalkane. [1]

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(iv) Given that each molecule of the halogenoalkane contains one bromine atom, determine its molecular formula. [1]

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(Question 7 continued)

(v) Deduce the structural formulas of **four** structural isomers of the halogenoalkane based on the molecular formula **and** label each isomer as primary, secondary or tertiary. (If you have not been able to determine the molecular formula in part (a) (iv), use $C_5H_{11}Br$ to deduce the four structural isomers.) [4]

(b) The reaction between a primary halogenoalkane drawn in part (a) (v) and sodium hydroxide follows a S_N2 mechanism.

Explain the mechanism of the reaction using curly arrows to represent the movement of electron pairs. [4]

(This question continues on the following page)

(Question 7 continued)

(c) (i) List the following compounds in order of **increasing** boiling point:
CH_3CHO, $CH_3CH_2CH_3$, CH_3COOH, CH_3CH_2OH. [2]

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(ii) Explain the order of boiling points in the compounds listed in part (c) (i), in terms of intermolecular forces. [4]

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(iii) CH_3CH_2OH can be oxidized in aqueous solution by acidified potassium dichromate(VI) by heating under reflux. Deduce the structural formula of the final product formed **and** state the colour change during the oxidation process. [2]

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