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CHEMISTRY
STANDARD LEVEL
PAPER 2

Candidate session number

Tuesday 18 November 2014 (afternoon)

1 hour 15 minutes

Examination code

8 8 1 4 – 6 1 0 5

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]*.

SECTION A

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

1. A student used a pH meter to measure the pH of different samples of water at 298 K.

Sample	pH ± 0.1
Rain water	5.1
River water	4.4
Tap water	6.5
Bottled water	7.1

(a) Use the data in the table to identify the most acidic water sample. *[1]*

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(b) Calculate the percentage uncertainty in the measured pH of the rain water sample. *[1]*

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(c) Determine the ratio of $[H^+]$ in bottled water to that in rain water.

$$\frac{\textbf{[H}^+\textbf{] in bottled water}}{\textbf{[H}^+\textbf{] in rain water}}$$

[2]

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(This question continues on the following page)

(Question 1 continued)

(d) The acidity of non-polluted rain water is caused by dissolved carbon dioxide. State an equation for the reaction of carbon dioxide with water. *[1]*

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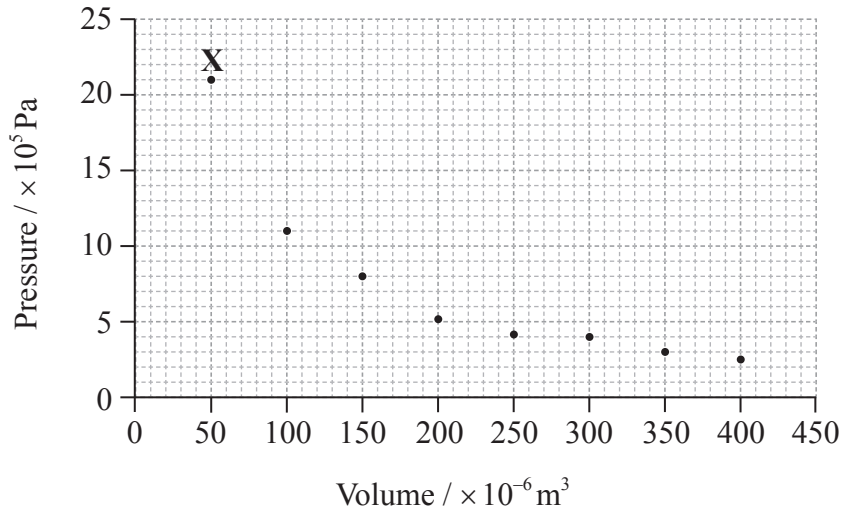
2. The graph below shows pressure and volume data collected for a sample of carbon dioxide gas at 330 K.



(a) Draw a best-fit curve for the data on the graph. *[1]*

(b) Deduce the relationship between the pressure and volume of the sample of carbon dioxide gas. *[1]*

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(c) Use the data point labelled **X** to determine the amount, in mol, of carbon dioxide gas in the sample. *[3]*

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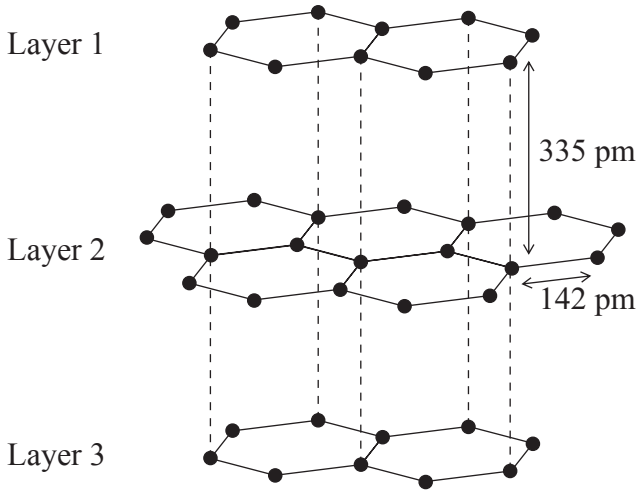
3. Graphite has a layered structure of carbon atoms. A section of the structure is shown below.



(a) Explain why the distance between adjacent carbon atoms within a layer is shorter than the distance between layers. *[3]*

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(b) Graphite is used as a lubricant. Discuss **two** other uses of graphite with reference to its layered structure. *[4]*

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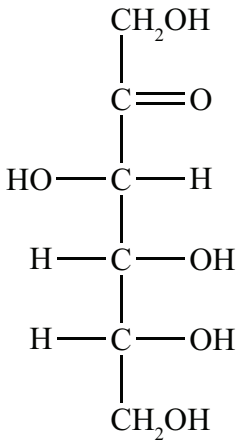
4. The open-chain structure of D-fructose is shown below.



(a) State the names of **two** functional groups in D-fructose. *[1]*

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(b) Deduce the empirical formula of D-fructose. *[1]*

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(c) Calculate the percentage composition by mass of D-fructose. *[2]*

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(Question 4 continued)

(d) State a balanced equation for the complete combustion of D-fructose. *[2]*

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5. The Contact process involves an exothermic reversible reaction.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad K_c \gg 1 \text{ at } 200\ ^\circ\text{C and } 1\text{ atm}$$

(a) Deduce the extent of the reaction at 200 °C and 1 atm. *[1]*

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(b) The Contact process operates at a temperature of 450 °C and a pressure of 2 atm as optimum conditions for the production of SO_3. Outline the reasons for choosing these conditions. *[4]*

Temperature:

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Pressure:

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(Question 5 continued)

(c) An engineer at a Contact process plant hypothesized that using pure oxygen, instead of air, would increase the profits. Comment on whether or not her hypothesis is valid, giving your reasons. *[2]*

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SECTION B

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

6. (a) A sample of magnesium contains three isotopes: magnesium-24, magnesium-25 and magnesium-26, with abundances of 77.44 %, 10.00 % and 12.56 % respectively.

(i) Calculate the relative atomic mass of this sample of magnesium correct to **two** decimal places. *[2]*

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(ii) By reference to the deflection and detection stages in the mass spectrometer, explain how the mass and abundance of an isotope are determined. *[2]*

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(iii) Predict the relative atomic radii of the three magnesium isotopes, giving your reasons. *[2]*

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(Question 6 continued)

(b) Describe the bonding in magnesium. *[2]*

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(c) State an equation for the reaction of magnesium oxide with water. *[1]*

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(d) Phosphorus(V) oxide, P_4O_{10} ($M_r = 283.88$), reacts vigorously with water ($M_r = 18.02$), according to the equation below.

$$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$$

(i) A student added 5.00 g of P_4O_{10} to 1.50 g of water. Determine the limiting reactant, showing your working. *[2]*

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(ii) Calculate the mass of phosphoric(V) acid, H_3PO_4, formed in the reaction. *[2]*

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(This question continues on the following page)

(Question 6 continued)

(iii) State a balanced equation for the reaction of aqueous H_3PO_4 with excess aqueous sodium hydroxide, including state symbols. *[2]*

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(iv) State the formula of the conjugate base of H_3PO_4. *[1]*

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(e) (i) Deduce the Lewis structure of PH_4^+. *[1]*

(This question continues on the following page)

(Question 6 continued)

(ii) Predict, giving a reason, the bond angle around the phosphorus atom in PH_4^+. *[2]*

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(iii) Predict whether or not the P–H bond is polar, giving a reason for your choice. *[1]*

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7. Consider the following list of organic compounds.

Compound 1: $CH_3CH_2CH(OH)CH_3$

Compound 2: $CH_3CH_2COCH_3$

Compound 3: $CH_3CH_2CH_2OH$

Compound 4: $CH_3CH_2CH_2CHO$

(a) Apply IUPAC rules to state the name of compound 1. *[1]*

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(b) (i) Define the term *structural isomers*. *[1]*

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(ii) Identify the two compounds in the list that are structural isomers of each other. *[1]*

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(c) Determine the organic product formed when each of the compounds is heated under reflux with excess acidified potassium dichromate(VI). If no reaction occurs write NO REACTION in the table. *[4]*

Compound	Organic product
$CH_3CH_2CH(OH)CH_3$	
$CH_3CH_2COCH_3$	
$CH_3CH_2CH_2OH$	
$CH_3CH_2CH_2CHO$	

(This question continues on the following page)

(Question 7 continued)

(d) Explain the mechanism for the substitution reaction of bromoethane with sodium hydroxide. Use curly arrows to represent the movement of electron pairs. *[4]*

(e) Hydrochloric acid neutralizes sodium hydroxide, forming sodium chloride and water.

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) \qquad \Delta H^{\ominus} = -57.9\,kJ\,mol^{-1}$$

(i) Define the term *standard enthalpy change of reaction*, $\Delta H^{\ominus}$. *[2]*

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(ii) Determine the amount of energy released, in kJ, when $50.0\,cm^3$ of $1.00\,mol\,dm^{-3}$ sodium hydroxide solution reacts with $50.0\,cm^3$ of $1.00\,mol\,dm^{-3}$ hydrochloric acid solution. *[2]*

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(Question 7 continued)

(iii) In an experiment, 2.50 g of solid sodium hydroxide was dissolved in 50.0 cm^3 of water. The temperature rose by 13.3 °C. Calculate the standard enthalpy change, in $kJ\,mol^{-1}$, for dissolving one mole of solid sodium hydroxide in water.

$$NaOH(s) \rightarrow NaOH(aq)$$ *[3]*

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(iv) Using relevant data from previous question parts, determine $\Delta H^{\ominus}$, in $kJ\,mol^{-1}$, for the reaction of solid sodium hydroxide with hydrochloric acid.

$$NaOH(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$ *[2]*

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8. Iron rusts in the presence of oxygen and water. Rusting is a redox process involving several steps that produces hydrated iron(III) oxide, $Fe_2O_3 \bullet nH_2O$, as the final product.
The half-equations involved for the first step of rusting are given below.

Half-equation 1: $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$

Half-equation 2: $O_2(aq) + 4e^- + 2H_2O(l) \rightarrow 4OH^-(aq)$

(a) (i) Identify whether half-equation 1 represents oxidation or reduction, giving a reason for your answer. *[1]*

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(ii) Identify the oxidation number of each atom in the three species in half-equation 2. *[2]*

$O_2(aq) + 4e^- + 2H_2O(l) \rightarrow 4OH^-(aq)$

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(iii) Deduce the overall redox equation for the first step of rusting by combining half-equations 1 and 2. *[1]*

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(iv) Identify the reducing agent in the redox equation in part (iii). *[1]*

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(This question continues on the following page)

(Question 8 continued)

(b) The oxygen in half-equation 2 is atmospheric oxygen that is found dissolved in water in very small concentrations. Explain, in terms of intermolecular forces, why oxygen is not very soluble in water. *[2]*

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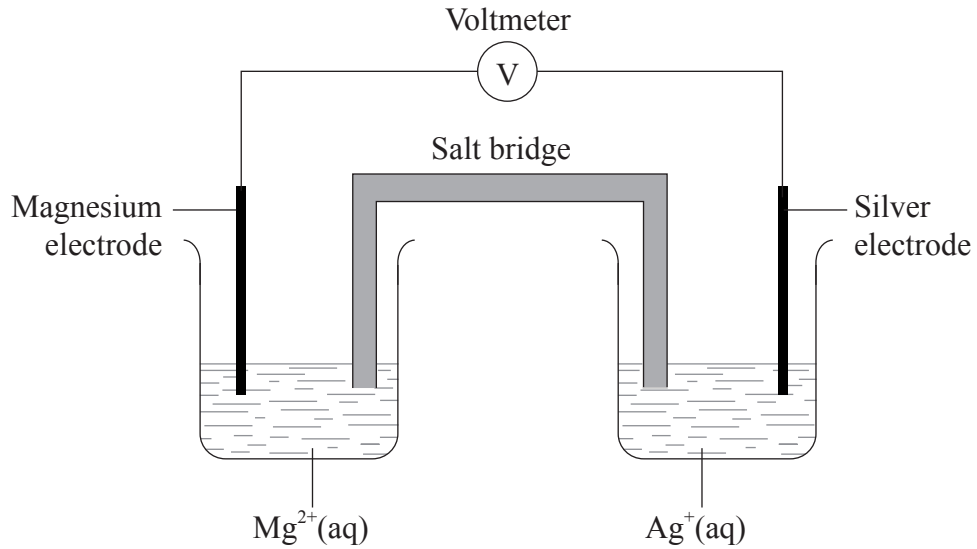
(c) A voltaic cell is made from a half-cell containing a magnesium electrode in a solution of magnesium nitrate and a half-cell containing a silver electrode in a solution of silver(I) nitrate.



(i) Given that magnesium is more reactive than silver, deduce the half-equations for the reactions occurring at each electrode, including state symbols. *[2]*

Negative electrode (anode):

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Positive electrode (cathode):

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(This question continues on the following page)

(Question 8 continued)

(ii) Outline **one** function of the salt bridge. *[1]*

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(d) (i) State the property that determines the order in which elements are arranged in the periodic table. *[1]*

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(ii) State the relationship between the electron arrangement of an element and its group and period in the periodic table. *[2]*

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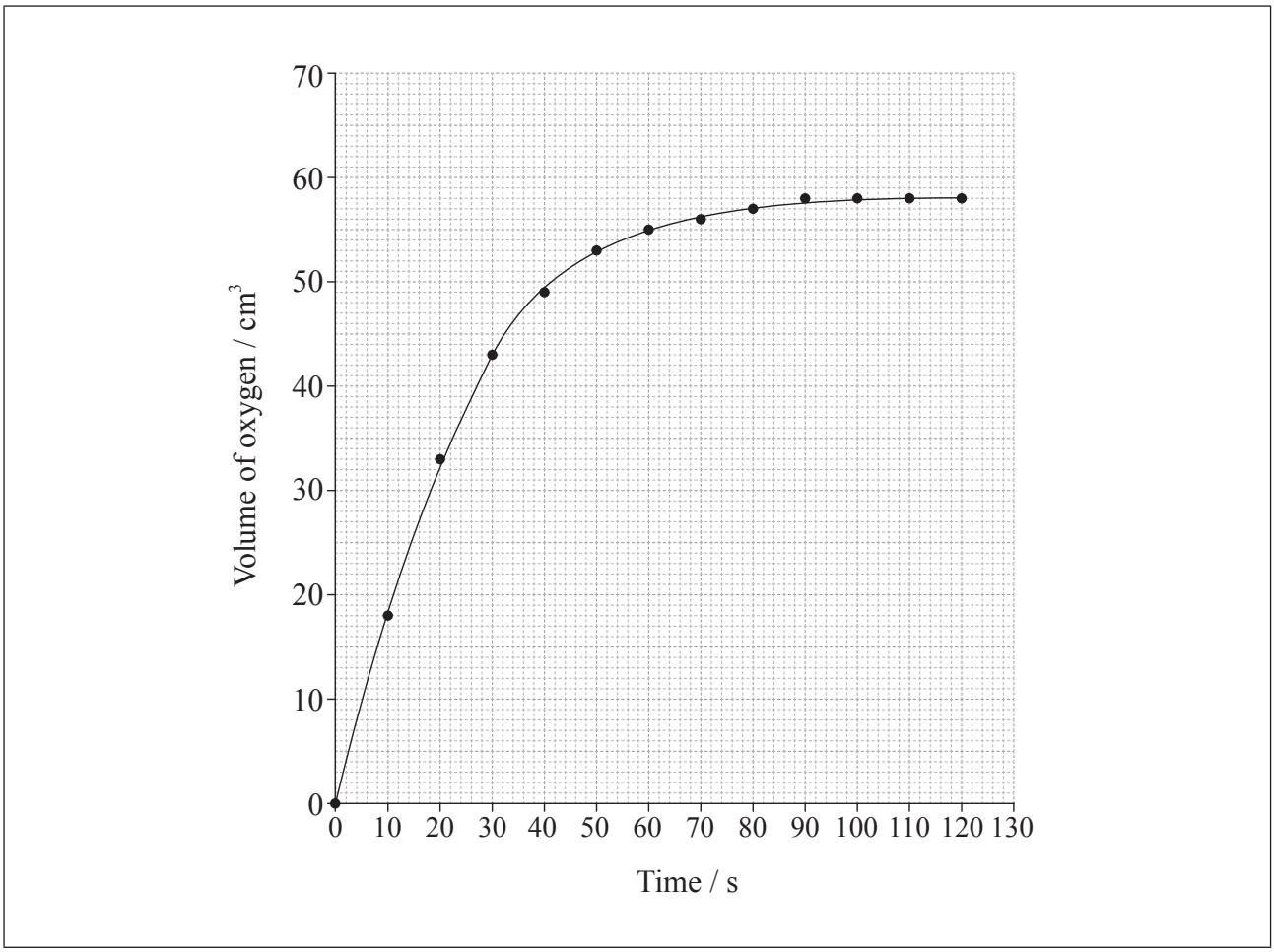
(Question 8 continued)

(e) Hydrogen peroxide decomposes according to the equation below.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

The rate of the decomposition can be monitored by measuring the volume of oxygen gas released. The graph shows the results obtained when a solution of hydrogen peroxide decomposed in the presence of a CuO catalyst.



(i) The experiment is repeated with the same amount of a more effective catalyst, MnO_2, under the same conditions and using the same concentration and volume of hydrogen peroxide. On the graph above, sketch the curve you would expect. *[1]*

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(Question 8 continued)

(ii) Outline how the initial rate of reaction can be found from the graph. *[2]*

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(iii) Outline a different experimental procedure that can be used to monitor the decomposition rate of hydrogen peroxide. *[1]*

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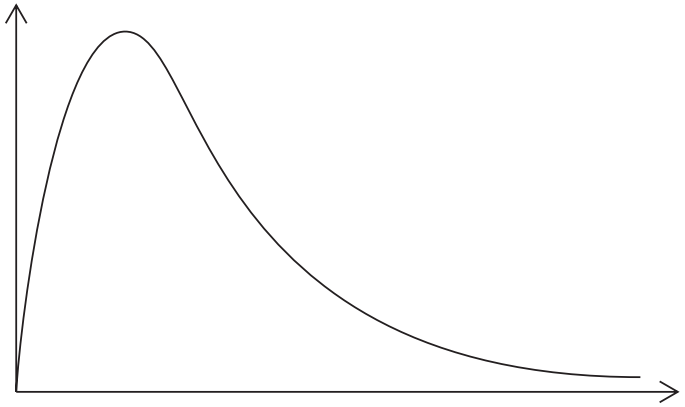
(iv) A Maxwell–Boltzmann energy distribution curve is drawn below. Label both axes and explain, by annotating the graph, how catalysts increase the rate of reaction. *[3]*



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