UNIVERSITY OF SIERRA LEONE

CHEM 111

FOURAH BAY COLLEGE

FIRST EXAMINATION FOR THE DEGREE OF B. Sc. HONOURS

LEVEL I

FIRST SEMESTER EXAMINATION

APRIL 2018

**PHYSICAL AND INORGANIC CHEMISTRY**

TIME ALLOWED: 3 HOURS PLUS 15 MINUTES READING TIME

INSTRUCTION: THIS PAPER IS DIVIDED INTO THREE SECTIONS: A, B AND C. ANSWER ALL QUESTIONS IN SECTION A AND A TOTAL OF THREE (3) QUESTIONS FROM SECTIONS B AND C, WHICH MUST INCLUDE AT LEAST ONE QUESTION FROM EACH SECTION.

**SECTION A (ANSWER ALL QUESTIONS)**

**SECTION B (ANSWER 1 OR 2 QUESTIONS)**

**SECTION C (ANSWER 1 OR 2 QUESTIONS)**

**The value of the molar gas constant R = 8.31 JK-1mol-1**

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# Section A

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| **1.** | Write the formulae of the following compounds: | | |
|  | (a) | copper (I) oxide | |
|  | (b) | potassium manganate (VII) | |
|  | (c) | calcium nitrate (V) | |
|  | (d) | aluminium sulphide | |
|  | (e) | sodium chlorate (V)  [5] | |
| **2.** | Hydrogen peroxide can be prepared by the treatment of barium peroxide (BaO2) with dilute sulphuric acid: BaO2(s) + H2SO4(aq) 🡪 BaSO4(s) + H2O2(aq)  A student added 5.0 g of BaO2 to 50 cm3 of 2.0 moldm-3 H2SO4. The total volume of the solution did not change. | | |
|  | (i) | Deduce which of the reactants is in excess and hence deduce the molarity of the H2O2 solution produced during this reaction. | |
|  | (ii) | Deduce the percentage atom economy of this reaction for the production of H2O2.  [5] | |
| **3.** | (a) | A hydrated salt was found to have the following mass composition: Ca 23.3%, S 18.6%, O 55.7% and H 2.3%. Deduce the empirical formula and suggest a possible unit formula for the compound. | |
|  | (b) | When heated, this salt becomes anhydrous. If a 5.0 g sample of the salt is heated, calculate the mass of solid remaining after heating to constant mass.  [5] | |
| **4.** | Potassium reacts vigorously with water according to the following equation:  2K(s) + 2H2O(l) 🡪 2KOH(aq) + H2(g)  A 2.5 g piece of potassium was dropped into a container containing 2 dm3 of water and allowed to react completely. The total volume of the solution did not change. Calculate:   1. The molarity of the KOH solution produced 2. The volume of hydrogen produced at 298 K and 100 kPa   [5] | | |
| **5.** | 2.35 g of sodium hydroxide was dissolved in water and the total volume of solution made up to 250 cm3. 25.0 cm3 of this solution was titrated against 0.20 moldm-3 HCl using a suitable indicator. | | |
|  | (a) | | Calculate the expected volume of HCl required to neutralise the NaOH solution. |
|  | (b) | | Identify the four measuring instruments likely to have been used in this experiment and calculate the percentage apparatus error for each measurement. |
|  | (c) | | Hence calculate the total apparatus error for the experiment and hence suggest a suitable number of significant figures for your answer.  [5] |

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| **6.** | One method for the manufacture of nitric acid involved the combustion of ammonia in the presence of a catalyst as follows:  4NH3(g) + 5O2(g)4NO(g) + 6H2O (g)  It is an exothermic reaction.  State and explain the effect on the percentage yield of NO of | |
|  | (a) | Increasing the temperature |
|  | (b) | Increasing the pressure |
|  | (c) | Removing the catalyst  [5] |
| **7.** | A chemical reaction between E and F reaches equilibrium as follows:  **E** (g)    +    2**F**(g)     2**G**(g)         *ΔH* = –50 kJ mol–1  A 2.0 mol sample of **E** was heated in a sealed container with a 1.0 mol sample of **F**. Equilibrium was established at a given temperature and the equilibrium mixture formed contained 0.80 mol of **G**.  Deduce the value of Kc for this reaction, giving suitable units  [5] | |
| **8.** | (a) | Calculate the molarity of a solution of KOH which has a pH of 13.74 |
|  | (b) | Calculate the pH of a solution of 0.05 moldm-3 CH3COOH (Ka = 1.8 x 10-5 moldm-3)  [5] |
| **9.** | (a) | Calculate the value of Ksp for PbCl2 given that its solubility in water is 0.011 moldm-3. |
|  | (b) | The Ksp of silver bromide (AgBr) is 7.7 x 10-13 mol2dm-6. Deduce the molar solubility of silver bromide.  [5] |
| **10.** | (a) | Sketch a curve to show how the pH changes when a solution of 0.05 moldm-3 NH3 is added gradually to 25 cm3 of 0.10 moldm-3 HCl. |
|  | (b) | Suggest, with a reason, a suitable indicator for this titration.  [5] |

# Section B

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| **1.** | This question is about different types of titrations. | |
|  | (a) | Succinic acid (H2X) is a diprotic acid, which reacts with sodium hydroxide as follows:  H2X + 2NaOH 🡪 Na2X + 2H2O  2.00 g of succinic acid were dissolved in water and the volume was made up to 250 cm3 in a volumetric flask. This solution was placed in a burette and 18.4 cm3 was required to neutralise 25 cm3 of 0.1 moldm-3 NaOH.  Deduce the molar mass of succinic acid.  [5] |
|  | (b) | 1.12 g of a metal chloride MCl2 was dissolved in water and the volume was made up to 250 cm3 in a volumetric flask. 25.0 cm3 of this solution was titrated against 0.050 moldm-3 AgNO3 and 21.6 cm3 of the AgNO3 solution was required to react completely with the MCl2 solution.   1. Write an ionic equation to show MCl2 dissolving in water 2. Write an ionic equation for the reaction taking place during the titration 3. Deduce the identity of the metal M   [7] |
|  | (c) | A solution of industrial hydrogen peroxide of volume 5 cm3 was diluted to 250 cm3 in a volumetric flask. A 25.0 cm3 portion of the diluted solution was acidified and titrated against 0.0150 moldm-3 potassium permanganate solution, and 19.7 cm3 were required.  Hydrogen peroxide is oxidized according to the following equation:  H2O2(aq) 🡪 2H+(aq) + O2(g) + 2e   1. Write an ionic equation for the reaction taking place during the titration 2. Deduce the molarity of the industrial hydrogen peroxide solution before dilution   [6] |
|  | (d) | The National Bank of Sierra Leone is planning to introduce a Le 1,000 coin, made from a mixture of copper and nickel.  One such coin weighing 1.72 g was completely dissolved in concentrated nitric acid until all of the copper in the coin had been oxidised to copper (II) ions. The excess nitric acid was then neutralised and the volume made up to 250 cm3 in a volumetric flask. 25 cm3 portions of this solution were then added to a conical flask and an excess of potassium iodide was then added. Cu2+ ions react with iodide ions as follows:  2Cu2+ + 4I- 🡪 2CuI + I2  The resulting solution was titrated against 0.1 moldm-3 Na2S2O3, and 15.7 cm3 was required.   1. Write an equation for the reaction taking place during the titration 2. Determine the percentage of copper in the coin   [6] |
|  | (e) | Estimate the total percentage apparatus error resulting from the titration in part (a) of this question.  [3]  max 25 marks |

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| **2.** | This question is about hydrochloric acid, which is a strong acid commonly used in the laboratory as well as in industry. | | |
|  | (a) | Industrial concentrated hydrochloric acid contains 36% HCl by mass and has a density of 1.18 gcm-3. It needs to be diluted before it is safe to use in the laboratory. | |
|  |  | (i) | Calculate the mass of 10.0 cm3 of concentrated hydrochloric acid. |
|  |  | (ii) | Hence calculate the mass of pure HCl in 10.0 cm3 of concentrated hydrochloric acid. |
|  |  | (iii) | Hence calculate the molarity of concentrated hydrochloric acid. |
|  |  | (iv) | Hence calculate the pH of concentrated hydrochloric acid.  [5] |
|  | (b) | Calculate the mass of concentrated hydrochloric acid which should be diluted to make 250 cm3 of a 0.10 moldm-3 solution of HCl.  [4] | |
|  | (c) | (i) | What is the pH of 0.050 moldm-3 HCl? |
|  |  | (ii) | What volume of water should be added to 25 cm3 of 0.050 moldm-3 HCl to increase this pH to 1.50? |
|  |  | (iii) | What will be the final pH of a solution when 10.0 cm3 of 0.075 moldm-3 NaOH is added to 25 cm3 of 0.050 moldm-3 HCl?  [9] |
|  | (d) | Concentrated HCl is a reducing agent; it can be oxidised to chlorine gas and it can reduce PbO2 to Pb2+ ions. | |
|  |  | (i) | Write the half-equation for the oxidation of hydrochloric acid to chlorine gas |
|  |  | (ii) | Write the half-equation for the reduction of PbO2 to Pb2+ |
|  |  | (iii) | Hence write an ionic equation for the reaction between PbO2 and HCl  [3] |
|  | (e) | Write equations to show how dilute hydrochloric acid reacts with:  (ionic equations are always acceptable) | |
|  |  | (i) | Ammonia |
|  |  | (ii) | calcium carbonate |
|  |  | (iii) | sodium hydrogencarbonate |
|  |  | (iv) | magnesium hydroxide |
|  |  | (v) | aqueous silver nitrate  [6]  max 25 marks |

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| **3.** | (a) | (i) | Outline briefly the process of scientific enquiry, and hence explain the difference between the terms “hypothesis”, “law” and “theory”. |
|  |  | (ii) | Explain the difference between a theory and a theorem, and the difference between induction and deduction. |
|  |  | (iii) | What is meant by the term “serendipity”?  [9] |
|  | (b) | (i) | What is the difference between the terms “molarity” and “molality”? |
|  |  | (ii) | When 90.00 g of glucose (C6H12O6) are dissolved in water and the volume made up to 250.0 cm3 using a volumetric flask, the resulting solution was found to have a density of 1.131 gdm-3. Calculate the molarity and the molality of the glucose solution. |
|  |  | (iii) | When 22.50 g of glucose was dissolved in 100.0 cm3 of water, the total volume of the solution increased to 108.3 cm3. Calculate the molarity and the molality of the glucose solution, assuming that the density of water is 0.997 gcm-3.  [8] |
|  | (c) | Three different reactions of sulphuric acid are described below: | |
|  |  | (i) | Sulphuric acid was dropped onto a solution containing bromide ions. The resulting mixture was found to contain both sulphur dioxide and bromine. |
|  |  | (ii) | Sulphuric acid was added gradually to a solution of barium chloride. |
|  |  | (iii) | Some copper (II) oxide powder was added to sulphuric acid. |
|  |  | In each case, state and explain the type of reaction occurring and write an equation for the reaction taking place. Ionic equations are acceptable.  [9]  max 25 marks | |

# Section C

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| **1.** | (a) | What is meant by the term “buffer solution”?  [2] | |
|  | (b) | Calculate the pH of the buffer solution formed when 10 cm3 of 0.10 moldm-3 NaOH is added to 25 cm3 of 0.080 moldm-3 C2H5COOH (Ka of C2H5COOH is 1.3 x 10-5 moldm-3).  [6] | |
|  | (c) | Explain, with the aid of equations, how this buffer solution works.  [5] | |
|  | (d) | Ammonia (NH3) is a weak base with a Kb of 1.7 x 10-5 moldm-3. | |
|  |  | (i) | Calculate the pH of 0.050 moldm-3 NH3. |
|  |  | (ii) | Suggest, with a reason, a substance which could be added to a solution of ammonia to make a buffer solution. |
|  |  | (iii) | Calculate the quantity of this substance (in moles) which should be added to 100 cm3 of 0.10 moldm-3 NH3 to make a buffer solution with a pH of 9.5.  [12]  Total 25 marks |
| **2.** | (a) | Explain the meaning of the terms “Bronsted-Lowry acid”, “Bronsted-Lowry base” and “acid-base conjugate pair”.  [3] | |
|  | (b) | Write an equation for the reversible reaction between HCOOH and H2O.  Use the equation to Identify: | |
|  |  | (i) | The Bronsted-Lowry acid and base in the forward reaction; |
|  |  | (ii) | The Bronsted-Lowry acid and base in the reverse reaction; |
|  |  | (iii) | The acid-base conjugate pairs in the reaction  [7] |
|  | (c) | The ionic product of water at 25 oC is 1.00 x 10-14 mol2dm-6, but at 50 oC it is 5.48 x 10-14 mol2dm-6. | |
|  |  | (i) | What does this information tell you about the enthalpy change for the auto-ionization of water? |
|  |  | (ii) | Calculate the pH of pure water at 25 oC and at 50 oC  [6] |
|  | (d) | Methylamine (CH3NH2) is a weak base with a Kb of 4.4 x 10-4 moldm-3. Ethanoic acid (CH3COOH) is a weak acid with a Ka of 1.8 x 10-4 moldm-3. | |
|  |  | (i) | Explain the meaning of the term “salt hydrolysis”. |
|  |  | (ii) | Deduce the pH of 0.050 moldm-3 CH3NH3Cl |
|  |  | (iii) | Deduce the pH of 0.050 moldm-3 CH3COONa |
|  |  | (iv) | Deduce the pH of 0.10 moldm-3 KCl  [9]  Total 25 marks |

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| **3.** | (a) | (i) | When a mixture of 0.345 mol of PCl3 and 0.268 mol of Cl2 was heated in a vessel of fixed volume to a temperature of 400 K, the following reaction reached equilibrium.  PCl3(g)   +   Cl2(g)      PCl5(g)           ΔH= –93 kJ mol–1  At equilibrium, 0.166 mol of PCl5 had been formed and the total pressure was 225 kPa.  Deduce the value of Kp |
|  |  | (ii) | Derive an expression to show the relationship between Kc and Kp, and hence calculate the value of Kc for the above reaction.  [9] |
|  | (b) | (i) | Consider the following equilibrium: NH4CO2NH2(s)2NH3(g) + CO2(g).  A solid sample of NH4CO2NH2 was allowed to decompose to equilibrium at 400 K in an evacuated container. The total gas pressure was found to be 36.3 kPa. Calculate Kp for the reaction. |
|  |  | (ii) | Hence calculate values of Kp for the following reactions:   1. 2NH3(g) + CO2(g)NH4CO2NH2(s) 2. ½NH4CO2NH2(s)NH3(g) + ½CO2(g)   [9] |
|  | (c) | During the industrial production of ammonia, nitrogen and hydrogen react according to the following equation: N2(g) + 3H2(g)2NH3(g), ΔH = -92 kJmol-1 | |
|  |  | (i) | Describe the conditions of temperature and pressure which would maximise the yield of ammonia in the above reaction. |
|  |  | (ii) | Suggest reasons why industrialists may not choose to use the conditions which give the best yield of ammonia.  [7]  Total 25 marks` |
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