CARIBBEAN EXAMINATIONS COUNCIL

ADVANCED PROFICIENCY EXAMINATION

CHEMISTRY

UNIT 2 – PAPER 01

1 hour 45 minutes

Candidates are advised to use the first 15 minutes for reading through this paper carefully. Writing may begin during this time.

READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This paper consists of NINE questions.

2. There are THREE questions from each Module. Answer ALL questions.

3. Write answers in this booklet.

4. ALL working must be shown in this booklet.

5. The use of non-programmable calculators is permitted.

6. A data booklet is provided.

MODULE 1

Answer ALL questions.

1. Lead (II) chloride ($PbCl_2$) is a sparingly soluble salt.

    (a) Write an expression for the solubility product of lead (II) chloride.

    _____

    [2 marks]

    (b) A saturated solution of $PbCl_2$ contains 0.025 mol dm^{-3} at 25 °C. Calculate the K_{sp} of $PbCl_2$.

    [3 marks]

(c) A student finds that on adding NaCl(aq) to a saturated solution of $PbCl_2$ a white precipitate forms.

Explain this observation.

_____

_____

_____

_____

_____

[5 marks]

Total 10 marks

2. When stung by an ant, a potent mixture containing an organic acid, methanoic acid (HCOOH), is injected into the skin. Typically, organic acids are weak acids.

(a) (i) Explain the meaning of the term 'weak acid'.

_____

_____

[2 marks]

(ii) Account for the sensation that occurs when stung by an ant.

_____

_____

[2 marks]

(b) A sample of the mixture responsible for the sting is extracted from the ants and analysed to determine the pH and acid concentration. The pH of the sample is 2.4.

(i) Suggest a simple method of determining pH.

_____

[1 mark]

(ii)   The acid concentration is determined by titrating the sample with a 0.05 mol dm^{-3} sodium hydroxide solution. $10 \, cm^3$ of sodium hydroxide reacts completely with $5 \, cm^3$ of the sample. Given that the equation for the reaction between sodium hydroxide and methanoic acid is

$$NaOH(aq) + HCOOH(aq) \rightarrow HCOO \, Na(aq) + H_2O(l)$$

a)   Suggest a suitable indicator for this titration.

_____

[1 mark]

b)   Calculate the concentration of the acid in the sample.

[1 mark]

c)   Use your answer to (ii) b) above and the pH value of the sample to calculate the value of K_a for the acid.

_____

_____

_____

_____

_____

[3 marks]

Total 10 marks

3. (a) The standard hydrogen electrode is the reference electrode with which other electrodes are compared to determine standard electrode potentials.

    (i) Draw a labelled diagram to show how the standard electrode potential for the Zn^{2+} (aq) / Zn (s) electrode can be found by combining it with the standard hydrogen electrode.

[3 marks]

    (ii) Which of the half cells is the positive electrode?

_____

[1 mark]

    (iii) Using arrows, indicate on the diagram drawn in (i) above, the direction in which the electrons flow through the external circuit.   [1 mark]

    (b) A Zn^{2+} (aq) / Zn (s) half cell is connected to a Ag^+(aq) / Ag (s) half cell as shown below

    Zn (s) / Zn^{2+} (aq) : : Ag^+ (aq) / Ag (s)

    (i) Write the equations for the reactions occurring at each half cell, using electrode potentials given in the data booklet.

    Positive electrode _____

    Negative electrode _____

[2 marks]

    (ii) Calculate the standard e.m.f. of the cell.

_____

_____

[1 mark]

(iii) A student sets up the Ag^+ (aq)/ Ag (s) half cell in (b) page 5, using a solution of 0.1 mol dm^{-3} Ag^+ ions instead of 1 mol dm^{-3} Ag^+ ions. Suggest how this would affect the e.m.f. of the cell. Give a reason for your answer.

_____

_____

_____

[2 marks]

Total 10 marks

MODULE 2

Answer ALL questions.

4. The Group II elements, beryllium to barium (Be to Ba), and their compounds show distinct trends / patterns in properties and behaviour.

(a) Write an equation for the first ionization energy of beryllium (Be).

_____

[1 mark]

(b) Using the data booklet provided, explain the trend in the first ionization energy with atomic radii for the Group II elements.
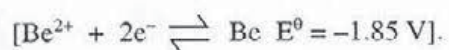
_____

_____

_____

_____

_____

_____

[2 marks]

(c) Write an equation for the reaction between ONE of the Group II elements and water.

_____

[2 marks]

(d)   Using standard electrode potentials, explain why the reaction in (c) would occur more vigorously with barium (Ba) than beryllium (Be), given

$[Be^{2+} + 2e^- \rightleftharpoons Be \quad E^0 = -1.85 \text{ V}]$.

_____

_____

_____

_____

_____

[2 marks]

(e)   Explain the variation in the solubility of the sulphates of Group II elements as the group is descended.

_____

_____

_____

_____

[3 marks]

Total 10 marks

5. (a) Part of the periodic table is shown in Figure 1 below.

	Mg					Al				Cl	
K					Fe						
										I	
	Ba						Pb				

Figure 1

Write an ion of an element shown in Figure 1, which will react with EACH of the following substances:

(i) Acidified aqueous silver nitrate to form a white precipitate

_____

(ii) Aqueous lead (II) nitrate to form a yellow precipitate

_____

(iii) Aqueous potassium hydroxide to form a red-brown precipitate

_____

(iv) Aqueous sodium carbonate to form a white precipitate

_____

[4 marks]

(b) X is a powdered mixture containing a soluble and an insoluble salt. A sample of X is treated in the following manner:

I. Water is added to X and the mixture is filtered.

II. The residue reacts completely with dilute nitric acid and a colourless gas evolves, which forms a white precipitate with aqueous calcium hydroxide. The resulting solution reacts with both aqueous ammonia and sodium hydroxide to form a white precipitate, that does not dissolve in excess of the reagents.

III. One sample of the filtrate reacts with acidified barium chloride to form a white precipitate. Another sample reacts with aqueous ammonia and sodium hydroxide to form a white precipitate which is soluble in excess of the reagents.

(i) Using the information given on page 8, deduce the possible ions present in the

    a)   residue

_____

[2 marks]

    b)   filtrate.

_____

[2 marks]

(ii) Write a balanced ionic equation for the reaction between nitric acid and the residue.

_____

[2 marks]

Total 10 marks

6.   (a)   Transition elements exhibit special characteristics, which distinguish them from Group I and Group II metals. For example, transition elements exhibit variable oxidation states.

    (i)   Determine the oxidation state of vanadium in VO_3^- and VO^{2+}.

_____

_____

[2 marks]

    (ii)   State TWO OTHER characteristics of transition elements.

_____

_____

_____

_____

[2 marks]

   (b)   Complete the electronic configuration of a

    (i)   chromium atom, Cr

         $1s^2 \quad 2s^2 \quad 2p^6 \quad 3s^2 \quad 3p^6$ _____

[1 mark]

    (ii)   chromium ion, Cr^{3+}.

         $1s^2 \quad 2s^2 \quad 2p^6 \quad 3s^2 \quad 3p^6$ _____

[1 mark]

GO ON TO THE NEXT PAGE

(c)   In an aqueous solution of chromium (III) chloride ($CrCl_3(aq)$), chromium forms the complex ion $[Cr(H_2O)_4Cl_2]^+$ (aq).

Deduce the likely shape and the bond angles in this complex ion.

Shape: _____

[1 mark]

Bond angle: _____

[1 mark]

(d)   It has been observed that a solution of aqueous chromium (III) ions, $[Cr(H_2O)_6]^{3+}$(aq) is weakly acidic. Suggest an explanation for this observation.

_____

_____

_____

_____

[2 marks]

Total 10 marks

MODULE 3

Answer ALL questions.

7.   Charles Hall and Paul Heroult independently developed the method for the large-scale production of aluminium from alumina. On application of the extraction procedure, 1900 kg of alumina (Al_2O_3), 70 kg of cryolite, 450 kg of carbon and 5.6×10^9 J yield 1000 g of aluminium metal.

(a)   Describe and explain the use of EACH of the following in the Hall-Heroult process.

(i)   Cryolite

_____

_____

_____

[2 marks]

(ii)   Carbon

_____

_____

_____

[2 marks]

(b)   Account for the requirement of 5.6×10^9 J of energy to produce 1000 kg of aluminium metal.

_____

_____

_____

[2 marks]

(c)   (i)   Calculate the theoretical yield of aluminium expected from 1900kg of Al_2O_3. Show all working.

_____

_____

_____

_____

_____

[3 marks]

     (ii)   Comment on the efficiency of the process in the extraction of aluminium from its ore.

_____

_____

[1 mark]

Total 10 marks

8.   Chlorofluorocarbons, CFCs, have found application in a variety of commercial products because of their special properties. However, CFCs can persist in the atmosphere for many years and scientists have provided evidence of their decomposition products in the stratosphere. The resistance has proven to be of concern regarding the impact on human health.

(a)   Give TWO commercial products in which CFCs could be found before regulations were implemented.

_____

_____

[2 marks]

(b)   State TWO properties of CFCs that make them applicable in the products given in (a).

_____

_____

_____

_____

[2 marks]

GO ON TO THE NEXT PAGE

(c) CF_2Cl_2 is a typical CFC. Use this molecule as an example and explain the significance of CFCs in the stratosphere. Include relevant equations.

_____

_____

_____

_____

                                                              [2 marks]

(d)   It has been estimated that a molecule of CF_2Cl_2 persists in the atmosphere for 120 years before it is destroyed.

   (i)   Suggest a reason for the persistence of this CFC in the atmosphere in terms of its molecular features.

_____

_____

_____

_____

                                                              [2 marks]

   (ii)   Explain the impact of CF_2Cl_2 in the atmosphere on human health.

_____

_____

_____

_____

                                                              [2 marks]

                                                       Total 10 marks

9. During the 20th century, human activities have contributed to atmospheric pollution by altering the natural concentrations of oxides of nitrogen and of carbon dioxide.

   (i)   Describe with the aid of an equation how nitrogen dioxide (NO_2) is produced naturally in the atmosphere.

   _____

   _____

   _____

   _____

   [2 marks]

   (ii) Identify ONE human activity that alters the atmospheric concentration of oxides of nitrogen and explain the chemistry involved in the production of the pollutant.

   _____

   _____

   _____

   [2 marks]

   (iii) Describe, with the aid of an equation, one environmental change that occurs due to the presence of nitrogen dioxide as a pollutant in the atmosphere.

   _____

   _____

   _____

   _____

   [3 marks]

   (iv) Recent newspaper reports indicate that it is no longer possible to complete a surface crossing of the Arctic Ocean from Alaska through the North Pole to Norway because there is insufficient ice. Suggest an explanation for this phenomenon.

   _____

   _____

   _____

   _____

   [3 marks]

   Total 10 marks

   END OF TEST