ADVANCED LEVEL NATIONAL EXAMINATIONS, 2017

SUBJECT: CHEMISTRY

PAPER II: THEORY

COMBINATIONS: - BIOLOGY-CHEMISTRY-GEOGRAPHY (BCG)
- MATHEMATICS-CHEMISTRY-BIOLOGY (MCB)
- PHYSICS-CHEMISTRY-BIOLOGY (PCB)
- PHYSICS-CHEMISTRY-MATHEMATICS (PCM)

DURATION: 3 HOURS

INSTRUCTIONS:

1. Write your names and index number on the answer booklet as written on your registration form, and **DO NOT** write your names and index number on additional answer sheets of paper if provided.

2. Do not open this question paper until you are told to do so.

3. This paper consists of two sections: A and B.

   **Section A:** Attempt **all** questions. (70 marks)

   **Section B:** Attempt any **three** questions. (30 marks)

4. **A sample of the Periodic Table is provided on page 8.**

5. Silent non-programmable calculator may be used.

6. Use a **blue** or **black** pen.
SECTION A: Attempt all questions. (70 marks)

1) (a) Describe the term "covalent bond". (2 marks)

(b) Draw diagrams to show the shapes of the following molecules and in each case state the name of the shape. (3 marks)
(i) BeCl₂
(ii) BF₃
(iii) SF₆.
(Atomic number: Be=4, Cl=17, B=5, F=9, S=16)

2) Explain the following observations:

(a) In group 1A of the periodic table, metallic character increases as you move down the group. (2 marks)

(b) The shape of CO₂ (carbon dioxide) is linear whereas that of water (H₂O) is bent (V-shaped). (4 marks)

3) (a) Complete this radioactive series:

\[
\begin{align*}
\frac{223}{88} \text{Ra} & \xrightarrow{\alpha} \frac{209}{86} \text{Rn} \xrightarrow{\alpha} \frac{205}{84} \text{Po} \xrightarrow{\beta^-} \frac{203}{82} \text{Pb} \xrightarrow{\alpha} \frac{201}{80} \text{Tl} \xrightarrow{\beta^-} \frac{200}{82} \text{Pb}
\end{align*}
\] (3 marks)

(b) A stable nuclide absorbs a neutron, emits an electron, and then splits into two α particles. Identify the nuclide. (3 marks)

(c) (i) One can produce sodium-24 by exposing stable sodium \( \frac{23}{11} \text{Na} \) to a flux of neutrons. Write down the formation reaction of sodium-24. (1 mark)

(ii) Sodium-24 is radioactive by emission of \( \beta^- \) and its half-life is 15 hours. Write down the equation for the decay of sodium-24. (1 mark)

(iii) One injects into the blood of an individual 10cm³ of a solution initially containing sodium-24 with a concentration of \( 10^{-3}\text{mol.l}^{-1} \). What is the number of moles of sodium-24 that have been injected into the blood? How much of it will remain after 6 hours? (2 marks)

4) Zinc oxide, ZnO is amphoteric. It dissolves in alkali to give the ion Zn(OH)₂⁻.

(a) Write the ionic equation for the reaction between ZnO and sodium hydroxide in water. (2 marks)

(b) Write the equation of reaction of ZnO with hydrogen ions. (2 marks)
5) (a) When Mn(OH)₂ is made by adding an alkali to a solution containing Mn²⁺ ions, the white precipitate formed quickly turns to brown and eventually goes black in an open test tube. Write the chemical formula of the compound that forms:

(i) Brown precipitate. (1 mark)

(ii) Black precipitate. (1 mark)

(b) Write a chemical reagent that you would use to distinguish between Mg²⁺ and Zn²⁺ ions in solution indicating the observable change and a chemical equation for a positive test if possible in any case. (3 marks)

6) Nitrogen monoxide (NO) can be converted to nitrogen dioxide (NO₂) gas when nitric acid is to be manufactured:

\[
2 \text{NO}(g) + \text{O}_2(g) \rightarrow 2 \text{NO}_2(g) \quad \Delta H = -114 \text{ KJ mol}^{-1}
\]

(a) State the colour of NO₂ gas. (1 mark)

(b) State and explain the effect of reducing pressure of the reacting mixture to the position of equilibrium. (2 marks)

7) Acetone and ethyl acetate are organic liquids that form an ideal mixture and are used as solvents. At 30°C, the vapour pressure of pure acetone is 285 mmHg and the vapour pressure of pure ethyl acetate is 118 mmHg. Calculate the total vapour pressure at 30°C of a solution prepared by dissolving 25.0 g of acetone and 225 g of ethyl acetate. (Molar mass: Acetone = 58.0 g mol⁻¹, ethyl acetate = 88 g mol⁻¹) (5 marks)

8) (a) There are various factors that affect the speed of migration of ions in solution during electrolysis. Mention 3 of those factors. (3 marks)

(b) Explain the reason why lithium ion, Li⁺ moves through a solution less rapidly than other cations such as Na⁺ during electrolysis, despite the fact that it (Li⁺) is far smaller than other metal ions. (2 marks)

9) An organic compound of 5.0 g by mass is dissolved in 100 g of benzene. The boiling point of this solution is 82.42 °C. The boiling point of pure benzene is 80.10 °C; Calculate the molar mass of the organic compound. (Ebullioscopic constant, \(K_b = 2.53 \text{ °C/m and } m=\text{mol Kg}^{-1}\)) (4 marks)
10) Write chemical equations of reaction (structural formulae) of the organic compounds given below and the products formed.

(a) 2-Pentene + ozone $\rightarrow$ (2marks)

(b) 2-Methyl 3-hexene + MnO$_4^-$ $\rightarrow_{Water}$ (2marks)

11) By giving appropriate reagents to be used in different equations of the steps of synthesis, write equations of reaction that enable the synthesis of methyl amine (CH$_3$NH$_2$) from chloroethane (CH$_3$CH$_2$Cl).

12) (a) Draw the structural formulae and write the IUPAC names (scientific names) of the products resulting from the reaction of lithium aluminium hydride and the following compounds:
   (i) Ethanal. (2marks)
   (ii) 2-pentanone. (2marks)

(b) Write the structural formulae of compounds obtained by the reaction of 3-butane and iodine in the presence of sodium hydroxide. (2marks)

13) (a) Octane can be cracked and converted into pentane and substance B (hydrocarbon).
   Give the name of substance B. (1mark)

(b) To improve octane's ability to behave as a good fuel, it undergoes catalytic reforming to obtain a branched isomer C.
   Draw the structure of isomer C and give its IUPAC name. (2marks)

14) The dissociation constant of ammonia is $1.8 \times 10^{-5}$.
    Calculate the pH of a 0.2 mole/litre solution of ammonia.
    $\text{NH}_3 + \text{H}_2\text{O} \leftrightharpoons \text{NH}_4^+ + \text{OH}^-$
    (NH$_3$ is a weak base). (3marks)

15) Diethyl ether (ethoxyethane) is an organic compound, (CH$_3$CH$_2$O)$_2$;
    (a) Write an equation of reaction including structural formula of Reactants to produce ethoxyethane. (2marks)

(b) Mention 2 uses of ethoxyethane. (2marks)
SECTIOm B: Attempt only three questions. (30 marks)

16) (a) Ammonia is manufactured by Haber-Bosch process. Explain how nitrogen to be used in this process is obtained on a large scale. (2 marks)

(b) The manufacture of ammonia requires N₂ and H₂ gases.

Production of hydrogen gas (H₂) requires a two stage process, primary and secondary reforming in which a mixture of hydrocarbons (naphtha) is passed in steam over a nickel catalyst.

**Primary stage**

\[ \text{CH}_4(g) + \text{H}_2\text{O}(g) \rightleftharpoons \text{CO}(g) + 3 \text{H}_2(g) \quad \Delta H = \text{positive} \]

**Secondary stage**:

\[ \text{CO}(g) + \text{H}_2\text{O}(g) \rightleftharpoons \text{CO}_2(g) + \text{H}_2(g) \quad \Delta H = \text{positive} \]

(i) Briefly state a chemical substance that can be used to remove CO₂ gas from the by-products of the reaction. (1 mark)

(ii) Explain the necessity of the use of nickel catalyst. (1 mark)

(iii) If 60 dm³ of CH₄ gas were made to react completely with 60 dm³ of H₂O gas; calculate the volume of H₂ gas produced in the primary stage. (2 marks)

(iv) State and explain the effect of reducing pressure to the position of equilibrium in the primary stage reaction. (2 marks)

(c) Ammonia is used to produce nitric acid; this requires the reaction between NH₃ and O₂ to produce NO gas.

Write a balanced chemical equation of reaction between NH₃ and O₂ to get NO gas. (2 marks)

17) (a) Given the following molar conductivities at infinite dilution \( \Lambda^\infty \):

NaCl=126.4, NaOH=248.4, NH₄Cl=149.8, Na⁺=50.1, OH⁻=198.3, Cl⁻=76.3.

(Units of molar conductivity at infinite dilution (\( \Lambda^\infty \)) are: S cm² mol⁻¹).

Calculate the molar conductivity of NH₄OH at infinite dilution. (3 marks)
(b) An experiment shows that for a strong electrolyte, a graph of molar conductivity \( \Lambda \) against \( \sqrt{\text{concentration}} \) (i.e. \( \sqrt{c} \)) is a straight line provided the concentration is not too large.

(i) Plot a sketch graph of molar conductivity against \( \sqrt{\text{concentration}} \) using the results of sodium hydroxide solution below.

<table>
<thead>
<tr>
<th>C/NaOH (mol dm(^{-3}))</th>
<th>0.01</th>
<th>0.04</th>
<th>0.09</th>
<th>0.16</th>
<th>0.25</th>
<th>0.36</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Lambda ) (S cm(^2)mol(^{-1}))</td>
<td>238</td>
<td>230</td>
<td>224</td>
<td>217</td>
<td>210</td>
<td>202</td>
</tr>
</tbody>
</table>

(ii) Show the point where molar conductivity corresponds to infinite dilution (\( \Lambda^\infty \)).

(iii) Explain the meaning of the term "Ionic interference" of strong electrolytes such as aqueous NaOH solution.

18) (a) When phosphorous (P) burns in air, it reacts with oxygen to produce an oxide.

(i) Write a chemical equation for the reaction of phosphorous with oxygen.

(ii) Write a chemical equation for the reaction of the resultant phosphorous oxide and water.

(b) Phosphorous pentachloride (PCl\(_5\)) can react with water (H\(_2\)O) to give products.

(i) Write the chemical equation of the reaction between phosphorous pentachloride (PCl\(_5\)) and water.

(ii) Deduce the oxidation state of phosphorous atom in phosphorous pentachloride (PCl\(_5\)) molecule.

(iii) Calcium phosphate Ca\(_3\)(PO\(_4\))\(_2\) reacts with sulphuric acid (H\(_2\)SO\(_4\)), write the equation of reaction that occurs between these two substances.

(iv) Mention one use of calcium dihydrogenophosphate.
19) (a) Write equations (successively) of reaction using structural formulae and appropriate reagents required for the conversion of benzoic acid to 3-amino methyl benzene. (4marks)

![Structural formula](image)

(b) Write the mechanism of reaction between propanoyl chloride, 
\((C_3H_5OCl)\) and ammonia \((NH_3)\). (3marks)

(c) Write the structural formula of the following amino acids:
   (i) Glutamine.
   (ii) Arginine.
   (iii) Methionine. (3marks)

20) Nitrogen monoxide gas \((NO)\) was allowed to react with hydrogen gas \((H_2)\) in a 1 litre container according to the equation:

\[
2NO(g) + 2H_2(g) \rightleftharpoons N_2(g) + 2H_2O(g)
\]

Initially before the reaction started; the concentration of each gas was:
\(NO(g) = 0.10\) mole/litre, \(H_2(g) = 0.050\) mole/litre, \(H_2O(g) = 0.10\) mole/litre, \(N_2(g) = 0.00\) mole/litre.

When the reaction reached equilibrium, the concentration of NO gas was equal to 0.062 mole/litre.

(a) Write the mathematical expression of equilibrium constant, \(Kc\). (1mark)

(b) Calculate the equilibrium constant, \(Kc\). (4marks)

(c) Determine the mathematical expression of equilibrium constant, \(Kp\) in relation to the equilibrium constant \(Kc\). (2marks)

(d) Calculate \(Kp\), by using the value of \(Kc\) (in 20.b) above.
   \((R = 0.082 \, \text{I.atm.K}^{-1}\text{mol}^{-1}, \text{temperature} \, K = 298 \, \text{Kelvin})\) (3marks)