ADVANCED LEVEL NATIONAL EXAMINATIONS, 2018

SUBJECT: CHEMISTRY II

PAPER II: THEORY CHEMISTRY

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

DURATION: 3 HOURS

INSTRUCTIONS:

1. Write your name 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. You do not need the periodic table.

5. Silent non-programmable calculators may be used.

6. Use a blue or black pen for answering and a pencil for drawing.
SECTION A: ATTEMPT ALL QUESTIONS (70Marks)

1) The atomic number of aluminium and oxygen are 13 and 8 respectively.
   (a) Write the electronic configuration of aluminium and that of oxygen (in terms of s,p,d and f notation). (2marks)
   (b) Write the chemical formula of the compound formed by the reaction between aluminium and oxygen. (2marks)

2) Explain the following observations:
   (a) Atomic radii of period 3 elements decrease from left to right in the period (from Na=11 to Ar=18). (2marks)
   (b) The thermal decomposition of group II nitrates Mg(NO₃)₂, Ca(NO₃)₂, Sr(NO₃)₂, Ba(NO₃)₂ increases down the group. (2marks)
   (c) CCl₄ does not hydrolyse in water whereas SiCl₄ hydrolys in water to produce SiO₂ and HCl. (2marks)
      (Carbon and silicon are in group IV of the periodic table). (Atomic number C=6, Si=14).

3) The table below contains data relating to the relative isotopic abundance of titanium element.

<table>
<thead>
<tr>
<th>Isotope</th>
<th>⁴⁶Ti</th>
<th>⁴⁷Ti</th>
<th>⁴⁸Ti</th>
<th>⁴⁹Ti</th>
<th>⁵⁰Ti</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Abundance</td>
<td>8.02</td>
<td>7.31</td>
<td>73.81</td>
<td>5.54</td>
<td>5.32</td>
</tr>
</tbody>
</table>

   (a) Describe the term "isotopic abundance". (2marks)
   (b) Using the data from the above table, calculate the relative atomic mass of titanium. (2marks)

4) (a) Describe the term "metallic bond" by giving an example. (2 marks)
   (b) Explain how bonding and structure lead to the typical metallic properties of electrical conductivity and malleability of some elements. (2marks)
(c) Suggest the reason why aluminium is a better conductor of electricity than magnesium.

(Atomic number: Al=13, Mg=12)  

(1 mark)

5) a) Describe "Hund's rule" about the order of filling electrons in orbitals of the same sub-energy level in an atom.  

(b) Describe 2 postulates that were suggested by "Niels Bohr" on the concept of electron energy levels in a hydrogen atom.  

(2 marks)

(2 marks)

6) Boron and aluminium are elements of group IIIa.

(a) Draw a sketch diagram of the structure of Al₂Cl₆ and that of BCl₃ molecules.  

(b) Explain the reason why BCl₃ has adopted this shape.  

(c) Write a balanced equation of the reaction of boron with concentrated nitric acid.  

(2 marks)

(2 marks)

(2 marks)

7) Write a balanced equation for the reaction between:

(a) Aluminium oxide, Al₂O₃ and sodium hydroxide, NaOH in water, H₂O.  

(b) Aluminium oxide, Al₂O₃ and dilute hydrochloric acid, HCl.  

(2 marks)

(2 marks)

8) An electric current of 2.5 amperes is passed through a solution of copper sulphate, CuSO₄ for 150 minutes.

(a) Calculate the mass of copper that is deposited (in g).  

(b) Calculate the volume of oxygen gas liberated at the anode at room temperature and pressure.  

(1 mole of a gas occupies 24 dm³ at room temperature and pressure, 1 Faraday = 96500 C/mol, molar mass of copper = 63.5 g/mol).

Equations:

Anode: 4OH⁻[aq] → 2H₂O(l) + O₂(g) + 4e⁻  

Cathode: Cu²⁺[aq] + 2e⁻ → Cu₁[s]
9) Study the labeled diagram of benzene derivatives shown below and answer the questions that follow:

\[ \text{CH}_3 \quad \xrightarrow{\text{S}} \quad \text{COOH} \quad \xrightarrow{\text{X}} \quad \text{S} + \text{Y} \]

\[ \text{HNO}_3(\text{conc.})/\text{H}_2\text{SO}_4(\text{conc.}) \]

(a) Write the chemical formula of substance S and X which are required in the respective transformation reactions. \( \text{(2 marks)} \)

(b) Draw the molecular structure of organic substance T. \( \text{(1 mark)} \)

(c) Write the chemical formula of substance Y. \( \text{(1 mark)} \)

10) The solubility product (Ksp) of PbCrO₄ in water is \( 1.8 \times 10^{-14} \) at 25 \(^\circ\)C.

(a) Calculate the solubility of PbCrO₄ in mol dm\(^{-3}\) in water at 25 \(^\circ\)C. \( \text{(2 marks)} \)

(b) Determine the solubility of PbCrO₄ in 1 litre of a 0.0002 mol dm\(^{-3}\) solution of Na₂CrO₄.

Equation: \( \text{PbCrO}_4(\text{s}) \rightleftharpoons \text{Pb}^{2+}(\text{aq}) + \text{CrO}_4^{2-}(\text{aq}) \)

(\( \text{Na}_2\text{CrO}_4 \) dissolves completely in water) \( \text{(2 marks)} \)

11) Consider the galvanic cell shown below:

Equations: \( \text{Cr}^{3+}(\text{aq}) + 3e^- \rightarrow \text{Cr}(s) \quad E^0 = -0.73 \text{ V} \)

\( \text{Br}_2(\text{aq}) + 2e^- \rightarrow 2\text{Br}^- (\text{aq}) \quad E^0 = +1.09 \text{ V} \)

(a) Indicate the direction of electrons in the external circuit. \( \text{(2 marks)} \)

(b) Calculate the standard e.m.f of the cell. \( \text{(2 marks)} \)
(c) Describe the observable colour change in the bromine solution as the reaction proceeds. (2 marks)

12) Consider the hydrides of halogens of HF, HCl, HBr and HI.
   (a) Explain the reason why HI is a stronger acid than HBr. (2 marks)
   (b) Write the equation for the reaction between Cl₂ and hot concentrated NaOH. (2 marks)
   (c) Explain the reason why HF has a higher boiling point than HCl, HBr and HI despite its lower molecular mass than these hydrides. (2 marks)

13) A buffer solution contains 0.25 mol dm⁻³ propanoic acid and 0.4 mol dm⁻³ sodium propanoate.
   (a) Describe briefly how a buffer solution functions to maintain the pH of the solution constant. (2 marks)
   (b) Calculate the pH of the buffer solution given above.
      (Ka of propanoic acid = 1.35 X 10⁻⁵ mol dm⁻³) (2 marks)
   (c) State 1 application of buffer solutions in nature. (1 mark)

14) (a) State a reagent and conditions that can be used to detect the presence of Ag⁺ ions in a solution and describe the observable colour change for a positive test. (2 marks)
   (b) State a reagent that can be used to distinguish between Mg²⁺ ions and Ca²⁺ ions and mention noticeable observable differences of the tests. (2 marks)

15) Lead has a melting point of 327.5 °C, its specific heat capacity is 0.128 J/g °C and its molar enthalpy of fusion is 4.80 KJ mol⁻¹. Calculate the heat (in kilojoules) that will be required to heat a 600g sample of solid lead from 25 °C to its melting point and then melt it. (4 marks)

(Molar mass: Pb = 207 gmol⁻¹)
SECTION B : ATTEMPT ANY THREE QUESTIONS (30Marks)

16) The initial rate of reaction between substance P and Q was measured in a series of experiments and the following rate equation was deduced:
\[ \text{Rate} = K[P]^2[Q]^1 \]

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Initial [P] (mol dm(^{-3}))</th>
<th>Initial [Q] (mol dm(^{-3}))</th>
<th>Initial rate (mol dm(^{-3}) S(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.20</td>
<td>0.30</td>
<td>4.8 X 10(^{-3})</td>
</tr>
<tr>
<td>2</td>
<td>0.10</td>
<td>0.10</td>
<td>(X)</td>
</tr>
<tr>
<td>3</td>
<td>0.40</td>
<td>(Y)</td>
<td>9.6 X 10(^{-3})</td>
</tr>
<tr>
<td>4</td>
<td>(Z)</td>
<td>0.60</td>
<td>19.2 X 10(^{-3})</td>
</tr>
</tbody>
</table>

(a) Using the data from the above table, calculate the value of the rate constant \(K\), and deduce its units. \(\text{[3marks]}\)

(b) Find the value of \(X\), \(Y\) and \(Z\) in the table. \(\text{[6marks]}\)

(c) Indicate a change in the reaction conditions that would cause the value of the rate constant to change. \(\text{[1mark]}\)

17) Consider the molecular structure of organic compound T given below and answer the questions that follow:

\[
\begin{array}{c}
\text{Br} \\
\text{H–C–C}_2\text{H}_5 \\
\text{CH}_3
\end{array}
\]

(a) Write the IUPAC name of organic compound T. \(\text{[1mark]}\)

(b) Organic compound T presents optical isomerism,

(i) Draw the molecular structure of the two optical isomers that are mirror images of each other. \(\text{[2marks]}\)

(ii) Show which form of the two isomers that is laevo rotatory and that which is dextro rotatory. \(\text{[2marks]}\)

(c) Organic compound T can react with NaCN in a substitution reaction to form X, then \(\text{H}_2\) is added in the presence of Ni to give organic compound Y. Write the molecular structure of X and Y. \(\text{[2marks]}\)

(d) Organic compound T is made to react with NaOH to give alcohol Z.

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Give a test reagent used to determine whether Z is a primary, secondary or tertiary alcohol and describe the observable changes. (3 marks)

18) Below is a diagram of a blast furnace used to extract iron from its ores, Fe₂O₃.

![Blast furnace diagram]

Blast furnace

(a) Write the equation for the reaction between Fe₂O₃ and CO gas. (2 marks)

(b) State 2 uses of iron metal on a large scale. (2 marks)

(c) Indicate 2 ways of preparing iron objects to prevent rusting. (2 marks)

(d) State the importance of slag in the blast furnace.

(Slag is a mixture of CaSiO₃ and CaCO₃) (1 mark)

(e) Stainless steel is an alloy of iron.

State a name of an element that is mixed with iron to make stainless steel. (1 mark)

(f) Describe 1 physical and 1 chemical means (using an instrument or a reagent) that is used to detect and identify iron element. (2 marks)
19) A mass of 0.3 g of a divalent metal, M was put in 20 ml of a 2 mole dm\(^{-3}\) HCl acid in a beaker to react. The unreacted HCl in the resultant solution was titrated with 30 ml of a 0.5 mole dm\(^{-3}\) NaOH solution to neutralise excess HCl.

(a) Calculate the number of moles of NaOH that reacted with HCl during titration. (2 marks)

(b) Determine the number of moles of HCl that reacted with NaOH. (1 mark)

(c) Calculate the number of moles of HCl in 20 ml of a 2 mole dm\(^{-3}\) HCl (2 marks)

(d) Calculate the number of moles of HCl that reacted with the metal M. (2 marks)

(e) Calculate the number of moles of the divalent metal M that reacted with HCl. (1 mark)

(f) Determine the atomic mass of metal M. (2 marks)

Equations:

\[
M(s) + 2\text{HCl}(aq) \rightarrow \text{MCl}_2(aq) + \text{H}_2(g)
\]

\[
\text{HCl}(aq) + \text{NaOH}(aq) \rightarrow \text{H}_2\text{O}(l) + \text{NaCl}(aq)
\]

20) Consider the complex compound \([\text{Co(NH}_3)_6]\text{Cl}_3\)

(a) Deduce the oxidation state of cobalt in this compound. (2 marks)

(b) Chloride ions form the tetrahedral complex ion \([\text{AlCl}_4]^–\) but fluoride ions form the octahedral complex ion \([\text{AlF}_6]^{3–}\). Suggest a reason for this difference. (2 marks)

(c) Write 2 factors that determine the formation of ligand bonds in transition metals. (2 marks)

(d) Suggest the reason why zinc does not form coloured compounds. (2 marks)

(e) State 4 characteristics of transition metals. (2 marks)