UNIVERSITY OF RUHUNA

BACHELOR OF SCIENCE GENERAL DEGREE LEVEL-I (SEMESTER-I) EXAMINATIONS – JUNE 2023

SUBJECT: Chemistry **TIME**: Two (**02**) hours

COURSE UNIT: CHE1112 General Chemistry and Basic Concepts in Analytical Chemistry

---

Instructions:

- *A Periodic Table is provided on the last page.*
- *Use of calculators* ***is allowed****.*
- *Answer* ***FOUR*** *questions only by selecting* ***two*** *questions from the Sections* ***A*** *and* ***B****.*

Section A

01. Answer **all** parts.

(a) " One of the important consequences of the **dual nature of an electron** is **the uncertainty principle**, developed by Warner Heisenberg"

(i) What is the dual nature of an electron and uncertainty principle?

(ii) Give two mathematical equations, which explain dual nature of electron and uncertainty principle. Clearly define the terms of those equations.

(20 marks)

(b) Give the ground-state electron configurations of following atom/ions in detail and also in Nobel gas notation.

(i) Fe^{2+}

(ii) S^{2-}

(iii) Cu

(iv) As (12 marks)

(c) Calculate the longest and shortest wavelengths possible for the Lyman series of hydrogen atom emission spectrum. Does any wavelength of the Lyman series lie in the visible region?

Note: the wavelength λ can be given by the following equation

$$\frac{1}{\lambda} = \Re\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

where, $\Re$- Rydberg constant, whose value $\Re = 1.097 \times 10^7 m^{-1}$ and n_i and n_f initial and final energy levels, respectively. (30 marks)

(d) (i) Provide orbital notation for electrons in orbitals defined by the following quantum numbers:

(I) $n = 2, l = 1, m_l = 1$

(II) $n = 4, l = 3, m_l = -2$

(III) $n = 3, l = 2, m_l = 0$

(15 mark

(ii) The wave functions of three different orbitals of hydrogen atom, named as **A**, **B** and **C** are given below

A $\Psi_A = \left(\frac{1}{4\sqrt{4\pi}}\right)\left(\frac{1}{a_0}\right)^{\frac{2}{3}}\left(2 - \frac{r}{a_0}\right)e^{\frac{-r}{a_0}}$

B $\Psi_B = \left(\frac{1}{\sqrt{32\pi}}\right)\left(\frac{1}{a_0}\right)^{\frac{2}{3}}\left(\frac{r}{a_0}\right)e^{\frac{-r}{2a_0}}cos(\theta)$

C $\Psi_C = \left(\frac{1}{81\sqrt{6\pi}}\right)\left(\frac{1}{a_0}\right)^{\frac{2}{3}}\left(\frac{r}{a_0}\right)^2 e^{\frac{-r}{3a_0}}(3cos^2(\theta) - 1)$

Magnetic quantum number for all three orbitals are zero. Possible principle quantum numbers of **A**, **B** and **C** are 2 and 3 only. Azimuthal quantum numbers for each orbitals are different. There are two more wave functions for **B** with degenerated energy and four more wave functions for **C** with degenerated energy.

When $r = 2a_0$, $\Psi_A = 0$ for **A**, but Ψ_B and Ψ_C will not be zero for any r values.

(I) Identify the orbitals **A**, **B** and **C**.

(II) Sketch radial distribution probability function of **A**, **B** and **C** in a one diagram.

(III) Sketch the angular shape of the orbitals **A**, **B** and **C**.

(23 marks)

02. Answer **all** parts.

(a) (i) What do you mean by effective nuclear charge?

(ii) Calculate effective nuclear charge for a 3d electron and for a 4s electron.

(iii) Comment the stability of 4s and 3d electron of Sc based on answer a(ii)

(30 marks)

(b) Deduce the hybridization of the central atom in the following molecules/ions and based on that predict the geometries of the them.

(i) SO_3 (ii) $HgCl_2$

(iii) NH_4^+ (iv) SF_4

(v) PF_6^-

(30 marks)

(c) There are four molecular shapes for trigonal bipyramidal electron-group arrangement. Explain the above statement by drawing the four molecular shapes and giving one example for each shape.

(20 marks)

(d) Explain the bond order and magnetic property of the molecule NO based on molecular orbital theory. You may use MO diagram or electron configuration of the molecule.

(20 marks)

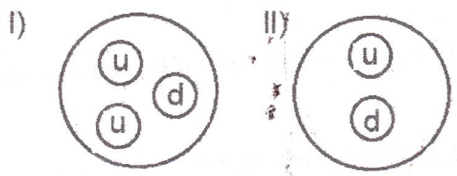
03. Answer **all** parts.

(a) The nucleus of an atom is made of quarks.

(i) What are the six quarks flavors?

(ii) Briefly explain the structure of a nucleus highlighting particles and forces present in it.

(iii) Figures I and II show structures of two particles.



(I) Of the above (I) and (II), which one is a baryon? Justify your answer.

(II) Calculate the total charge of each of the above (I) and (II).

(25 marks)

(b) The integrated rate law of radioactive decay can be expressed as follows.

$ln\frac{[N_0]}{[N_t]} = kt$ where, N – number of particles or activity, k - decay constant, t - time

(i) Show that the half-life of a radioactive matter $(t_{1/2})$ can be expressed as $t_{1/2} = \frac{0.693}{k}$.

(ii) ^{14}C was found to be undergoing 97% radioactive decay in 28,000 years. Calculate the half-life of ^{14}C.

(35 marks)

(c) Nuclear fission reaction of $^{235}_{92}U$ and nuclear fusion reaction of $^{2}_{1}H$ and $^{3}_{1}H$ are given below.

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + \text{neutrons} + \text{Energy}$$

$$^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + \text{neutrons} + \text{Energy}$$

(i) Using above two equations, briefly explain what is meant by nuclear fission and fusion reactions.

(ii) Find the number of neutrons released in each reaction.

(iii) Calculate the energy released in MeV per a nucleon, if 0.1900 a.m.u are converted to energy for every nucleus of $^{235}_{92}U$.

(iv) Calculate the energy released in MeV per nucleon of deuterium in the second reaction, if the masses of $^{2}_{1}H$, $^{3}_{1}H$, $^{4}_{2}He$ and a neutron are 2.0141, 3.0161, 4.0026 and 1.0087 a.m.u., respectively.

(v) Compare the energies released from above two reactions. (40 marks)

(**Note:** Atomic mass unit, *amu* = 1.661 x 10^{-27} kg, Velocity of light, c = 2.997 x 10^{8} m s^{-1}, 1 eV = 1.6022 x 10^{-19} J and Avogadro number, N_A = 6.022 x 10^{23} mol^{-1})

Section B

04. Answer **all** parts.

(a) Explain briefly the following terms used in volumetric analysis.

(i) Primary standards

(ii) Equivalence point

(iii) End point (30 marks)

(b) A student has performed a titration of a 50.00 mL of 0.1000 *mol* dm^{-3} $NaHCO_3$ with 0.1000 *mol* dm^{-3} HCl.

(i) Draw a suitable titration curve for this titration.

(ii) Select the most appropriate indicator that can be used for this titration from the three indicators; Methyl orange (pK_{In} = 3.46), Bromothymol blue (pK_{In} = 7.51) and Phenolphthalein (pK_{In} = 9.10). Give reasons for your choice.

(iii) Calculate the pH of the solution after adding 30.00 mL of 0.1000 *mol* dm^{-3} HCl. (*Note: K_a for $H_2CO_3/NaHCO_3$ is 4.26 x 10^{-7}. Consider that the amount of dissociation of H_2CO_3 is negligible*)

(35 marks)

(c) A 1.2175 g sample of commercial KOH contaminated with K_2CO_3 and other impurities was dissolved in distilled water and diluted to a volume of 500.0 mL. This solution was labeled as **K**. A 50.00 mL of **K** was treated with 40.00 mL of 0.0535 *mol* dm^{-3} HCl and boiled the solution to remove CO_2. To titrate the excess acid, it was required 4.80 mL of 0.0500 *mol* dm^{-3} NaOH with phenolphthalein indicator. Another 50.00 mL portion of solution **K** was treated with an excess amount of neutral $BaCl_2$ to precipitate the carbonate as $BaCO_3$. The solution was then titrated with 0.0535 *mol* dm^{-3} HCl and it required 28.50 mL to reach the phenolphthalein end point.

Using the above data, calculate the percentages of KOH and K_2CO_3 in the sample.

Assume that none of the other impurities are basic and only K_2CO_3 reacts with $BaCl_2$ in the sample and the molecular weights of KOH and K_2CO_3 are 56.11 and 138.21 g/mol, respectively.

(35 marks)

15. Answer **all** parts.

The reliability of a chemical analysis depends on several factors which include accurate measurement, reporting the measured values correctly, and performing the calculations retaining the proper number of significant figures. Three identical cubes were provided to three students (**A**, **B**, and **C**), and asked to measure the length (L), width (W), and depth (D) of the cubes using a ruler of their choice. The measurements made by the three students are reported in the table below with the measured units. The numbers given in *italics* in the last three rows are the computed values using a calculator.

Measurement	**Unit**	**Student A**	**Student B**	**Student C**
Length (L)	cm	5.243	5.2	5.24
Width (W)	cm	3.429	3.4	3.43
Depth (D)	cm	1.208	1.2	1.21
		Computed values from a calculator		
(L + W + D)	p	*9.88*	*9.8*	*9.88*
(L x W x D)	q	*21.71772238*	*21.216*	*21.747572*
{(W + D) /L}	r	*0.884417318*	*0.884615385*	*0.885496183*

Answer the following considering the data given in the above table.

(a) Assume that each of the students has used the same ruler for all three measurements of L, W, and D and reported the measurements with the correct number of significant figures.

(i) Comment on the calibrations of the rulers used by students **A**, **B**, and **C**.

(ii) Write **expressions for relative uncertainties** for measurement L by students **A**, **B**, and **C**.

(15 marks)

(b) Copy the below table to your answer script and answer the following parts.

Measurement	**Unit**	**Student A**	**Student B**	**Student C**
(L + W + D)	p			
(L x W x D)	q			
{(W + D) /L}	r			

(i) Replace p, q, and r in the table with the appropriate units.

(ii) Write the correct calculated figures in the table. (35 marks)

(c) Write **expressions for uncertainties** for (L + W + D) and (L x W x D) for student **A**.

(20 marks)

(d) Using the scientific notation, express the measured value of L by student **C**,

(i) in meters

(ii) in nanometres

(10 mark

(e) The ppm levels of Cr in a water body were measured for 9 samples. The sum of the 9 measurem (Σx_i) is 0.72 and the sum of the squares of the measurements (Σx_i^2) is 0.058. Calculate the mea standard deviation, and coefficient of variation for the measurements. The following equation ma help you to do the calculation.

$$s = \sqrt{\frac{n\Sigma(x_i^2) - (\Sigma x_i)^2}{n(n-1)}}$$

(20 marks)

06. Answer **all** parts.

(a) EDTA is a widely used titrant in complexometric titrations.

(i) Draw the chemical structure of EDTA.

(ii) Why EDTA is widely used as the titrant in the analysis of metal ion solutions?

(iii) What are the five types of titration methods employed in EDTA titrations?

(30 marks)

(b) EBT is the common indicator used in EDTA titrations.

(i) Give the chemical reactions involved in the titration of Zn^{2+} with EDTA (H_2Y^{2-}) using the EBT (HIn^{2-}) as the indicator. (*Use the standard notations given in the brackets*)

(ii) Assume that you have carried out a back titration to determine the concentration of Ni^{2+} with EDTA using the second metal ion as Zn^{2+}. The indicator used was EBT. Comments on the stabilities of the metal-EDTA complexes and metal-EBT complex that you would expect to form in this titration.

(iii) In the above titration, if 25.00 mL of 0.0500 *mol* dm^{-3} EDTA was added to 25.00 mL Ni^{2+} solution. To titrate the excess EDTA, it was required 12.50 mL of 0.0200 *mol* dm^{-3} Zn^{2+} solution with the EBT as the indicator. Calculate the concentration of Ni^{2+} in the solution.

(50 marks)

(c) Briefly describe the Volhard method used in argentometric titrations. Give chemical equations wherever necessary. (20 marks)

@@@@@@@@@@@@@

Periodic Table of the Elements

Atomic Number → 1, H ← Symbol; Name → Hydrogen, 1.008 ← Atomic Weight

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	57 - 71 Lanthanoids	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	89 - 103 Actinoids	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr