

UNIVERSITY OF RUHUNA
BACHELOR OF SCIENCE GENERAL DEGREE LEVEL-I (SEMESTER-I)
EXAMINATIONS - NOVEMBER/DECEMBER 2020

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.
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Physical constants

Atomic mass unit, amu	=	$1.661 \times 10^{-27} \text{ kg}$
Avogadro number, N_A	=	$6.022 \times 10^{23} \text{ mol}^{-1}$
Boltzmann constant, k	=	$1.381 \times 10^{-23} \text{ J K}^{-1}$
Electron charge, e	=	$1.602 \times 10^{-19} \text{ C}$
Electron mass, m_e	=	$9.10 \times 10^{-31} \text{ kg}$
Faraday constant, F	=	$9.6485 \times 10^4 \text{ C mol}^{-1}$
Planck's constant, h	=	$6.626 \times 10^{-34} \text{ J s}$
Proton mass, m_p	=	$1.673 \times 10^{-27} \text{ kg}$
Universal gas constant, R	=	$8.314 \text{ J K}^{-1} \text{ mol}^{-1}$
	=	$0.0802 \text{ dm}^3 \text{ atm K}^{-1} \text{ mol}^{-1}$
Vacuum permittivity, ϵ_0	=	$8.854 \times 10^{-12} \text{ J}^{-1} \text{ C}^2 \text{ m}^{-1}$
Velocity of light, c	=	$2.997 \times 10^8 \text{ m s}^{-1}$

Important conversion factors

$$1 \text{ atm} = 760 \text{ mmHg} = 1.01325 \text{ bar} = 101325 \text{ Pa}$$

$$2.303 (RT/F) = 59.15 \text{ mV at } 298.15 \text{ K}$$

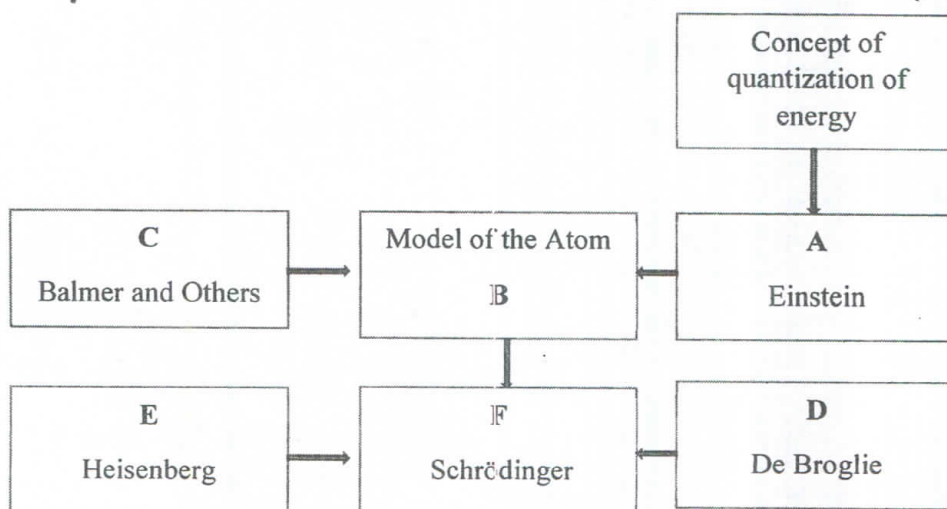
$$1 \text{ eV} = 1.6022 \times 10^{-19} \text{ J}$$

Section A

01. Answer all parts.

- (a) Since Dalton developed his ideas, scientists have made significant progress in furthering our understanding of atomic structure. The present atomic structure model is not developed by a single person. Following diagram shows historical persons/ideas responsible for the development of the modern atomic model. Complete either the missing name or theory labelled as A, B, C, D, E and F.

(05 x 6 marks)



- (b) Sodium atomic spectrum has a yellow emission line at 590 nm. What is the energy and frequency of a photon of this emitting light?

(30 marks)

- (c) What is the maximum number of electrons allowed to have the following set of quantum numbers in an atom?

- (i) $n = 4$ and $m_l = +2$
- (ii) $n = 3$ and $l = 1$
- (iii) $n = 1$ and $m_s = +1/2$

(05 x 3 marks)

- (d) Sketch the radial distribution function $P(r)$ for 2s, 2p and 3d orbitals

(15 marks)

- (e) Sketch the shapes of d_{xy} , and d_{z^2} orbitals

(10 marks)

02. Answer all parts.

(a) What is **Aufbau Principle**? (10 marks)

(b) Write down complete electron configuration of following ion and element

(i) Fe^{3+}

(ii) Cu (10 marks)

(c) (i) Clearly defining all the terms, write down the Bohr equation in terms of **Effective Nuclear Charge, Z^*** .

(10 marks)

(ii) Calculate effective nuclear charge for valence electron of oxygen atom.

(20 marks)

(d) Give the missing information **R - Z** of the following table relevant to sp^3d hybridization

hybridization	Number of orbitals combined	Resulting number of hybridized orbitals	Ideal bond angles	Geometry	Possible shapes	Number of lone pairs
sp^3d	R	S	T	V	W	0
			U		X	1
			Y		2	
			Z		3	

(30 marks)

(e) Predict the bond order and the magnetism of F_2^+ ion using its molecular orbital diagram

(20 marks)

03. Answer all parts.

(a) Deuterium (${}^2\text{H}$) is a stable isotope of hydrogen, found in natural hydrogen compounds.

(i) Briefly explain what an isotope is. (10 marks)

(ii) List all the fundamental particles present in the deuterium atom by performing a systematic breakdown. Indicate relevant names for the parts you found in this breaking down process. (15 marks)

(iii) Calculate the charge of the deuterium nucleus by using the charge of fundamental particles. (10 marks)

(iv) What is the nuclear binding energy of ${}^2\text{H}$ in MeV, if the observed mass is 2.014103 amu?

Note: Mass of a proton and a neutron are 1.007277 amu and 1.008665 amu respectively. Assume that the mass of electrons can be neglected.

(20 marks)

(v) Briefly explain the fundamental force which keeps fundamental particles together in a nucleus. (10 marks)

(b) ${}_{11}^{24}\text{Na}$ is an unstable isotope of sodium with the half-life of 15 hours.

(i) Derive an equation to show the relationship between radioactive decay constant and the half life, if the rate of the decay is given by the equation $\ln\left(\frac{N_t}{N_0}\right) = -\lambda t$.

where N_0 – Number of nuclei initially present, N_t – number of nuclei at time t and λ – decaying constant.

(20 marks)

(ii) Calculate the radioactive decay constant for ${}_{11}^{24}\text{Na}$. (15 marks)

Section B

04. Answer **all** parts.

(a) Briefly describe the following terms pertaining to analytical chemistry.

- (i) Qualitative analysis
- (ii) Quantitative analysis
- (iii) Equivalence point
- (iv) End point

(20 marks)

(b) Give two advantages and two disadvantages of titrimetric analysis compared to instrumental analysis.

(20 marks)

(c) A titration was carried out using 40.00 cm^3 of $0.1000 \text{ mol dm}^{-3}$ NH_3 solution in a titration flask with $0.1000 \text{ mol dm}^{-3}$ HCl solution.

(i) Sketch a suitable titration curve for this titration considering the pH for the y-axis and the volume of HCl for the x-axis.

(10 marks)

(ii) Indicate the buffering region of this titration (if any) in the same plot.

(10 marks)

(iii) Select the most suitable indicator to determine the end point of this titration among the three indicators phenolphthalein (8.1-10.2), methyl red (4.4-6.2), methyl orange (3.1-4.4). The indicator colour change intervals are given in the parentheses. Give reasons for your selection.

(15 marks)

(iv) If the above titration was stopped after addition of 20.00 cm^3 of $0.1000 \text{ mol dm}^{-3}$ HCl into the titration flask. Calculate the pH of the resultant solution in the flask. (consider that K_b of NH_3 as 1.75×10^{-5})

(25 marks)

05. Answer all parts.

(a) Define the following terms.

- (i) Accuracy
- (ii) Precision

(10 marks)

(b) The following results were obtained by measuring the weight of a coin four times using an analytical balance, which has a considerable uncertainty: 4.5241, 4.3456, 4.4783, and 4.5404 g. The coin itself indicated that its weight is 4.5000 g.

- (i) Calculate the mean and the standard deviation for the above data set.
- (ii) Comment on the accuracy and the precision of the data set.
- (ii) What type of error (random/systematic) is associated with the analytical balance? Give reasons to your answer.

(30 marks)

(c) Calculate the following and give the answer with correct number of significant figures.

- (i) the mass of a heterogeneous mixture containing 139.3 g sand, 34.99 g gravel, and 9.372 g salt.
- (ii) the mass of a concrete slab, which has the dimensions of 51.0 cm long, 17.34 cm deep, and 6.2 cm tall, with a density of 5.3 g/cm³.

(20 marks)

(d) The maximum contaminant level for arsenic is 0.010 ppm for drinking water per SLS regulations. The arsenic concentration for the drinking water sample of a municipality was measured to be 4.92×10^{-6} mol dm⁻³. Atomic mass of arsenic is 74.9216 g/mol.

- (i) What is the arsenic concentration of the water sample in ppm? Assume that the drinking water sample has a density of 1.0000 g/mL.
- (ii) Does this water sample meet SLS guidelines?

(20 marks)

(e) The sulfur content of an ore was determined gravimetrically by reacting the ore with concentrated nitric acid and potassium chlorate, converting all sulfur to sulfate. The excess nitrate and chlorate were removed and the sulfate was precipitated as barium sulfate (233.43 g/mol) using excess BaCl₂ solution. Analysis of a 10.1830-g ore sample yielded the 13.0221 g of BaSO₄. Atomic mass of S is 32.065 g/mol

- (i) Give the balanced chemical equations for the above precipitation reaction.
- (ii) Determine the percent of sulfur by mass in the ore

(20 marks)

06. Answer all parts.

(a) Ethylenediaminetetraacetic acid (EDTA) and Eriochrome Black T (EBT) are widely used in complexometric determination of certain metal ions.

(i) What are the advantages of using EDTA as a complexing agent?

(10 marks)

(ii) Briefly explain the chemistry behind the detection of the end point of an EDTA titration with a metal ion using EBT as the indicator. Give the relevant chemical equations whenever necessary.

(You may use common abbreviations, M^{2+} , H_2Y^{2-} and HIn^{2-} for a divalent metal ion, EDTA and EBT indicator, respectively.)

(20 marks)

(iii) Write down **three (03)** significant factors influencing EDTA titrations.

(10 marks)

(iv) Propose a suitable complexometric method to determine concentration of SO_4^{2-} ions in an aqueous solution.

(15 marks)

(b) A student was given an impure zinc salt in order to determine the percentage of Zn. He dissolved 0.7100 g of the given salt in 25.00 mL distilled water and the pH of the solution was adjusted to 10. It was titrated with $0.0160 \text{ mol dm}^{-3}$ EDTA solution using EBT as the indicator and obtained the average volume of 21.00 mL from triplicate readings for the end point. Determine the gram percentage of Zn in this sample. Assume that Zn is the only metal ion which reacts with EDTA in this sample. (atomic mass of Zn is 65.38g)

(20 marks)

(c) A solution prepared by mixing 0.10 mol dm^{-3} sodium chloride and 0.10 mol dm^{-3} sodium chromate was titrated with silver nitrate. Determine the first precipitating compound using a suitable calculation.

(K_{SP} , $AgCl = 1.8 \times 10^{-10}$, $Ag_2CrO_4 = 3.6 \times 10^{-12}$)

(25 marks)

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Periodic Table of the Elements

Atomic Number		Symbol		Name		Atomic Weight	
1	1	H	H	Hydrogen	1.008		
2	2	He	He	Helium	4.0026		
3	3	Li	Li	Lithium	6.941		
4	4	Be	Be	Beryllium	9.0122		
5	5	B	B	Boron	10.81		
6	6	C	C	Carbon	12.011		
7	7	N	N	Nitrogen	14.007		
8	8	O	O	Oxygen	15.999		
9	9	F	F	Fluorine	18.998		
10	10	Ne	Ne	Neon	20.180		
11	11	Na	Na	Sodium	22.990		
12	12	Mg	Mg	Magnesium	24.305		
13	13	Al	Al	Aluminum	26.982		
14	14	Si	Si	Silicon	28.086		
15	15	P	P	Phosphorus	30.974		
16	16	S	S	Sulfur	32.06		
17	17	Cl	Cl	Chlorine	35.453		
18	18	Ar	Ar	Argon	39.948		
19	19	K	K	Potassium	39.098		
20	20	Ca	Ca	Calcium	40.078		
21	21	Sc	Sc	Scandium	44.956		
22	22	Ti	Ti	Titanium	47.88		
23	23	V	V	Vanadium	50.942		
24	24	Cr	Cr	Chromium	51.996		
25	25	Mn	Mn	Manganese	54.938		
26	26	Fe	Fe	Iron	55.845		
27	27	Co	Co	Cobalt	58.933		
28	28	Ni	Ni	Nickel	58.71		
29	29	Cu	Cu	Copper	63.546		
30	30	Zn	Zn	Zinc	65.38		
31	31	Ga	Ga	Gallium	69.723		
32	32	Ge	Ge	Germanium	72.64		
33	33	As	As	Arsenic	74.922		
34	34	Se	Se	Selenium	78.96		
35	35	Br	Br	Bromine	79.904		
36	36	Kr	Kr	Krypton	83.798		
37	37	Rb	Rb	Rubidium	85.468		
38	38	Sr	Sr	Strontium	87.62		
39	39	Y	Y	Yttrium	88.906		
40	40	Zr	Zr	Zirconium	91.224		
41	41	Nb	Nb	Niobium	92.906		
42	42	Mo	Mo	Molybdenum	95.94		
43	43	Tc	Tc	Technetium	98		
44	44	Ru	Ru	Ruthenium	101.07		
45	45	Rh	Rh	Rhodium	102.91		
46	46	Pd	Pd	Palladium	106.42		
47	47	Ag	Ag	Silver	107.868		
48	48	Cd	Cd	Cadmium	112.411		
49	49	In	In	Indium	114.818		
50	50	Sn	Sn	Tin	118.710		
51	51	Sb	Sb	Antimony	121.757		
52	52	Te	Te	Tellurium	127.60		
53	53	I	I	Iodine	126.905		
54	54	Xe	Xe	Xenon	131.29		
55	55	Cs	Cs	Cesium	132.905		
56	56	Ba	Ba	Barium	137.327		
57-71	57-71	Lanthanoids					
58	58	La	La	Lanthanum	138.905		
59	59	Ce	Ce	Cerium	140.12		
60	60	Pr	Pr	Praseodymium	140.908		
61	61	Nd	Nd	Neodymium	144.24		
62	62	Sm	Sm	Samarium	150.36		
63	63	Eu	Eu	Europium	151.964		
64	64	Gd	Gd	Gadolinium	157.25		
65	65	Tb	Tb	Terbium	158.925		
66	66	Dy	Dy	Dysprosium	162.50		
67	67	Ho	Ho	Holmium	164.930		
68	68	Er	Er	Erbium	167.26		
69	69	Tm	Tm	Thulium	168.934		
70	70	Yb	Yb	Ytterbium	173.054		
71	71	Lu	Lu	Lutetium	174.967		
72	72	Hf	Hf	Hafnium	178.49		
73	73	Ta	Ta	Tantalum	180.948		
74	74	W	W	Tungsten	183.84		
75	75	Re	Re	Rhenium	186.207		
76	76	Os	Os	Osmium	190.23		
77	77	Ir	Ir	Iridium	192.222		
78	78	Pt	Pt	Platinum	195.084		
79	79	Au	Au	Gold	196.967		
80	80	Hg	Hg	Mercury	200.59		
81	81	Tl	Tl	Thallium	204.38		
82	82	Pb	Pb	Lead	207.2		
83	83	Bi	Bi	Bismuth	208.98		
84	84	Po	Po	Polonium	209		
85	85	At	At	Astatine	210		
86	86	Rn	Rn	Radon	222		
87	87	Fr	Fr	Francium	223		
88	88	Ra	Ra	Radium	226		
89-103	89-103	Actinoids					
89	89	Ac	Ac	Actinium	227		
90	90	Th	Th	Thorium	232.038		
91	91	Pa	Pa	Protactinium	231.036		
92	92	U	U	Uranium	238.029		
93	93	Np	Np	Neptunium	237		
94	94	Pu	Pu	Plutonium	244		
95	95	Am	Am	Americium	243		
96	96	Cm	Cm	Curium	247		
97	97	Bk	Bk	Berkelium	247		
98	98	Cf	Cf	Californium	251		
99	99	Es	Es	Einsteinium	252		
100	100	Fm	Fm	Fermium	257		
101	101	Md	Md	Mendelevium	258		
102	102	No	No	Nobelium	259		
103	103	Lr	Lr	Lutetium	260		
104	104	Rf	Rf	Rutherfordium	261		
105	105	Db	Db	Dubnium	262		
106	106	Sg	Sg	Seaborgium	266		
107	107	Bh	Bh	Berkelium	264		
108	108	Hs	Hs	Hassium	265		
109	109	Mt	Mt	Moscovium	268		
110	110	Ds	Ds	Darmstadtium	271		
111	111	Rg	Rg	Roentgenium	272		
112	112	Cn	Cn	Copernicium	285		
113	113	Nh	Nh	Nihonium	284		
114	114	Fl	Fl	Flerovium	289		
115	115	Mc	Mc	Moscovium	288		
116	116	Lv	Lv	Livermorium	293		
117	117	Ts	Ts	Tennessine	289		
118	118	Og	Og	Oganesson	284		