General Chemistry

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Introduction to General Chemistry, its Syllabus and Evaluation Patterns

Syllabus of General Chemistry

KATHMANDU UNIVERSITY

SCHOOL OF SCIENCE

- B. E. / B. Pharm. / B.Sc.

Existing

- **Course No** : **CHEM 101(3 Cr.) - 48 Hrs.**
- **Course Title** : **General Chemistry**
- **Text Book** : **University Chemistry 3rd edition, by B.H. MAHAN (Narosa Pub. House, INDIA)**
- **General Physical Chemistry: Concept and Numerical Problems with Solutions**. Published by *Readmore* Publisher and Distribution.1st Edition (2078)

Topics	No. of lectures*	Ref. to textbook
1. Mole concept	1	1.3 - 1.6
2. Properties of solution:		
-Phase equilibria, energetics of phase change, liquid-vapour equilibrium, the equilibrium state	1	4.2
-Temperature dependence of vapor pressure, types of solution, concentration unit, the ideal solution	1 1	4.2, 4.4 4.4
-Boiling and freezing points of solutions	1	4.4 - 4.5
-Solutions of two volatile components, non ideal solutions -Osmosis, solubility, effect of temperature on solubility	1	4.4, 4.6
3. Chemical Equilibrium :		
-Introduction, the nature of chemical equilibrium	1	5.1
-The equilibrium constant and calculations with the equilibrium constant	2	5.2, 5.5 5.3
-External effects on equilibria	1	
4. Ionic equilibria in aqueous solutions:		
-Sparingly soluble salts, selective precipitation	1	6.1
-Acids and bases: different concepts of acid and base.	1	6.2
-Strength of acid and base, pH scale, self ionization of water, weak acids and bases	2	6.3
-Hydrolysis	1	6.4
-Buffer solution, Indicators	2	6.5
-Acid-base titrations	1	6.7

5. Oxidation-Reduction Reactions :		
-Oxidation states, the half-reaction concept, balancing Redox reactions	self study	7.1 - 7.3
-Galvanic cells	2	7.4
-Nernst equation	1	7.5
-Redox titration	1	7.6
-Electrolysis, electrochemical application	1	7.7 - 7.8
6. Chemical thermodynamics :		
-Introduction, system, state and state function, work and heat	2	8.1 -8.2
-The first law of thermodynamics	1	8.3
-Thermochemistry	2	8.4
-Criteria for spontaneous change	1	8.5
-Entropy and the second law	2	8.6
-Molecular interpretation of entropy, absolute entropies and the third law	1	8.7 - 8.8
Free energy, criteria for equilibrium, free energy and equilibrium constant	2	8.9 - 8.10
-Electrochemical cells, temperature dependence of equilibria	2	8.11- 8.12

7. Chemical kinetics :		
-Introduction, concentration effect , differential and Integrated rate laws	1	9.1
-Experimental determination of rate laws, order and molecularity	1	9.1
-Rreaction mechanisms, elementary processes, mechanism and rate laws, the steady state approximation, chain reactions, reaction rate and equilibria	2	9.2 - 9.3
-Collision theory of gaseous reactions, temperature effect on reaction rate	2	9.4 - 9.5
-Rates of reactions in solutions, problems	1	9.6
-Catalysis - homogeneous, heterogeneous and Enzyme catalysis	2	9.7
Total	**45**	

Evaluation: (25- Internal Evaluation, 75- End Sem.)

- **25- Internal Evaluation**
  - **20 Marks (Written Exam)**
    - **3 Internal Test (final be average of three test)**
      - **MCQ**
      - **Subjective**
      - **Or Viva-voce**
  - **5 Marks**
    - **Attendance**
    - **Assignments (3 Assignments)**
    - **Class Activities or performance**

Chapter 1: Mole Concept

Mole Concept:

1. **Mole Concept**
2. **A mole/gram atom/ gram molecule**
3. **Avogadro's Number(N)**
4. **Number of moles (in Atom, molecule, ionic compound, ions, gases, if in molar conc., in mmoles)**
5. **Chemical equation and its significance**
6. **Soichiometric coefficient**
7. **Principle of atom conservation**
8. **Emperical formula**
9. **Molecular formula**
10. **Other principle (Avogadro' hypothesis, Gravimetric factor)**

Mole Concept……

- The atoms and molecules are in fact regarded as the **fundamental unit** of chemical thought.

- **Quantitative explanation** of matter in terms of number of atoms and molecules is relatively **unfavorable in practical life**.

- Because even a **very small quantity of a matter contains very large number** of such entities (atoms, molecules or ions).

- So, the **method** to **measure and express** the number of molecules or atoms in any chemical system is of the foremost important.

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- The development of the ***atomic theory*** led to the conclusion that **equal number of atoms are contained in *one gram atomic weight* of each element** and the **same number of molecules is found in *one gram molecular weight* of any compound**.

- These terms were used to refer a ***fixed number of particles***.

- But it is more convenient to use the new term '**mole**' to represent for **the amount of materials which contains fixed number of particles**.

- '**One mole**' is the amount of a substance that contains as many **elementary entities** (atoms, molecules, or other particles) as there are atoms in exactly 12 gm of the carbon-12 isotope.

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- **Avogadro's number(N):** The number of **carbon atoms in exactly 12 gm of C^{12} isotope** is called Avogadro's number. Avogadro's number (N) is equal to 6.022×10^{23} particles.

- **One mole** is the amount of materials which contains **Avogadro's number of particle**.

- Thus , a mole is defined as **the amount of any substances** (atoms, ions, molecules etc.) **which contains 6.022×10^{23} particles** (*Avogadro's number*).

- We can conclude that '**one mole' of molecule** has the mass equal to **molecular weight in gms**. Similarly, **'one mole' of atom** has a mass equal to atomic weight in gms.

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- For example, 1mole of H_2O ≈ Formula wt. of H_2O ≈ 18 gms. of H_2O ≈ 1 gram molecular wt. of H_2O ≈ 6.022×10^{23} molecules (Avogadro's number).

- For example, 1 mole of hydrogen atom ≈ Atomic wt. of hydrogen ≈ 1.008 gms ≈ 1 gram atomic weight ≈ 6.022×10^{23} atoms (Avogadro's number).

- Let's try yourself: 1 mole of CO_2 , 1 mole of N_2, 1 mole of Copper (Cu) and 1 mole of Zinc (Zn) etc.

Some formulas to convert into mole

1. No. of moles (atoms) = [Wt. in gms / At. Wt.]

2. No. of moles (molecule) = [Wt. in gms / Mol. Wt.]

3. No. of moles (ionic compd.) = [Wt. in gms / Formula Wt.]

4. No. of moles (ions) = Wt. in gms / Ionic. Wt.

5. No. of moles (Gases) = Volume (L) at NTP / 22.4 litres.

6. No. of moles (if in molar conc.) = Molarity X Volume in L

(No of mmoles = Molarity X Volume in mL)

Solve some problems

Q.N.1. Calculate the weight of one atom oxygen. (Ans. **2.656×10^{-23}gm**)

Q.N.2. Find the absolute weight of one atomic mass unit (amu). (Ans. **1.66×10^{-24} gm**)

Q.N.3. How many oxygen atoms are there in 8 gms. of oxygen atoms? (**Ans. 3.01×10^{23}atoms**)

Q.N.4. Calculate the weight of one molecule of $MgSO_4$. (Ans. **1.99×10^{-22}**)

Q.N.5. Find the weight of 100 ml of CO_2 gas a NTP. (Ans. **0.196 gm**)

Q.N.6. On the electrolysis of dil. Acid solution, hydrogen ions are discharged at cathode according to the reaction, $H^+ + e^- \rightarrow H$. Then, find number of mole of electrons required to discharge 5 moles of H^+ ions. Also calculate total charge gained by H^+ ions in the process. (Ans. **5 moles of electrons, 481,760 C**)

The Chemical equation

- The notation of reaction in terms of **symbol** and **formula.**

- The chemical equation always represent the **qualitative and quantitative significances of chemical reactions.**

- The **mole concept** is useful tool to **solve the problems based on chemical equations.**
  - For example., $2Ag^{+}(aq) + H_2S\ (aq) = Ag_2S(s) + 2H^{+}(aq)$

- The **stoichiometric coefficients** which appear in a balanced chemical equation express the **quantitative aspect of a chemical reaction**.

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- **These coefficients** also represent the *relative number of molecules* or *atoms* which participate in a chemical reaction. The ***relative number of molecules*** ultimately corresponds to *relative number of moles* for that reaction. This is basis for stoichiometric calculation. i.e. The mole to mole relation in a chemical reaction

- The **chemical equation** is an example of a ***conservation equation***. The *principle of atom conservation* states that the number of atoms of each element in a chemical reaction is always constant or conserved. This principle is the basis for balancing the equations.
  - For example, $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$; $2CO + O_2 \rightarrow 2CO_2$

- Furthermore, the **equation** represents the fact that ***net electrical charge*** *is* ***neither created nor destroyed by chemical reactions***. The *principle of charge conservation* is very helpful in balancing redox equation.

Empirical formula and Molecular formula

- The **empirical formula** of a chemical compound is the simplest whole number ratios of atoms present in a compound.

- Example of this concept: the empirical formula of sulfur monoxide, or SO, would simply be SO, as is the empirical formula of disulfur dioxide, S_2O_2. Thus, sulfur monoxide and disulphur dioxide, both compounds of sulphur and oxygen, have the same empirical formula. Like wise, E.F. of glucose = CH_2O, mercurous chloride is HgCl. Molecular formula: $C_6H_{12}O_6$ & Hg_2Cl_2.

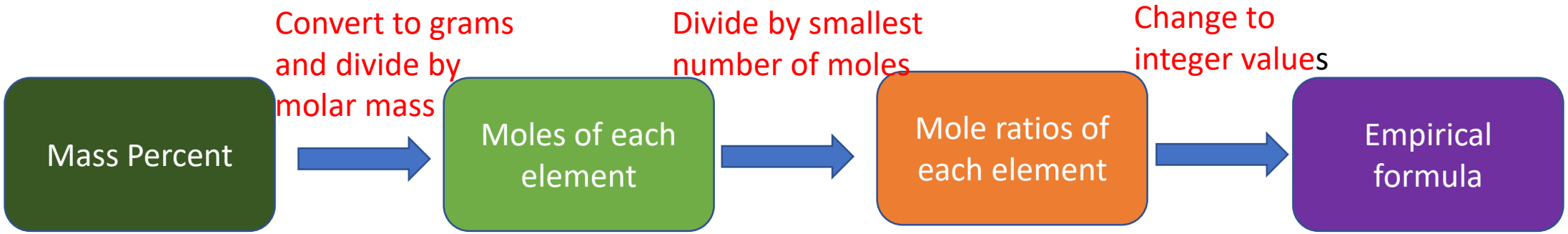
- However, their molecular formulas, which express the number of each type of atom in each molecule of a chemical compound, are not the same

Percent composition by mass

- The **chemical formula** and the **molecular mass** of a compound enables us to calculate the **percent composition by mass** – the percent by mass of each element in a compound.
- The ratio of **total weight of one element** to **the molecular weight** in terms of percentage gives the percentage composition of the element in that compound.
- Percent composition of an element = $\frac{n \; x \; molar \; mass \; of \; element}{molar \; mass \; of \; compound}$ x 100%
  - **'n'** is the **number of moles of the element** in **1 mole of the compound** during the study.

- For example, in sulphur dioxide (SO_2)
  - percent composition of sulphur = $\frac{1 \; x \; 32}{64}$ x 100% = **50 %**
  - percent composition of oxygen = $\frac{2 \; x \; 16}{64}$ x 100% = **50 %**

Calculation of empirical formula from percentage composition



- In order find molecular formula, **Molecular Formula = Empirical formula x n**
- Where, n = $\frac{\boldsymbol{Molecular\ formula\ weight}}{\boldsymbol{Empirical\ formula\ weight}}$ [n is the whole number]

Some Numerical Problems

1. **Calculate the weight of carbon dioxide which can be obtained from the combustion of 12.0 gm of carbon monoxide in excess of oxygen. Also calculate the weight of oxygen consumed.[18.9gm, 6.85gm]**
2. **A certain sulfide of iron contains 46.5% iron and 53.5% sulfur by weight. What is the empirical formula of the sulfide? (Given, At. Wt. of Fe =55.8 and S=32) [FeS_2]**
3. **A certain sample of $KClO_3$ when decomposed yielded 637 cubic centimeters of oxygen gas, measured at 273 K and one atmosphere pressure. Calculate the original weight of $KClO_3$ and the weight of the KCl produced. [2.32gm,1.41gm]**
4. **A sample of pure calcium metal weighing 1.35gm was quantitatively converted to 1.88gm of pure CaO. If the atomic weight of oxygen is taken to be 16,what is the atomic weight of calcium? [40.9]**

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5. In the gravimetric determination of Phosphorus, an aqueous solution of Dihydrogenphosphate ion, $H_2PO_4^-$, is treated with a mixture of ammonium and magnesium ions to precipitate Magnesium ammonium phosphate, $MgNH_4PO_4.6H_2O$.This is heated and decomposed to Magnesium pyrophosphate, $Mg_2P_2O_7$, which is weighed. A solution of $H_2PO_4^-$ yielded 1.054gm of $Mg_2P_2O_7$.What weight of NaH_2PO_4 was present originally?

The reactions are : $H_2PO_4^- + Mg^{++} + NH_4^+ + 6H_2O = MgNH_4PO_4.\ 6H_2O + 2H^+$

$2MgNH_4PO_4.\ H_2O = Mg_2P_2O_7 + 2NH_3 + 13H_2O$ [**1.136gm**]

6. A sample of K_2CO_3 weighing 27.6 gm was treated by a series of reagents so as to convert all of its carbon to $K_2Zn_3[Fe(CN)_6]_2$. How many grams of this product were obtained? [**11.6gm**]

contd…

7. One gram of a gaseous compound of carbon and hydrogen gives upon combustion 3.3 gm of carbon and 0.899 gm of water. In a separate experiment, the density of a gaseous sample of this compound is found to be 1.78gm\liter under standard condition of temperature and pressure. What is the empirical and molecular formula of the compound? [C_3H_4]

8. One volume of a gaseous compound of Hydrogen, Carbon and Nitrogen gave upon combustion 2 volumes of CO_2, 3.5 volumes of H_2O and 0.5 volume of N_2 , all measured at the same temperature and pressure. What is the empirical formula of the compound? Can the molecular formula be found from these data? [C_2H_7N, ethyl amine]

9. A 1 gm mixture of Cuprous oxide, Cu_2O and Cupric oxide, CuO, was quantitatively reduced to 0.839 gm of metallic copper. What was the weight of CuO in the original sample? (Given At. Wt. of Cu=63.5) [0.55 gm]

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10. A mixture of Aluminium and Zinc weighing 1.67 gm was completely dissolved in acid and evolved 1.69 litres of Hydrogen, measured at 273K and 1 atm pressure. What was the weight of Aluminium in the original mixture? (Given, At.wt. of Zn = 65.4) [1.24 gm]

- The equations are,
- $Zn + 2H^+ = Zn^{++} + H_2$
- $Al + 3H^+ = Al^{3+} + 3/2\ H_2$

11. A carefully purified sample of Potassium chlorate, $KClO_3$, weighing 4.008 gm, was quantitatively decomposed to 2.438 gm of Potassium chloride, KCl, and Oxygen.The potassium chloride was dissolved in water and treated with a silver nitrate solution. The result was a precipitate of Silver chloride, AgCl , weighing 4.687 gm. Under further treatment the silver chloride was found to contain 3.531 gm of silver. What are the atomic weights of *silver, chlorine and potassium* relative to O=15.999? [107.9, 35.4 and 39.1]

Solve Yourself (Exercise problems of Mole concept)

- **From 1.1 to 1.6**
- **From 1.11 to 1.17**

1.1 An oxide of Antimony is found to contain 24.73% oxygen.What is its empirical formula? (At.wt. of Sb =121.8) **[Sb_2O_5]**

1.2 When 0.210 gm of a compound containing only hydrogen and carbon was burned, 0.660 gm of CO_2 was recovered.What is the empirical formula of the compound? A determination of the density of this hydrocarbon gave a value of 1.87gm/liter at 273K and 1 atm. What is the molecular formula of the compound? **[CH_2 ; C_3H_6]**

1.3 A sample of Europium dichloride, $EuCl_2$,weighing 1 gm is treated with excess aqueous Silver nitrate , and all the chloride is recovered as 1.29 gm of AgCl. What is the atomic weight of Europium? (Ag = 107.87, Cl = 35.5) **[151.29]**

1.4 A sample of an oxide of iron weighing 1.6 gm was heated in a stream of hydrogen gas until it was completely converted to 1.12 gm of metallic iron.What is the empirical formula of the iron oxide? (Given At.wt.=55.8) **[Fe_2O_3]**

1.5 When Barium bromide , $BaBr_2$, is heated in a stream of chloride gas , it is completely converted to Barium chloride, $BaCl_2$. From 1.5 gm of $BaBr_2$ just 1.05 gm of $BaCl_2$ is obtained .Calculate the atomic weight of Barium from these data. (Given, Cl = 35.5, At.wt. Br =79.9) **[136.2 gm]**

1.6 A 0.578 gm sample of pure tin is treated with gaseous fluorine until the weight of the resulting compound is constant at a value of 0.944 gm. What is the empirical formula of the tin fluoride formed? Write an equation for its synthesis. **(**Given, F = 19, Sn = 118.7) **[SnF_4]**

1.11 Equal weights of zinc metal and iodine are mixed together and the iodine is completely converted to ZnI_2.What fraction by weight of the original zinc remains unreacted? (Given, I =126.9, Zn = 65.38) **[0.74]**

1.12 A 4.22 gm sample of a mixture of $CaCl_2$ and NaCl was treated to precipitate all the calcium as $CaCO_3$, which was then heated and converted to pure CaO. The final weight of the CaO was 0.959gm. What was the percentage by weight of $CaCl_2$ in the original mixture? **[44.64%]**

1.13 An alloy of Aluminium and Copper was treated with aqueous HCl. The aluminium dissolved according to the reaction the reaction $Al + 3H^+ \rightarrow Al^{3+} + 3/2H_2$, but the copper remained as the pure metal. A 0.35 gm sample of the alloy gave 415cc of H_2 measured at 273K and 1 atm-pressure. What is the weight percentage of Al in the alloy? (Given, Al = 27; Cu = 63.5) **[95%]**

1.14 A sample of pure lead weighing 2.07 gm is dissolved in nitric acid to give a solution of lead nitrate .This solution is treated with hydrochloric acid, chlorine gas, and ammonium chloride.The result is a precipitate of Ammonium hexachloroplumbate,$(NH_4)_2PbCl_6$ (Mol. Wt. *456.2*). What is the maximum weight of this product that could be obtained from the lead sample? (Given, **Pb = 207.2,** } **[4.5576 gm]**

1.15 A 0.596 gm sample of a gaseous compound containing only Boron and Hydrogen occupies 484cc at 273 K and 1-atm pressure. When the compound was ignited in excess oxygen, all its hydrogen was recovered as 1.17 gm of H_2O , and all the boron was present as B_2O_3.What is empirical formula , the molecular formula, and the molecular weight of the Boron-hydrogen compound ?What weight of B_2O_3 was produced by the combustion?
[BH_3; B_2H_6 ; 27.6 gm; 1.5 gm]

1.16 A sample of an unknown oxide of barium gave upon exhaustive heating 5gm of pure BaO and 366cc of oxygen gas measured at 273 K and 1 atm-pressure. What is the empirical formula of the unknown oxide? What weight of oxide was present initially? (Given, Ba = 137.33) **[BaO_2]**

1.17 A mixture of KBr and NaBr weighing 0.56 gm was treated with aqueous Ag+ and all the Bromide ion was recovered as 0.97 gm of pure AgBr. What was the fraction by weight of KBr in the original sample? (Given, Ag = 107.87, Na = 23, Br = 79.9, K = 39) **[37.7%]**