Analytical chemistry

Is the branch of chemistry concerned with the determination of the type as well as the amount of substances it consists of the followings:-

Chemistry analysis methods:- can be classified into two major groups:-

A-Qualitative analysis

Comprises the tests that enable the chemist to determine what species are present.

B-Quantitative analysis

Provides the means for determining how much of some component is present in a unit quantity of sample. there are many methods of determining these amounts all based on chemical molecules and ions.

1.Volumetric analysis

It is involve the measurement of volume of solution of know strength that required the react with specific amount of the sample acid-base titration.

2. Gravimetric analysis

The final measurement involves the determination of weigh determination the weight of silver in the sample from the weight of silver chloride AgCl produced by the addition of chloride ion to the sample according to the reaction

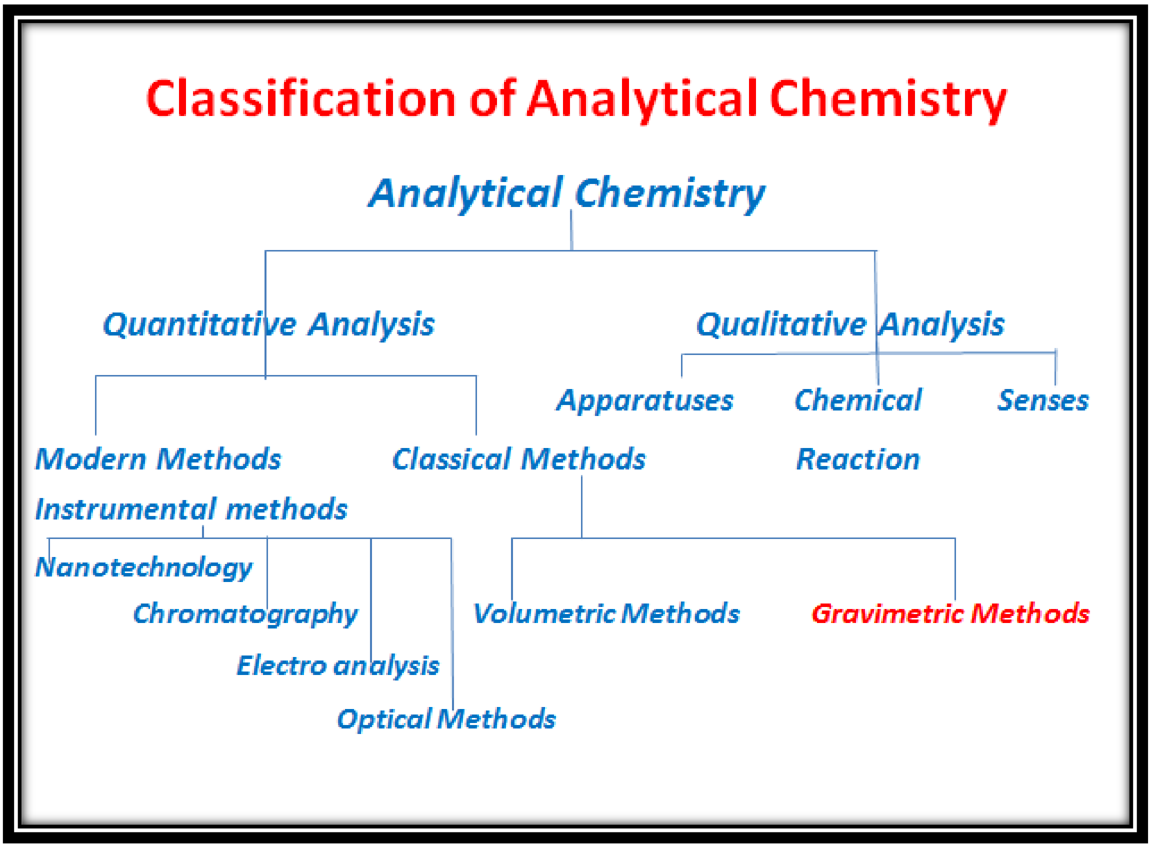
$$Ag^{+} + Cl^{-} \rightarrow AgCl$$

3. **instrumental analysis**

This type of measurement methods is based on measuring certain physical properties of the sample which can be classified to two major categories.

A. Optical methods

B. Electroanalytical methods



Separation methods

Most commonly used method is chromatography this technique is based on separation of mixture into its components by difference in adsorption or relative adherence of component molecules to stationary phase and mobile phase passes over it.

Steps of chemical analysis:-

The chemical analysis process consists of the following steps:-

1.Sampling :the sample must be

*Homogenous and representative of the whole substance

*Size of sample may vary from a few grams or less to several pound depending on the type of bulk material.

This portion is called Gross sample

The portion of this sample that can be taken for analysis is called analysis sample the accuracy of measurements is highly limited by the sampling process

2.Pretreating the sample:-

In some the analysis sample must be chemically or physically pretreated before the chemical analysis such as (dissolving, dilution, crushing…..)

3.Method selection

The selection of the method employed for sensitivity, precision, selectivity and cost.

4.Measurements or taking the analysis data

Several replicate analysis may be performed on the same sample and the standard procedures that put by professional societies.

5.Data handling and obtaining the results

The laboratory data observed from chemical analysis or instrumental reading must be mathematically treated in order to
observe a meaningful results.

Application of chemical analysis :

1- Chemical analysis of air and water to determine the pollution.

2- Medicine relies heavily on chemical analysis to diagnose illness properly and to monitor the progress of patients.

3- Chemical analysis of raw materials and final products for quality control of industrial products.

4- The flue gas analysis can be used to evaluate the energy produce from combustion processes of fuel.

5- Chemical analysis of soil and plants is used to determine the type of fertilizer which must be added to the soil increase productivity

6- Most of the applied researches in many scientific fields as chemical, biological, engineering…, cannot be performed without chemical analysis.

Chemical Methods for Expressing concentration

Atomic weight:
The atomic weight of element is the mass of an atom of that element based on amass of exactly 12 to carbon isotope C^{12}.

Molecular or formula weight
It is the sum of atomic weights of the elements that constitute molecule of the substance given by the molecule formula.

M.wt of water (H_2O) =2(1) + 1(16) =18
M.wt of hydrogen (H_2) = 2(1) =2

These weight are all relative to the mass of C^{12} atom as 12.00 with (SI) system of units molecular weight is expressed by g/mol.

Ex. Calculate the molecular weight of (Na2SO4) and (CaSO4.7H2O) ????

The mole unit :
The mole (or gram or gram molecular weight) can be define as the amount of the substance that contain number of constitutional species (molecules) equal to that exactly 12 grams of C^{12} .

Number of moles is computed as:-
No.of mole=mass of the substance in gm/ M.wt in g/mol

Ex.calculate the number of moles in 500 mg of sodium tungstate(Na_2WO_4). Na=22.9, W=183.8, O=16.

Sol.

M.wt of Na_2WO_4 =2(22.9)+183.8+4(16) = 293.8 g/mol

No.of mole = (500mg*g/1000)/293.8g/mole

= 0.00170mol

=1.7mmol

Molarity (M): Is the total number of moles of a solute in 1L of solution. Or the total number of millimoles in 1 mL.

$$M = \frac{no.moles\ (solute)}{V.\ Soln.L}$$

No. = number.

Soln. = Solution.

$$Moles = \frac{W}{M.wt.}$$

$$M = \frac{\frac{W}{M.Wt.}}{V} \leftrightarrow \frac{W}{M.wt. \times V.L}$$

$$M = \frac{W \times 1000}{M.Wt. \times VmL}$$

This law used for ***solid state*** material

mole/L, mmol/mL → Molar

No. of moles = M × $V_{(L)}$

No. of millimoles = M ×$V_{(mL)}$

$$M = \frac{Sp.gr.\times\%\times 10}{M.Wt.}$$ Molarity of ***liquid state*** solution

$$\textit{Specific gravity}: Sp.gr. = \frac{Density\ of\ Substance}{density\ of\ Water}$$

∵Density of water (H_2O) d (H_2O) = 1 ∴ Sp.gr. = d

Dilution Law

Number of moles of concentration solution = number of moles of dilution solution.

Conc. Soln.		***dil. Soln,***
no. of moles	=	no. of moles
no. of millimoles	=	no. ofmillimoles

$$M_1 \cdot V_1 = M_2 \cdot V_2$$

Ex.1. Prepare 0.1M of calcium carbonate $CaCO_3$ in 2 litter?

A.wt. : Ca = 40, C= 12, O =16

Ex.2. Calculate the volume of NH_3 conc. which used to prepare 500 mL of 0.1 M NH_3, sp.gr. of concentrated solution = 0.9 and the percentage = 28%, M.wt. = 17.?

2- ***Normality (N):*** It is the number of equivalents of solute in liter of solution.

$$N = \frac{no.of\ equivalent}{Vol.of\ solution\ (L)}$$

$$no.eq. = \frac{Wt.}{eq.Wt.} \quad ....$$

The equivalent weight (eq.wt.) of a substance is not a constant quantity, but it’s value depend upon the reaction, in which it is taken part.

Since; $Eq.wt = \frac{Mwt.}{n}$ n : the reacting units

$$N = \frac{W \times 1000}{eq.wt. \times VmL}$$ For **solid state** material

$$N = eq/L,\ m.eq./mL \rightarrow Normal$$

$$N = \frac{Sp.gr. \times \% \times 10}{eq.wt.}$$ For **liquid state** solution

To calculate the equivalent weight (eq.wt.):

$$eq.wt. = \frac{M.wt.}{n}$$

n =active unite.

n = H^+ (acids).

n = OH^- (bases).

n = charge × number of ions (salt).

n = no.of electrons lost or gained (oxidation –reduction).

Calculate the equivalent weight:

A. Of Element

$$eq.wt. = \frac{A.wt.}{no.of\ oxidant}$$

Ex. 1. What is the eq.wt. of Mg? A.wt. = 24

$$Eq.wt. = \frac{A.wt.}{no.of\ oxidant} = \frac{24}{2} = 12$$

B. *Of Acid*

$$eq.wt. = \frac{A.wt.}{no.of\ hydrogen\ atoms\ interacting}$$

Ex.1. Calculate the equivalent weight of HCl? M.wt. = 36.5

$$HCl \rightarrow H^+ + Cl^-$$

$$\text{eq.wt. of HCl} = \frac{\text{M.wt.}}{\text{no.of proton replacable of base}}$$

$$\text{eq.wt. of HCl} = \frac{36.5}{1} = 36.5$$

Ex.2. Calculate the equivalent weight of H_2SO_4? M.wt. = 98.

$$H_2SO_4 \rightarrow 2H^+ + SO_4^-$$

$$\text{eq.wt. of } H_2SO_4 = \frac{\text{M.wt.}}{\text{no.of proton replacable of base}}$$

$$\text{eq.wt. of } H_2SO_4 = \frac{98}{2} = 49$$

So, H_2SO_4 has two reacting units of proton ; there are two equivalents of proton in each mole. While HCl has one reacting unit of proton, there is one equivalent of proton in each mole. So the normality of H_2SO_4 solution is twice its molarity

$$N \text{ of } H_2SO_4 = M \times 2$$

C. ***Of Base***

$$eq.wt. = \frac{M.wt.}{no.of\ reactivehydroxil\ groups}$$

Ex.1. Calculate the equivalent weight of NaOH? M.wt. = 40

$$\text{eq.wt. of NaOH} = \frac{\text{M.wt.}}{\text{no.of reactivehydroxil groups}}$$

$$\text{eq.wt. of NaOH} = \frac{40}{1} = 40$$

Ex.1. Calculate the equivalent weight of $Mg(OH)_2$? M.wt.58

$$\text{eq.wt. of } Mg(OH)_2 = \frac{\text{M.wt.}}{\text{no.of reactivehydroxil groups}}$$

$$\text{eq.wt. of } Mg(OH)_2 = \frac{58}{2} = 29$$

D. ***Of Salt***

$$eq.wt. = \frac{M.wt.}{number\ of\ metal\ atoms \times no.of\ charge\ or\ no.of\ oxidant}$$

Ex.: Calculate the eq.wt. of Na_2CO_3?M.wt. = 106

$$\text{eq.wt. of } Na_2CO_3 = \frac{\text{M.wt.}}{2\times(+1)}$$

$$= \frac{106}{2\times(+1)} = 53$$

E. *Of material that suffer oxidation reduction*

$$eq.wt.\ of\ oxidation = \frac{M.wt.}{number\ of\ loss\ electrons}$$

$$eq.wt.\ of\ reduction = \frac{M.wt.}{number\ of\ gain\ electrons}$$

Ex.: Calculate the eq.wt. of manganese Mn^{+2} and ferrous Fe^{+2} in the equation below?

$$\mathbf{MnO_4 + Fe^{+2} + 8H^+ + 5e^- \rightarrow Mn^{+2} + Fe^{+3} + 4H_2O}$$

$$eq.wt.\ of\ Mn^{+2} = \frac{M.wt.}{number\ of\ loss\ electrons}$$

$$eq.wt.\ of\ Mn^{+2} = \frac{M.wt.}{5}$$

$$eq.wt.\ of\ Fe^{+2} = \frac{M.wt.}{number\ of\ gain\ electrons}$$

$$eq.wt.\ of\ Fe^{+2} = \frac{M.wt.}{1}$$

F. *Of Complex Formation Reaction*

$$\textit{eq.wt.} = \frac{\textit{M.wt.}}{\textit{no.of oxidant of ion which contact with ligand}}$$

Ex.: Calculate the eq.wt. of Nickle Ni^{+2} in the equation below?

$$\mathbf{Ni^{+2} + 2DMG \rightarrow Ni(DMG)_2\downarrow}$$

DMG:

$CH_3 - CH - N - OH$
$\quad\quad\quad |$
$CH_3 - CH - N - OH$

$$\text{eq.wt.} = \frac{\text{M.wt.}}{\text{no.of oxidant of ion which contact with ligand}}$$

$$\text{eq.wt.} = \frac{\text{M.wt.}}{2}$$

- What is the relationship between Molarity or Normality with part per million ppm?

$$\text{C ppm} = \frac{\text{Wt.g}}{\text{V.mL}} \times 10^6$$

$$\text{M} = \frac{\text{W} \times 1000}{\text{M.Wt.} \times \text{VmL}}$$

Multiple denominator and numerator by 10^6

$$\text{M} = \frac{\text{W} \times 1000}{\text{M.Wt.} \times \text{VmL}}$$

$$\text{M} = \frac{\text{ppm} \times 1000}{\text{M.Wt.} \times 106}$$

$$\text{M} = \frac{\text{ppm}}{\text{M.Wt.} \times 1000}$$

$$\therefore \textit{ppm} = \textit{M} \times \textit{M.wt.} \times 1000$$

$$\textit{ppm} = \textit{N} \times \textit{eq.wt.} \times 1000$$

Aqueous Solution and Chemical Equilibria

Electrolysis: are solutes which are ionized in solution to produce an electrically conducting medium. There are two types of electrolytes.

Strong electrolytes: the compounds which are completely ionized or dissociate in solution.

$$HCl \rightarrow H^{+} + Cl^{-}$$

Weak electrolytes: the compounds which are partially dissociate in Solution.

$$CH_3COOH \rightleftharpoons CH_3COO^{-} + H^{+}$$

Conjugate Acids and Bases

$Acid_1 \rightleftharpoons Base_1 + H^{+}$ (Conjugate base of the parent acid)

$Base_2 + H^{+} \rightleftharpoons Acid_2$ (Conjugate acid of the parent base)

The result in an acid /base or neutralization reaction :

$Acid_1 + Base_2 \rightleftharpoons Base_1 + Acid_2$

A conjugate acid: is formed when a base accepts aproton.
A conjugate base: is formed when an acid losses a proton.

e.g. acetate ion is conjugate base of acetic acid.

Neutralization Reaction:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

$$HCl \rightarrow H^{+} + Cl^{-}$$

$$NaOH \rightarrow Na^{+} + OH^{-}$$

$$NH_3 + H_2O \rightleftharpoons NH_4^{+} + OH^{-}$$

Conjugated of NH_3 Conjugated base of H_2O

NH_3 , NH_4^+ are conjugate pain.

Chemical Equilibrium

Many reaction used in analytical Chemistry never result in complete conversion of reactants to products.

Instead, they proceed to a state of chemical equilibrium that describe the concentrations of reactants existing among reactants product is constant.

Equilibrium constant expressions are algebraic equation that describe the concentration relationships existing among reactants and products at equilibrium.

Equilibrium- Constant Expressions:

A generalized equation for a chemical equilibrium is:

$$aA + bB \rightleftarrows cC + dD$$

where the capital letters represent the formulas of participating chemical species and the lower case are the small whole numbers required to balance the equation.

A,b,c,d = mole of A,B,C,D.

The equilibrium –constant expression of the above reaction is :

$$K_{eq.} = \frac{[C]^c}{[A]^a} \frac{[D]^d}{[B]^b}$$

Ex. 1. :

$$\mathbf{S_2O_8 + 3I^- \rightleftarrows 2SO_4^{-2} + I_3^-}$$

H.W

Ex.2

Calculate the concentration of each of A,B of equilibrium state of 0.1 M AB solution (AB: weak electrolyte). $K_{eq} = 3\times10^{-6}$.