Types of solutions based on physical state of solute/solvent

Solute	*Solvent*	*Example*
Gas	Gas	Air
Gas	Liquid	Soda water
Gas	Solid	H_2 in Pd metal
Liquid	Liquid	H_2O in C_2H_5OH
Liquid	Solid	Hg in gold
Liquid	Gas	Water in air
Solid	Liquid	Salt in water
Solid	Solid	Zn in Cu (brass)
Solid	Gas	Camphor in air

Based on the relative amounts of the dissolved solute, the solutions can be classified into three types.

They are :

(*i*) Saturated solutions

(*ii*) Unsaturated solutions

(*iii*) Supersaturated solutions.

(*i*) Saturated Solution

A solution containing maximum amount of the dissolved solute at a given temperature is called saturated solution. This solution can't dissolve any more of solute. A saturated solution contains little amount of undissolved solute.

A dynamic equilibrium exists between undissolved solute and dissolved solute of saturated solutions.

$$\text{Solute (undissolved)} \longleftrightarrow \text{Solute (dissolved)}$$

If a little solute is added to saturated solutions, it settles undissolved.

(*ii*) Unsaturated Solution

A solution in which the amount of dissolved solute is less than that required for saturation is called unsaturated solution. If a little amount of solute is added to the unsaturated solution, that solute is dissolved.

(*iii*) Supersaturated Solution

A solution containing more amount of solute than required for saturation at a given temperature is called supersaturated solution. A supersaturated solution is metastable. It readily forms saturated

solutions on slight disturbance on addition of a small crystal of the solute.

2:1. Analytical chemistry

Is a measurement science consisting of a set of powerful ideas and methods that are useful in all fields of science and medicine.

Type of Analysis

Chemical analysis is divided into two types which :

1-*Quantitative analysis*:(*how much present*)

Indicates the *amount* of each substance in a sample.

2-*Qualitative analysis*:(*what is present*)

Reveals the *identity* of the elements and compounds in a sample. This type is divided into main sections which are :

(A)*Qualitative analysis of inorganic compounds:* It's reveals the presence or absence of cat ions or anion of sample salt or a mixture of salt and this type of analysis *depends* on the chemical reaction, as well as tests on the flams .

(B)*Qualitative analysis of organic compounds:* It's *detected* carbon , halides , sulfur , nitrogen ,……etc. , also to identify the molecules or organic compounds in the sample .

2:2. Method of Analysis

Can be divided into two types which are :

1-Chemical analysis methods

This type of analysis methods *depends on* the chemical reaction .Its relies on sample tools such as the burette and balance of the sensitive and *not dependent* on complex apparatus , and called this type of analysis methods with **conventional methods** , its used to measure high concentrations ,examples of this type on analysis methods :

(A) *Volumetric or Titrimetric method of analysis .*

Include a large and powerful group of quantitative procedures that are based on measuring the amount of a reagent of known concentration that is consumed by an analytic.

Volumetric titrimetry involves measuring the volume of a solution of known concentration that is needed to react essentially completely with the analyte.
Gravimetric titrimetry differs only in that the mass of the reagent is measured instead of it′s volume.
In **coulometric titrimetry,** the "reagent" is a constant direct electrical current of known magnitude that consumes the analyte; here, the time required (and thus the total charge) to complete the electrochemical reaction is measured.
(B)*Gravimetric method of analysis .*Gravimetric methods are quantitative methods that are based on determining the mass of a pure compound to which the analyte is chemically related. Classifications of Gravimetric methods
I-Precipitation gravimetry.
И-Volatilization gravimetry.
Ш-Electrogravimetry.

2-Instrumental methods of analysis

This type *depends* on measuring some properties that are related to a qualitative are directly or indirectly with the concentration of the analyte such as absorption , emission , density , refractive index , electrical conductivity , voltage , thermal changes ,…..etc. it′s *depends* on apparatus is more complex and used to estimate the concentrations of very small accurately , high sensitivity (ppm ,ppb) .examples of this type on analysis methods:
(A) Methods of Spectral analysis .
(B) Methods of Electrolysis .
(C) Methods of Thermal analysis .
(D) Methods of Kinetic analysis .
(E) Methods of Chromatographic analysis .

2:3.Unit for expression of concentration

Measurements usually consist of a unit and a number expressing the quantity of that unit. Unfortunately, many different units may be used to express the same physical measurement. Scientists use a common set of fundamental units, several of which are listed in Table 2.1.

These units are called **SI units** after the *Système International d'Unités.*

Fundamental SI Units

Table 2.1 Fundamental SI Units

Measurement	Unit	Symbol
mass	kilogram	kg
volume	liter	L
distance	meter	m
temperature	kelvin	K
time	second	s
current	ampere	A
amount of substance	mole	mol

Chemists frequently work with measurements that are very large or very small.

A mole, for example, contains 602,213,670,000,000,000,000,000 particles, and some analytical techniques can detect as little as 0.000000000000001 g of a compound. For simplicity, we express these measurements using **scientific notation;** thus, a mole contains 6.0221367×10^{23} particles, and the stated mass is 1×10^{-15} g.

Sometimes it is preferable to express measurements without the exponential term, replacing it with a prefix. A mass of 1×10^{-15} g is the same as 1 *femtogram.*

Table 2.2 Other SI and Non-SI Units

Measurement	Unit	Symbol	Equivalent SI units
length	angstrom	Å	$1\ Å = 1 \times 10^{-10}\ m$
force	newton	N	$1\ N = 1\ m \cdot kg/s^2$
pressure	pascal	Pa	$1\ Pa = 1\ N/m^2 = 1\ kg/(m \cdot s^2)$
	atmosphere	atm	1 atm = 101,325 Pa
energy, work, heat	joule	J	$1\ J = 1\ N \cdot m = 1\ m^2 \cdot kg/s^2$
power	watt	W	$1\ W = 1\ J/s = 1\ m^2 \cdot kg/s^3$
charge	coulomb	C	$1\ C = 1\ A \cdot s$
potential	volt	V	$1\ V = 1\ W/A = 1\ m^2 \cdot kg/(s^3 \cdot A)$
temperature	degree Celsius	°C	°C = K − 273.15
	degree Fahrenheit	°F	°F = 1.8(K − 273.15) + 32

Table 2.3 Common Prefixes for Exponential Notation

Exponential	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

2:3:1.The Mole

The **mole** (abbreviated *mol*) is the SI unit for the amount of a chemical species. It is always associated with a chemical formula and represents Avogadro's number (6.022×10^{23}) of particles represented by that formula. The **molar** mass ($\mathcal{M}$) of a substance is the mass in grams of 1 mol of that substance. Molar masses are calculated by summing the atomic masses of all the atoms appearing in a chemical formula.The number of moles of a substance is calculated from:

$$\text{Moles} = \frac{\text{Weight (g)}}{\text{Formula weight(g/mol)}}$$

Where formula weight represents the atomic or molecular weight of substance.

2:3:2.The Millimole

Sometimes it is more convenient to make calculations with millimoles (mmol) rather than moles; the millimole is 1/1000 of a mole. The mass in grams of a millimole, the millimolar mass (m$\mathcal{M}$),is likewise 1/1000 of the molar mass.The number of mmoles of a substance is calculated from:

$$\text{Millimole} = \frac{\text{Weight (mg)}}{\text{Formula weight(mg/mmol)}}$$

2:3:3.Calculating the Amount of a Substance in Moles or Millimoles

This example that follow illustrate how the number of moles or millimoles of a species can be determined from its mass in grams or from the mass of a chemically related species.

Example1

How many moles and millimoles of benzoic acid *(*MW= 122.1 *g/mol)* are containedin 2.00 g of the pure acid?.

If we use HBz to represent benzoic acid, we can write that 1 mol of HBz has a mass of 122.1 g.

amount of HBz = (2.00 g / 122.1 *g/mol*)= 0.0164 *mol* HBz

To obtain the number of mill moles , we divide by the mill molar mass (0.1221 *g/mmol).*
amount HBz = (2.00g / 0.1221 *g/mmol*)= 16.4 *mmol* HBz

H.W

1-Calculate the number of grams in one mole of $CaSO_4.7H_2O$?
(Atomic weight Ca=40 ,S=32 ,O=16 ,H=1).

2-Calculate the number of moles in 500 mg Na_2WO_4?.
(MW of Na_2WO_4=293.8 mg/mmol)

2:4. Concentration of Solutions

Chemists express the concentration of species in solution in several ways. The most important ways are described in this section.

2:4:1a . Molarity and Formality

Both molarity and formality express concentration as moles of solute per liter of solution. There is, however, a subtle difference between molarity and formality. **Molarity** is the concentration of a particular chemical species in solution. **Formality,** on the other hand, is a substance's total concentration in solution without regard to its specific chemical form. There is no difference between a substance's molarity and formality if it dissolves without dissociating into ions. The molar concentration of a solution of glucose, for example, is the same as its formality. For substances that ionize in solution, such as NaCl, molarity and formality are different. For example, dissolving 0.1 mol of NaCl in 1 L of water gives a solution containing 0.1 mol of Na^+ and 0.1 mol of Cl^-. The molarity of NaCl, therefore, is zero since there is essentially no dissociated NaCl in solution. The solution, instead, is 0.1 M in Na^+ and 0.1 M in Cl^-. The formality of NaCl, however, is 0.1 F because it represents the total amount of NaCl in solution. The rigorous definition of molarity, for better or worse, is largely ignored in the current literature, as it is in this text. When we state that a solution is 0.1 M NaCl we understand it to consist of Na^+ and Cl^- ions. The unit of formality is used only when it provides a clearer description of solution chemistry. Molar concentrations are used so frequently that a symbolic notation is often used to simplify its expression in equations and writing.

The use of square brackets around a species indicates that we are referring to that species' molar concentration. Thus, $[Na^+]$ is read as the "molar concentration of sodium ions."

2:4:1b . Molar Concentration

The **molar concentration** *Ci* of a solution of a chemical species *i* is the number of moles of that species that is contained in 1 L of the solution .The unit of molar concentration is **molarity,** M, which has the dimensions of mol L^{-1}.Molarity also expresses the number of millimoles of a solute per milliliter of solution. *Molarity" redirects here. It is not to be confused with Molality.*

In chemistry, the **Molarity**, c_i is defined as the amount of a constituent n_i (usually measured in moles – hence the name) divided by the volume of the mixture V or Molarity *is the concentration of a particular chemical species in solution. It's the number of moles of solute per liter of solution (M).*

$$\text{Molarity} = \frac{\textit{No. of moles}}{\textit{liter of solution}} \quad \text{or} \quad c_i = \frac{n_i}{V}$$

It is also called molarity, amount of substance concentration, amount concentration, substance concentration, or simply concentration. The volume V in the definition $c_i = n_i/V$ refers to the volume of the solution, *not* the volume of the solvent. One litre of a solution usually contains either slightly more or slightly less than 1 litter of solvent because the process of dissolution causes volume of liquid to increase or decrease.In chemistry, the **Normality** of a solution is defined as the molar concentration c_i divided by an equivalence factor f_{eq}:

$$\text{Normality} = \frac{\textit{No. of equivalents}}{\textit{liter of solution}} \quad \text{or} \quad N = \frac{c_i}{f_{eq}}$$

Equivalent :The moles of a species that can donate one reaction unit.
Equivalent weight:The mass of a compound containing one equivalent (eqw).

$$eqw = \frac{MW}{n}$$

Normality can be used for acid-base titrations. For example, sulfuric acid (H_2SO_4) is a diprotic acid. Since only 0.5 mol of H_2SO_4 are needed to neutralize 1 mol of OH^-, the equivalence factor is:

$$f_{eq}(H_2SO_4) = 0.5$$

If the concentration of a sulfuric acid solution is $c(H_2SO_4)$ = 1 mol/L, then its normality is 2 N. It can also be called a "2 normal" solution.

Similarly, for a solution with $c(H_3PO_4)$ = 1 mol/L, the normality is 3 N because phosphoric acid contains 3 acidic H atoms .

The following simple relationship exists between Normality and Molarity :

$$N = n \times M$$

To calculate **molality (mol/kg)**, we need the number of moles of solute, and the mass of solvent used to dissolve the solute! Normally, we are given the mass of solute, and mass of solvent, therefore we calculate the moles of the solute from the mass, then use the mass of the solvent to calculate the molality.

Remember: **Molality** is different from **Molarity .Molality** is based on mass, and is independent of temperature or pressure (unlike **molarity**)

$$\textbf{\textit{Molality}} = \frac{\textit{amount(mol) of solute}}{\textit{mass(kg) of solvent}}$$

Example 2

Calculate the equivalent weight and normality for a solution of 6.0 M H_3PO_4 given the following reactions:

(a) $H_3PO_4(aq) + 3OH^-(aq) \rightleftharpoons PO_4^{3-}(aq) + 3H_2O(\ell)$

(b) $H_3PO_4(aq) + 2NH_3(aq) \rightleftharpoons HPO_4^{2-}(aq) + 2NH_4^+(aq)$

(c) $H_3PO_4(aq) + F^-(aq) \rightleftharpoons H_2PO_4^-(aq) + HF(aq)$

Solution

For phosphoric acid, the number of equivalents is the number of H^+ ions donated to the base. For the reactions in (a), (b), and (c) the number of equivalents are 3, 2, and 1, respectively. Thus, the calculated equivalent weights and normalities are

(a) $EW = \frac{FW}{n} = \frac{97.994}{3} = 32.665 \qquad N = n \times M = 3 \times 6.0 = 18\ N$

(b) $EW = \frac{FW}{n} = \frac{97.994}{2} = 48.997 \qquad N = n \times M = 2 \times 6.0 = 12\ N$

(c) $EW = \frac{FW}{n} = \frac{97.994}{1} = 97.994 \qquad N = n \times M = 1 \times 6.0 = 6.0\ N$

Example 3

Determine the **molality** and **molarity** of a solution preparedby dissolving 75.0g $Ba(NO_3)_2$ (s) in to 374.00g of water at 25 ^oC?.

Plan: We convert the quantity of $Ba(NO_3)_2$to moles using the molar mass and then divide by the volume of H_2O in liters (using water density = 0.99707 g/ml^3).

Solution: molar mass of $Ba(NO_3)_2$ = 261.32 g/mol

$$\text{moles } Ba(NO_3)_2 = \frac{75.0\ g}{261.32\ g/mol} = 0.28700 \text{ mole}$$

$$\text{molality} = \frac{0.28700 \text{ mole}}{0.37400\ kg} = 0.76739\ m = 0.767\ m$$

Molarity - we need the volume of solution, and can assume thataddition of the salt did not change the total volume.

$$V = \frac{374.00\ g\ H_2O}{0.99707\ g/ml} = 375.099\ ml = 0.375099\ L$$

$$M = \frac{0.28700 \text{ mole}}{0.375099 \text{ L}} = 0.765 \text{ M}$$

2:4:1c . CALCULATION OF EQUIVALENT WEIGHT OF SUBSTANCES

The equivalent weight of a substance is the weight of it that reacts with 1g of hydrogen or 8 g of oxygen.

1. Equivalent weight of an acid: It is the ratio of molecular weight to its basicity.

$$E_{Acid} = \frac{\text{Molecular weight}}{\text{Basicity}}$$

Basicity is the number of displaceable hydrogen atoms present in an acid.

Name of acid	Formula of acid	Basicity	Equivalent weight
Hydrochloric acid	HCl	1	36.5/1 = 36.5
Nitric acid	HNO_3	1	63/1 = 63
Sulphuric acid	H_2SO_4	2	98/2 = 49
Acetic acid	CH_3COOH	1	60/1 = 60
Phosphoric acid	H_3PO_4	3	98/3 = 32.66
Oxalic acid	$H_2C_2O_4$	2	90/2 = 45

2. Equivalent weight of a base: It is the ratio of molecular weight to its acidity.

$$E_{Base} = \frac{\text{Molecular weight}}{\text{Acidity}}$$

Acidity is the number of replaceable hydroxyl groups of the base is called acidity.