

## Lecture 2,3

General chemistry

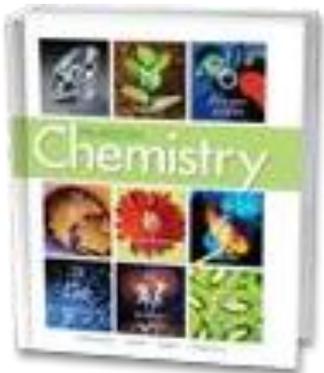
Methods of analysis

Types of Solution, preparation of standard solution unit, concentration , percentage ,

First Year

Subject Lecturer

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The Chemical analysis methods can be divided into three main branches:



- ❑ **Volumetric analysis (Titrimetric analysis):** The analyte reacts with a measured volume of the reagent of known concentration, in a process called titration.
- ❑ **Gravimetric analysis:** usually involves the selective separation of the analyte by precipitation, followed by the very nonselective measurement of mass (of the precipitate).
- ❑ **Instrumental analysis:** They are based on the measurement of a physical property of the sample, for example, an electrical property or the absorption of electromagnetic radiation. Examples are spectrophotometry (ultraviolet, visible, or infrared)
- ❑ **Electroanalytical analysis:** Measure electrical properties such as potential, current, resistance, and quantity of electrical charge.
- ❑ **Spectroscopic analysis:** Explore the interaction between electromagnetic radiation and analyte atoms or molecules or the emission of radiation by analytes

# Fundamental Concepts

## 1- Atomic weight of element:

The mass of a single atom in grams is much too small a number for convenience, and chemists therefore use a unit called an atomic mass unit (amu) also known as a Dalton (Da).

## 2-Molecular weight:

The sum of the atomic weights of all the atoms in a molecule; *Molecular weight = Summation of atomic weight*

**Example: Calculate the molecular mass or molar mass of glucose (C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>)?**

**Solution:**

The molar mass of glucose =  $(6 \times 12) + (12 \times 1) + (6 \times 16)$

M.wt = Mm = 180 g/mol.

### 3-Equivalent weight (Eq. wt) :

- ❑ The equivalent weight can be thought of as the weight (or mass, to be precise) of a substance that will contain a single reactive proton (or hydrogen ion) or a single reactive hydroxide ion.
- ❑ The reason the concept of equivalent weight is needed is that some compounds can donate or accept more than one proton, meaning that for every mole present, the substance is in effect doubly reactive. The equivalent weight can be determined by:

$$\text{Equivalent Weight (Eq. wt)} = \frac{\text{Molecular weight (or molar mass)}}{\text{Number of equivalents}}$$

#### Examples1 :

##### Sulfuric acid: $\text{H}_2\text{SO}_4$ :

Molar mass of  $\text{H}_2\text{SO}_4 = 98 \text{ g/mol}$

Looking at the formula, there are 2 hydrogen atoms, so "n" will be 2 when determine the equivalent weight:


$$\text{Equivalent Weight} = \frac{\text{molecular weight (or molar mass)}}{\text{Number of equivalents}}$$

$$\text{Equivalent Weight} = \frac{98 \text{ g/mol}}{2}$$

$$\text{Equivalent Weight} = 49$$

## Examples2 :

### Sodium Chloride NaCl:

Molar mass of NaCl = 58.5 g/mol

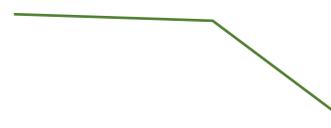
Looking at the formula, because there are no hydrogen or hydroxide atoms, the number of equivalents is 1, because there will always be at least one equivalent before a reaction can occur.

## Examples3 :

### Sodium Hydroxide (NaOH):

Molar mass of NaOH = 40 g/mol

In looking at the formula, there is 1 hydroxide (OH) atom, so the equivalent is 1.


$$\text{Equivalent Weight} = \frac{\text{molecular weight (or molar mass)}}{\text{Number of equivalents}}$$

$$\text{Equivalent Weight} = \frac{40 \text{ g/mol}}{1}$$

$$\text{Equivalent Weight} = 40$$

## Examples2 :

### Sodium Carbonate $\text{Na}_2\text{CO}_3$ :

Molar mass of  $\text{Na}_2\text{CO}_3 = 106 \text{ g/mol}$ .

The salt  $\text{Na}_2\text{CO}_3$  ionizes to form  $2\text{Na}^+$  and  $\text{CO}_3^{2-}$ , so the **charge** present on both is 2.



$$\text{Equivalent Weight} = \frac{\text{molecular weight (or molar mass)}}{\text{Number of equivalents}}$$

$$\text{Equivalent Weight} = \frac{106 \text{ g/mol}}{2}$$

$$\text{Equivalent Weight} = 53$$

**Note: A salt determines its equivalents differently because there are no hydrogen or hydroxide atoms involved, so we look at the charge.**

### 3. Mole (Mol) :

It Is the number of Avogadro's number of atom, molecule, electron and proton ( $6.022 \times 10^{23}$ ).

The numbers of moles of substance is calculated from.

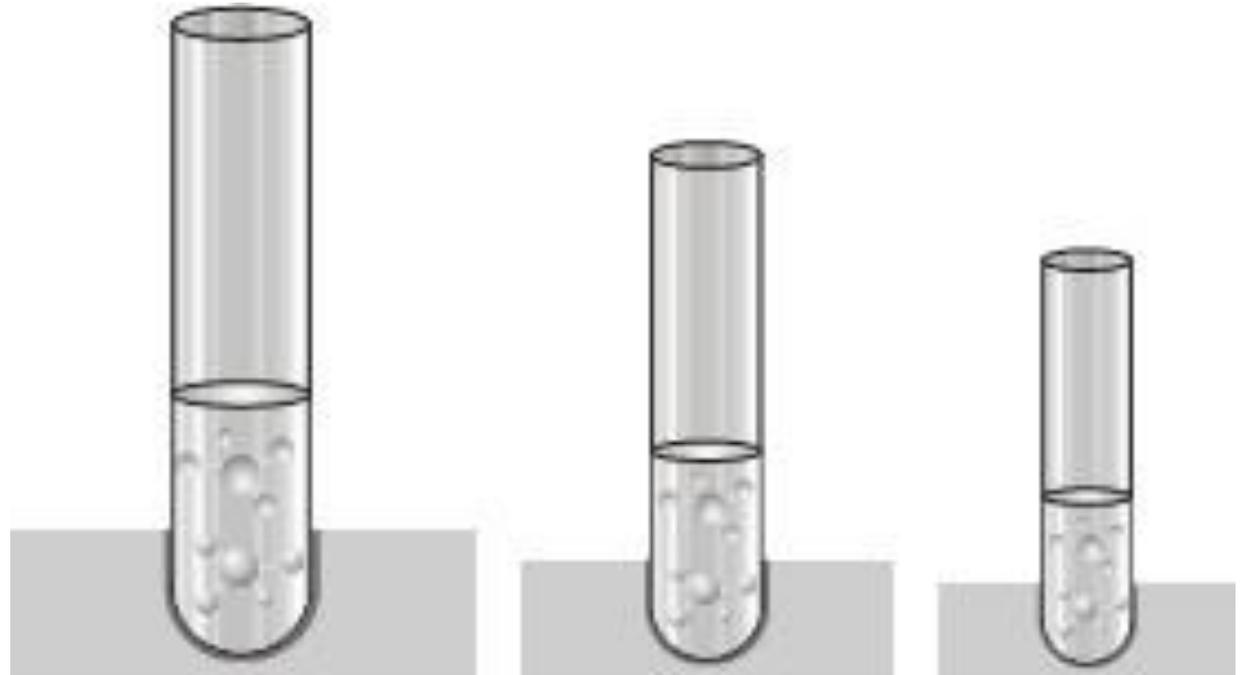
$$\text{No. of Moles} = \frac{\text{Mass of Substance (g)}}{\text{Molar mass (Molecular weight)} \left(\frac{\text{g}}{\text{mol}}\right)}$$

### 4. The millimole Mole (mmol) :

The millimole (mmol) is 1/1000 of a mole. Sometimes it is more convenient to make calculations with millimoles (mmol) rather than mole.

# Liquid Solution

- ❑ A solution is a homogenous mixture of two or more substances.
- ❑ Substance which is to be dissolved is called *Solute*.
- ❑ The dispersion medium in which the solute is dispersed to get a homogenous mixture is called the *Solvent*.



# Types of solutions

The main three types of saturation are explained below.

## Saturated Solution

A solution with solute that dissolves until it is unable to dissolve anymore, leaving the undissolved substances at the bottom.

### Saturated Solution

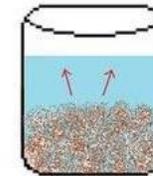


Figure 1.1



Figure 1.2

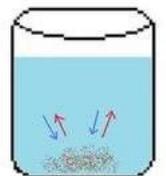


Figure 1.3

## Unsaturated Solution

A solution (with less solute than the saturated solution) that completely dissolves, leaving no remaining substances.

### Unsaturated Solution

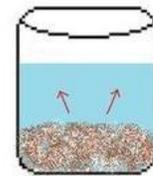


Figure 2.1

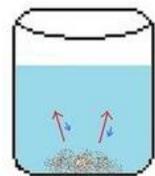


Figure 2.2



Figure 2.3

## Supersaturated Solution

A solution (with more solute than the saturated solution) that contains more undissolved solute than the saturated solution because of its tendency to crystallize and precipitate.

### Supersaturated Solution

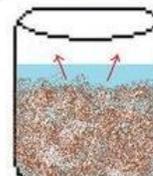


Figure 3.1

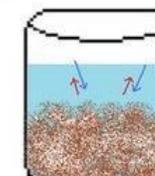


Figure 3.2

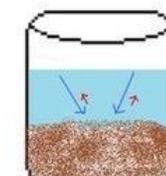
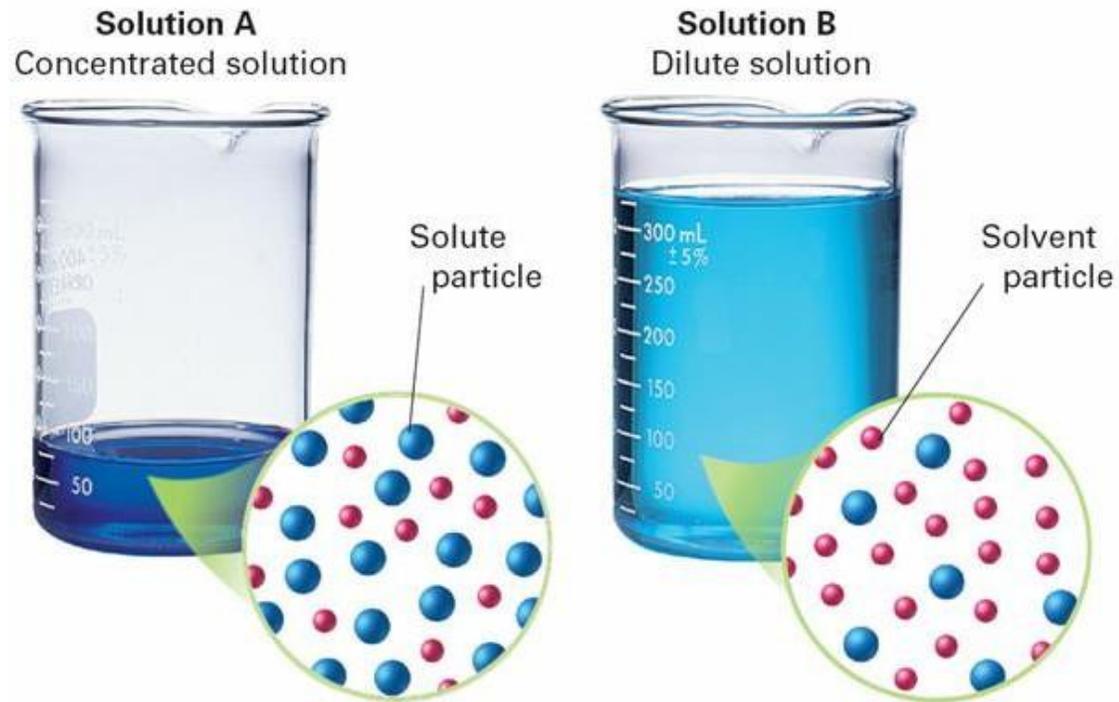


Figure 3.3

The **concentration** of a solution is a measure of the amount of solute that is dissolved in a given quantity of solvent.

- ❑ **A dilute solution** is one that contains a small amount of solute.
- ❑ **A concentrated solution** contains a large amount of solute.



## Expressions of Concentration:

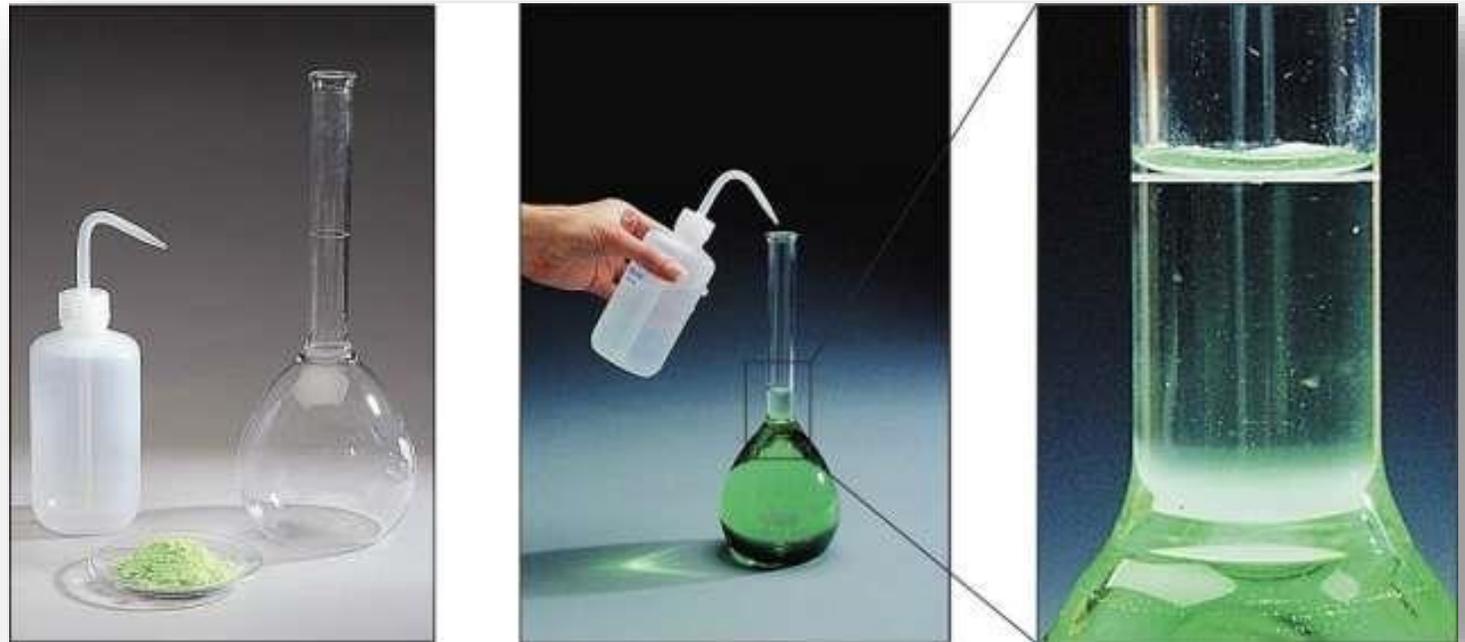
- ❑ The usage of solutions in the quantitative analysis requires some basis for the expression of solution concentration.
- ❑ The concentration of solution can be expressed in various ways as shown below.

### ❑ Relative concentration units

- ✓ Percent of Concentration
- ✓ Part Per million (ppm)

### ❑ Molarity

### ❑ Normality



## Relative Concentration Units

Concentrations are often expressed in terms of relative units (e.g. percentages) with three different types of percentage concentrations commonly used

❑ **Mass Percent:** The mass percent is used to express the concentration of a solution when the mass of a solute and the mass of a solution is given:

$$\text{Mass Percent} = \frac{\text{Mass of Solute}}{\text{Mass of Solution}} \times 100\%$$

❑ **Volume Percent:** The volume percent is used to express the concentration of a solution when the volume of a solute and the volume of a solution is given

$$\text{Volume Percent} = \frac{\text{Volume of Solute}}{\text{Volume of Solution}} \times 100\%$$

❑ **Mass/Volume Percent:** Another version of a percentage concentration is mass/volume percent, which measures the mass or weight of solute in grams (e.g., in grams) vs. the volume of solution (e.g., in mL).

$$\text{Mass/Volume Percent} = \frac{\text{Mass of Solute (g)}}{\text{Volume of Solution (mL)}} \times 100\%$$

An example would be a 0.9% (w/v) NaCl solution in medical saline solutions that contains 0.9 g of NaCl for every 100 mL of solution (see figure below).

- ❑ The mass/volume percent is used to express the concentration of a solution when the mass of the solute and volume of the solution is given.
- ❑ Since the numerator and denominator have different units, this concentration unit is not a true relative unit (e.g. percentage), however it is often used as an easy concentration unit since volumes of solvent and solutions are easier to measure than weights.

**Example 1:** Find the Vol% of a solution of 5.0 ml HCl diluted to 100 ml with water?

$$\text{Percent by volume (\% (v/v))} = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\%$$

**Answer:**

$$\begin{aligned}\text{Vol\%} &= \frac{5.0 \text{ ml}}{100} \times 100 \\ \text{Vol\%} &= 5.0\%\end{aligned}$$

Solution = solvent + solute



**Example 3:** What is the percent by volume concentration of a solution in which 75.0 ml of ethanol is diluted to a volume of 250.0 ml?

**Answer**

$$\text{The volume percent (V/V)\%} = \frac{75.0 \text{ ml}}{250.0 \text{ ml}} \times 100 = 30.0\%$$

**Example 4:** What volume of acetic acid is present in a bottle containing concentration? 350.0 ml of a solution which measures 5.00%

**Answer**

**By applying the equation of (V/V)%**

$$\text{The volume percent of (V/V)\%} = \frac{x}{350.0 \text{ ml}} = 0.05$$

$$x = 17.5 \text{ ml}$$

**Example 5:** Find the percent by mass in which 41.0 g of NaCl is dissolved in 331 grams of water.

**Answer**

$$\text{Percent by mass (\% (m/m))} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$$

Or

$$\text{Percent by Weight (\% (}\frac{W}{W}\text{))} = \frac{\text{Weight of solute}}{\text{Weight of solution}} \times 100\%$$

$$\frac{41 \text{ g}}{372 \text{ g}} \times 100 = 11.0\%$$

## Expressions of Concentration → 2. Part per million (ppm)

When a solute is present in trace quantities, it is convenient to express the concentration in parts per million (ppm). t is the number of parts of solute per million ( $10^6$ )

$$ppm = \frac{\text{mass of solute component}}{\text{Total mass of solution}} \times 10^6$$

**Example 5:** A one liter solution has a mass of 1200 milligrams.

What is its concentration in ppm?

**Answer**

$$\begin{aligned} \text{PPM} &= \frac{\text{Mass of the Solute}}{\text{Volume of the Solution}} \\ &= \frac{1,200}{1} \\ &= 1,200 \end{aligned}$$

# Expressions of Concentration → 4. Molarity

**Molarity (M)** : Molarity of a solution is the number of moles of the solute per litre of solution (or number of millimoles per ml. of solution). Unit of molarity is mol/litre or mol/dm<sup>3</sup>.

$$\text{Molarity (M)} = \frac{\text{moles of solute (n)}}{\text{Litre of solution (V)}}$$

Example: What is the molarity of 50 ml solution containing 2.355 g of Sulfuric Acid (H<sub>2</sub>SO<sub>4</sub>)?

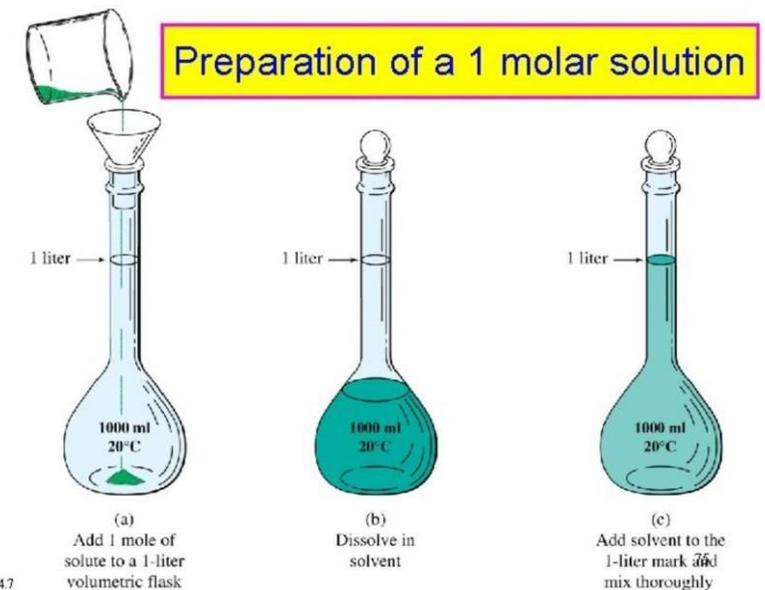
**Answer:**

**Molar mass of H<sub>2</sub>SO<sub>4</sub> = 98 g/mol.**

$$n = \frac{m}{M} = \frac{2.355 \text{ g}}{98 \text{ g/mol}} = 0.0240 \text{ mol.}$$

Volume of solution (V) = 50/1000 = 0.050 L.

$$\text{Molarity} = \frac{n}{V} = \frac{0.0240}{0.050 \text{ L}} = 0.480 \text{ mol/L}$$



**Question:**

3.65 gm of HCL gas is present in 100 mL of its aqueous solution. What is the molarity?

$$\begin{aligned}\text{Molarity} &= \text{moles of solute} / \text{V of solution in litre} \\ &= 3.65/36.5 \times 1000/100 \\ &= 0.1 \times 10 \\ &= 1 \text{ M.}\end{aligned}$$

# Expressions of Concentration → 5. Normality

**Normality** is a useful parameter to indicate the strength of the solutions based on the activity of their constituents. It is frequently used in standard lab procedures.

## Normality, N

Formula

$$N = \frac{\text{wt(g)} \times 1000}{\text{Equivalent weight} \times V} \rightarrow \frac{\text{wt(g)} \times 1000}{\text{Eq. wt.} \times V}$$

$$\text{Equivalent weight} = \frac{\text{Molecular weight}}{\text{Number of H}^+ \text{ in acid or OH}^- \text{ in base}} \rightarrow \frac{\text{M. W}}{n}$$

$$N = \frac{\% \text{ Purity} \times \rho \times 10}{\text{Eq. Wt}}$$

$\rho$  = The density of solution

OR another formula

$$N = \frac{Eq}{V}$$

$N$  = Normality

Eq = Number of gram equivalent

$V$  = Volume of solvent in liters

The relationship between the Normality and Molarity

$$N = M \times n$$

## Section Quiz.

1. To make a  $1.00M$  aqueous solution of  $\text{NaCl}$ ,  $58.4\text{ g}$  of  $\text{NaCl}$  are dissolved in

A. 1.00 liter of water.

B. enough water to make 1.00 liter of solution

C. 1.00 kg of water.

D. 100 mL of water.

## Section Quiz.

2. What mass of sodium iodide (NaI) is contained in 250 mL of a 0.500M solution?

A. 150 g

B. 75.0 g

C. 18.7 g

D. 0.50 g

4. In a 2000 g solution of glucose that is labeled 5.0% (m/m), the mass of water is

A. 2000 g.

B. 100 g.

C. 1995 g.

D. 1900 g.