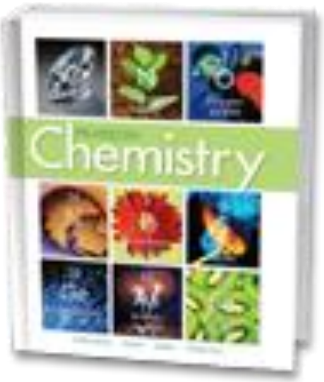
Lecture Two

Analytical chemistry

Methods of analysis

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



First Year

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What is Analytical Chemistry?

Analytical chemistry is the branch of chemistry that deals with the analysis of different substances.

Analytical chemistry involves the **separation, identification, and the quantification of matter.** It involves the use of classical methods along with modern methods involving the use of scientific instruments.

Methods Used in Analytical Chemistry

Analytical methods can be separated into classical and instrumental.

1. Classical Methods

- Classical methods (also known as wet chemistry methods) use separations such as precipitation, extraction, and distillation and qualitative analysis by color, odor, or melting point.
- Classical quantitative analysis is achieved by measurement of weight or volume. [Note: It is called "wet chemistry" since most analyzing is done in the liquid phase].

Instrumental Methods

Instrumental methods use an apparatus to measure physical quantities of the analyte such as light absorption, fluorescence, or conductivity.

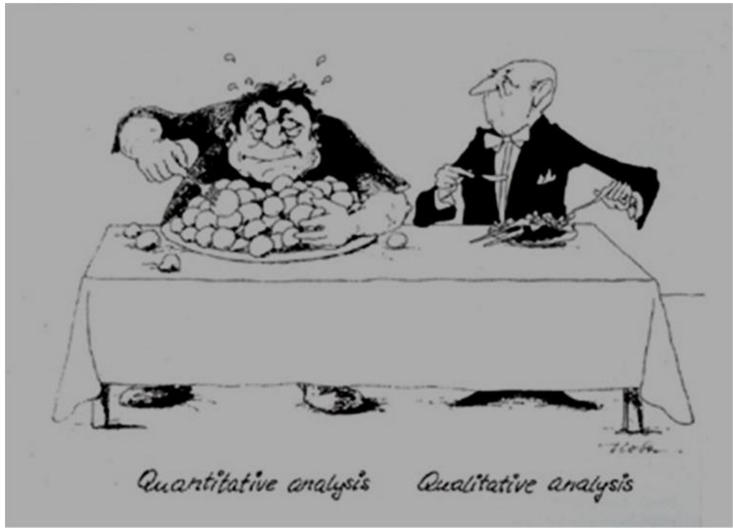
Branches of Analytical Chemistry

Two sub-branches come under analytical chemistry namely quantitative analysis and qualitative analysis which can be explained as follows. These two methods form the backbone of many educational labs of analytical chemistry.

Analytical chemistry can be classified into:

(A) Qualitative analysis: which deals with the identification of elements, ions, or compounds present in a sample (tells us what chemicals are present in a sample).

(B) Quantitative analysis: which is dealing with the determination of how much of one or more constituents is present (tells how much amounts of chemicals are present in a sample).



Applications of Analytical Chemistry

Some important applications of this branch of chemistry are listed below.

- The shelf lives of many medicines are determined with the help of analytical chemistry.
- It is used to check for the presence of adulterants in drugs.
- Soil can be tested to check for appropriate concentrations of minerals and nutrients that are necessary for plant growth.
- It is employed in the process of chromatography where the blood samples of a person are classified.
- The concentration of the pesticide residues and the contaminants in a given food sample can also be determined via analytical chemistry.
- It also has many important applications in medicine, with its use in the testing of cholesterol and glucose levels in a blood sample.
- Analytical chemistry is an integral part of forensic science, clinical analysis, and even environmental analysis

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), fluorimetry, atomic spectroscopy (absorption, emission),mass spectrometry, nuclear magnetic resonance spectrometry (NMR), X-ray spectroscopy (absorption, fluorescence).

- **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). One amu is defined as exactly 1/12 the mass of carbon isotope 12C and equal to 1 .66054 xl0-24 g.

2-Molecular weight:

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

Example1: Calculate the molecular mass or molar mass of Ethyl alcohol (Ethanol) Molecular formula of ethanol provided is: C_2H_5OH, The atomic wight of H=1, C=12, and O=16.

Solution:
The molar mass of ethanol = (2x12)+(6x1)+(1x16)
M.wt= Mm= 46 g/mol.

Example2: Calculate the molecular mass or molar mass of glucose ($C_6H_{12}O_6$)?

Solution:
The molar mass of glucose = (6x12)+(12x1)+(6x16)
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:

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

Examples1 :

Sulfuric acid: H_2SO_4:

Molar mass of H_2SO_4 = 98 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 rection can occur.

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

$$\text{Equivalent Weight} = \frac{58.5\ \text{g/mol}}{1}$$

$$\text{Equivalent Weight} = 58.5$$

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 Na_2CO_3:

Molar mass of Na_2CO_3 = 106 g/mol.

The salt Na_2CO_3 ionizes to form $2Na^+$ and 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 x 1023).

The numbers of moles of substance is calculated from.

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

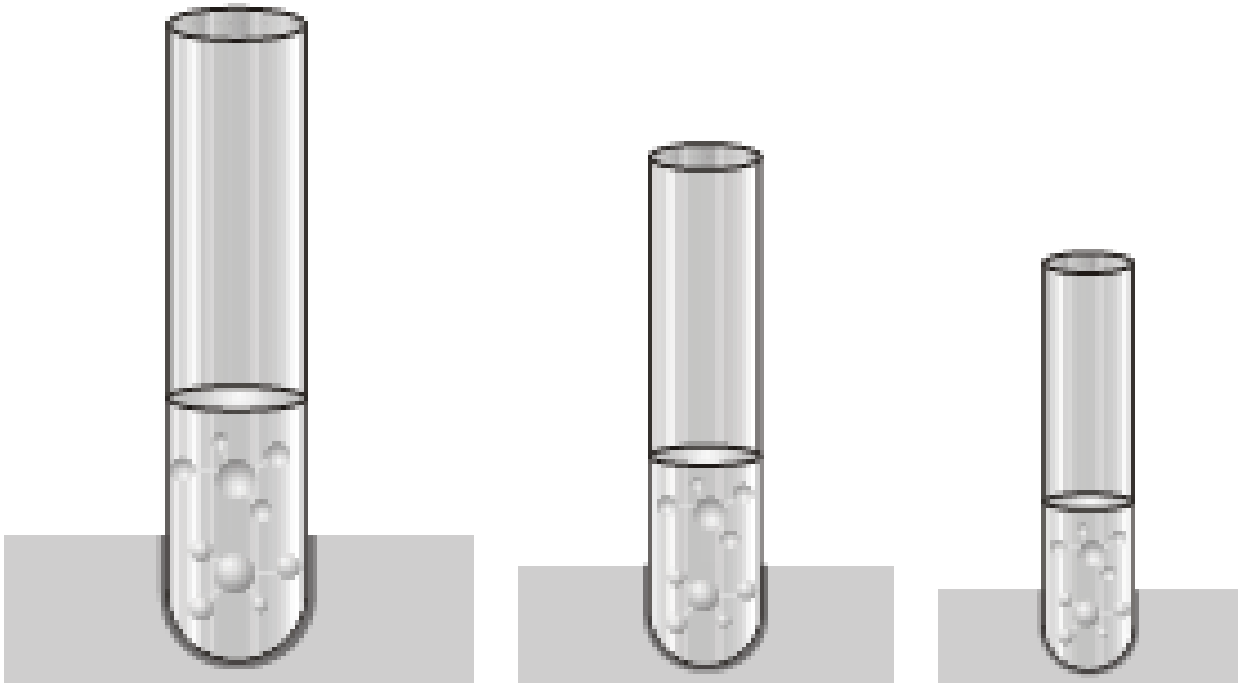
4. The millimole Mole(mmol) :

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

The mass in grams of a millimole of a substance is known as the millimolar mass which is 1/1000 of the molar mass 1 m mol = 10-3 mol

Liquid Solution

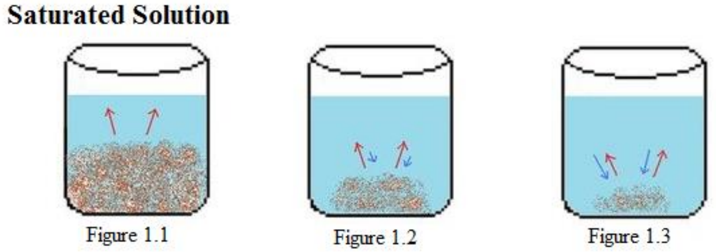
- A solution is a homogenous mixture of two or more substances.
- Substance which is to be dissolved is called ***Solute***.
- The dispersion medium in which the solute is dispersed to get a homogenous mixture is called the ***Solvent***.



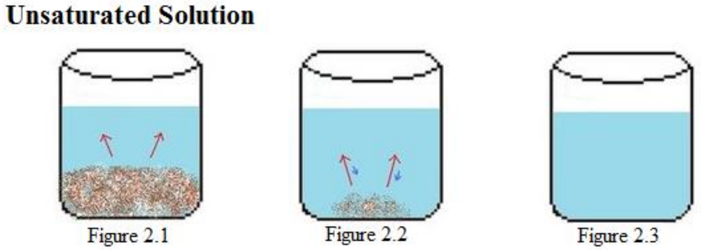
Types of solutions

The main three types of saturation are explained below.

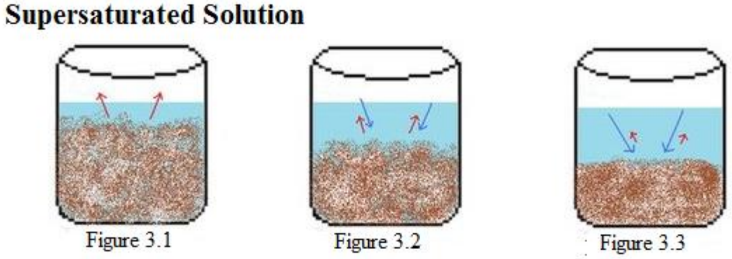
Saturated Solution	A solution with solute that dissolves until it is unable to dissolve anymore, leaving the undissolved substances at the bottom.



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

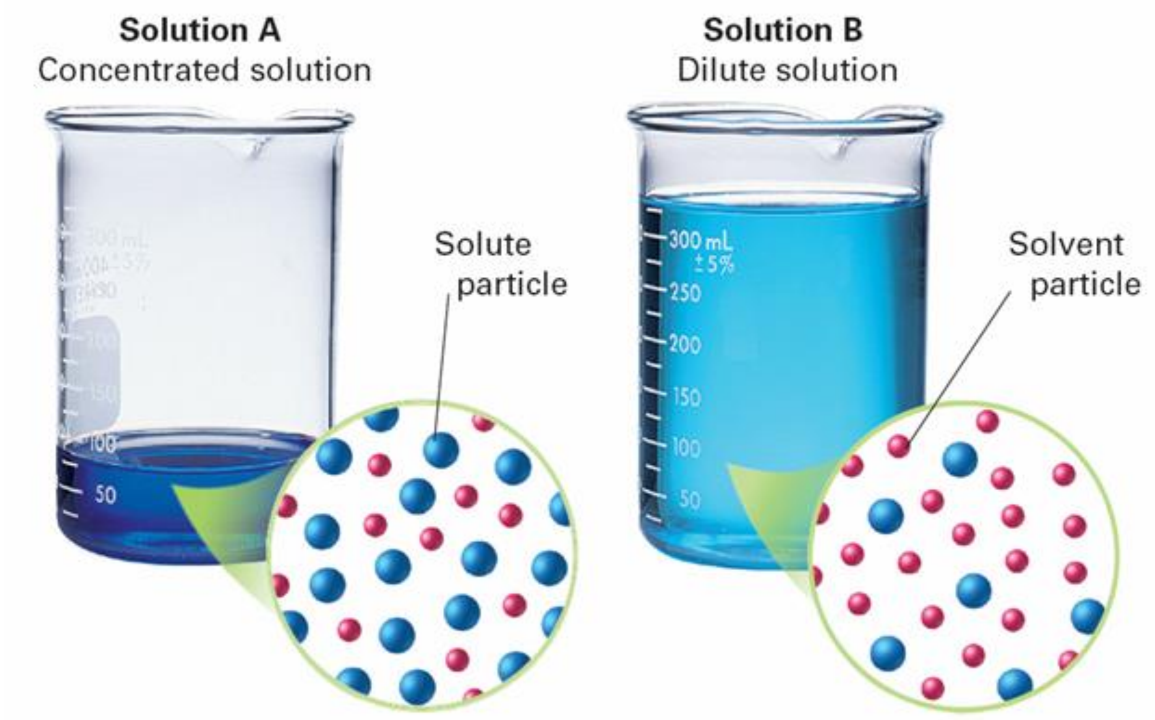


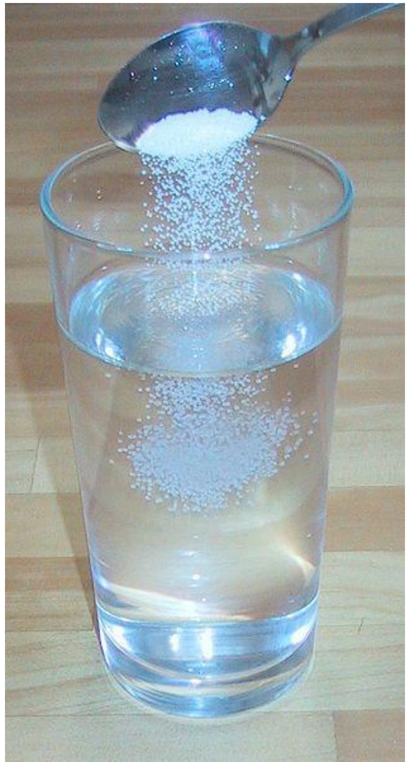
Supersaturated Solution	A solution (*with more solute than the saturated solution*) that contains more undissolved solute than the saturated solution because of its tendency to crystallize and precipitate.



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.

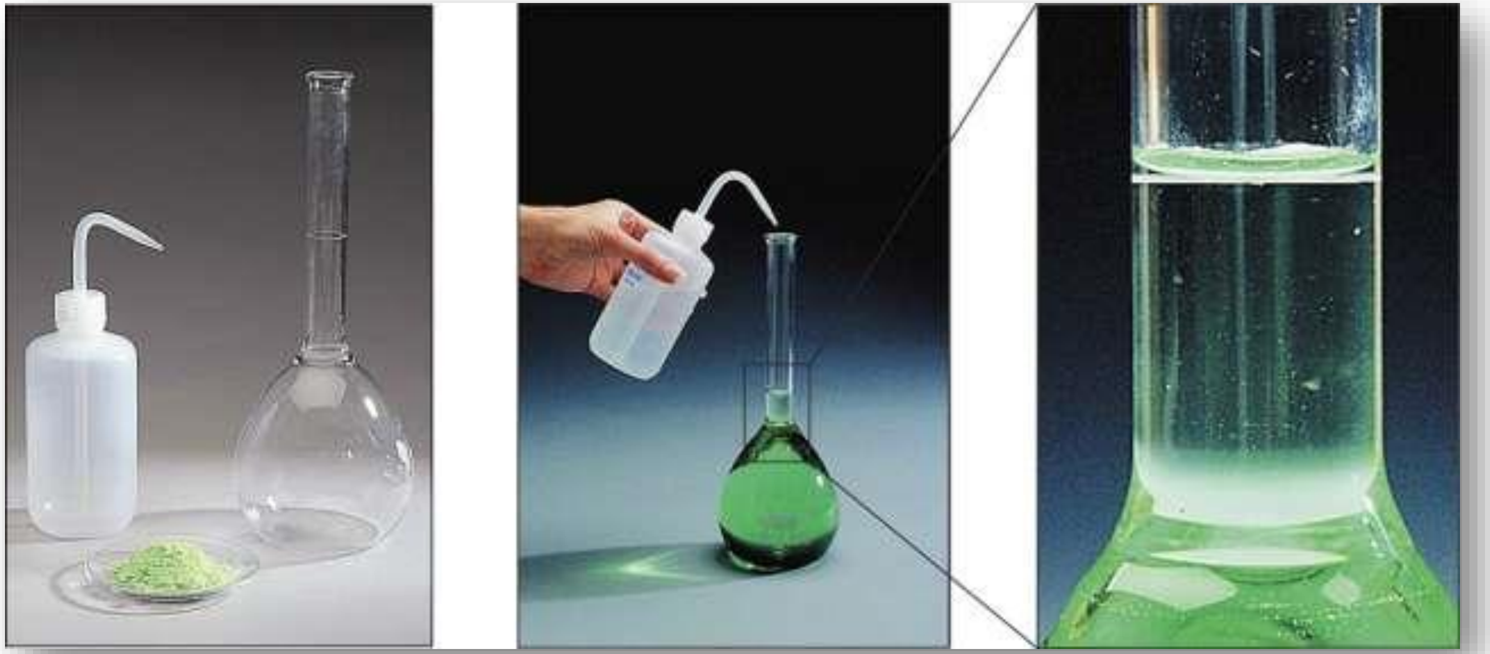




Expressions of Concentration:

- 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 unites (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?**

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

Answer:

$$\text{Vol\%} = \frac{5.0\ ml}{100} \text{x } 100$$

$$\text{Vol\%} = 5.0\%$$

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

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

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)%

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

$$x = 17.5\ ml$$

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

Answer

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

Or

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

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

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

$$PPM = \frac{\text{Mass of the Solute}}{\text{Volume of the Solution}}$$

$$= \frac{1,200}{1}$$

$$= 1,200$$

GIVE IT SOME THOUGHT

A solution of SO_2 in water contains 0.00023 g of SO_2 per liter of solution. What is the concentration of SO_2 in ppm?

1. 23 ppm
2. 2.3 ppm
3. 0.23 ppm
4. 230 ppm

Answer

$$ppm = \frac{0.00023 g}{1 L} \times 10^6 = \frac{0.23 mg}{1 L} = 0.23 ppm$$

or

If density of solution = 1g/ ml

$$ppm = \frac{0.00023 g}{1 L} \times 10^6 = \frac{0.23 mg}{1 L} = 0.23 ppm$$

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/dm³** .

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

Example: What is the molarity of 50 ml solution containing 2.355 g of Sulfuric Acid (H2SO4) ?

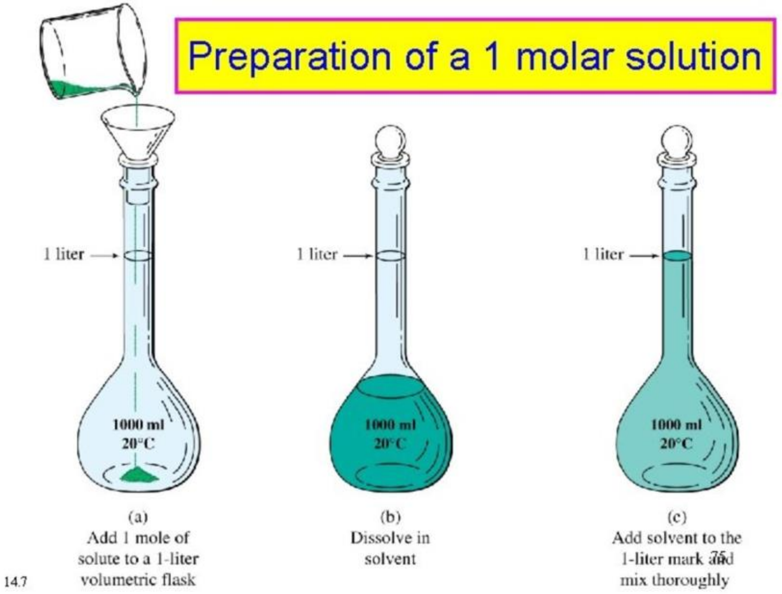
Answer:

Molar mass of H2SO4 = 98 g/mol.

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

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

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



Question:

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

Molarity = moles of solute / V of solution in litre

$= 3.65/36.5 \times 1000/100$

$= 0.1 \times 10$

$= 1$ M.

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

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

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

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

ρ = 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 1.00*M* aqueous solution of NaCl, 58.4 g of 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 0.500*M* solution?

A. 150 g

B. 75.0 g

C. 18.7 g

D. 0.50 g

Section Quiz.

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.

Unsolved questions

- What is the volume of a 0.1 M HCl solution containing 1.46 grams of HCl?
- How many grams of HNO_3 are required to prepare 500 mL of a 0.601 M HNO_3 solution?
- What is the molarity of a solution containing 5.035 grams of $FeCl_3$ in enough water to make 500 mL of solution?
- What is the molarity of a solution containing 72.9 grams of HCl in enough water to make 500 mL of solution?
- What is the molarity of a solution containing 11.522 grams of KOH in enough water to make 350 mL of solution?
- What is the molarity of a solution containing 72.06 grams of $BaCl_2$ in enough water to make 800 mL of solution?

Note: Take advantage of the following information in solving the above questions:
Atomic masses of the following elements: Fe= 56, H= 1, N= 14; O= 16; Ba= 137.32; Cl= 35.5

Some Important Units of Measurement SI units:

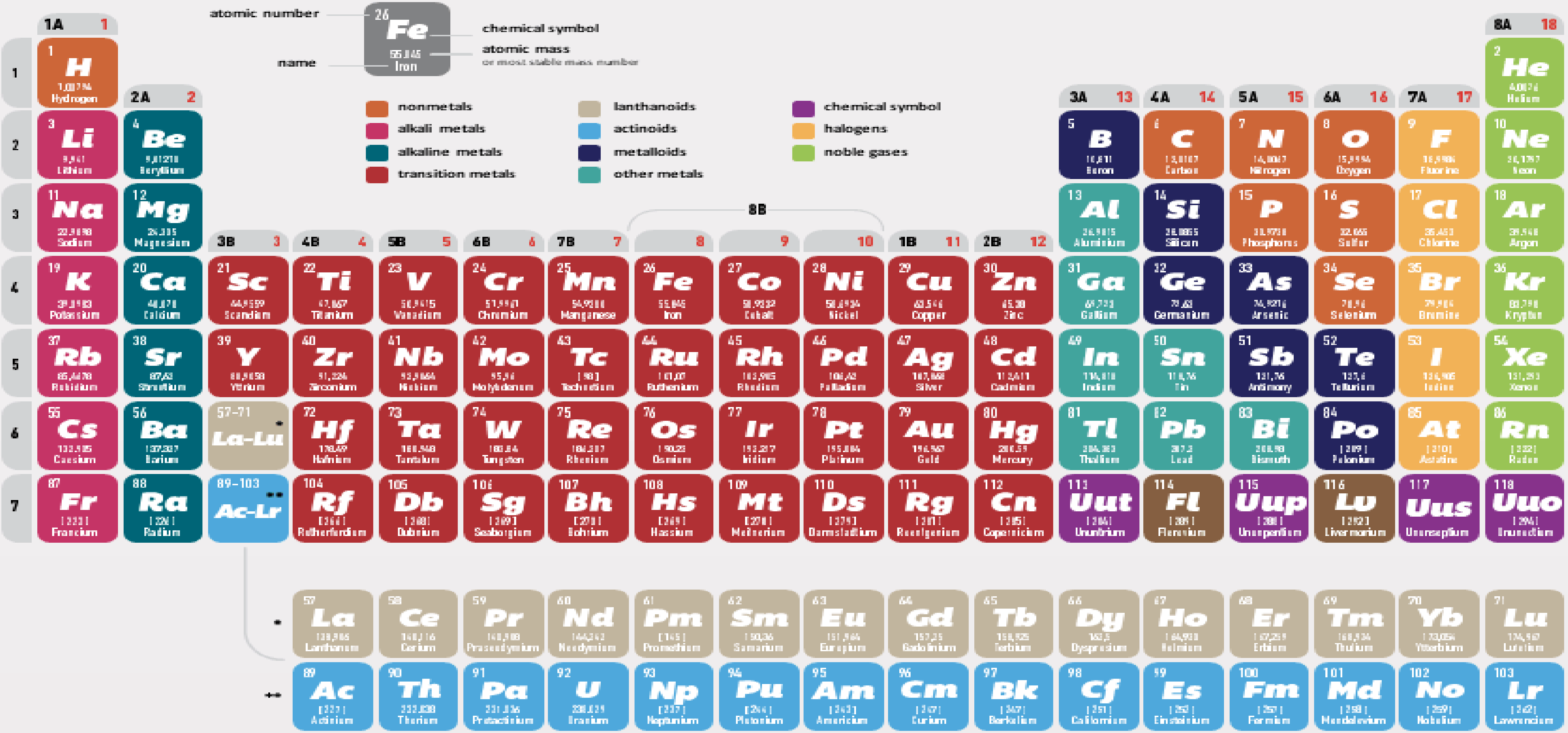
- Scientists throughout the world have adopted a standardized system of units known as the International System of Units or SI units.

- Prefixes are used with the base units and other derived units to express small or large measured quantities in terms of a few simple digits (such as:

Giga: 10^9 ; mega: 10^6 ; Kilo: 10^3 ; Deci: 10^{-1} ; Centi: 10^{-2} : Milli: 10^{-3} ; Micro: 10^{-6} ; nano: 10^{-9}

Quantity	Name	Symbol
tempetature	kelvin	K
distance	meter	m
electric current	amper	A
time	second	s
amount of substance	mole	mol
mass	kilogram	Kg
intensity of light	candela	cd

The Periodic Table for PowerPoint



The End of Lecture One