Some Important Concepts and Fundamentals

1- Chemical Measurements

Fundamental SI (*System International)* Units of Measure

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

The tables below provide a list of other important 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

Using Prefixes as Multipliers

Prefix	Symbol	Factor	Prefix	Symbol	Factor
yotta	Y	10^{24}	deci	d	10^{-1}
zetta	Z	10^{21}	centi	c	10^{-2}
exa	E	10^{18}	milli	m	10^{-3}
peta	P	10^{15}	micro	μ	10^{-6}
tera	T	10^{12}	nano	n	10^{-9}
giga	G	10^{9}	pico	p	10^{-12}
mega	M	10^{6}	femto	f	10^{-15}
kilo	k	10^{3}	atto	a	10^{-18}
hecto	h	10^{2}	zepto	z	10^{-21}
deca	da	10^{1}	yocto	y	10^{-24}

Some analytical techniques can detect as little as 0.000000000000001 g of a compound. The stated mass is 1×10^{-15} g. And is the same as 1 **femtogram.**

0.000000001 **g =** 1×10^{-9} g **= 1 nanogram.**

0.001 **mol =** 1×10^{-3} mol = **1 mmol**

0.000001 **mol =** 1×10^{-6} mol = **1 µmol**

1000 mL = 1 L

1 cm^3 = 1 mL

(L = 10^{-3} m^3)

(mL = 10^{-6} m^3)

0. 21361= 0. 214

2- Fundamental to Quantitative Calculations

Atomic Weight is the weight of a specified number of atoms of that element, and that number is the same from one element to another.

Molecular Weight (mw) defined as the sum of the atomic weights of the atoms that make up a compound. (grams per mole g/mol)

Formula Weight (fw) is a more accurate description for substances that don't exist as molecules but exist as ionic compounds (strong electrolytes—acids, bases, salts). (grams per mole)

The term **molar mass** is sometimes used in place of formula weight.

Example 1 : Calculate the weight of one mole of $CaSO_4 \cdot 7H_2O$.

Solution

One mole is the formula weight expressed in grams. The formula weight is

Ca	40.08
S	32.06
11O	176.00
14 H	14.11
	262.25 g/mol

Moles: The number of moles of a substance is calculated from

$$\text{Moles} = \frac{\text{grams}}{\text{formula weight (g/mol)}}$$

$$\text{Millimoles} = \frac{\text{milligrams}}{\text{formula weight (mg/mmol)}}$$

Example 2: Calculate the number of moles in 500 mg Na_2WO_4 (sodium tungstate). (293.8 g/mol)

Example 3: What is the weight, in milligrams, of 0.250 mmol Fe2O3 (ferric oxide)? 159.7 mg/mmol

3- **Chemical Concentration** (How Do We Express Concentrations of Solutions):

Concentration states how much solute is contained in a given volume or mass of solution or solvent.

- **Molarity** (M):- The number of moles of solute per liter of solution.

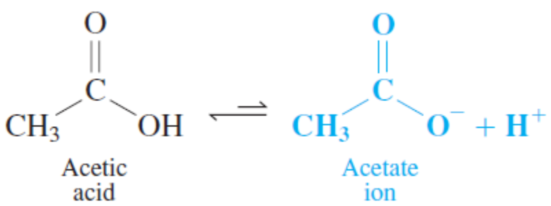
$$M = \text{molarity} = \frac{\text{mol solute}}{\text{L solution}}$$

- **Formality** (F)**:-** The number of moles of solute, regardless of chemical form, per liter of solution.

(Formality is numerically the same as molarity)

Sometimes the molarity of a strong electrolyte is called the **formal concentration** (F)**.**

For a *weak electrolyte* such as acetic acid, CH_3COOH, some of the molecules dissociate into ions in solution



Formal concentration	Percent dissociated
0.10 F	1.3%
0.010 F	4.1%
0.001 0 F	12%

Example 5: How many grams per milliliter of NaCl are contained in a 0.250 *M* solution? 58.4 mg/mmol

Example 6: How many grams Na_2SO_4 should be weighed out to prepare 500mL of a 0.100 *M* solution? 142 mg/mmol

Example 7:

(a) Typical seawater contains 2.7 g of salt (sodium chloride, NaCl) per 100 mL (100×10^{-3} L). What is the molarity of NaCl in the ocean?

(b) $MgCl_2$ has a concentration of 0.054 M in the ocean. How many grams of $MgCl_2$ are present in 25 mL of seawater? 22.99 g/mol (Na) and 35.45 g/mol (Cl)

Answer: a) 0.46 M b) 0.13 g

- **Molality** (*m*) is concentration expressed as moles of substance per kilogram of solvent (not total solution).
  Molality is independent of temperature.
  Molarity changes with temperature because the volume of a solution usually increases when it is heated.

$$m = \text{molality} = \frac{\text{mol solute}}{\text{kg solvent}}$$

- **Normality** (N): The number of equivalents of solute per liter of solution.

Density Calculations:

- **Density** is the weight per unit volume at the specified temperature, usually g/mL or g/cm3 at 20°C.

Specific gravity is defined as the ratio of the mass of a body (e.g., a solution), usually at 20°C, to the mass of an equal volume of water at 4°C (or sometimes 20°C).

Density of solution at 20°C = Specific gravity of solution × 0.99821 g/mL

- **<u>Percent Composition for the SOLID SAMPLES</u>**:

The percentage of a component in a mixture or solution is usually expressed as a **weight percent** (wt%):

$$\%(\text{wt/wt}) = \left[\frac{\text{wt solute (g)}}{\text{wt sample (g)}}\right] \times 10^2 \ (\%/\text{g solute/g sample})$$

- <u>**Percent Composition for the LIQUID SAMPLES**</u>

- **Percent Composition for the LIQUID- SOLID SAMPLES**

$$\%(\text{wt/vol}) = \left[\frac{\text{wt solute (g)}}{\text{vol sample (mL)}}\right] \times 10^2 \ (\%/\text{g solute/mL sample})$$

- <u>**Parts per Thousand, Parts per Million and Parts per Billion For SOLID SAMPLES**</u>

parts per thousand (ppt), **parts per million** (ppm), or **parts per billion** (ppb).

$$\text{ppt (wt/wt)} = \left[\frac{\text{wt solute (g)}}{\text{wt sample (g)}}\right] \times 10^3 \ (\text{ppt/g solute/g sample})$$

$$\text{ppm (wt/wt)} = \left[\frac{\text{wt solute (g)}}{\text{wt sample (g)}}\right] \times 10^6 \ (\text{ppm/g solute/g sample})$$

$$\text{ppb (wt/wt)} = \left[\frac{\text{wt solute (g)}}{\text{wt sample (g)}}\right] \times 10^9 \ (\text{ppb/g solute/g sample})$$

- <u>**Parts per Million, Parts per Billion and Parts per Trillion For SOLID- Liquid SAMPLES**</u>

$$\text{ppm (wt/vol)} = \left[\frac{\text{wt solute (g)}}{\text{vol sample (mL)}}\right] \times 10^6 \text{ (ppm/g solute/mL sample)}$$

$$\text{ppb (wt/vol)} = \left[\frac{\text{wt solute (g)}}{\text{vol sample (mL)}}\right] \times 10^9 \text{ (ppb/g solute/mL sample)}$$

$$\text{ppt (wt/vol)} = \left[\frac{\text{wt solute (g)}}{\text{vol sample (mL)}}\right] \times 10^{12} \text{ (ppt/g solute/mL sample)}$$

Example : A 2.6 g sample of plant tissue was analyzed and found to contain 3.6 μg zinc. What is the concentration of zinc in the plant in ppm? In ppb?

Converting Parts per Billion into Molarity

The concentration of $C_{29}H_{60}$ in summer rainwater collected in Hannover, Germany is 34 ppb. Find the molarity of $C_{29}H_{60}$ and express the answer with a nano prefix

H.W) How many ppm of $C_{29}H_{60}$ are in 23 µM C29H60? (***Answer***: 9.4 ppm)

Preparing Solutions:

To prepare a solution with a desired molarity from a pure solid or liquid, we weigh out the correct mass of reagent and dissolve it in a *volumetric flask*

Example : A solution is prepared by dissolving 1.26 g $AgNO_3$ in a 250-mL volumetric flask and diluting to volume. Calculate the molarity of the silver nitrate solution. How many millimoles $AgNO_3$ were dissolved? 169.9 g/mol

- **Dilution Calculations:**

Dilution formula:

$$\underbrace{M_{conc} \cdot V_{conc}}_{\text{Moles taken from concentrated solution}} = \underbrace{M_{dil} \cdot V_{dil}}_{\text{Moles placed in dilute solution}}$$

Example : The molarity of "concentrated" HCl purchased for laboratory use is approximately 12.1 M. How many milliliters of this reagent should be diluted to 1.000 L to make 0.100 M HCl?

H.W) You wish to prepare 500mL of a 0.100 *M* $K_2Cr_2O_7$ solution from a 0.250 *M* solution. What volume of the 0.250 *M* solution must be diluted to 500 mL? **Answer**= 200 mL

Example : How many milliliters of concentrated sulfuric acid, 94.0% (g/100 g solution), density 1.831 g/cm3, are required to prepare 1 liter of a 0.100 *M* solution?

Example : A 25.0-μL serum sample was analyzed for glucose content and found to contain 26.7 μg. Calculate the concentration of glucose in μg/mL and in mg/d

H.W) (a) Calculate the molar concentrations of 1mg/L (1.00 ppm) solutions each of Li^+ (6.94 g Li/mol) and Pb^{2+} (207 g Pb/mol).
Answer (1.44 × 10^{-4} mol/L Li and 4.83 × 10^{-6} mol/L Pb)
(b) What weight of $Pb(NO_3)_2$ will have to be dissolved in 1 liter of water to prepare a 100 mg/L (100 ppm) Pb^{2+} solution? **Answer= 0.137 g $Pb(NO_3)_2$**

- **p-function**

A function of the form p*X*, where p*X* = -log(*X*).

Example : What is pNa for a solution of 1.76×10^{-3} M Na_3PO_4?

Example : What is the $[H^+]$ in a solution that has a pH of 5.16?