Calculations in analytical chemistry

Why use the SI System?

In the U.S. they use the English or Standard System, most of the rest of the world uses the Metric or SI System.

International System of Units

SI

le Système International d'unités

The SI (International System of Units) system is the form of measurement typically used by scientists.

Why use the SI System?

Scientists use the SI System worldwide because:

International System of Units

SI

le Système International d'unités

- Measurements are easily understood by all scientists
- Measurements are easier to convert than the English system

Measurement System Comparisons

MEASUREMENT	ENGLISH	SI SYSTEM
LENGTH	Yard / Inch	Meter / Centimeter
MASS	Ounce / Pound	Gram / Kilogram
VOLUME	Quart	Liter
TEMPERATURE	Fahrenheit	Celsius / Kelvin
TIME	Second	Second

All Measurement systems have **standards**.
Standards are exact quantities that everyone agrees to use as a basis of comparison.

The SI System uses the following prefixes:

Kilo	1000
Hecto	100
Deca	10
UNIT	1
Deci	1/10
Centi	1/100
Milli	1/1000

This system works with any SI measurement.

The UNIT becomes whichever type of measurement you are making. (mass, volume, or length)

It is the same system regardless if you are measuring length, mass, or volume.

What is Solution Concentration?

- Concentration is a measure of the amount of solute dissolved in a volume of solution.
- Solution concentration can be measured in different units depending on:
- The type of solution,
- The ratio of solute to solution and
- The purpose for the solution.

Why are there so many different ways to express Concentration?

- This is because there are so many different solutions.
- Solutions have very different components, mixed in different proportions.
- Solutions have different uses in many fields - pharmaceuticals, metallurgy, jewellery, agriculture, laboratory work, cleaning…

Molarity (M)

Number of moles of solute present in one litre of solution.

$$M = \frac{\text{Moles of solute}}{\text{Volume (in litre)}}$$

$$M = \frac{wt}{m.wt} * \frac{1000}{(v)\ ml}$$

Moles = Molarity x volume (in litre)

Milli moles = Molarity x volume (in ml)

Exercise

A 0.115 g of pure sodium metal was dissolved in 500 ml distilled water. The molarity of the solution would be
(Na = 23)

(a) 0.010 M (b) 0.00115 M

(c) 0.023 M (d) 0.046 M

Solution:

$$M = \frac{wt}{m.wt} * \frac{1000}{(v)ml}$$

$$= \frac{0.115}{23 \times 500} \times 1000 = 0.01M$$

Hence, answer is (a)

Example

Calculate the molarity of a solution of NaOH in which 0.40g NaOH dissolved in 500 ml solution.

Solution:

$$M = \frac{0.40}{40 \times 500} \times 1000$$

$$= 0.02 \text{ M}$$

Normality (N)

Number of equivalents of solute present in one litre of solution.

$$N = \frac{\text{Equivalent of solute}}{\text{Volume of solution in litre}}$$

$$N = \frac{wt}{eq.wt} * \frac{1000}{(v)ml}$$ (Solids)

$$N = \frac{sp.gr * \% * 1000}{eq.wt}$$ Liquids

Equivalents = N x V (in litre)

Milli equivalents = N x V (in ml)

Equivalent weight of Acid

Equivalent weight of acid = $\frac{\text{m. wt of acid}}{\text{number of replacable H}^{+}}$

Example:

Equivalent weight of HCl and H_2SO_4

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

$$H_2SO_4 \longrightarrow 2H^{+} + SO_4^{--}$$

$$equivalent\ weight\ of\ HCl = \frac{1 + 35.5}{1} = 36.5$$

$$equivalent\ weight\ of\ H_2SO_4 = \frac{(2 * 1) + 32 + (4 * 16)}{2} = 49$$

Equivalent weight of Base

Equivalent weight of base = $\frac{\text{m. wt of base}}{\text{number of replacable OH}^{+}}$

Example:

Equivalent weight of NaOH and $Ca(OH)_2$

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

$$Ca(OH)_2 \longrightarrow Ca^{++} + 2OH^{-}$$

$$\textbf{Equivalent weight of NaOH} = \frac{23 + 16 + 1}{1} = 40$$

$$\textbf{Equivalent weight of } Ca(OH)_2 = \frac{40 + (2 * 16) + (2 * 1)}{2} = 37$$

Equivalent weight of salt

$$Equivalent\ weight\ of\ salt = \frac{m.wt\ of\ salt}{total\ number\ of\ possitive\ or\ negative\ charge}$$

Example:

Equivalent weight of NaCl and $MgCl_2$

$$NaCl \longrightarrow Na^{+} + Cl^{-}$$

$$\textbf{Equivalent weight of NaCl} = \frac{23 + 35.5}{1} = 58.5$$

$$MgCl_2 \longrightarrow Mg^{++} + 2Cl^{-}$$

$$\textbf{Equivalent weight of } MgCl_2 = \frac{240 + (2 * 35.5)}{2} = 47.5$$

Example

Find the normality of H_2SO_4 having 49g of H_2SO_4 present in 500 ml of solution.

Solution:

$$N = \frac{wt}{eq.wt} * \frac{1000}{(v)ml}$$

$$N = \frac{49 \times 1000}{\frac{98}{2} \times 500} = 2N$$

Relation between normality and molarity

$N = M \times n$ factor

For HCl,	n = 1
H_2SO_4,	n = 2
H_3PO_4,	n = 3
NaOH,	n = 1
$Ca(OH)_2$,	n = 2

For monovalent compound (n = 1) Normality and molarity is same.

Example

Calculate molarity of 0.6 N $AlCl_3$ solution.

Solution:

$$AlCl_3 \longrightarrow Al^{+++} + 3Cl^{-}$$

n = 3

$$\therefore M = \frac{0.6}{3} = 0.2M$$

Example

Calculate the molarity and normality of a solution containing 0.5 g of NaOH dissolved in 500 ml.

Solution:

$$Molarity\ (M) = \frac{wt}{m.wt} * \frac{1000}{(v)ml}$$

$$= \frac{0.5}{40} \times \frac{1000}{500} = 0.025\ \text{M}$$

$$Normality\ (N) = \frac{wt}{eq.wt} * \frac{1000}{(v)ml}$$

$$= \frac{0.5}{\frac{40}{1} \times 500} \times 1000 = 0.025\ \text{N}$$

Or for monovalent compound like NaOH normality and molarity are same.

Strength of solution

Amount of solute present in one litre solution.

$$Strength = \frac{weight\ of\ solute}{Volume\ of\ solution\ (L)}$$

$$Strength = Molarity\ * m.wt$$

$$Strength = Normality\ * eq.wt$$

Example

Calculate strength of 0.01 N of NaOH solution.

Solution:

$$Strength = Normality \ * eq.wt$$

= 0.01 x 40

= 0.4 g/litre

Concentration - % W/V (%m/v)

- This concentration usually describes a solid solute dissolved in a liquid solvent.

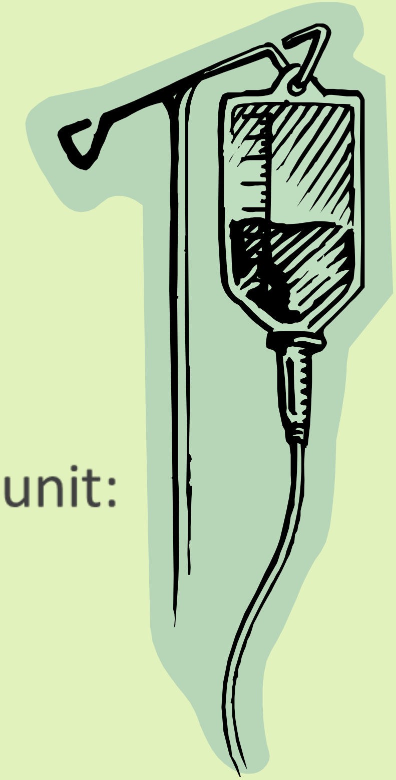
- $$\%\left(\frac{w}{v}\right) = \frac{weight\ of\ solute\ (g)}{volume\ of\ solution\ (mL)} * 100$$

- Example of a solution that uses this concentration unit:

- Intravenous solution is

  0.90% (m/v) NaCl

(this means 0.90g NaCl dissolved in 100mL of solution)



Concentration - % W/W (%m/m)

- This concentration usually describes a solid solute in a solid solvent.

- $\% \left(\frac{w}{w}\right) = \frac{weight\ of\ solute\ (g)}{weight\ of\ solution\ (g)} * 100$

- Example of a solution that uses this concentration unit:

- Toothpaste is

  0.24% (m/m) SnF_2

(this means 0.24g SnF_2 dissolved in100g of solution)

Concentration - % V/V (%v/v)

- This concentration usually describes a liquid solute in a liquid solvent.
- $$\%\left(\frac{v}{v}\right) = \frac{volume\ of\ solute\ (mL)}{volume\ of\ solution\ (mL)} * 100$$

- Example of a solution that uses this concentration unit:

- Wine is

  11.0% (v/v) Ethanol (C_2H_5OH)

(this means 11.0 mL of ethanol is dissolved in 100mL of solution.)

Concentration - ppm

- This concentration describes very small masses of any solute in a mass of solution.

- $$(ppm) = \frac{weight\ of\ solute\ (g)}{weight\ \ of\ solution\ (g)} * 10^6$$

- Example of a solution that uses this concentration unit:

- Bottled water contains

  280 ppm of HCO_3^{1-}, 118 ppm Ca…

(this means every 1 000 000 parts of solution contain 280 parts of HCO_3^{1-} solute)

*1ppm = 1 drop of water in a bathtub

Expressing ppm in various units

1ppm = $1\ g/10^6\ mL$

1 g/1000 L

1 mg/L

1 mg/kg

1 ug/g

*Choose the unit that matches the information given in the example you are calculating.

Concentration - ppb

- This concentration describes extremely small masses of any solute in a mass of solution.

- $$(ppb) = \frac{weight\ of\ solute\ (g)}{weight\ \ of\ solution\ (g)} * 10^9$$

- Example of a solution that uses this concentration unit:

- Trace amounts of pollutants in food products, air and water

(a concentration of 25 ppb means every 1 000 000 000 parts of solution contain 25 parts of solute)

The relation between molar concentration and ppm

$$ppm = M * m.wt * 1000$$

Exercise : Calculate the molarity of a dye concentration given the molecular weight of the dye 327 g/mol and a dye concentration of 2 ppm.

Solution:

$$ppm = M * m.wt * 1000$$

$$2 = M * 327 * 1000$$

$$M = 6.1 \times 10^{-6}$$

Dilution

A 20 ml of 10 N HCl are diluted with distilled water to form one litre of the solution. What is the normality of the diluted solution?

Solution:

$$N_1V_1 = N_2V_2$$

$$\frac{20}{1000} \times 10 = N_2 \times \frac{1000}{1000}$$

$$N_2 = 0.2\ N$$