Methods of Expressing Concentration of Solutions

A solution:- is a homogeneous mixture of one substance dissolved in another substance.

Concentration:- is a ratio of the amount of solute to the amount of solvent**.**

Molarity

is the number of moles of solute dissolved in one liter of solution. The units, therefore are **moles per liter**, specifically it's **moles of solute** per **liter of solution**.

$$\text{molarity} = \frac{\text{moles of solute}}{\text{liter of solution}}$$

Example 1. What is the molarity of a 5.00 liter solution that was made with 10.0 moles of KBr ?

Solution: We can use the original formula. Note that in this particular example, where the number of moles of solute is given, the identity of the solute (KBr) has nothing to do with solving the problem.

$$\text{Molarity} = \frac{\text{n.of moles of solute}}{\text{Liters of solution}}$$

Given: n. of moles of solute = 10.0 moles
Liters of solution = 5.00 liters

$$\text{Molarity} = \frac{\text{10.0 moles of KBr}}{\text{5.00 Liters of solution}} = 2.00\ \text{M}$$

Answer = 2.00 M

$$\text{n. of moles} = \frac{\text{Weight(grams)}}{\text{M.wt (g/mol)}}$$

$$\text{Molarity} = \frac{\text{Weight (g)}}{\text{Molecular Weight (g/mol)}} \times \frac{1000}{\text{Volume (ml)}}$$

Molecular Weight = Sum. Of atomic weight

Example : Prepare 0.1 M of NaCl in 250 ml of D.Water from Solid?

Wt= M x M.wt. x V(ml) / 1000

= 0.1 x 58.5 x 250 / 1000

= 1.38 g

Example 2 : What is the molarity of 5.30 g of Na_2CO_3 dissolved in 400.0 mL solution?

Ans: 0.167 mol/L

Normality

is the number of equivalents of solute dissolved in one liter of solution. The units, therefore are **equivalents per liter**, specifically it's **equivalents of solute** per **liter of solution**.

$$\text{Normality} = \frac{\text{No. of equivalents of solute}}{\text{liter of solution}}$$

$$\text{No. of equivalents} = \frac{\text{Weight (g)}}{\text{Equivalent Weight (g/eq)}}$$

$$\text{Normality} = \frac{\text{Weight(g)}}{\text{Equivalent weight (g/eq)}} \times \frac{1000}{\text{Volume(ml)}}$$

$$\text{Eq.Wt} = \frac{\text{M.Wt}}{n}$$

n = No. of (H) atoms for acids

for HCl n=1

n = No of OH groups for bases

for NaOH n=1

n = No of Cation atoms (M+) for salts

for Na_2CO_3 n= 2

n = No. of gained or lost electrons for oxidants and reductants

for $KMnO_4$ n= 7

Relationship between Molarity and Normality

$$\text{Molarity} = \frac{\text{Weight (g)}}{\text{Molecular Weight (g/mol)}} \times \frac{1000}{\text{Volume (ml)}}$$

$$\text{Normality} = \frac{\text{Weight(g)}}{\text{Equivalent weight (g/eq)}} \times \frac{1000}{\text{Volume(ml)}}$$

$$Eq.Wt = \frac{M.Wt}{n}$$

$$N = M \times n$$

Q / what is the normality of 0.1 mol /L of Na_2SO_4 ?

N = 0.1 * 2 = 0.2 N

Weight – Volume Percentage (% w/v)

It's the amount of solute present in 100 **mL** of solution.

$$\% \, w / v = \frac{\text{Weight of solute (g)}}{\text{Volume of solution (ml)}} \times 100$$

Example : 2.0 L of an aqueous solution of potassium chloride contains 45.0 g of KCl. What is the weight/volume percentage concentration of this solution in g/100mL?

Sol/
Convert the units (mass in grams, volume in mL):

Mass of KCl = 45.0g, volume of solution = 2.0 L = 2.0 ~~L~~ × 10^3 mL~~L~~ = 2000 mL

w/v (%) = [mass solute (g) ÷ volume solution (mL)] × 100

Substitute in the values and solve:

w/v (%) = [45.0 ÷ 2000 mL] × 100 = 2.25 g/100mL (%)

Weight – Weight Percentage (% w/w)

It's the amount of solute present in 100 **g** of solution.

$$\% \text{ w / w} = \frac{\text{Weight of solute (g)}}{\text{Weight of solution (g)}} \times 100$$

Example: An aqueous solution contains 42% by mass ethanol. What mass of ethanol is present in 250 g of solution?

Sol/

1- Extract the data from the question:

Aqueous solution is made up of two components, a solute (ethanol) and a solvent (water), mass % ethanol = 42 %,

$\text{mass}_{(\text{solution})} = \text{mass}_{(\text{ethanol})} + \text{mass}_{(\text{water})} = 250$ g

$\text{mass}_{(\text{ethanol})} = ?$ g

2- Write the equation for finding mass % ethanol:

mass % ethanol = mass(ethanol) ÷ mass(solution) × 100

Re-arrange the equation to find mass of ethanol:

mass(ethanol) = mass % ethanol × mass(solution) ÷ 100

3- Substitute the values into the equation and solve:

mass(ethanol) = 42 × 250 ÷ 100 = 105 g

Volume – Volume Percentage (% v / v)

It's the volume of solute present in 100 **mL** of solution.

$$\%\ v/v = \frac{\text{Volume of solute (ml)}}{\text{Volume of solution (ml)}} \times 100$$

Example 2:

A solution is prepared by dissolving 90 mL of hydrogen peroxide in enough water to make 3000 mL of solution. Identify the concentration of the hydrogen peroxide solution.

Sol/

The given parameters are

Volume of solute = 90 mL

Volume of solution = 3000 mL

Substitute the values in the given formula,

Volume percent = volume of solute /volume of solution x 100%

= 90 mL/ 3000mL x 100%

Volume percent = 3 %

Q/ What is the weight/volume percentage concentration of 250mL of aqueous sodium chloride solution containing 5g NaCl?

Calculate the weight/volume (%) = mass solute ÷ volume of solution x 100
mass solute (NaCl) = 5g
volume of solution = 250mL

w/v (%) = 5g ÷ 250mL x 100 = 2g/100mL (%)

Q / 2.0L of an aqueous solution of potassium chloride contains 45.0g of KCl. What is the weight/volume percentage concentration of this solution in g/100mL?

a. Convert the units (mass in grams, volume in mL):
   mass KCl = 45.0g
   volume of solution = 2.0L = 2.0 x 10^3mL = 2000mL
b. Calculate w/v (%) = mass solute (g) ÷ volume solution (mL) x 100
   w/v (%) = 45.0 ÷ 2000mL x 100 = 2.25g/100mL (%)

Q / If you have 10.0 grams of Br_2 and dissolve it in 1.00 L of cyclohexane, what is the molality of the solution? The density of cyclohexane is 0.779 kg/l at room temperature.

Solution /

First, work out the number of moles of bromine. Br_2 has a molecular weight of 159.8 g/mole, so we have

10 g / (159.8 g/mole) = 0.063 moles Br_2

Next, convert the volume of solvent to the weight of solvent using the density
1.0 L * 0.779 kg/l = 0.779 kg

Now just divide the two to get the molality
0.63 les Br_2/ 0.779 kg cyclohexane = **0.080 molal**

Parts per Millions (PPM)

It is defined as the parts of a component per million parts (10^6) of the solution. It is widely used when a solute is present in trace quantities.

$$PPM = \frac{\text{Weight of solute (g)}}{\text{Volume of Solution (ml)}} \times 10^6$$

Relationship between PPM and Molarity and Normality

$$PPM = M \times M.Wt \times 1000$$

$$PPM = N \times Eq.Wt \times 1000$$

Converting weight/volume (w/v) concentrations to ppm
ppm = $1g/m^3$ = 1mg/L = 1µg/mL

1. A solution has a concentration of 1.25g/L.
What is its concentration in ppm?

a. Convert the mass in grams to a mass in milligrams:
   1.25g = 1.25 x 1000mg = 1250mg
b. Re-write the concentration in mg/L = 1250mg/L = 1250ppm

2. A solution has a concentration of 0.5mg/mL.
What is its concentration in ppm?

a. Convert the volume to litres:
   volume = 1mL = 1mL ÷ 1000mL/L = 0.001L
b. Re-write the concentration in mg/L = 0.5mg/0.001L = 500mg/L = 500ppm

Converting weight/weight (w/w) concentrations to ppm
1ppm = 1mg/kg = 1µg/g

1. A solution has a concentration of 0.033g/kg.
What is its concentration in ppm?

a. Convert mass in grams to mass in milligrams:
   0.033g = 0.033g x 1000mg/g = 33mg
b. Re-write the concentration in mg/kg = 33mg/kg = 33ppm

2. A solution has a concentration of 2250µg/kg.
What is its concentration in ppm?

a. Convert mass in µg to mass in mg:
   2250µg = 2250µg ÷ 1000µg/mg = 2.25mg
b. Re-write the concentration in mg/kg = 2.25mg/kg = 2.25ppm

Parts Per Million (ppm) Concentration Calculations
1. 150mL of an aqueous sodium chloride solution contains 0.0045g NaCl.
Calculate the concentration of NaCl in parts per million (ppm).

a. ppm = mass solute (mg) ÷ volume solution (L)
b. mass NaCl = 0.0045g = 0.0045 x 1000mg = 4.5mg
   volume solution = 150mL = 150 ÷ 1000 = 0.150L
c. concentration of NaCl = 4.5mg ÷ 0.150L = 30mg/L = 30ppm

2. What mass in milligrams of potassium nitrate is present in 0.25kg of a 500ppm $KNO_{3(aq)}$?

a. ppm = mass solute (mg) ÷ mass solution (kg)
b. Re-arrange this equation to find the mass of solute:
   mass solute (mg) = ppm x mass solution (kg)
c. Substitute in the values:
   mass KNO_3 = 500ppm x 0.25kg = 125mg

3. A student is provided with 500mL of 600ppm solution of sucrose.
What volume of this solution in millilitres contains 0.15g of sucrose?

a. ppm = mass solute (mg) ÷ volume solution (L)
b. Re-arrange this equation to find volume of solution:
   volume solution (L) = mass solute (mg) ÷ ppm
c. Substitute in the values:
   volume solution (L) = (0.15g x 1000mg/g) ÷ 600 = 0.25L
d. Convert litres to millilitres: volume solution = 0.25L x 1000mL/L = 250mL