Chapter Three

Methods of expressing concentration of solutions

3 Methods of expressing concentration of solutions

3.1 Mass units :

The mass of substance is usually determined in such metric as kilogram (kg=1000g) , the gram (g=1000mg) , the milligram (mg=10^{-3}g) , the microgram (μg=10^{-6}g), the nanogram (ng=10^{-9}g) and the picogram (pg =10^{-12}g).

It is more convenient for chemical calculations to employ mass units which express the weight relationship or stoiciometry among reacting species in terms of small whole numbers. The gram formula weight, the gram molecular weight, and the gram equivalent weight are employed in analytical computations for this reason.

These terms are always shortened to the formula weight(fw), the molecular weight(mw) and equivalent weight(ew).

3.2 Chemical formulas : formula weights and molecular weights

Empirical formula is the simplest combination of atoms in a substance.

Molecular formula is actual expression of the structure of the substance or compound.

The formula weight may equal the empirical formula such as chemical formula of H_2. On other hand, the chemical formula may or may not actually exist. For example NaCl is not found as NaCl in its solid state or in aqueous solution and it is existed as sodium ions (Na^+) and chloride ions(Cl^-). However, the formula as NaCl is convenient for stoiciometric accounting.

Gram Formula weight is the summation of atomic weights in grams of all the atoms in the chemical formula of a substance. Therefore, the gram formula weight of H_2 =2×1.008=2.016g, for NaCl it is equal =35.45+22.99=58.44g.

The gram molecular weight is employed in stead of gram formula weight when the real chemical species is concerned. Therefore the gram molecular weight of H_2 is its gram formula weight (2.016g), while NaCl in water, it should be assigned as gram ionic weight of Na^+ (23.00g) and gram ionic weight of Cl^- (35.45g).

One molecular weight of a species contains 6.023×10^{23} particles of that species. This quantity is referred to the mole of the species.

A mole is the amounts of molecular compounds, free elements and ions.

1 mole of	H_2O	Contains	18.01g
1 mole of	Na_2SO_4	Contains	142.04g
1 mole of	Na^+	Contains	23g
1 mole of	Cl_2	Contains	70.90g
1 mole of	Cl^-	Contains	35.45g

Therefore, the number of moles are calculated of grams divided by formula weight of the species.

$$\text{Moles of urea} = \frac{\text{grams}}{60.06}$$

$$\text{Moles of Sulphate } (SO_4^{2-}) = \frac{\text{grams}}{96.06}$$

$$\text{Moles of silver (Ag)} = \frac{\text{grams}}{107.87}$$

3.3 Formula concentration (Formality), F :

It is the number of formula weights of substance contained in one litre of solution. The term also expresses the number of milliformula weights per millilitre of solution.

$$F = \frac{\text{wt of substance per litre of solution}}{\text{gfw}}$$

$$F = \frac{\text{number of fw}}{\text{litre of solution}} = \frac{\text{number of m fw}}{\text{ml of solution}}$$

$$F = \frac{\text{gram of solute}}{\text{litre of solution} \times \text{gfw}} = \frac{\text{gram of solute}}{\text{gfw}} \times \frac{1000}{\text{ml of solution}}$$

Ex: 4.57 of $BaCl_2.2H_2O$ (gfw=244) were dissolved in water and diluted to 250 ml in volumetric flask. Calculate the formality concentration of $BaCl_2.2H_2O$ and Cl^-.

The solution:

$$F = \frac{\text{gram of solute}}{\text{Its gfw}} \times \frac{1000}{\text{ml of solution}}$$

$$= \frac{4.57}{244} \times \frac{1000}{250} = 0.0750 \text{ mfw / ml or fw / lit}$$

$$BaCl_2 \longrightarrow Ba^{2+} + 2\,Cl^-$$

0.075 F　　0.075 F　　2× 0.075 F

$\therefore F_{Cl^-} = 2 \times 0.75 = 0.15$ mfw / ml or fw / lit

0.075

3.4 Molar concentration (Molarity), M :

It is the number of gram molecular weights or moles of solute per litre of solution. It is also the number of millimoles per millilitre of solution.

$$M = \frac{\text{wt of solute per litre of solution}}{\text{gmw}}$$

$$M = \frac{\text{No. of moles}}{\text{litre of solution}} = \frac{\text{No. of m moles}}{\text{ml of solution}}$$

$$M = \frac{\text{gram of solute}}{\text{litre of solution} \times \text{gmw}} = \frac{\text{Wt. of solute}}{\text{Its gmw}} \times \frac{1000}{\text{ml of solution}}$$

Mg

Ex: Calculate the Formal and Molar concentrations of the constituents in:

(a) 2.30g of ethanol (gfw=46.1) in 3.50 litres of aqueous solution.

(b) 285 mg of trichloroacetic acid (gfw=163) in 10 ml of aqueous solution (its percentage of ionization = 73%).

The solution:

(a)

$$F_{ethanol} = \frac{2.30\ g}{46.1\ g / fw} \times \frac{1\ litre}{3.50\ lit} = 0.0143\ fw / lit$$

Ethanol is non-electrolyte, therefore the solute ethanol remains as it is in aqueous solution.

$$M_{ethanol} = \frac{2.30\ g}{46.1\ g / mole} \times \frac{1\ ml}{3.50\ lit} = 0.0143\ moles / lit$$

Therefore in this example F = M = 0.0143

(b)

$$F_{HA} = \frac{285\ mg_{HA}}{163\ mg_{HA} / mfw} \times \frac{1\ ml}{10\ ml} = 0.175\ m\ fw / ml$$

73% of trichloroacetic acid is ionized, therefore 27% of the acid is unionized .

$$M_{HA} = \frac{285 \times 0.27\ mg}{163\ mg_{HA} / m\ mole} \times \frac{1\ litre}{10\ ml} = 0.0472\ m\ mole / ml$$

$$Cl_3CCOOH \rightleftharpoons Cl_3CCOO^- + H^+$$

$M_{H^+} = M_{Cl_3CCOO^-} = 0.175 - 0.0472 = 0.128$ m mole / ml.

3.5 Molal concentration (Molality), m :

It is the number of molecular weights or moles of solute per 1000 g (or 1 kg) of solution:

$$m = \frac{\text{Wt. of solute}}{\text{Its gmw}} \times \frac{1000\ g}{\text{Weight of solution}}$$

of Solvent

Ex: Calculate the Formal and Molal concentrations of solution prepared by dissolving 8g of NaOH in 500 g of water.

The solution:

$$m = \frac{8}{40} \times \frac{1000}{500+8} = \frac{8}{40} \times \frac{1000}{508} = 0.4\ mol / kg$$

This concentration is always used in physical chemistry where the weight is not changed by temperature.

3.6 Mole fraction :

It is the number of moles of solute divided by the total moles of solute and solvent, or the number of moles of solvent divided by the total number of moles of solute and solvent.

Ex: 80 grams of NaOH are dissolved in 1000 g of water. Calculate the mole fraction of NaOH and water. in the mixture.

The solution:

Molecular wt. of NaOH =23+16+1=40 g/mol

Molecular wt. of water =(2×1)+16=18 g/mol

$$\text{Number of moles of NaOH} = \frac{80}{40} = 2 \text{ moles}$$

$$\text{Number of moles of water} = \frac{1000}{18} = 55.5 \text{ moles}$$

$$\text{Mole fraction of NaOH} = \frac{2}{2+55.5} = 0.035$$

$$\text{Mole fraction of water} = \frac{55.5}{2+55.5} = 0.965$$

The summation of total mole fractions should always be equal to 1.

Thus : 0.035+0.965 = 1.000

3.7 Normal concentration (Normality), N :

It is the number of equivalents of solute per litre of solution, or the number of milliequivalents per millilitre of solution.

$$\text{Number of equivalents} = \frac{\text{Wt. of solute}}{\text{Its eq.wt.}}$$

$$N = \frac{\text{Wt. of solute per litre of solution}}{\text{Its equivalent wt.}}$$

$$N = \frac{\text{No. of eq.}}{\text{Litre of solution}} = \frac{\text{No. of meq.}}{\text{ml of solution}}$$

$$N = \frac{\text{gram of solute}}{\text{litre of solution} \times \text{eq.wt}} = \frac{\text{gram of solute}}{\text{Its eq.wt}} \times \frac{1000}{\text{ml of solution}}$$

In order to calculate the normality of solutions, the equivalent weight of solute should be known .

3.7.1 Equivalent wt. of acids :

Equivalent wt of an acid is its weight which reacts or replaces one unit of hydrogen that can be ionized.

$$\text{Eq. wt. of HCl} = \frac{HCl}{1} = \frac{1+35.5}{1} = 36.5$$

$$\text{Eq. wt. of } H_2SO_4 = \frac{H_2SO_4}{2} = \frac{2\times1+1\times32+4\times16}{2} = 49$$

$$\text{Eq. wt. of } H_3PO_4 = \frac{H_3PO_4}{3} = \frac{3\times1+1\times31+4\times16}{3} = 32.7$$

3.7.2 Equivalent wt. of bases :

Equivalent wt of a base is its weight which contains or produce one hydroxide group (OH^-) that can react or be replaced.

$$\text{Eq. wt of NaOH} = \frac{NaOH}{1} = \frac{23+16+1}{1} = 40$$

$$\text{Eq. wt of } Ca(OH)_2 = \frac{Ca(OH)_2}{2} = \frac{40+(2\times17)}{2} = 37$$

$$\text{Eq. wt of } Al(OH)_3 = \frac{Al(OH)_3}{3} = \frac{27+(17\times3)}{3} = \frac{78}{3} = 26$$

$$\text{Eq. wt of } NH_3\text{(ammonia)} = \frac{14+3}{1} = 17$$

3.7.3 Equivalent wt. of salts :

Equivalent wt of salt is its weight which equivalent to one ionic wt. of cation or anion.

$$\text{Eq. wt of NaCl} = \frac{23+35.5}{1} = 58.5$$

$$\text{Eq. wt of } CaCl_2 = \frac{40+35.5\times2}{2} = 55.5$$

$$\text{Eq. wt of } FeCl_3 = \frac{55.85+3\times35.5}{3} = 54.12$$

If there is hydrated water combined with the salt, it should be involved in the calculations.

$$\text{Eq. wt. of } CaCl_2.2H_2O = \frac{40+2\times35.5+2\times18}{2} = 73.5$$

$$\text{Eq.wt. } CuSO_4.5H_2O = \frac{63.54+32+4\times16+5\times18}{2} = 124.77$$

For acidic salt, the eq.wt. is calculated relative to the required ion:

$$\text{Eq.wt. } NaH_2PO_4 = \frac{NaH_2PO_4}{1} \quad \text{, relative to } Na^+$$

$$\text{Eq.wt. } NaH_2PO_4 = \frac{NaH_2PO_4}{2} \quad \text{, relative to } H^+$$

$$\text{Eq.wt. } NaH_2PO_4 = \frac{NaH_2PO_4}{3} \quad \text{, relative to } PO_4^{3-}$$

For double salt, equivalent weight is calculated relative to the required ion, for example the double salt $K_2SO_4.Al_2(SO_4)_3.24H_2O$:

Eq.wt. of $K_2SO_4.Al_2(SO_4)_3.24H_2O = \frac{K_2SO_4.Al_2(SO_4)_3.24H_2O}{2}$ Relative to K^+

Eq.wt. of $K_2SO_4.Al_2(SO_4)_3.24H_2O = \frac{K_2SO_4.Al_2(SO_4)_3.24H_2O}{6}$ Relative to $2Al^{3+}$

Eq.wt. of $K_2SO_4.Al_2(SO_4)_3.24H_2O = \frac{K_2SO_4.Al_2(SO_4)_3.24H_2O}{8}$ Relative to $4SO_4^{2-}$

3.7.4 Equivalent wt. of oxidants and reductants :

Equivalent wt. of an oxidant or reductant is its weight which accepts or donates one mole of electrons in oxidation-reduction reaction.

Ex(1):

$$SnCl_2 + 2FeCl_3 \longrightarrow SnCl_4 + 2FeCl_2$$

+2 —— -2e —— +4

+3 —— +1e —— +2

Eq. wt. of $SnCl_2 = \frac{SnCl_2}{2}$

Eq. wt. of $FeCl_3 = \frac{FeCl_3}{1}$

For the two salts in oxidation-reduction reaction.

While the Eq. wt. of $FeCl_3$ as usual salt $= \frac{FeCl_3}{3}$

Ex(2):

$$2KMnO_4 + 10FeSO_4 + 8H_2SO_4 \longrightarrow K_2SO_4 + 2MnSO_4 + 5Fe_2(SO_4)_3 + 8H_2O$$

+7 —— +5e —— +2

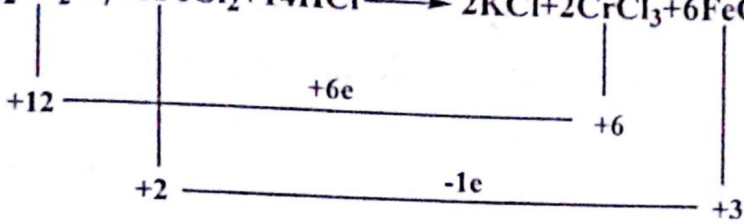
+2 —— -1e —— +3

Eq. wt. of $KMnO_4 = \frac{KMnO_4}{5}$

$$\text{Eq. wt. of } FeSO_4 = \frac{FeSO_4}{1}$$

Ex(3):

$$K_2Cr_2O_7 + 6FeCl_2 + 14HCl \longrightarrow 2KCl + 2CrCl_3 + 6FeCl_3 + 7H_2O$$



$$\text{Eq.wt. of } K_2Cr_2O_7 = \frac{K_2Cr_2O_7}{6} \qquad \text{Eq.wt. of } FeCl_2 = \frac{FeCl_2}{1}$$

Some compounds may have more than one equivalent weight. For example, when silver ion is titrated with a solution of potassium cyanide, an end point can be detected for either the two following reactions :

$$2CN^- + 2Ag^+ \longrightarrow Ag[Ag(CN)_2]$$

$$2CN^- + Ag^+ \longrightarrow Ag(CN)_2^-$$

In the first reaction, the equivalent wt. of potassium cyanide would be identical to its formula weight. In the second reaction, it would be twice the formula weight. The second reaction is an example of an equivalent weight greater than formula weight.

3.8 Percentage concentration :

Chemists frequently express concentrations in term of percentage. Common methods include:

a. Weight percent (wt/wt) :

It is the number of grams of solute per 100g of solvent or solution (wt/wt)

$$\text{weight percent (wt/wt)} = \frac{\text{wt. of solute}}{\text{wt. of solution}} \times 100$$

b. Weight -Volume percent (wt/v) :

It is the number of grams of solute per 100ml of solvent or solution (wt/v)

$$\text{Volume percent (wt/v)} = \frac{\text{wt. of solute}}{\text{volume of solution}} \times 100$$

Weight

Example is the preparation of solution by dissolving 10g of NaCl in 100g of solvent or solution(wt/wt), or dissolving of 10g of NaCl in 100ml of solvent or solution(wt/v). The final wt. is 100g and the final volume is 100ml.

c. Volume percent (v/v):

It is the number of millilitres of solute per 100ml of solvent or solution (v/v).

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

Example is the preparation of solution by dissolving 10ml of ethanol in 100ml of solution(v/v).

Ex(1): Calculate the wt. percent of Na_2SO_4 solution which prepared by dissolving 25g in 200g of solution.

The solution:

$$\text{wt. percent} = \frac{25}{200} \times 100 = 12.5\% \text{ (wt/wt)}$$

Ex(2): Calculate the wt. percent of 5g of $AgNO_3$ in 200ml of solution. The density of solution is 1g/ml.

The solution:

wt. of solution =200ml×1g/ml=200g

$$\text{wt. percent} = \frac{5}{200} \times 100 = 2.5\% \text{ (wt/wt)}$$

$$\text{wt. percent} = \frac{5}{200} \times 100 = 2.5\% \text{ (wt/v)}$$

Ex(3): Calculate the volume percent of solution prepared by dissolved 50ml of methanol in 250ml of water.

The solution:

$$\text{volume percent(v/v)} = \frac{50}{50+250} \times 100 = 16.7\% \text{ (v/v)}$$

3.9 The relation between molarity (M) and morality (N) :

Normality is either equal molarity or larger than it. Therefore $N \geq M$ and $N=nM$, n is a factor obtained by dividing the molecular wt. of the material on its equivalent weight. It is an integral number.

When equivalent wt. = molecular wt. such as HCl, NH_3 and NaCl :
$\therefore$ n=1 and N=M.

When equivalent wt. is less than molecular wt., such as H_2SO_4, $Ca(OH)_2$ and $BaCl_2.2H_2O$

Then N > M or N=nM

Where n=1,2,3 ....etc.

In case of H_2SO_4 $\quad n=\frac{98}{49}=2$

$\therefore$ N=2M where n=2

In case of $AlCl_3$

$$n=\frac{133.5}{44.5}=3 \quad \therefore N=3M$$

Therefore, either of N or M is known the unknown is calculated from the above relation.

3.10 Titer expression of concentration :

Titer : It is weight of substance which is chemically equivalent to one millilitre of solution. Therefore, a silver nitrate solution having a titer of 1mg of chloride will contain enough concentration of silver nitrate in each millilitre to react completely with that weight of Cl^- ion.

The titer may be expressed in g or mg of KCl, $BaCl_2$ and NaI or any other compound which reacts with $AgNO_3$. This type of concentration is usually used in titration methods when the titration is frequently repeated with special reagent as a titrant. If the titer is known, the weight can be calculated from : Titer × the volume of titrant.

The titer can be altered into normality (N) from the following relations:

$$T = mg/ml\ ,\quad N = T\ mg/ml \times \frac{1}{Eq.wt.}\quad ,T = N \times Eq.wt.$$

If the titer of HCl solution = 4.00mg/ml of NaOH, therefore the normality of the solution (N) can be obtained by dividing the titer on the eq.wt. of NaOH :

$$N = T\ mg/ml \times \frac{1}{Eq.wt.} = 4.00 mg/ml \times \frac{1}{40 mg/meq} = 0.1 meq/ml$$

Ex(1):

Calculate a) NH_3 titer from 0.12N HCl.

b) BaO titer from 0.12N HCl.

The solution:

$$Eq.wt.\ of\ NH_3 = \frac{14+3\times1}{1} = \frac{17}{1} = 17\ mg/meq.$$

$$Eq.wt.\ of\ BaO = \frac{153.4}{2} = 76.7\ mg/meq.$$

$$T_{NH_3} = N \times Eq.wt.NH_3 = 0.12 \times 17 = 2.04\ mg/ml\ \ NH_3$$

$$T_{BaO} = N \times Eq.wt.\ BaO = 0.12 \times 76.7 = 9.204\ mg/ml\ BaO$$

Ex(2): A solution of NaOH has a titer of oxalic acid (mol.wt. =126) =9.45mg/ml. Calculate the normality of NaOH solution.

The solution:

$$N = T\ mg/ml \times \frac{1}{Eq.wt.} = 9.45\ mg/ml \times \frac{1}{63 mg/meq} = 0.15 meq/ml\ or\ Eq./lit$$

Ex(3): What is the normality of $AgNO_3$ solution which has a titer of 5.63mg $BaCl_2.2H_2O$ /ml.

The solution:

$$Eq.wt.of\ BaCl_2.2H_2O = \frac{137.43+2\times35.5+2\times18}{2} = 122.171$$

$$N = T\ mg/ml \times \frac{1}{Eq.wt.} = 5.63\ mg/ml \times \frac{1}{122.171} = 0.046\ meq/ml$$

Ex(4): What is the normality of solution of $KMnO_4$ has a titer =11mg Fe_2O_3/ml for the reaction.

$$MnO_4^- + 5Fe^{2+} + 8H^+ \longrightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

The solution:

$$N = T\ mg/ml \times \frac{1}{Eq.wt.}$$

$$Eq.wt.\ of\ Fe_2O_3 = \frac{2\times55.58 + 3\times16}{6} = 26.62$$

$$N = 11 \times \frac{1}{26.62} = 0.4132\ meq/ml$$

$$= 0.4132\ Eq/lit$$

Ex(5): 25ml of Na_2CO_3 solution of titer 0.0053g/ml was titrated with H_2SO_4 solution. The volume of latter was 25.50 ml, calculate the titer of H_2SO_4.

The solution:

wt. of Na_2CO_3 in 25ml=25×0.0053 =0.1325g/25ml

$$Na_2CO_3 + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O + CO_2$$

Every 53mg/meq $Na_2CO_3 \equiv$ 49 mg/meq H_2SO_4

0.1325 $Na_2CO_3 \equiv$ 0.1225 g H_2SO_4 in 25.5ml

$$T_{H_2SO_4} = \frac{0.1225}{25.50} = 0.005\ g/ml.$$

3.11 Part per million (ppm) and Part per billion (ppb) :

These two types of concentration are used in trace analysis. A 1ppm solution contain 1 mg of solute per 10^6 mg of a solvent. Since 1 litre of water is about one million milligrams, a 1 ppm solution also contain about 1 mg of solute per litre of solution. ppm is always defined as mg/litre, even though a litre of the solution may weigh somewhat more or less than 1 kg. When dealing with solids, the ppm unit must be used in terms of mg of constituent per kg of solid.

$$1ppm = 1mg/litre = 10^{-3}\ g/litre .$$

$$\text{or } 1ppm = \frac{\text{wt. of solute}}{\text{wt. of solution}} \times 10^{6}$$

Thus, the aqueous solution which contains 0.0003% (wt/wt) of Ni can be expressed as ppm which =3ppm.

If the water is a solvent and the solute is in traces which renders the density = 1g/ml:

$$ppm = \frac{\text{wt. of solute}}{\text{volume of solution}} \times 10^{6}$$

If a solution contains 63.3 ppm of substance, it means that one litre of solution contains 63.3 mg.

In the same way the ppb is expressed as follows :

$$ppb = \frac{\text{wt. of solute}}{\text{wt. or volume of solution}} \times 10^{9}$$

$1ppb = 1mg/ml = 10^{-3}\ g/ml = 1\mu g\ /litre.$

$1\mu g$ = one microgram which equals $10^{-6}\ g = 10^{-3}$ mg.

<u>Example(1):</u> How can you prepare 500 ml of solution containing 1000 ppm Ca from $CaCl_2$, Ca= 40, Cl =35.5 .

<u>The solution:</u>

$1ppm = 1\ mg/lit = 10^{-3}\ g/lit,\quad 1000\ ppm = 1000\ mg/lit = 1\ g/lit$

Thus, the solution should contain 1 g of calcium in litre of solution. But the weighed material is $CaCl_2$ rather than Ca. Therefore, the weight of $CaCl_2$ should be calculated in 500 ml of solution to give 1000 ppm Ca.

Mol.wt. of $CaCl_2$ 40+ 2×35.5 = 111

$$\text{Wt. of } CaCl_2 = 1\times \frac{111}{40} \times \frac{500}{1000} = 1.3875 \text{ g of } CaCl_2$$

Therefore, when 1.3875 g of $CaCl_2$ is dissolved in 500 ml of solution it gives 1000 ppm of Ca.

Example(2): A solution of KCl (its volume =500ml) contains 7.45 ppm KCl. Calculate its Molarity and Normality.

The solution:

7.45 ppm KCl = 7.45 mg/lit =7.45×10^{-3} g/lit

$$M = N = \frac{\text{wt. of solute per lit}}{\text{mol.wt. =Eq.wt.}}$$

$$M = N = \frac{7.45\times10^{-3}}{74.5} = $$ 10^{-4} Eq/lit or meq/ml or mol/lit or mmol/ml

Example(3): A solution of NaCl has concentration of 0.01N. Express the concentration in ppm as NaCl, Na^+ and Cl^- .

The solution:

Wt. of NaCl in litre of solution

=N×Eq.wt. → =0.01×58.5 → =0.585g/lit → =585mg/lit

→ =585ppm as NaCl.

$585\times\frac{23}{58.5}$ =230mg/lit =230ppm as Na^+

$585\times\frac{35.5}{58.5}$ =355mg/lit =355ppm as Cl^-

Example(4): A solution contains 55ppb of Ca, calculate its molar and normal concentrations.

The solution:

55ppb =55mg/ml → =55×10^{-3} g/ml → =55μg/lit

55μg/lit =55×10^{-6}g/lit

$$M=\frac{\text{wt. per litre}}{\text{Mol.wt.}}=\frac{55\times10^{-6}}{40}=1.4\times10^{-6}\ \text{mol/lit}$$

$$N=\frac{\text{wt. per litre}}{\text{Eq.wt.}}=\frac{55\times10^{-6}}{20}=2.8\times10^{-6}\ \text{eq/lit}$$

Example(5): 38.2g of borax ($Na_2B_4O_7.10H_2O$) is dissolved in 1080 g of water. Calculate the molarity, normality, %(wt/wt), %(wt/v), molality and mole fraction of this solution. the density of the solution =1.01g/ml.

The solution:

Mol. wt. of borax ($Na_2B_4O_7.10H_2O$)=2×23+ 4×11+ 7×16+ 10×18 =382

$$\text{Eq.wt. of } Na_2B_4O_7.10H_2O=\frac{382}{2}=191$$

$$\text{Volume of solution}=\frac{1080}{1.01}=1069.3\text{ml}$$

$$M=\frac{\text{wt.}}{\text{Mol.wt.}}\times\frac{1000}{V}=\frac{38.2}{382}\times\frac{1000}{1069.3}=0.0935\ \text{mol/lit}$$

$$N=\frac{\text{wt.}}{\text{Eq .wt.}}\times\frac{1000}{V}=\frac{38.2}{191}\times\frac{1000}{1069.3}=0.1870\text{eq/lit}$$

$$m=\frac{\text{wt.}}{\text{mol.wt.}}\times\frac{1000}{\text{wt. of solution}}=\frac{38.2}{382}\times\frac{1000}{1080}=0.0.0926\ \text{mol/kg}$$

$$\text{Wt percent}=\frac{38.2\times100}{1080}=3.54\ \%(\text{wt/wt})$$

$$\text{Wt-vol percent}=\frac{38.2\times100}{1069.3}=3.6\ \%(\text{wt/v})$$

$$\text{Number of moles of borax}=\frac{38.2}{382}=0.1$$

$$\text{Number of moles of water}=\frac{1080}{18}=60$$

$$\text{Mole fraction of borax}=\frac{0.1}{0.1+60}=0.0017$$

$$\text{Mole fraction of water}=\frac{60}{0.1+60}=0.9983$$

3.12 Density and specific gravity :

The density of a substance measures its mass per unit volume whereas the specific gravity of a material is the ratio of its mass to that of an equal volume of water at 4°C. In the metric system, density has units of kg/litre or g/ml. Specific gravity on the other hand, is unitless and is thus not tied to any particular system of units: for this reason it is widely used in describing items of commerce. Because water at 4°C has a density of exactly 1g/ml density and specific gravity are used interchangeably .

3.13 Problems:

1- A solution was prepared by dissolving exactly 2.42g of $MgCl_2$ in water and diluting to two litres. Calculate (a) the formal concentration of $MgCl_2$. (b) the molar concentration of Cl^- . (c) the weight volume percent of $MgCl_2$ if the density of solution is 1.01g/ml.

2- The average concentration of silica (SiO_2) in the world's rivers is 15ppm. What is the corresponding formal concentration, assuming the density of water is 1.00g/ml.

3- The average concentration of Ca^{2+} in the world's rivers is 55ppm. What is the corresponding molar concentration, assuming the density of water is 1.00g/ml.

4- How many formula weights and how many milliformula weights are contained in (a) 27.3g Mn_3O_4. (b) 163μg BF_3. (c) 6.92 litre of 0.04F $Na_2B_4O_7$. (d) 10ml of 2×10^{-3} F $HgCl_2$. (e) 10ml of an aqueous solution containing 143ppm SO_2.

5- How many grams are contained in (a) 2moles of CO_2. (b) 1.84mfw of benzene(gfw=78.1). (c) 40fw of NaOH. (d) 6.24ml of 0.121F sucrose (gfw=342.3). (e) 3.33litres of 12.2F of HCl.

6- Calculate the Wt/Wt percent for a 200g solution containing 25g of Na_2SO_4.

7- Calculate the Wt/Vol percent for 500ml of solution containing 5g $AgNO_3$. Density of water =1g/ml.

8- Calculate the Vol/Vol percent for a solution prepared by addition 50ml of methanol to 200ml of water. Consider no change of total volume i.e. the total volume equals the summation of both solute and solvent.

9- Sulphuric acid solution contains 4g of H_2SO_4 in 400ml of solution. Calculate the molar and normal concentration of this solution.

10- A solution of NaCl has percentage of 0.58%. Calculate its molar and normal concentrations .

11- Calculate the normality of a solution prepared by dissolving 100g NaOH in 1000ml of solution.

12- 7.1g of Na_2SO_4 was dissolved in 200ml of solution. Calculate the normality of this solution and calculate weight of solute in litre of solution.

13- Calculate the Na_2CO_3 titer for 0.1037N HCl.

14- Calculate the titer of SO_4^{2-} for $BaCl_2$ solution prepared by dissolving 24.43g of $BaCl_2.H_2O$ in litre of solution.

15- Calculate the molar concentration of H_3PO_4 if the phosphate concentration =0.250N.

16- What is the molar concentration of H_2SO_4 if its normal concentration =0.1 eq/litre.

17- Calculate the BaO titer for 0.05M $BaCl_2$ solution.

18- Calculate the molar and normal concentrations for the following solutions : (a) 18.194g $NaH_2AsO_4.H_2O$ in 250ml solution. (b) 4.904g H_2SO_4 in 200ml H_2SO_4. (c) 5.207g $BaCl_2$ in 500ml solution. (d)61.08g $BaCl_2.2H_2O$ in 2 litres of solution. (e) 8.0423g $AgNO_3$ in 500ml solution. (f)1.714g $Ba(OH)_2$ in 333ml of solution.

19- Express the following concentrations by titer: (a) Titer Cl^- by 0.5N $AgNO_3$ solution. (b) Titer Cl^- by 8.495g $AgNO_3$ in 500ml solution. (c) Titer NaCl by 3.523%(Wt/Vol) $AgNO_3$. (d) Titer Na_2O by 0.106N HCl. (e) Titer $CaCO_3$ by 0.02M EDTA. (f) Titer $CaCl_2$ for EDTA solution has titer 1mg/ml $CaCO_3$.

20- Calculate the normality and molarity of Ag_2O titer and $AgNO_3$ titer for solution contains 4g NaCl in 100ml water has density =1.02g/ml.

21- A sample weighs 20g contains 2mg Ca^{2+}. Calculate the concentrations of calcium by ppm &calculate the molar &millimolar weights of Ca^{2+}.

22- 20g of Na_2CO_3 and 117mg of NaCl were dissolved in 100ml of distilled water, calculate the molar concentration of the solution relative to Na^+.

23- Calculate the weight in grams for each of the following : (a) 40 molecular wts of NaOH. (b) 3.33 litres of 12.2M HCl. (c) 0.842 moles of Br^-.

24- Calculate the number milliequivalents of each of the followings in 20ml : (a) 0.1N $Ba(OH)_2$. (b) 0.1M $K_2Cr_2O_7$ according to the following equation : $Cr_2O_7^{2-} + 14H^+ \longrightarrow 2Cr^{3+} + 7H_2O$.

25- Calculate the weight of solute in grams for each of the following solutions : (a) 43.5ml of 0.175N $Hg(NO_3)_2$. (b) 10ml of 0.03N KI if the reaction product is AgI. (c) 5litres of 0.25N $K_2Cr_2O_7$ in acidic medium.

26- A solution of 0.005M H_2S, express its concentration in ppm and ppb.

27- A solution of copper sulphate ($CuSO_4$) has 200ppm of Cu^{2+}. Calculate the molarity and normality of this solution.

28- A solution of $CaCl_2$ contains 500ppm of Ca^{2+} . Calculate the molarity and normality of this solution.

29- A solution of 6.88×10^{-4}M of $K_4[Fe(CN)_6]$, calculate its concentration in ppm as K^+ and as $K_4[Fe(CN)_6]$.

30- A solution of 10^{-3}M $NaHCO_3$, calculate its concentration as ppm as $NaHCO_3$, Na^+, H^+ and CO_3^{2-}.