Chemical Calculations of Volumetric Titrations.

Chemical calculations which associate with titration process in volumetric analysis are very significant since they illustrate the idea about the accuracy of titration data which refer to the precision of measurements that lead to accurate results.

The reaction in volumetric analysis should be rapid and complete. The reactions are expressed in balanced equations and from these reactions one can know the ratio of reactants since they involve equivalents of the reactants at equivalence point.

Normal concentration gives simple and rapid calculations because they involve equivalent amounts of the reactants.

Molar concentrations require some attention and recognition.

For example, if NaOH solution is titrated with HCl solution, there is no difference in using normality or molarity because the reaction is performed in 1:1 ratio between NaOH and HCl

$$NaOH + HCl \longrightarrow NaCl + H_2O$$

But the case is different in titration of Na_2CO_3 solution with HCl solution.

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + CO_2 + H_2O$$

Where two moles of HCl react with one mole of Na_2CO_3. This means that the strength of Na_2CO_3 is twice of HCl. If the molar concentration is used, a precaution should be given to the factor 2 in HCl.

$$(V \times M)_{Na_2CO_3} = (V \times M)_{HCl}$$

This equality is incorrect if molar concentration is used. Therefore, a factor of 2 should be used at the left side of the above reaction in order to express correctly the reaction between Na_2CO_3 and HCl.

$$2(V \times M)_{Na_2CO_3} = (V \times M)_{HCl}$$

But if the normal concentration is employed for both solutions, the following reaction is correct because the reaction is performed on the basis of equivalents or milliequivalents.

$$(V \times N)_{Na_2CO_3} = (V \times N)_{HCl}$$

The same treatment is considered in precipitation, oxidation-reduction and complex formation titrations.

Calculations of acid-base titrations or neutralization titrations (one of the products is water).

Ex(1): Calculate the weight of H_2SO_4 in 5 litres if 25 ml of this solution requires 22.5 ml of 0.095 N KOH.

The solution:

$$\textbf{Eq. wt. of } H_2SO_4 = \frac{2\times1 + 32 + 4\times16}{2} = \frac{98}{2} = 49$$

No. of meqts of KOH = No. of meqts of H_2SO_4

$$(22.5 \times 0.095)_{KOH} = (N \times 25)_{H_2SO_4}$$

$$N_{H_2SO_4} = \frac{22.5 \times 0.095}{25} = 0.0855 \text{ eq/lit}$$

$$\textbf{Wt. of } H_2SO_4 \textbf{ in 5 litres} = N \times \text{eq. wt.} \times \frac{5}{1}$$

$$= 0.0855 \times 49 \times 5 = 20.9475 \text{ g}$$

Ex(2): A solution of Na_2CO_3 contains 795 mg per litre of solution. Calculate the normality of this solution. What is the volume of H_2SO_4 of 0.1 N that equivalent to 10 ml of Na_2CO_3 solution.

The solution:

$$N = \frac{0.795}{53} = 0.015 \text{ meq/ml normality of } Na_2CO_3$$

$$(V\times 0.1)_{H_2SO_4} = (0.015\times 10)_{Na_2CO_3}$$

$$V_{H_2SO_4} = \frac{0.015 \times 10}{0.1} = 1.5 \text{ ml } H_2SO_4 \text{ required to equivalent10 ml of 0.1 N } Na_2CO_3$$

Ex(3): 30 g of $KHC_2O_4.H_2C_2O_4.2H_2O$ is dissolved in distilled water and completed to litre. 40 ml of this solution is titrated with KOH which required 20 ml. Calculate the normality of KOH.

The solution:

$$\text{Eq. wt. } KHC_2O_4.H_2C_2O_4.2H_2O = \frac{39+3\times 1+4\times 12+8\times 16+2\times 18}{3}$$

$$= \frac{254}{3} = 84.67$$

$$\text{N of this solution} = \frac{30}{84.67} = 0.3543 \text{ eq/lit or meq/ml.}$$

meqts of this acidic solution = meqts of KOH

$$(40\times 0.3543)_{\text{acidic solution}} = (20\times N)_{KOH} \longrightarrow N_{KOH} = \frac{40\times 0.3543}{20} = 0.7086 \text{ meq/ml.}$$

Ex(4): 10 ml of vinegar has density of 1.055 g/ml and requires 39.82 ml of 0.225 N of a base to reach equivalence point. Calculate the percentage of acetic acid in vinegar (w/w).

The solution:

Wt. of vinegar sample = volume × density

= 10 × 1.055 = 10.55 g

No. of meqts. of vinegar solution = No. of meqts. of base.

$$0.255 \times 39.82 = N_{CH_3COOH} \times 10$$

$$N_{CH_3COOH} = \frac{0.255 \times 39.82}{10} = 1.01541 \text{ eq/lit or meq/ml}$$

$$\text{wt. of acetic acid in vigenar} = N \times \text{eq. wt.} \times \frac{10}{1000}$$

$$\text{Eq.wt of } CH_3COOH = \frac{2\times12 + 2\times16 + 4\times1}{1} = \frac{60}{1} = 60$$

$$= 1.01541 \times 60 \times \frac{10}{1000} \longrightarrow = 0.6092 \text{ g}$$

$$\% \text{ of CH3COOH in vinegar} = \frac{0.6092}{10.55} \times 100 = 5.77 \ \%(w/w)$$

Ex(5): 0.3542 g of Na_2CO_3 was dissolved in water and titrated with HCl which consumed 30.32 ml of the acid. Calculate the normality of HCl solution.

The solution:

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + CO_2 + H_2O$$

1 mol of Na_2CO_3 requires two moles of HCl.

∴ 2×No. of mmols of Na_2CO_3 = No. of mmols of HCl.

$$2\times\frac{0.3542}{106} \times 1000 = M_{HCl} \times 30.32$$

$$M_{HCl} = 2.21 \text{ mol / lit or mmol / ml}$$

Calculations of precipitation titrations.

In precipitation titrations, one of the products is slightly soluble salt called precipitate.

Ex(1): Calculate the percentage of silver in silver alloy if a solution prepared by dissolving 0.3g of the alloy requires 23.80ml of 0.1N NH_4SCN. (Ag=108)

$$Ag^{+} + SCN^{-} \longrightarrow AgSCN\downarrow$$

white precipitate

The solution:

No. of meqts. of Ag^{+} = No. of meqts of SCN^{-}

$$\frac{\text{wt. of silver}}{\text{its eq. wt.}} \times 1000 = (V \times N)_{SCN^{-}} \longrightarrow \frac{\text{wt. of silver}}{108} \times 1000 = 23.80 \times 0.1$$

$$\text{wt. of silver} = \frac{108 \times 0.1 \times 23.80}{1000} = 0.257\ g$$

$$\therefore \quad \%\ Ag = \frac{0.257}{0.3} \times 100 = 85.67\ \%$$

Ex(2): Find the weight of $BaCl_2$ in 250 ml of solution where 40 ml in excess of 0.102 N $AgNO_3$ was added to 25 ml of $BaCl_2$. The excess of $AgNO_3$ solution was titrated with 0.098 N SCN^{-}.

The solution:

$$BaCl_2 + 2AgNO_3 \longrightarrow Ba(NO_3)_2 + 2AgCl$$

$$AgNO_3 + SCN^{-} \longrightarrow AgSCN + NO_3^{-}$$

No. of meqts of $AgNO_3$ = No. of meqts of SCN^{-} + No. of meqts of $BaCl_2$.

$$(0.102 \times 40)_{AgNO_3} = (N \times 25)_{BaCl_2} + (0.098 \times 15)_{SCN^-}$$

1.47 + 25 N = 4.08

$$N = \frac{2.61}{25} = 0.1044 \text{ meq / ml normality of } BaCl_2 \text{ solution.}$$

$$\text{Wt. of } BaCl_2 \text{ in 250 ml} = N_{BaCl_2} \times \text{its eq. wt.} \times \frac{250}{1000}$$

$$= 0.1044 \times 104.17 \times \frac{250}{1000} \longrightarrow = 2.72 \text{ g } BaCl_2 \text{ / 250 ml.}$$