① How many moles of K_2CO_3 will contain 117 kg K.

molecular weight of K_2CO_3 = 39×2 + 12 + 16×3
= 138

138 kg K_2CO_3 ——— 78 kg K

78 kg K ——— 138 kg K_2CO_3

117 kg K ——— $\frac{117 \times 138}{78}$ = 207 kg

moles of K_2CO_3 = $\frac{207}{138}$ = 1.5 moles.

② The available nitrogen in an urea sample is found to be 45% by weight. Find the actual urea content of the sample.

Basis : 100 kg urea.

NH_2CONH_2

molecular weight of urea = 14 + 2 + 12 + 16 + 14 + 2 = 60

60 kg urea contains 28 kg nitrogen.

28 kg nitrogen present in 60 kg urea

45 kg nitrogen ——— $\frac{45 \times 60}{28}$ = 96.42 kg urea

2.5 LIQUIDS AND SOLUTIONS

As mentioned in Sec. 2.1, the volumes of pure liquids are usually specified. Along with the volume, the density and temperature of the liquids are also specified.

Regarding the solutions, there are various ways in which they can be expressed. A solution means a solute is dissolved in the solvent. The solute can be a solid, a liquid or a gas. In the case of solids, the solubility is expressed in g/100 g solvent at a definite temperature. This means that the maximum amount of solid which can be dissolved in the solvent will be equal to its solubility at that particular temperature. Solubility data can be found from various sources[4,5]. The weight % and mole % of components are expressed for liquids and solutions, the former being more common. In addition to these two, the volume % of a component is sometimes given, e.g., the alcohol content in wine. Very often, the weight % of the key component or the useful component of the solute present is also expressed, e.g., Na_2O content in caustic soda lye, P_2O_5 content of phosphoric acid, etc..

The trace impurities are either expressed in mg/l or ppm. When the solution is "watery" (i.e. its density nearly equals 1.0 kg/l),

$$1 \text{ mg/l} = 1 \text{ ppm}$$

In water treatment and effluent treatment problems, the analysis is given in ppm or mg/l, which are both taken as being similar.

Example 2.10 A saturated solution of salicylic acid in methanol contains 64 kg salicylic acid per 100 kg methanol[5] at 298 K (25°C). Find (a) the weight % and (b) mole % compositions of the solution.

Solution Basis: 100 kg methanol

Solution contains 64 kg salicylic acid.

$$\text{Weight of the solution} = 100 + 64 = 164 \text{ kg}$$

$$\text{Weight \% salicylic acid} = \left(\frac{64}{164}\right) \times 100 = 39.02$$

$$\text{Weight \% methanol} = 100 - 39.02 = 60.98$$

Ans. (a)

Molecular weight of methanol (CH_3OH) = 32

Molecular weight of salicylic acid (HOC_6H_4COOH) = 138

$$\text{Moles of methanol} = \frac{100}{32} = 3.125 \text{ kmol}$$

$$\text{Moles of salicylic acid} = \frac{64}{138} = 0.464 \text{ kmol}$$

$$\text{Total amount} = 3.125 + 0.464 = 3.589 \text{ kmol}$$

$$\text{Mole \% methanol} = \left(\frac{3.125}{3.589}\right) \times 100 = 87.07$$

$$\text{Mole \% salicylic acid} = 100 - 87.07 = 12.93 \qquad \textit{Ans.}(b)$$

Note: Graphical solution of Example 2.10 may be tried.

(15) An aqueous solution of common salt (NaCl contains) 25 % salt by weight at 298 K (25°C), Find the mole % of NaCl in the solution.

Soln:- Basis : 100 Kg Salt solution.

100 kg salt soln contains 25 Kg NaCl.

Molecular weight of NaCl = 58.45 Kg/Kmol.

Na 23
Cl 35.45
58.45

$$\text{K mol} = \frac{\text{wt}}{\text{mol. wt.}}$$

$$= \frac{25}{58.45}$$

$$= 0.4276 \text{ Kmol.}$$

$$= 4276 \text{ mol}$$

5845) 25000 (0.4276
23380
01620
11690
45100
40915
04185

0.4276
4.1660
4.5936

18) 75 (4.166
72
30
18
120
108
12

Rest 75 Kg water

$$\text{K mol water} = \frac{75}{18} = 4.166 \text{ Kmol } H_2O$$

Total mole = 0.4276 + 4.166
= 4.5936

$$\text{Mole \% of NaCl} = \frac{0.4276}{4.5936} \times 100$$

$$= 9.3$$

(2.16) The solubility of methyl bromide in methanol is 44 Kg per 100 Kg at 298 K (25°C). Find the weight fraction and mole fraction of methanol in the saturated solution

Methyl Bromide (CH_3Br) Formula weight 94.95.

Basis: 44 Kg Methyl bromide + 100 Kg CH_3OH

12
3
79.95
94.95

CH_3OH mol. wt = 32

12
4
16
32

$$\text{Wt-fraction methanol} = \frac{100}{44 + 100}$$

$$= 0.69$$

$$\text{Mole fraction methanol} = \frac{\frac{100}{32}}{\frac{100}{32} + \frac{44}{94.95}}$$

$$= \frac{3.125}{3.125 + 0.463}$$

$$= \frac{3.125}{3.588}$$

$$= 0.8709$$

(2.17) An aqueous solution contains 19.0 wt. % NH_3, 65.6 wt. % NH_4NO_3 and 6.0 wt. % urea (by wt). Calculate the available nitrogen content of the solution.

Basis: 100 kg solution.

Component	Wt %	mol. wt
NH_3	19.0	17
NH_4NO_3	65.6	80
NH_2CONH_2	6.00	60
H_2O	9.4	18

N_2	28			N_2 =	28
H_4	4			H_4 =	4
O_3	48				12
	80				16
					60

19.00
65.60
6.00
90.60

17 kg NH_3 contains — 14 kg Nitrogen

19 kg NH_3 — ?

$$\frac{19 \times 14}{17} = 15.647$$

80 kg NH_4NO_3 — 28 kg Nitrogen

65.6 kg NH_4NO_3 — $\frac{65.6 \times 28}{80} = 22.785$

60 kg urea — 28 kg Nitrogen

6 kg — $\frac{6 \times 28}{60} = 2.8$

15.647 kg
22.785 kg
2.8 kg

41.232 kg

(2-15) Ethanol is present in the aqueous solution to the extent of 1000 mg/l. Find TOC and ThOD of the solution in mg/l.

Basis: 1 litre of solution.

C_2H_5OH Mol. wt = 46.

C_2 - 24
H_6 6
O 16
46

1 ~~kmol~~ kmol ethanol contains ~~2~~ kmol Carbon.

~~Molecular weight of ethanol = 46~~

46 kg ethanol contains 24 kg Carbon

1000 mg/l ethanol contains ?

$$\frac{1000\ mg/l \times 24\ kg}{46\ kg} \qquad 32\times3$$

TOC = 521 mg/l, Carbon

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$.

46 kg ethanol requires ~~3×32~~ kg oxygen

1000 mg/l — ?

$$\frac{1000\ mg/l \times (3\times32)\ kg}{46\ kg}$$

ThOD = 2086.9 mg/l

Q.19 The strength of phosphoric acid is found to be 35% P_2O_5 (by weight). Find out the actual concentration of H_3PO_4 (by wt) in the acid.

$$2H_3PO_4 \longrightarrow P_2O_5 + 3H_2O$$

Molecular wt of H_3PO_4 = ~~97.97~~ 100.

H_3	3
P	30.97
O_4	64.00
	97.97

Molecular wt. of P_2O_5 = 142

P_2	62
O_5	80
	142

Basis : 100 kg phosphoric acid soln

100 kg soln contain 35 kg P_2O_5

142 kg P_2O_5 —— 100 × 2 kg H_3PO_4

35 kg P_2O_5 —— ?

$$\frac{35 \times 200}{142} = 49.29 \text{ kg}$$

49.29 wt % H_3PO_4

Q.20 An aqueous solution of soda ash contains 20% (by weight) soda ash. Express the composition as weight % Na_2O.

$$Na_2CO_3 \longrightarrow Na_2O + CO_2$$

Basis : 100 kg solution of Na_2CO_3

100 kg soln contain 20 kg Na_2CO_3

Na_2	46
C	12
O_3	48
	106

Mol. wt. of Na_2CO_3 — 106 kg/kmol

Mol. wt of Na_2O — 62 kg/kmol.

Na_2	46
O	16
	62

~~62 kg Na_2O —— 106 kg Na_2CO_3~~

106 kg Na_2CO_3 —— 62 kg Na_2O

20 kg Na_2CO_3 —— ?

$$\frac{20 \times 62}{106} = 11.69 \text{ Na}_2\text{O}$$

11.69 wt % Na_2O.

(2.22) A sample of aqueous triethanolamine (TEA) solution contains 47 %. Triethanolamine (vol basis). If the density of pure TEA is 1125 Kg/m³, find the weight % of TEA in the solution.

Basis: 100 m^3 solution

100 m^3 solution contains 47 m^3 TEA.

$$\text{density} = \frac{\text{mass}}{\text{vol.}}$$

$$\text{Wt. of TEA} = 47\ m^3 \times 1125\ \frac{Kg}{m^3}$$

$$\text{Wt. of TEA} = 52875\ Kg$$

$$\text{Volume of water} = (100 - 47) = 53\ m^3.$$

$$\text{weight of water} = \text{vol. of water} \times \text{density of water}$$

$$= 53 \times 1000$$

$$= 53000\ kg$$

$$\text{Wt\% TEA} = \frac{52875}{52875 + 53000}$$

$$= \frac{52875}{105875} \times 100$$

$$= 49.94\ \%$$

(2.23) A sample of wine contains 20 % alcohol (ethanol) on volume basis. Find the weight % of alcohol in the wine. Assume the densities of alcohol and alcohol free liquid (essentially water) to be 0.79 Kg/l and 1.0 Kg/l respectively.

Soln: Basis: 100 m3 of ~~ethanol~~ ~~alcohol~~ wine.

Contain 20 m3 of ethanol.

mole = wt / mol.wt

density = mass / vol.

Wt. of ethanol = 20 × 790

= ~~790 kg~~ 15,800 kg

$1 m^3$ = 1000 ltr.

1000 ltr — 1 m3

1 ltr — 0.001.

0.79 × 1000

790.00

Wt of water = 80 × 1000

Wt. of water = 80000 kg

790 × 20

15800

Wt % ethanol = $\frac{15800}{15800 + 80000}$

= $\frac{158}{958}$

80000
15800
95800

79
479

Wt.% Ethanol = 16.49 ~~wt~~.

479) 790 (0.1649
479
3110
2874
~~~~~~~~~~~~

Wt.% Ethanol = 16.49
~~~~~~~~~~~~