**MEASURING CONCENTRATION**

**Introduction**

• There are many concentration units for solutions in different areas of science. For example ppm for $SO_2$ content in air for environmental chemistry, percent concentration of sugar in a food for biochemistry, molarity of $H_2SO_4$ in a car battery.

• Concentration of man made products are so important in living organisms.

**1. Percent Concentration**

It is the simplest concentration unit, can be either by mass or by volume.

**1. Mass Percent**

• It expresses the mass of solute present in a given mass of solution.

$$\text{Mass percent} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

***Example 1***

Find the mass percent of a salt solution prepared by mixing 10 g NaCl and 200 g water.

*Solution*

$$\text{Mass percent} = \frac{\text{10 g of NaCl}}{\text{10 g NaCl + 200 g water}} \times 100 = \frac{10}{210} \text{x} 100 = 4.76\ \%$$

***Example 2***

Find the mass of sugar in 360 g of 25 % sugar solution by mass

*Solution*

$$25 = \frac{\text{Mass of sugar}}{\text{360 g solution}} \times 100 \Rightarrow \text{Mass of sugar} = \frac{360\text{x}25}{100} = 90 \text{ g}$$

***Example 3***

How many g of water must be added to 200 g of 50% NaOH solution by mass in order to make it 20% solution?

*Solution*

Mass of NaOH in the original solution,

$$50 = \frac{\text{Mass of NaOH}}{\text{200 g solution}} \times 100 \Rightarrow \text{Mass of NaOH} = \frac{200\text{x}50}{100} = 100 \text{ g}$$

Mass of water in 20% solution,

$$20 = \frac{\text{100 g NaOH}}{\text{Mass of solution}} \times 100 \Rightarrow \text{Mass of solution} = \frac{100\text{x}100}{20} = 500 \text{ g}$$

Mass of water = 500 - 200 = 300 g

***Example 4***

How many g of $NH_3$ must be added to 300 g of 20% $NH_3$ solution by mass in order to make it 50% solution?

*Solution*

Mass of $NH_3$ in the original solution,

$$20 = \frac{\text{Mass of NH}_3}{\text{300 g solution}} \times 100 \Rightarrow \text{Mass of NH}_3 = \frac{20\text{x}300}{100} = 60 \text{ g}$$

Mass of $NH_3$ in 50% solution,

$$50 = \frac{\text{Mass of NH}_3 \text{ added} + 60}{240+60 \ + \text{Mass of NH}_3 \text{ added}} \times 100$$

Mass of $NH_3$ added = 240 g

**2. Volume Percent**

• It is generally preferred for the solutions formed by liquids.

$$\text{Volume percent} = \frac{\text{Volume of solute}}{\text{Volume of solution}} \times 100$$

***Example 5***

An acetone solution is prepared by mixing 10 mL acetone and 340 mL water. What is the volume percent of the solution?

*Solution*

$$\text{Volume percent} = \frac{\text{10 mL}}{\text{10 mL + 340 mL}} \times 100 = 2.86\ \%$$

***Example 6***

There are two alcohol-water solutions, 50% and 20% by volume respectively. How many mL of each solution must be mixed to obtain 400 mL of 40% solution by volume?

*Solution*

Total volume is 400 mL. Lets assume the volume of first solution is x mL, volume of second solution will be 400-x mL.

Volume of alcohol in the final solution is $\frac{40\text{x}400}{100} = 160$ mL.

Volume of alcohol in the first solution is $\frac{50.\text{X}}{100} = \frac{\text{X}}{2}$ mL.

Volume of alcohol in the second solution is $\frac{20.(400\text{-X})}{100} = \frac{400\text{-X}}{5}$ mL

$160 = \frac{\text{X}}{2} + \frac{400\text{-X}}{5} \Rightarrow$ X= 267 mL is first solution,

and 400 - 267 = 133 mL is second solution.

***Example 7***

Equal volumes of 15% and 35% HCl solutions by volume are mixed. What is the percent concentration of the new solution?

*Solution*

Since the volume of each solution is equal,

final percent concentration is $\frac{15+35}{2} = 25\%$.

**2. Molarity**

• Molarity is the most common concentration unit.

It is defined as mole number of a solute dissolved per liter of solution.

$$\text{Molarity} = \frac{\text{Mole number of solute}}{\text{Volume of solution in liter}}, \ \text{M} = \frac{\text{n}}{\text{V}}, \ \frac{\text{mol}}{\text{L}}$$

***Example 8***

A 1-L sample of sea water contains 3.5 g NaCl. What is the molarity of NaCl in the sample? (Na:23, Cl: 35.5)

*Solution*

$$n_{NaCl} = \frac{3.5 \text{ g}}{58.5 \text{ g/mol}} = 0.06 \text{mol}, \ M_{NaCl} = \frac{0.06 \text{ mol}}{1 \text{ L}} = 0.06 \text{ M}.$$

***Example 9***

4 g NaOH is dissolved in 10 L water. What is the molarity of NaOH solution obtained? (Na:23, O: 16, H: 1)

*Solution*

$n_{NaOH} = \frac{4\ g}{40\ g/mol} = 0.1 mol$, $M_{NaOH} = \frac{0.1\ mol}{10\ L} = 0.01\ M.$

***Example 10***

How many g of $H_2SO_4$ must be dissolved in 200 mL of water in order to obtain 5 M solution? (S:32, O: 16, H: 1)

*Solution*

$M_{H_2SO_4} = 5 = \frac{n\ mol}{0.2\ L} \Rightarrow n_{H_2SO_4} = 1\ mol \Rightarrow m_{H_2SO_4} = 1x98 = 98\ g$

***Example 11***

What is the molarity of 63% by mass of $HNO_3$ solution whose density is 1.4 g/mL? (N:14, O: 16, H: 1)

*Solution*

Assume the solution is 1000 mL,

$m_{HNO_3}$ solution = 1.4x1000 = 1400 g

$m_{HNO_3} = \frac{1400x63}{100} = 882\ g$, the $n_{HNO_3} = \frac{882\ g}{63\ g/mol} = 14\ mol.$

$M_{HNO_3} = \frac{14\ mol}{1\ L} = 14\ M$

***Example 12***

What is the molarity of the solution obtained by mixing 300 mL of 0.4 M $NH_3$ solution with 600 mL of 0.6 M $NH_3$ solution?

*Solution*

$V_f = V_1 + V_2$ so $V_f = 300 + 600 = 900\ mL = 0.9\ L$,

$n_f = n_1 + n_2$, then $M_f.V_f = M_1.V_1 + M_2.V_2$

$M_f \times 0.9 = 0.4 \times 0.3 + 0.6 \times 0.6$

$M_f = 0.53\ M$

$M_f.V_f = M_1.V_1 + M_2.V_2 + M_3.V_3 ..... + M_n.V_n$

***Example 13***

How many mL of 0.5 M and 0.8 M $H_2SO_4$ solutions must be mixed to prepare 800 mL of 0.6 M $H_2SO_4$ solution?

*Solution*

$800 = V_1 + V_2$ ,

$M_f.V_f = M_1.V_1 + M_2.V_2$

$0.6 \times 0.8 = 0.5 \times V_1 + 0.8 \times (0.8 - V_1)$

$V_1 = 0.53\ L = 530\ mL$ then $V_2 = 800 - 530 = 270\ mL$

**3. The Preparation of A Solution With A Desired Concentration**

• A standard solution is a solution whose concentration is accurately known. Chemists often need standard solutions for chemical reactions.

***Example 14***

Explain step by step the preparation of a 500 mL of 0.5 M NaOH solution.

*Solution*

Initially mole number of solute, NaOH, is calculated.

n = 0.5x0.5 = 0.25 mol, then its mass m = 0.25x40 = 10 g

Secondly, 10 g NaOH is put into 500 mL volumetric flask, and some water is added to dissolve completely.

Finally water is added to the volume marked on the neck of volumetric flask to complete the volume of solution 500 mL

***Example 15***

What volume (in mL) of a 0.5 M solution of copper(II) sulfate, $CuSO_4$, is needed to react with an excess of aluminum to provide 11.0 g of copper?(Cu: 63.55).

*Solution*

$3CuSO_4(aq) + 2Al(s) \rightarrow 3Cu(s) + Al_2(SO_4)_3(aq)$

$n_{Cu} = \frac{11\ g}{63.55\ g/mol} = 0.173\ mol$ $\qquad 0.5\ M = \frac{0.173\ mol}{V}$

3 mol $CuSO_4$ produce 3 mol Cu $\Rightarrow V = 0.346\ L = 346\ mL$

$\frac{x\ mol \qquad 0.173\ mol}{x = 0.173\ mol}$

***Example 16***

What is the concentration of 400 mL of NaOH prepared by the reaction of 2.3 g of Na with enough water?(Na: 23).

***Example 17***

What is the concentration of hydrogen ions in 500 mL of $H_2SO_4$ solution prepared by the dilution of 200 mL of 30% $H_2SO_4$ solution with a density of 0.96 g/mL?(S: 32, H:1, O:16).