Solutions and concentration

Solution: a homogeneous mixture of two or more substances. Example: water, sugar, flavor mixture (Coke). The substances are physically combined, not chemically combined or bonded to each other.

Nanoscale pictures: Figs. 5.1, 5.4, and 5.5

Solvent: usually the substance in the greater amount. The substance used to dissolve the solute or solutes. Example: water.

Solute: usually the substance in the lesser amount. The substance dissolved by the solvent. Example: sugar.

<u>Concentration</u>: the ratio of the amount of solute to the total amount of solution. Examples: 80 proof alcohol, 3% hydrogen peroxide, 12 M HCl.

In chemistry, we use **molarity** (M) because it's based on moles and the mole ratio concept (Chapters 3 and 4).

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{Volume of solution}} = \frac{\text{mol}}{\text{L}} = \text{M}$$

M = [   ]

<u>Example</u>:
What is the molarity of a sugar solution of 3.42 g sugar dissolved in a total volume of 100* mL? Sugar = $C_{12}H_{22}O_{11}$ = 342 g/mol.

$M_{sugar} = [C_{12}H_{22}O_{11}] = ?$

Example: Titration to reach equivalence point.
Remember for titration that …

1. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ (N.I.E.)
2. moles H^+ = moles OH^-

0.3256 g of sulfamic acid requires 24.10 mL of NaOH solution to reach the equivalence point (to be neutralized, to be titrated). What is the concentration (in M) of the NaOH solution?

Titration example: moles OH^- = moles H^+
17.85 mL of 0.104 M NaOH solution is needed to titrate 20.00 mL of H_2SO_4 solution. What is the concentration of the H_2SO_4 solution?

Stoichiometry (mole ratio) in H_2SO_4

H_2SO_4 has two acidic protons (H^+).

When titrating H_2SO_4 with OH^-, keep in mind that 2 OH^- are needed for every 1 H_2SO_4!

<u>Dissolved ions example</u>: 1.75 g $(NH_4)_2SO_4$ is dissolved in enough water to make 250* mL of solution. What is the concentration (in M) of each ion present in the solution?
MM of $(NH_4)_2SO_4$ = 132.139 g/mol.

Mass % for solutions (not in textbook)

$$\text{mass \%} = \frac{\text{mass of component in solution}}{\text{total mass of solution}} \times 100\%$$

Examples:

3% hydrogen peroxide solution means
3 grams H_2O_2 are in 100 grams of solution, or

$$\frac{3 \text{ g } H_2O_2}{100 \text{ g of solution}} \times 100\% = 3\% \; H_2O_2 \text{ solution}$$

What is the molarity of 20% KOH solution?
(density$_{soln}$ = 1.19 g/mL)

$$\frac{20 \text{ g KOH}}{100 \text{ g of solution}} \times$$

MM (KOH) = 56.1056 g/mol

<u>Dilution</u>: a process in which the concentration (molarity) of a solution is lowered. The amount of solute (atoms, moles, grams, etc.) remains the same, but the volume is increased by adding more solvent.

<u>Example</u>: orange juice from frozen concentrate.

$$\text{moles}_{\text{stock}} = \text{moles}_{\text{diluted}}$$

<u>Stock solution</u>: the more concentrated solution that is used to make the less concentrated solution. A sample of the stock solution is diluted by adding more solvent to the sample.

$$M_{\text{stock}} \times V_{\text{stock}} = \text{moles}_{\text{stock}} = \text{moles}_{\text{diluted}} = M_{\text{diluted}} \times V_{\text{diluted}}$$

$$\frac{\text{moles}}{\text{L}} \times \text{L} = \text{moles}$$

$$\text{moles}_{\text{stock}} = \text{moles}_{\text{diluted}}$$

<u>Example</u>: $\text{moles}_{stock} = \text{moles}_{diluted}$

A stock solution of urea $(NH_2)_2CO$ has a concentration of 2.94×10^{-2} M. How many milliliters (mL) of the stock solution are needed to prepare 500* mL of a solution with a concentration of 1.35×10^{-3} M?

$V_{stock} = ?$

More on molarity and mole calculations

Four variables involved in dilutions:

1. Find concentration of diluted solution (M_f).
2. Find volume of diluted solution (V_f).
3. Find original (stock) concentration (M_i).
4. Find original (stock) volume (V_i).

Similar to four variables involved in titrations:

1. Find concentration of acid solution (M_{acid}).
2. Find volume of acid solution (V_{acid}).
3. Find concentration of base solution (M_{base}).
4. Find volume of base solution (V_{base}).

Figure 5.15 summarizes calculations so far using **mole ratio concept** for chemical formulas (Ch 3) and chemical reactions (Ch 4) to convert between moles A <--> moles B.

Figure 5.15 summarizes calculations so far to relate moles of a substance using **MM concept** (Ch 3) to convert between grams <--> moles and using **molarity** (Ch 5) to convert between volume (liters) <--> moles.

More on precipitation reactions

Precipitation: a process in which a solid forms from a solution.

Soluble: a term that describes a solid that easily dissolves in a solvent. Dissolve = soluble. Example: NaCl in water.

Insoluble: a term that describes a solid that does not easily dissolve in a solvent.
Not dissolve = insoluble. Example: $CaCO_3$ (chalk, seashells, etc.) in water.

Soluble and insoluble are actually the two extremes on a scale of solubility.

We oversimplify when we classify a solid as either extreme.

Practice: 5.14 g of Na_3PO_4 is dissolved in enough water to make 500. mL of solution. What is the molarity of sodium phosphate? What is the concentration of each ion present in the solution?