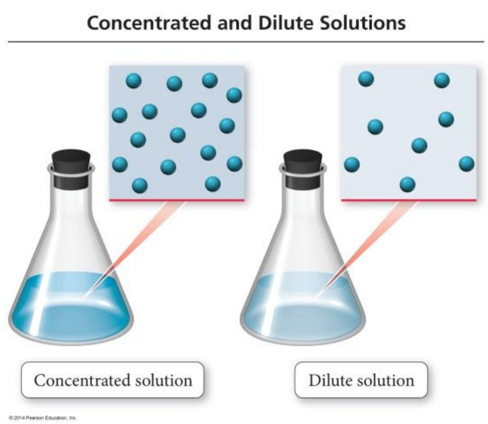
SOLUTON CONCENTRATION

- Many chemical reactions involve reactants that are dissolved in water. These reactants are referred to as solutions and are a very important part of chemistry.
- A solution is a homogeneous mixture of two substances: ***solute*** and ***solvent***.
- ***Solute*** is the substance being dissolved (present in lesser amount), while ***solvent*** is the substance doing the dissolving (present in larger amount).
- An ***aqueous*** solution is one in which water is the solvent.

Solution Concentrations:

- The amount of solute in a solution is variable. Solutions that have little solute are called ***dilute***, while solutions that have large amount of solute are called ***concentrated***.



- Concentration can be define in general terms as the ***amount of solute*** dissolved in a certain ***amount of solution***:

$$\textbf{Concentration} = \frac{\textbf{amount of solute}}{\textbf{amount of solution}}$$

MOLARITY

- The most common unit of concentration used in the laboratory is **molarity (M).** Molarity is defined as:

$$\textbf{Molarity} = \frac{\textbf{moles of solute}}{\textbf{Liter of solution}}$$

Examples:

1. What is the molarity of a solution containing 1.4 mol of acetic acid in 250 mL of solution?

$$250\ \cancel{\text{mL}} \times \frac{1\ \text{L}}{1000\ \cancel{\text{mL}}} = 0.25\ \text{L}$$

$$\text{Molarity} = \frac{1.4\ \text{mol of acetic acid}}{0.25\ \text{L of solution}} = 5.6\ \text{M}$$

2. What is the molarity of a solution prepared by dissolving 60.0 g of NaOH in 0.250 L of solution?

First, calculate the number of moles of solute:

$$60.0\ \text{g of NaOH} \times \frac{1\ \text{mol}}{40.0\ \text{g}} = 1.50\ \text{mol of NaOH}$$

Next, calculate the molarity of solution:

$$\text{M} = \frac{1.50\ \text{mol of NaOH}}{0.250\ \text{L of solution}} = 6.00\ \text{M}$$

3. What is the molarity of a solution that contains 75 g of KNO_3 in 350 mL of solution?

Calculate moles of solute:

Calculate molarity:

USING MOLARITY

- Molarity can be used as a conversion factor between moles of solute and volume of solution. Examples below show how amount of solute can be calculated from volume and molarity of solution.

Examples:

1. How many moles of nitric acid are in 325 mL of 16 M HNO_3 solution?

$$325\ \cancel{\text{mL}} \times \frac{1\ \text{L}}{1000\ \cancel{\text{mL}}} = 0.325\ \text{L}$$

$$0.325\ \text{L of solution} \times \frac{16\ \text{mol}}{1\ \text{L of solution}} = 5.2\ \text{mol of } HNO_3$$

2. How many grams of KCl would you need to prepare 0.250 L of 2.00 M KCl solution?

First, calculate the number of moles of solute:

$$0.250\ \text{L of solution} \times \frac{2.00\ \text{mol}}{1\ \text{L of solution}} = 0.500\ \text{mol of KCl}$$

Next, calculate the mass of solute:

$$0.500\ \text{mol of KCl} \times \frac{74.6\ \text{g}}{1\ \text{mol}} = 37.3\ \text{g of KCl}$$

3. How many grams of $NaHCO_3$ are in 325 mL of 4.50 M solution of $NaHCO_3$?

Calculate moles of solute:

Calculate mass of solute:

USING MOLARITY

- Examples below shown how volume of solution can be calculated from amount of solute and molarity of solution.

Examples:

4. What volume (L) of 1.5 M HCl solution contains 6.0 moles of HCl?

$$6.0 \text{ mol HCl} \times \frac{1 \text{ L solution}}{1.5 \text{ mol HCl}} = 4.0 \text{ L of solution}$$

5. What volume (mL) of 2.0 M NaOH solution contains 20.0 g of NaOH?

First, calculate the number of moles of NaOH:

$$20.0 \text{ g NaOH} \times \frac{1 \text{ mol}}{40.0 \text{ g}} = 0.500 \text{ mol of NaOH}$$

Next, calculate the volume of solution:

$$0.500 \text{ mol NaOH} \times \frac{1 \text{ L solution}}{2.0 \text{ mol NaOH}} = 0.25 \text{ L of solution}$$

$$0.25 \text{ L} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 250 \text{ mL}$$

6. How many mL of a 0.300 M glucose ($C_6H_{12}O_6$) intravenous solution is needed to deliver 10.0 g of glucose to the patient?

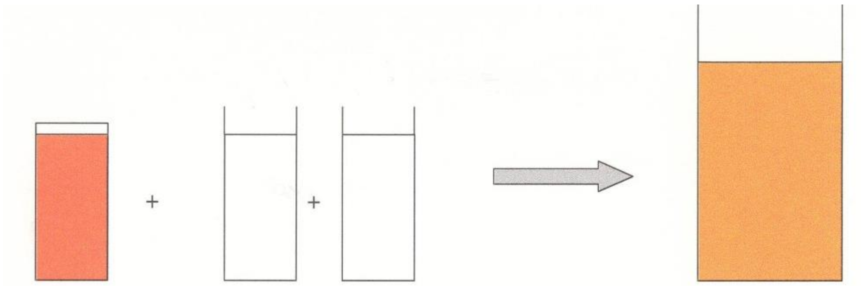
Calculate mole of solute:

Calculate volume of solution:

DILUTION

- Solutions are often prepared from more concentrated ones by adding water. This process is called ***dilution***.

- When more water is added to a solution, the ***volume increases***, causing a ***decrease in concentration***. However, the ***amount of solute does not change***.



Volume and Concentration are inversely proportional

- The amount of solute depends on the concentration and the volume of the solution. Therefore,

$$\mathbf{M_1 \times V_1 = M_2 \times V_2}$$

<u>Examples:</u>

1. What is the molarity of the final solution when 75 mL of 6.0 M KCl solution is diluted to 150 mL?

$M_1 = 6.0$ M $\quad V_1 = 75$ mL

$M_2 = ???$ $\quad V_2 = 150$ mL

$$M_2 = \frac{M_1 V_1}{V_2} = \frac{(6.0\text{ M})(75\text{ mL})}{150\text{ mL}} = 3.0\text{ M}$$

2. What volume (mL) of 0.20 M HCl solution can be prepared by diluting 50.0 mL of 1.0 M HCl?

$M_1 =$ $\quad V_1 =$

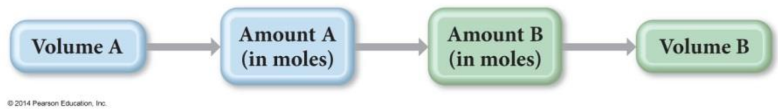
$M_2 =$ $\quad V_2 =$

SOLUTION STOICHIOMETRY

- In aqueous reactions, amounts of reactants and products are often specified in terms of volume and concentrations. A chemical equation, however, is based on mole relationships between reactants and products.

- A knowledge of conversion of volume and concentration data into mole quantities and subsequent calculations based on the stoichiometric relationships in the chemical equation are referred to as ***solution stoichiometry***.

- The general concept for doing these calculations is shown below:



Examples:

1. What volume (in L) of a 0.150 M KCl solution will completely react with 0.150 L of a 0.175 M $Pb(NO_3)_2$ solution as shown below:

$$2\ KCl\ (aq)\ +\ Pb(NO_3)_2\ (aq)\ \rightarrow\ PbCl_2\ (s)\ +\ 2\ KNO_3\ (aq)$$

2. If it takes 55.6 mL of a 0.10 M NaOH solution to neutralize 125 of an HCl solution, what is the concentration of the HCl?

ACID-BASE TITRATIONS

- Principles of solution stoichiometry can be used to solve problems in a common laboratory procedure called ***titration***.

- In a titration, a substance of known concentration is reacted with another substance of unknown concentration. For example, consider the acid-base reaction between HCl and NaOH shown below:

$$HCl\ (aq) + NaOH\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l)$$

- When a solution of NaOH with a known concentration is added slowly to a known volume of HCl with an unknown concentration, the H^+ and OH^- ions combine to form water. (Note that the Na^+ and Cl^- ions forming NaCl are omitted from this discussion, since they are spectator ions).

- After addition of enough OH^- to neutralize all of the H^+ present (***equivalence point***), the solution becomes neutral and the titration is complete. The equivalence point is usually detected by addition of an ***indicator***, a dye that changes color based on the acidity of the solution.

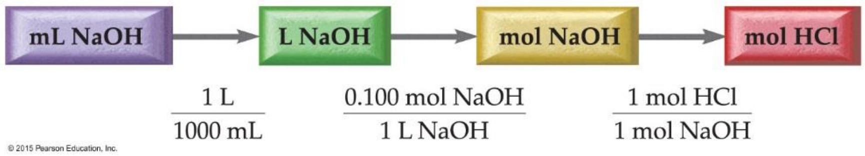
- Stoichiometric calculations based on concentration of know substance (NaOH) and volume of both solutions can yield the concentration of the unknown substance (HCl).

ACID-BASE TITRATIONS

Examples:

1. The titration of 10.00 mL of an HCl of unknown concentration requires 12.54 mL of a 0.100 M NaOH solution to reach the equivalence point. What is the concentration of the unknown HCl solution?

$$HCl\ (aq) + NaOH\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l)$$



2. The titration of a 20.00-mL sample of an H_2SO_4 solution of unknown concentration requires 22.87 mL of a 0.158 M KOH solution to reach equivalence point. What is the concentration of the unknown H_2SO_4 solution?