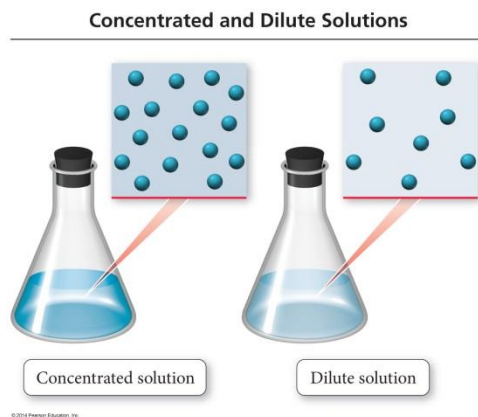


SOLUTION CONCENTRATION

- 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*:

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

MOLARITY

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

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

Examples:

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

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

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

- 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:

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

- What is the molarity of a solution that contains 75 g of KNO₃ 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 HNO₃ solution?

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

$$0.325 \text{ L of solution} \times \frac{16 \text{ mol}}{1 \text{ L of solution}} = 5.2 \text{ mol of HNO}_3$$

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 NaHCO₃ are in 325 mL of 4.50 M solution of NaHCO₃?

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 (C₆H₁₂O₆) intravenous solution is needed to deliver 10.0 g of glucose to the patient?

Calculate mole of solute:

Calculate volume of solution:

ION CONCENTRATION

- The concentration of ionic substances in solution reflects the concentration of the solute before it dissolves.
- The concentration of the ions dissolved in solution can be calculated by noting the number of each ion present in the formula unit.
- For example, a 1.0 M CaCl₂ solution has the following ion concentrations:

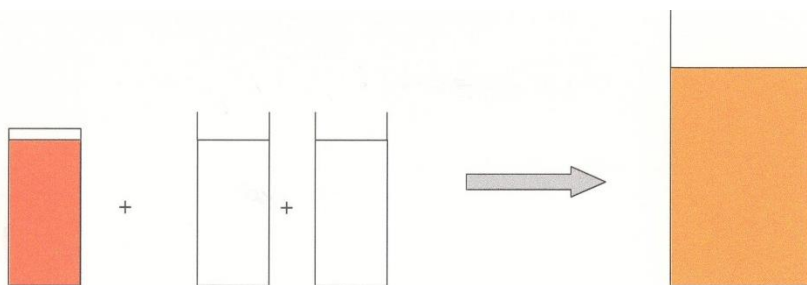
**Examples:**

1. Determine the molar concentrations of Na⁺ and PO₄³⁻ in a 1.50 M Na₃PO₄ solution.

2. Which solution below has the greatest concentration of NO₃⁻?
 - a) 0.10 M Ca(NO₃)₂
 - b) 0.15 M KNO₃
 - c) 0.075 M Cr(NO₃)₃

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,

$$M_1 \times V_1 = M_2 \times V_2$$

Examples:

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

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

$$M_2 = ??? \quad V_2 = 150 \text{ mL}$$

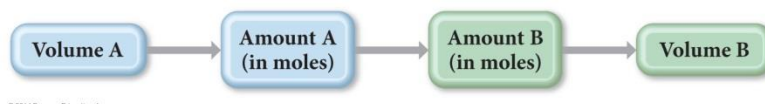
- What volume (mL) of 0.20 M HCl solution can be prepared by diluting 50.0 mL of 1.0 M HCl?

$$M_1 = \quad V_1 =$$

$$M_2 = \quad V_2 =$$

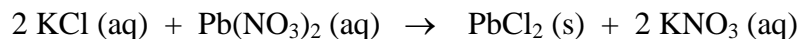
SOLUTION STOICHIOMETRY

- 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:

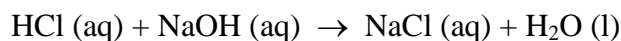
1. What volume (in L) of a 0.150 M KCl solution will completely react with 0.150 L of a 0.175 M Pb(NO₃)₂ solution as shown below:



2. If it takes 55.6 mL of a 0.10 M NaOH solution to neutralize 125 mL 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:



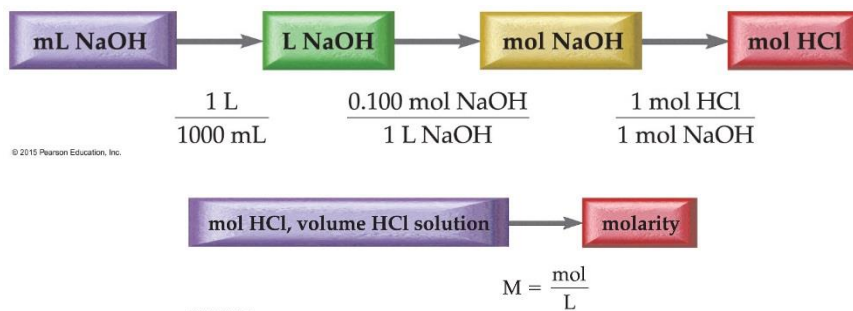
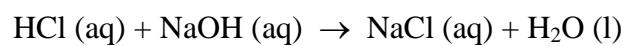
- When a solution of NaOH with a known concentration is added slowly to a known volume of HCl with an unknown concentration, the H^+ and OH^- ions combine to form water. (Note that the Na^+ and Cl^- ions forming NaCl are omitted from this discussion, since they are spectator ions).
- After addition of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



ACID-BASE TITRATIONS

Examples:

- 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?



- The titration of a 20.00-mL sample of an H₂SO₄ 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 H₂SO₄ solution?