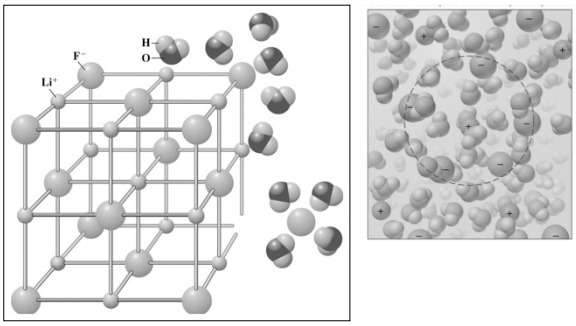
Solutions & Concentration

Silberberg – Section 3.5

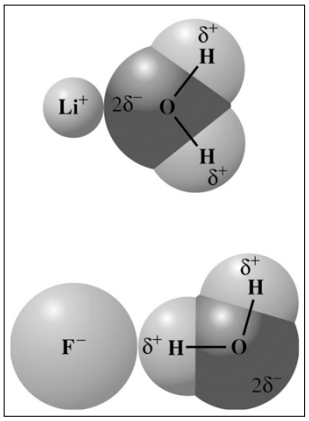
Solutions

- A **solution** is a homogeneous mixture composed of a **solvent** and one or more **solutes**.
- A **solute** is a substance dissolved in the solvent.
- The **solvent** is the substance that dissolves the solute or solutes.
- ***Note:*** Sometimes it is not clear what is the solvent or the solute. The solvent is *generally* considered to be the most abundant substance.
- **Aqueous (aq)** means "dissolved in water".

Dissolution of Lithium Fluoride in Water



Attraction of water molecules to ions because of the ion-dipole force.

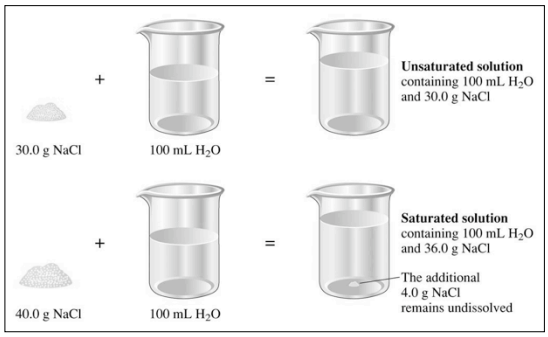


Degrees of Saturation:

- **Unsaturated** – more solute may be dissolved in a solution.
- **Saturated** – the maximum amount of solute is dissolved in a solution.
- **Supersaturated** – more solute is dissolved in a solution than is stable at that temperature.

  (A precipitate is likely to form.)

Comparison of Unsaturated and Saturated Solutions



Molarity

- **Concentration** is the measure of the amount of solute in a solution (part / whole).
- **Molar concentration**, or **molarity** is a measure of the moles of a solute in one liter of solution.

$$\text{Molarity} = \frac{n}{V} = \frac{\text{moles of solute}}{\text{volume of solution}} = \frac{\text{mol solute}}{\text{L solution}} = M$$

- Brackets around a formula indicate the concentration of the substance is being discussed:

  [NaCl] means "the molarity of NaCl"

Calculating Concentration

- *Example #1:* What is the concentration of a solution found to contain 0.00834 mol of $BaCl_2$ in a 20.0 mL sample of solution?

- *Example #2:* What is the concentration of sodium hypochlorite solution prepared by dissolving 5.66 g of NaOCl in enough water to make 250.0 mL of solution?

Preparing a Solution

- To prepare a solution of known concentration from a solid substance soluble in water:
  1. Determine the mass required to make the desired volume of the solution.
  2. Dissolve that quantity of solid in the appropriate volumetric flask.

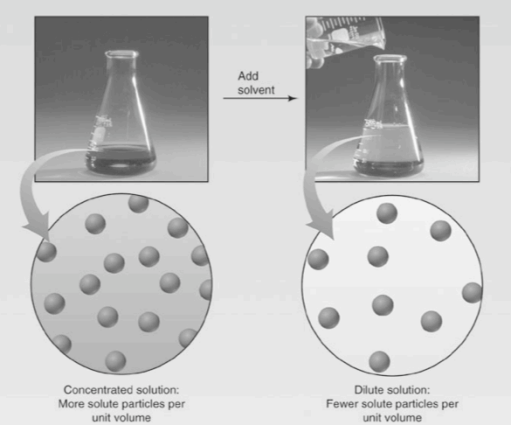
- *Example:* An experiment calls for 250.0 mL of 0.2000 *M* solution of $CuSO_4$. Describe how to prepare this solution starting with solid $CuSO_4 \cdot 5H_2O$.

Dilutions

- When you have a stock solution of known concentration, you may prepare less concentrated solutions by diluting the stock solution with water.
- When a quantity of solution is diluted, the number of moles of solute does not change, only the total volume, therefore:

  mol solute in the concentrated solution = mol solute in the dilute solution

- Because: **concentration x volume = mol**
- We can use the relationship: $\mathbf{M_1V_1 = M_2V_2}$



Dilution Examples

1. What volume of a 0.333 *M* NaOH stock solution is required to make 250.0 mL of a 0.100*M* NaOH solution? Describe its preparation.

3. What is the concentration of a solution prepared by diluting 2.00 mL of a 0.250 *M* solution of sucrose to 25.0 mL?

Compounds and Ions in solution

- Ionic compounds often dissociate into their ions when dissolved in water.
- Compounds that undergo complete (100%) dissociation (like NaCl) are called **strong electrolytes** because their solutions are good electrical conductors.
- Some ionic compounds only partially dissociate in water (like H_3PO_4) and are called **weak electrolytes**, because their solutions are poor electrical conductors.

Compounds and Ions in solution

- Covalent compounds (like glucose, $C_6H_{12}O_6$) do NOT dissociate in water and are called **nonelectrolytes**, because their solutions do not conduct electricity.
- Note: Pure water (which we rarely actually have) is a very poor electrical conductor.

Dissociation of Ionic Compounds

- When an ionic compound like NaCl dissociates in water, one sodium ion and one chloride ion are released into solution for each formula unit:

$$NaCl_{(s)} \xrightarrow{H_2O} NaCl_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$$

- What is the concentration of sodium ions and chloride ions in a solution that is 0.500 *M* NaCl?

Dissociation of Ionic Compounds

- When an ionic compound like $MgBr_2$ dissociates in water, one magnesium ion and two bromide ions are released into solution for each formula unit:

$$MgBr_{2(s)} \xrightarrow{H_2O} MgBr_{2(aq)} \rightarrow Mg^{2+}_{(aq)} + 2\,Br^-_{(aq)}$$

- What are the concentrations of Mg^{2+} ions and Br^- ions in a 0.30 *M* solution of $MgBr_2$?

- What are the concentrations of iron and phosphate ions in a 0.10 *M* iron (II) phosphate solution?

Mass Percent

$$\text{Mass \%} = \frac{\text{mass solute}}{\text{mass solution}} \times 100\%$$

- Calculate the percent by mass of magnesium chloride in a solution if 18.3 g dissolved in 250.0 mL of of pure water. (D_{H2O}=1.00 g/mL)
- What mass of aluminum nitrate is in 500.0 mL of a solution that is 7.85% aluminum nitrate?
  The density of the solution is 1.093 g/mL.

Parts per million (ppm)

$$\text{ppm} = \frac{\text{mass solute}}{\text{mass solution}} \times 1 \times 10^6$$

- Calculate the ppm concentration of a solution that contains 265 mg of mercury ions in 8.00 L of solution (D = 1.00 g/mL)
- Express the above ppm concentration as a percent by mass.