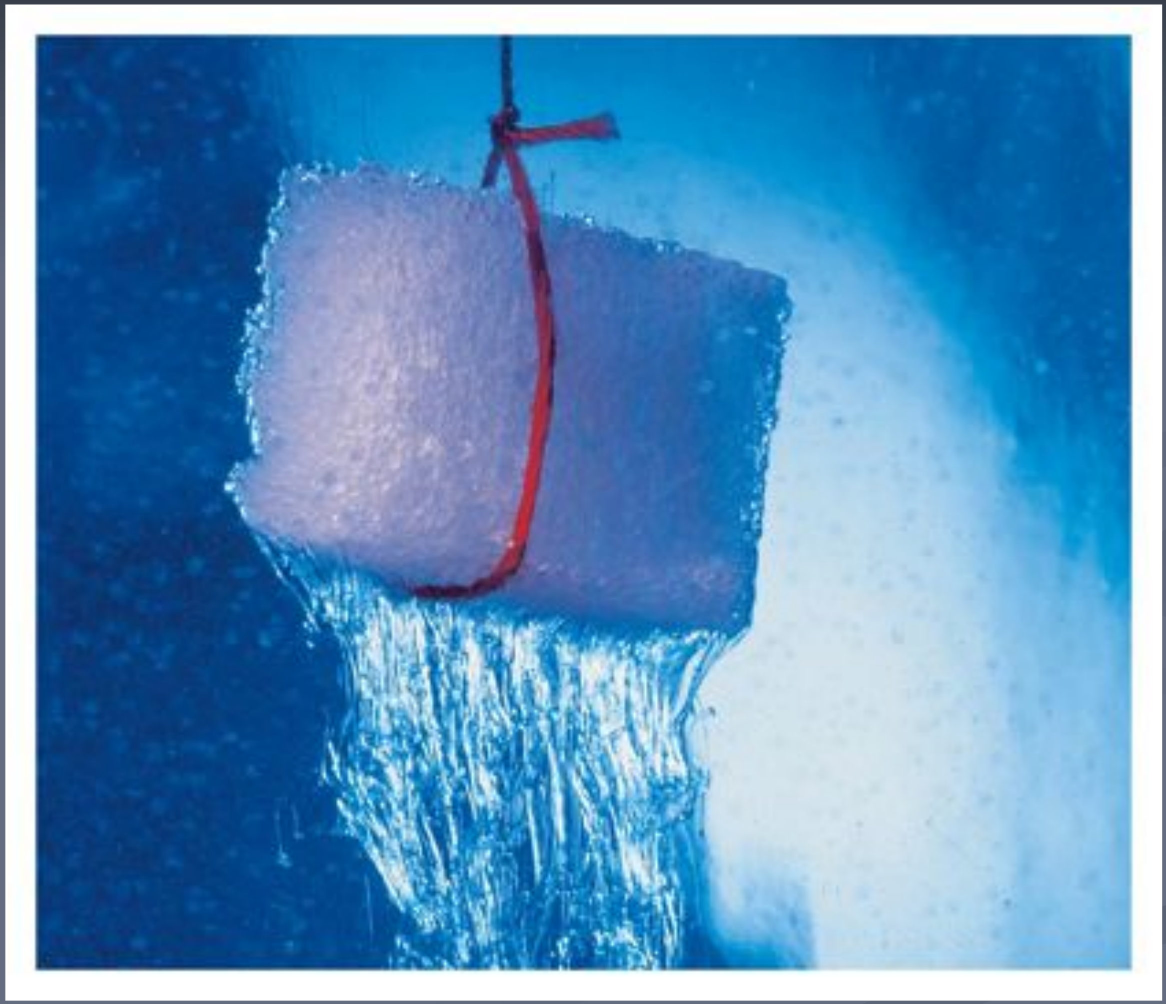
Solutions & Concentration

Silberberg – Sections 4.1 & 3.5

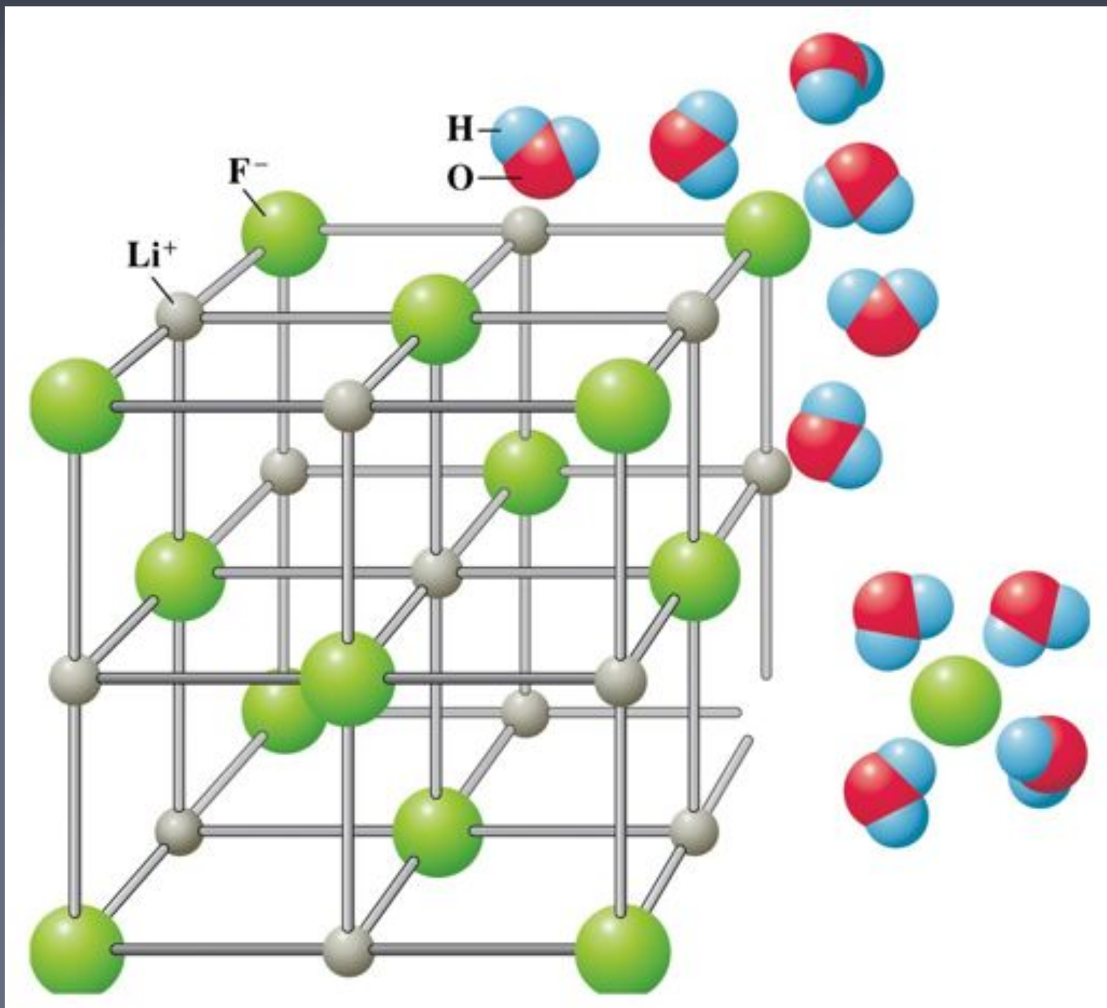
Solutions

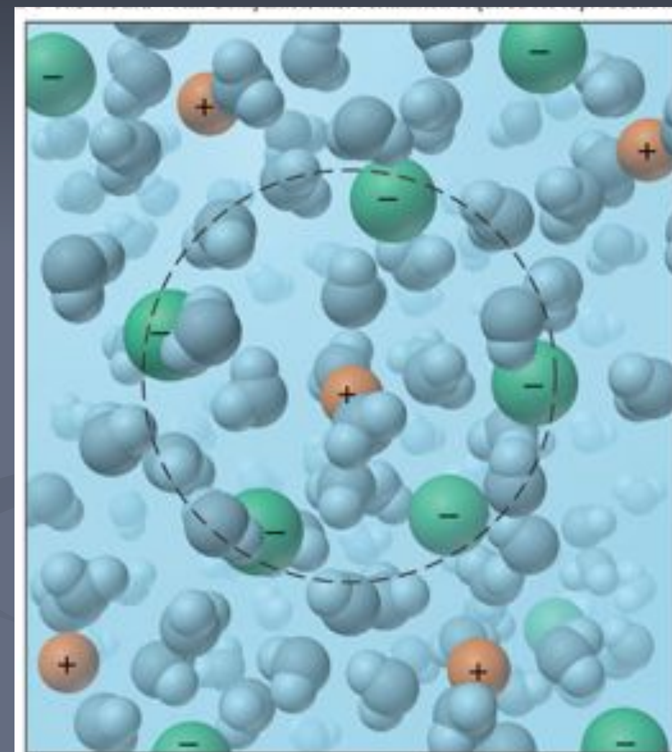
- A **solution** is a homogeneous mixture composed of a **solvent** and one or more **solutes**.
- A **solute** is a substance dissolved in the solvent.
- The **solvent** is the substance that dissolves the solute or solutes.
- ***Note:*** Sometimes it is not clear what is the solvent or the solute.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

Sugar Cube Dissolving in Water.

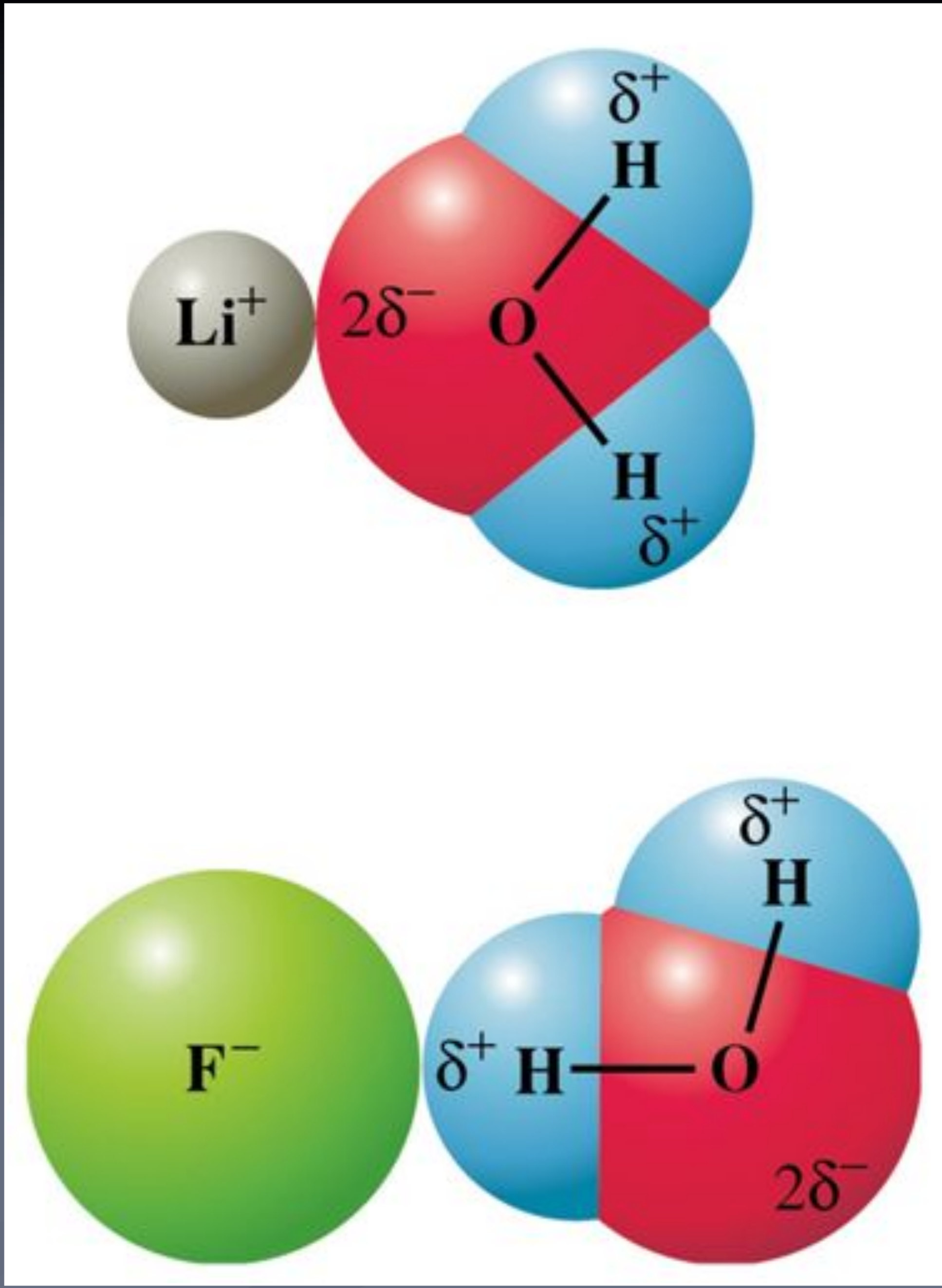


Dissolution of Lithium Fluoride in Water

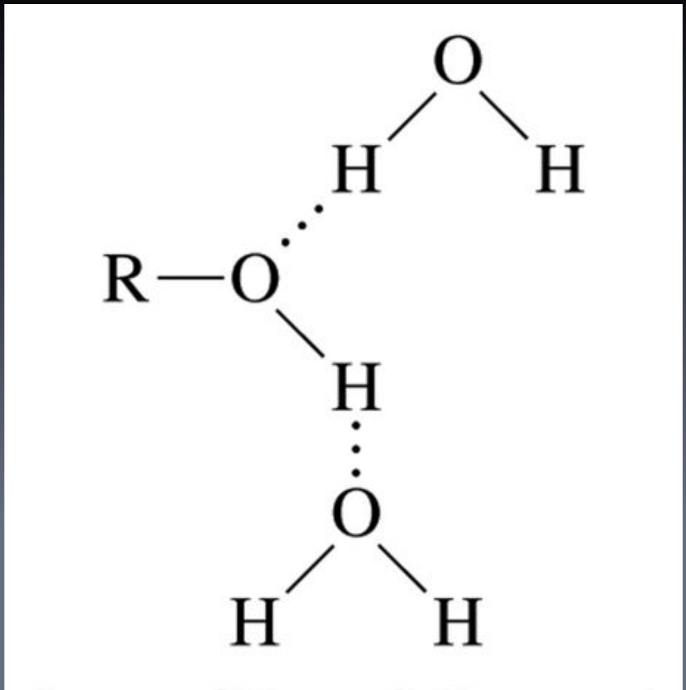




Attraction of water molecules to ions because of the ion-dipole force.



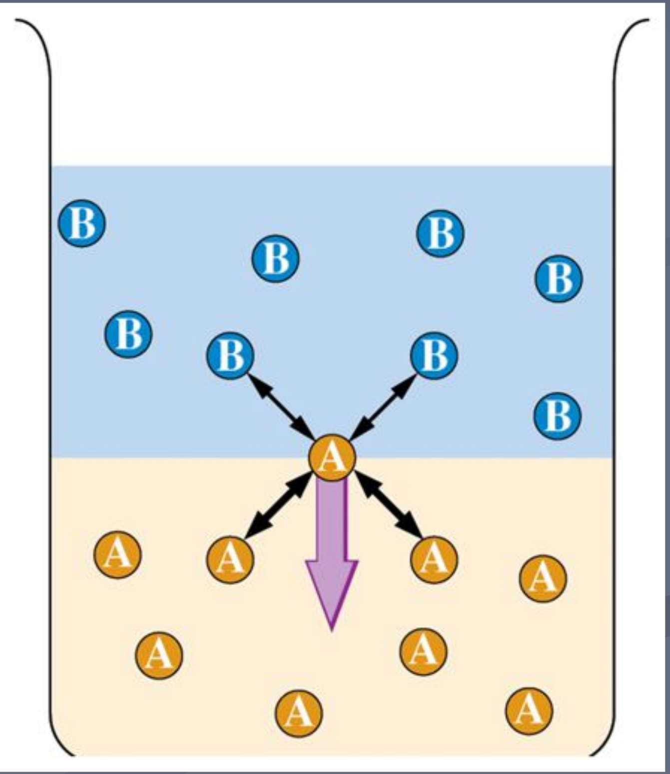
Immiscible and Miscible Liquids



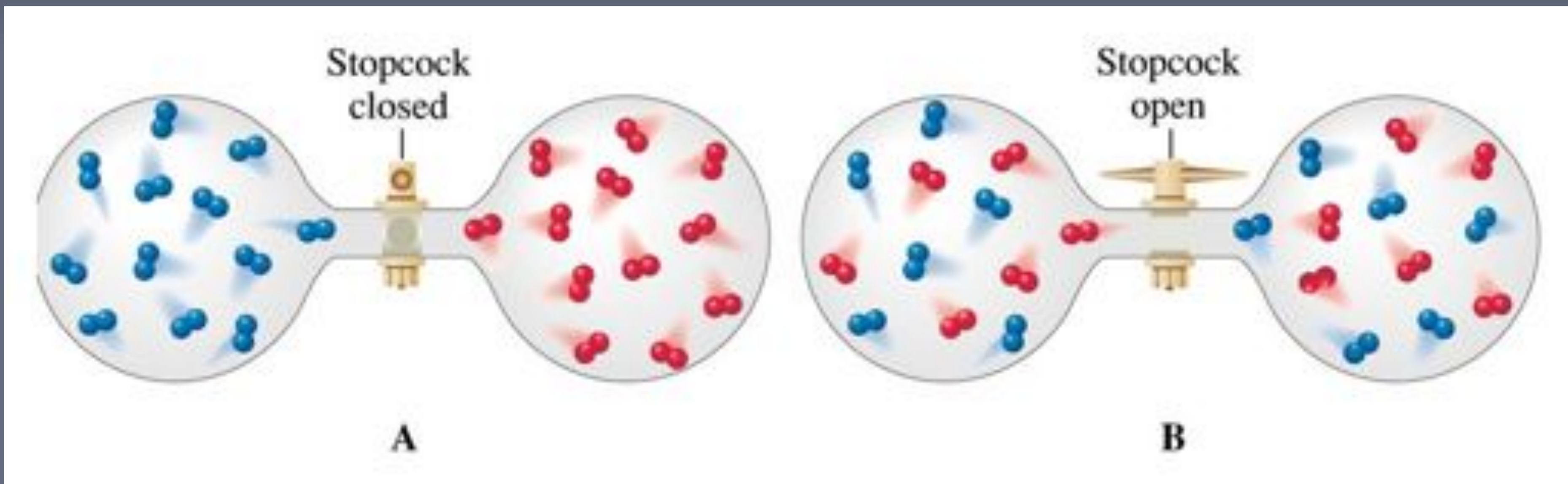
$(R— = CH_3—, C_2H_5—, \text{etc.})$

Hydrogen Bonding Between Water and Alcohol Molecules

The Immiscibility of Liquids



The Mixing of Gas Molecules

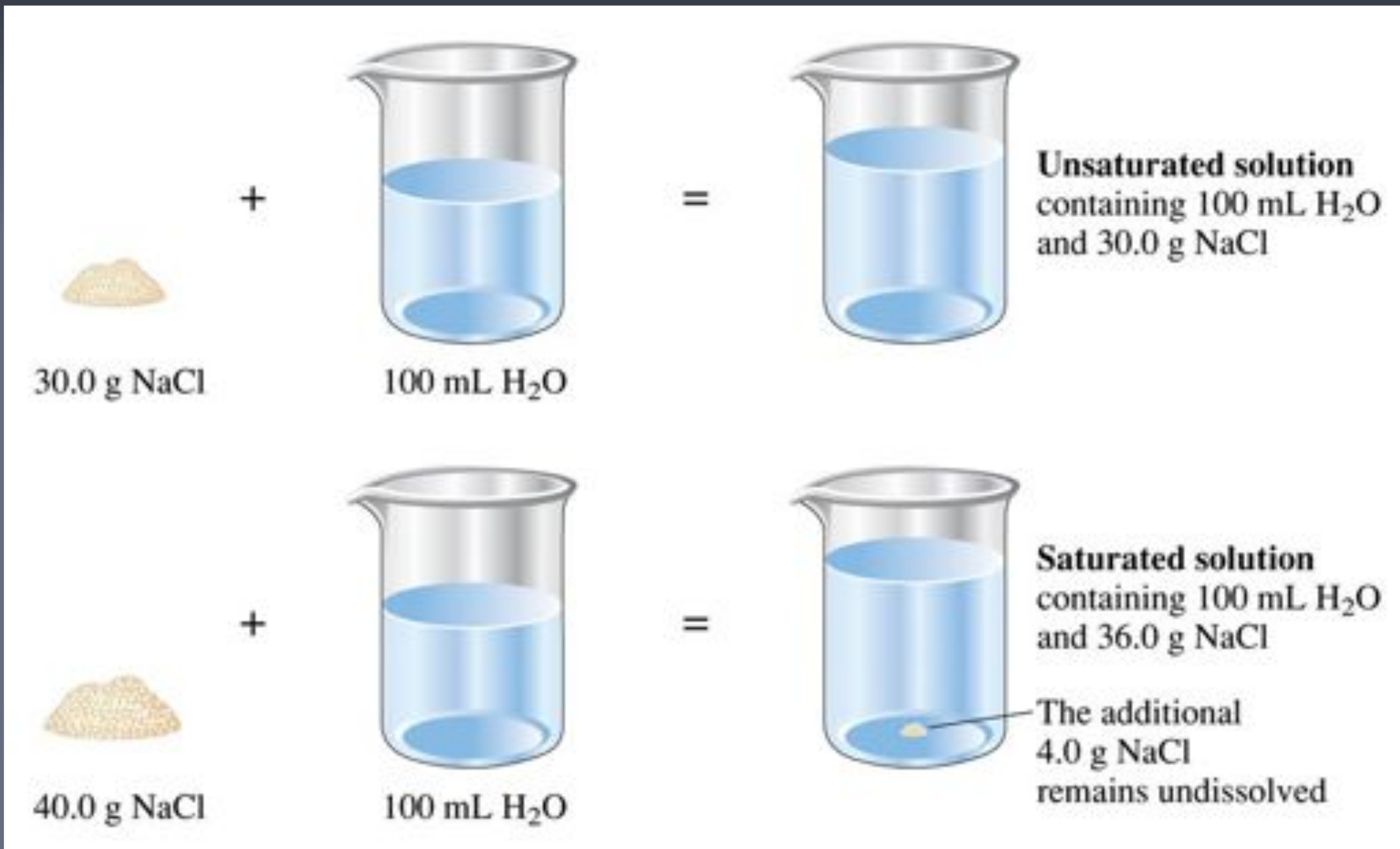


Degrees of Saturation:

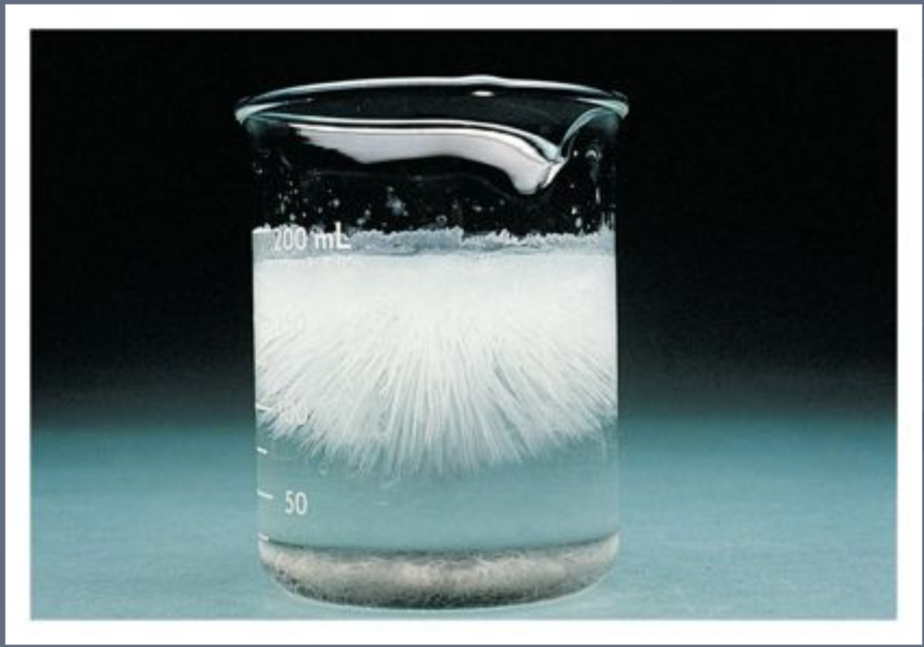
- Unsaturated – more solute may be dissolved in a solution.
- Saturated – the maximum amount of solute is dissolved in a solution.
- Supersaturated – more solute is dissolved in a solution than is stable at that temperature.

  (A precipitate is likely to form.)

Comparison of Unsaturated and Saturated Solutions



Crystallization from a Supersaturated Solution of Sodium Acetate



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 $CuSO_4 \cdot 5H_2O$.

The calculated amount of the solid compound is massed out on an analytical balance.

The copper (II) sulfate pentahydrate is then transferred carefully to the volumetric flask.

Water is added to bring this solution level to the mark on the neck of the 250-ml volumetric flask.

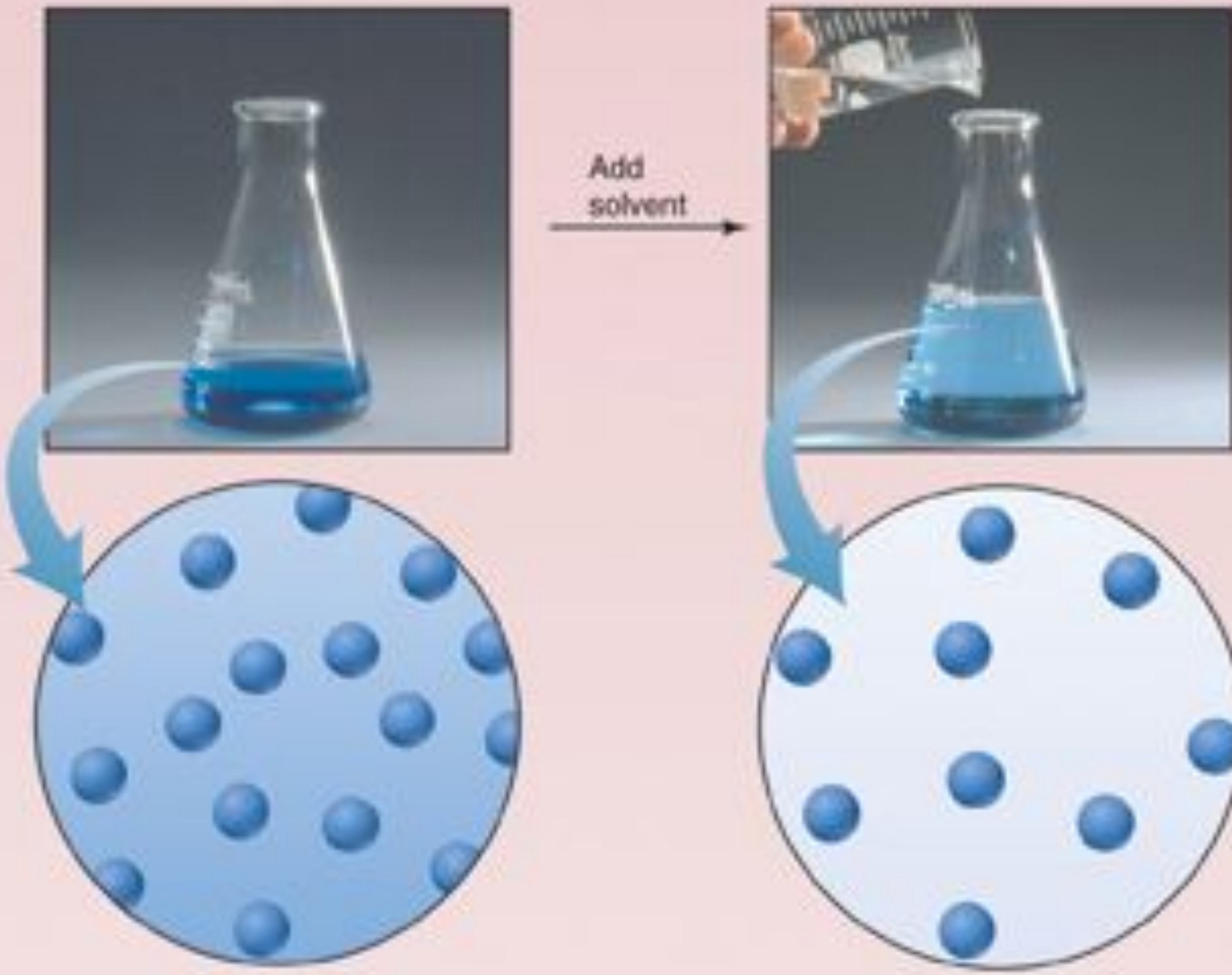
Dilutions

- 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: $M_1V_1 = M_2V_2$



Concentrated solution:
More solute particles per
unit volume

Dilute solution:
Fewer solute particles per
unit volume

Dilution Examples

1. A 1-L bottle of 0.333 *M* NaOH stock solution is provided in the lab. What volume of that NaOH stock solution is required to make 250.0 mL of a 0.100*M* NaOH solution? Describe its preparation.

2. 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?

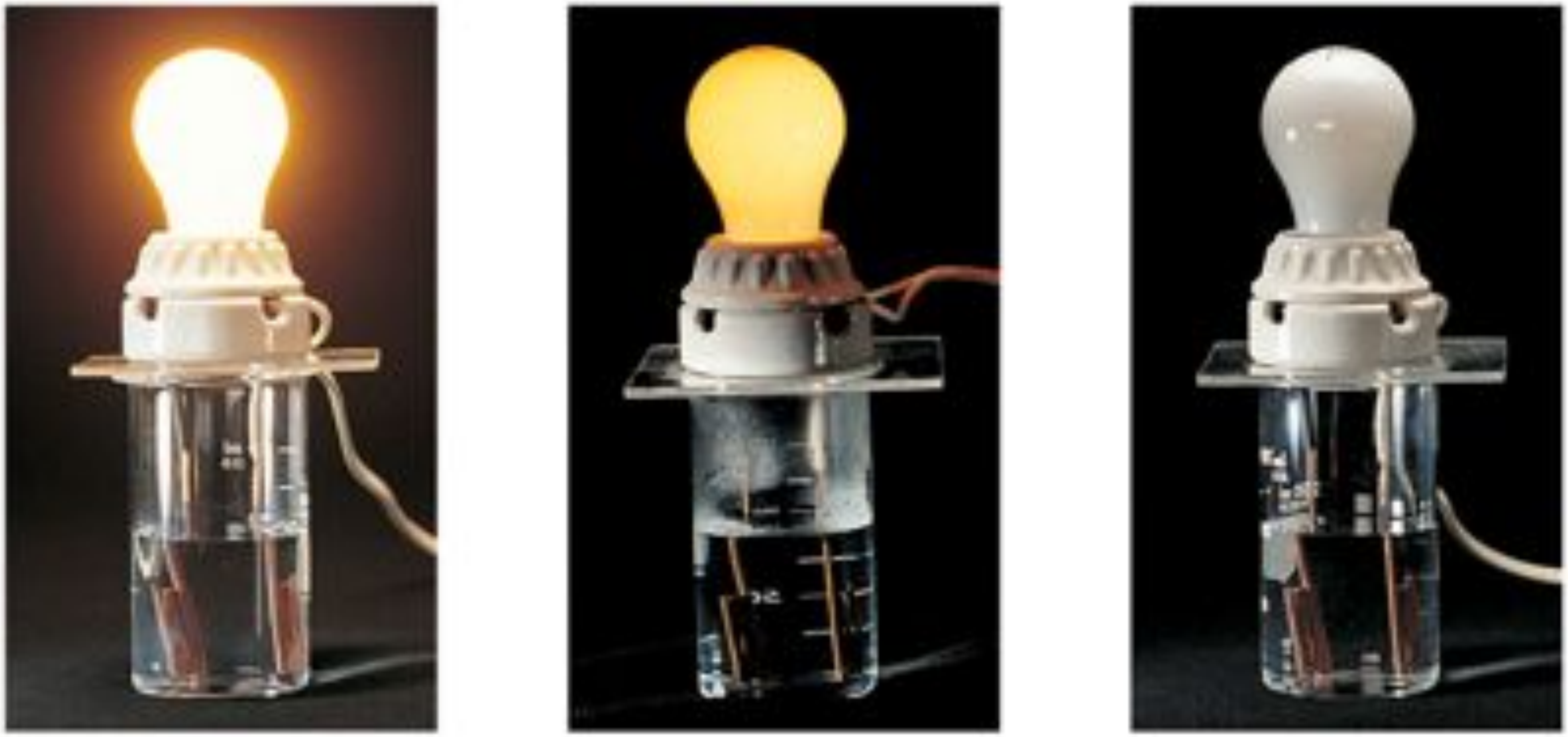
Compounds and Ions in solution

- 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.



A Strong electrolyte B Weak electrolyte C Nonelectrolyte

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 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)

$$\text{ppm} = \frac{\text{mass solute}}{\text{mass solution}} \times 1\times10^{6}$$

- 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.