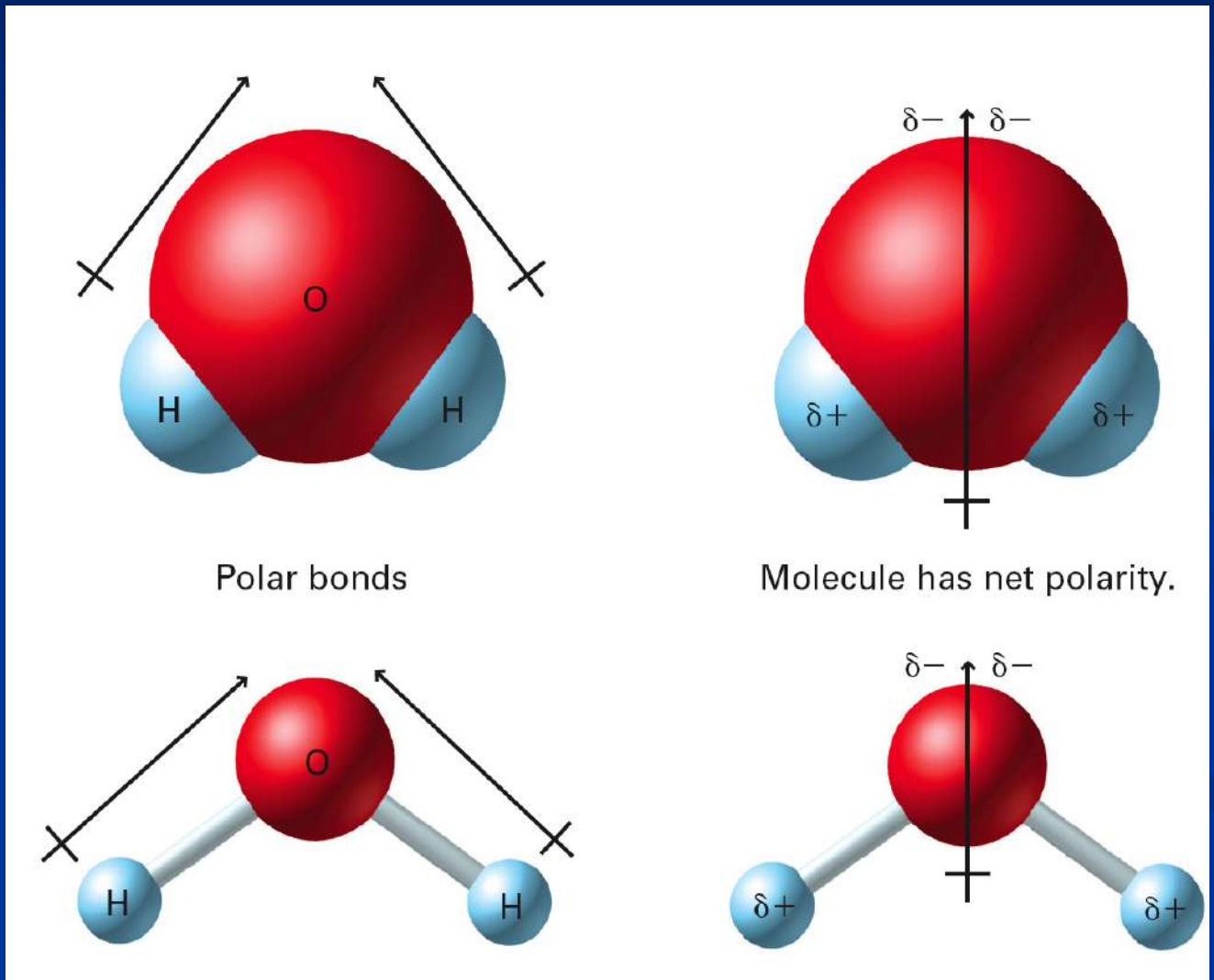
# Chapter 15: Water and Aqueous Systems

## 15.1 Water and its Properties

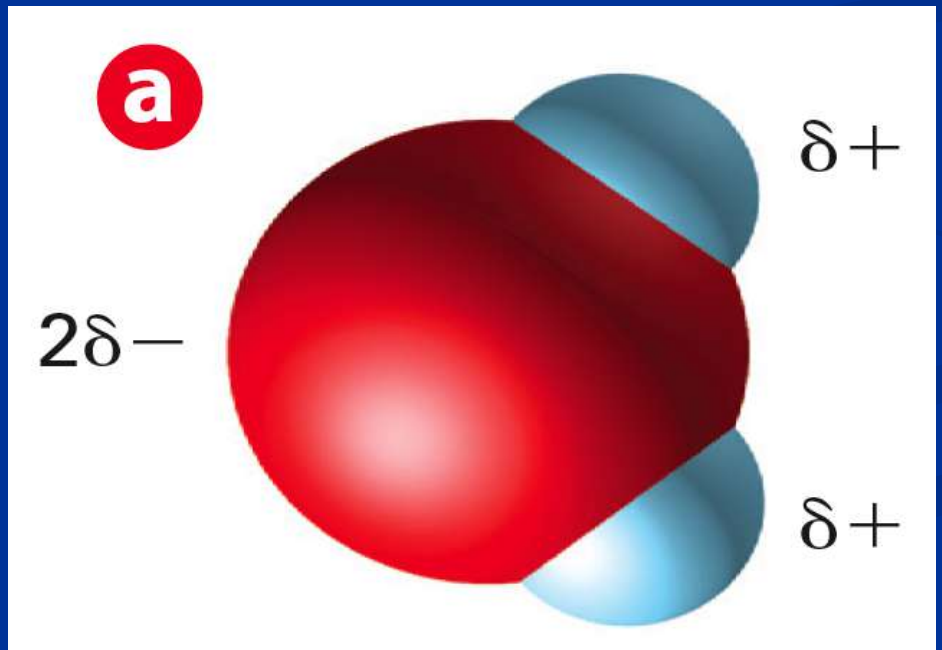
# Water in the Liquid State

- A water molecule is polar.



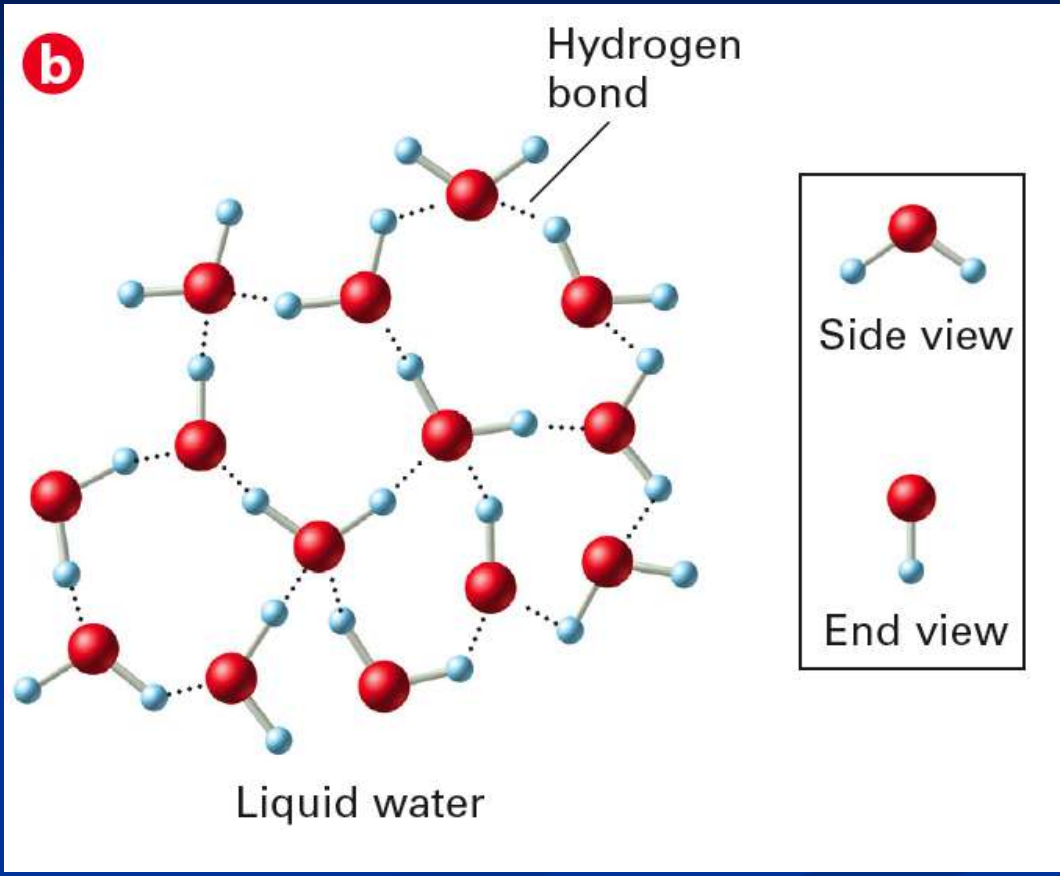
# Water in the Liquid State

- Polar molecules are attracted to one another by dipole interactions. The negative end of one molecule attracts the positive end of another molecule.



# Water in the Liquid State

- The intermolecular attraction among water molecules results in the formation of hydrogen bonds.



# Water in the Liquid State

- Many unique and important properties of water—including its high surface tension and low vapor pressure—result from hydrogen bonding.

# Water in the Liquid State

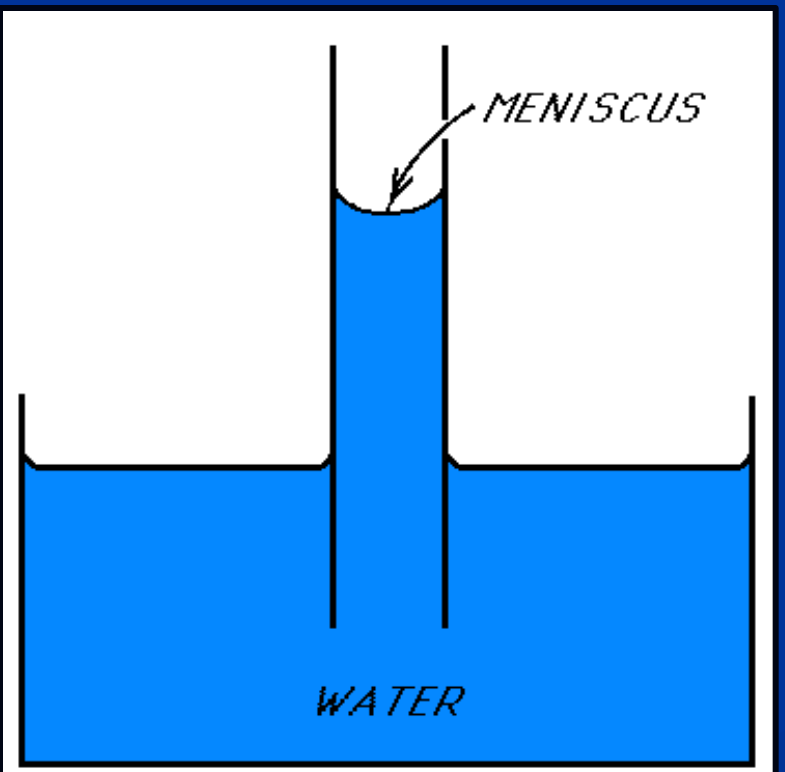
- Surface Tension
  - The inward force, or pull, that tends to minimize the surface area of a liquid is called **surface tension.**
  - All liquids have a surface tension, but water's surface tension is higher than most.

# Water in the Liquid State

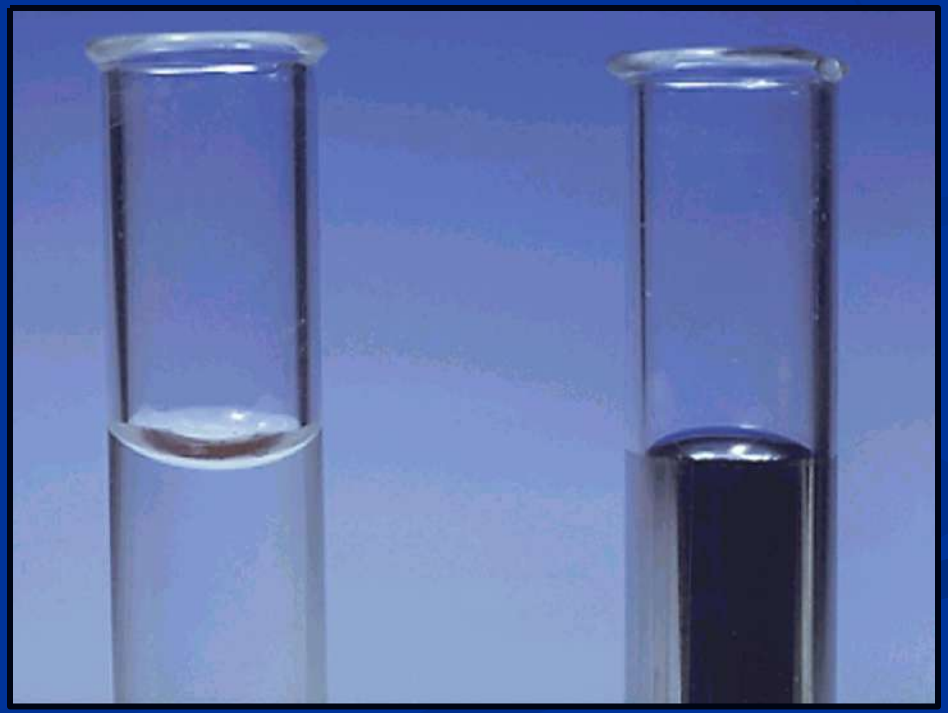
- A **surfactant** is any substance that interferes with the hydrogen bonding between water molecules and thereby reduces surface tension.

# Capillary Action

- attractive force between the surface of a liquid and the surface of a solid



Water rising in a small glass tube by capillary action.


water mercury

# Water in the Liquid State

- Vapor Pressure
  - Hydrogen bonding between water molecules also explains water's unusually low vapor pressure. Because hydrogen bonds hold water molecules to one another, the tendency of these molecules to escape is low, and evaporation is slow.

# Water in the Solid State

- As water begins to cool, it behaves initially like a typical liquid. It contracts slightly and its density gradually increases. When the temperature of the water falls below 4°C, the density of water starts to decrease.

# Water in the Solid State

- The structure of ice is a regular open framework of water molecules arranged like a honeycomb.
- **When ice melts, the framework collapses, and the water molecules pack closer together, making liquid water more dense than ice.**

# 15.1 Section Quiz.

- 1.Many of the unusual properties of water are the result of

  a) hydrogen bonding.

  b) nonpolar molecules.

  c) low molar mass.

  d) dispersion forces.

# 15.1 Section Quiz.

- 2.A surfactant causes water to spread out over a surface. This spreading occurs because the surfactant

  a) attaches to the surface.

  b) interferes with hydrogen bonding.

  c) lowers the vapor pressure.

  d) lowers the density of water.

# 15.1 Section Quiz.

- 3.Ice is less dense than liquid water because in ice the water molecules

  a) expand because of weakened covalent bonds.

  b) have a regular open honeycomb framework.

  c) expand because of weakened hydrogen bonds.

  d) have a more disorderly arrangement with lower density.

# 15.2 Homogeneous Aqueous Systems

# Solvents and Solutes

An **aqueous solution** is water that contains dissolved substances.

- In a solution, the dissolving medium is the **solvent**.
- In a solution, the dissolved particles are the **solute**.

# The Solution Process

- The process by which the positive and negative ions of an ionic solid become surrounded by solvent molecules is called **solvation.**

# The Solution Process

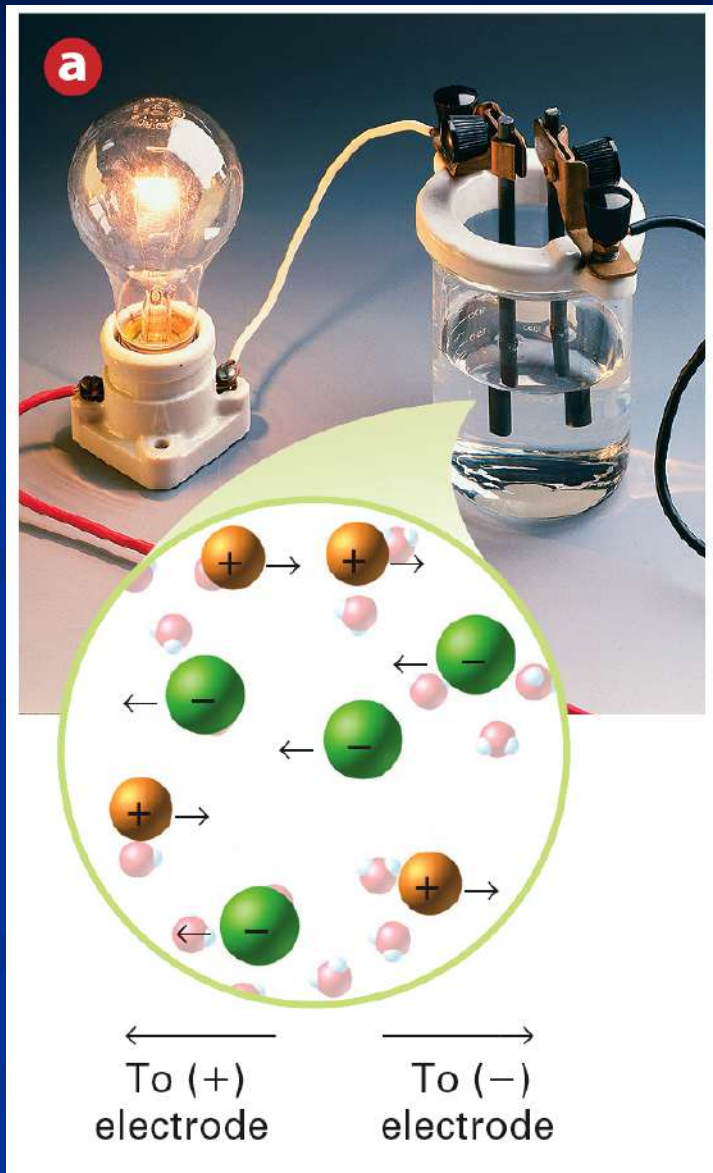
- Polar solvents such as water dissolve ionic compounds and polar compounds.
  - Nonpolar solvents such as gasoline dissolve nonpolar compounds.

# Electrolytes and Nonelectrolytes

- An **electrolyte** is a compound that conducts an electric current when it is in an aqueous solution or in the molten state.
  - All ionic compounds are electrolytes because they dissociate into ions.

# Electrolytes and Nonelectrolytes

- The bright glow shows that sodium chloride is a **strong electrolyte** because nearly all the dissolved sodium chloride exists as separate $Na^+$ and $Cl^-$ ions.



# Electrolytes and Nonelectrolytes

- A **weak electrolyte** conducts electricity poorly because only a fraction of the solute in the solution exists as ions.

# Electrolytes and Nonelectrolytes

- A compound that does not conduct an electric current in either aqueous solution or the molten state is called a **nonelectrolyte.**

# Hydrates

- A compound that contains water of hydration is called a **hydrate.**

- In writing the formula of a hydrate, use a dot to connect the formula of the compound and the number of water molecules per formula unit.

# Hydrates

- To determine what percent of a hydrate is water, first determine the mass of the number of moles of water in one mole of hydrate. Then determine the total mass of the hydrate. The percent by mass of water can be calculated using this equation.

$$\text{percent } H_2O = \frac{\text{mass of water}}{\text{mass of hydrate}} \times 100\%$$

# Sample Problem 15.1

## Finding the Percent of Water in a Hydrate

Calculate the percent by mass of water in washing soda, sodium carbonate decahydrate ($Na_2CO_3 \cdot 10H_2O$).

# Practice Problem For Sample Problem 15.1

**6.** What is the percent by mass of water in $CuSO_4 \cdot 5H_2O$?

# Hydrates

- Deliquescent Compounds
  - Deliquescent compounds remove sufficient water from the air to dissolve completely and form solutions. These compounds become wet when exposed to normally moist air.

# 15.2 Section Quiz.

- 1.Choose the correct words for the spaces. In any solution, the material that is dissolved is called the _____ and the material in which the substance is dissolved is called the _____ .

  a) solid, liquid

  b) solvent, solute

  c) solute, solvent

  d) crystal, disperser

# 15.2 Section Quiz.

- 2.In the solution process, the

  a) solvent molecules are surrounded by positive and negative ions.

  b) solvent molecules become dispersed in an ionic crystal.

  c) ions become emulsified in the solvent.

  d) positive and negative ions are surrounded by solvent molecules.

# 15.2 Section Quiz.

- 3.All ionic compounds are electrolytes because they

  a) conduct electricity in the solid state.

  b) dissociate into ions in the aqueous and/or the molten state.

  c) remain as positive-negative pairs even when dissolved.

  d) only conduct electricity in the molten state.

# 15.2 Section Quiz.

- 4.The formula for iron(II) sulfate heptahydrate is
  - a) $FeSO_4(H_2O)_7$
  - b) $FeSO_4 \cdot (H_2O)_7$
  - c) $Fe \cdot 2SO_4 \cdot 7H_2O$
  - d) $FeSO_4 \cdot 7H_2O$

# 15.3 Heterogeneous Aqueous Systems

# Suspensions

- A **suspension** is a mixture from which particles settle out upon standing.
  - A suspension differs from a solution because the particles of a suspension are much larger and do not stay suspended indefinitely.

# Colloids

- A **colloid** is a heterogeneous mixture containing particles that range in size from 1 nm to 1000 nm. The particles in a colloid are spread throughout the dispersion medium.

# Colloids

- The Tyndall Effect
  - The scattering of visible light by colloidal particles is called the **Tyndall eff**

# Colloids

- Particles in colloids and suspensions reflect or scatter light in all directions. Solutions do not scatter light.

# Colloids

- Brownian Motion
  - The chaotic movement of colloidal particles, which was first observed by the Scottish botanist Robert Brown (1773–1858), is called **Brownian motion.**
  - Brownian motion is caused by collisions of the molecules of the dispersion medium with the small, dispersed colloidal particles.

# Colloids

- Coagulation
  - A colloidal system can be destroyed, or coagulated, by the addition of ions having a charge opposite to that of the colloidal particles.
  - The added ions neutralize the charged colloidal particles. The particles can clump together to form heavier aggregates and precipitate from the dispersion.

# Colloids

- Emulsions
  - An **emulsion** is a colloidal dispersion of a liquid in a liquid. An emulsifying agent is essential for the formation of an emulsion and for maintaining the emulsion's stability.

# 15.3 Section Quiz.

1. One characteristic that is unique to a suspension is that the particles in it

   a) settle due to gravity.

   b) are too small to be seen.

   c) cannot be filtered.

   d) produce the Tyndall effect.

# 15.3 Section Quiz.

- 2.Homogenized milk contains finely divided particles that do not settle out rapidly and are not readily filtered. Thus, homogenized milk is a

  a) colloid.

  b) substance.

  c) suspension.

  d) solution.

# 15.3 Section Quiz.

3. The scattering of light known as the Tyndall effect can be seen in

a) emulsions and solutions.

b) colloids and suspensions.

c) solutions and suspensions.

d) colloids and solutions.