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World of CHEMISTRY

Chapter 15

- **Solutions**

Overview

- Process of dissolving & why certain substances dissolve in water
- Concentration of solutions
- Factors that affect rate of dissolving
- Mass percent & molarity
- Calculating concentration after dilution
- Problem solving in solution reactions
- Acid-base reaction calculations
- Normality & equivalent weight
- Effect of solute on solution properties

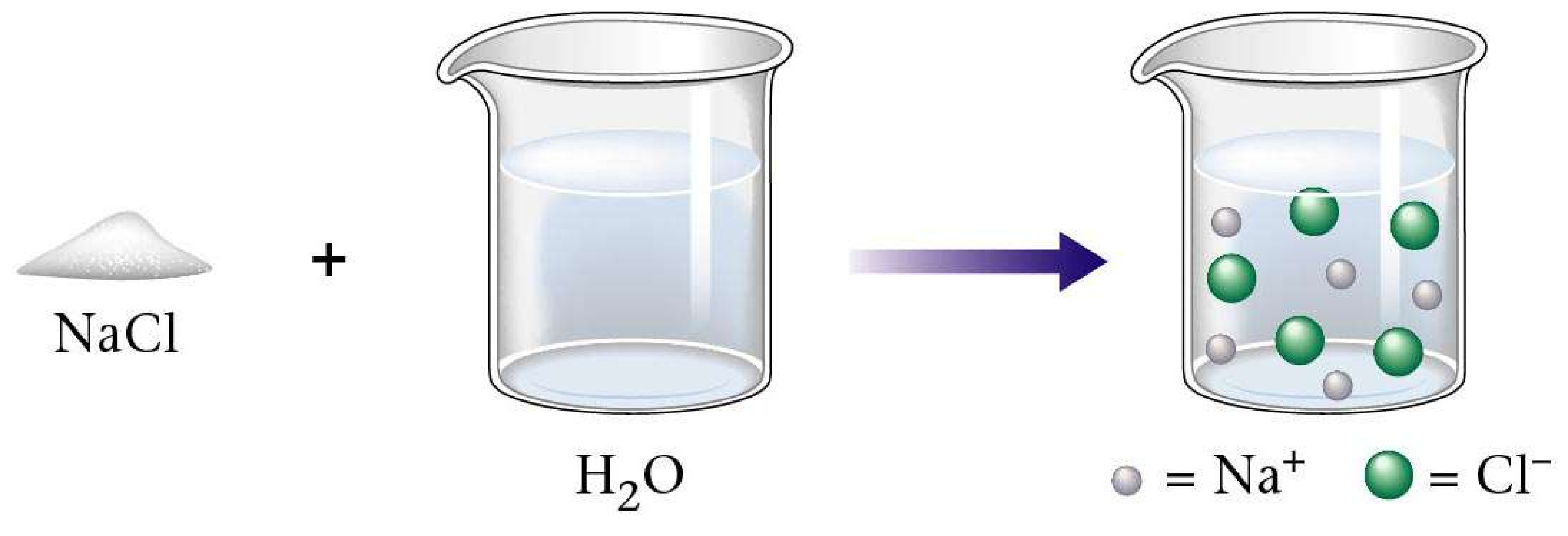
Solution: *a homogeneous mixture*

- Can be solid, liquid, or gas
  - Liquid solution: Coffee – good to the last drop (first sip is the same as the last sip!)
  - Gaseous solution: air – mixture of O_2, N_2, etc.
  - Solid solution: brass – mixture of Cu & Zn
- ***Solvent***: substance present in largest amount
- ***Solute***: other substance(s)
  - Sugar dissolved in water (sugar=solute, water=solvent)

Aqueous Solutions

- Solution where water is the solvent
- Most of the important chemistry that keeps plants, animals, and humans functioning occur in aqueous solutions
- Water we drink is aqueous solution

Figure 15.1: Dissolving of solid sodium chloride.



Solubility

- Ionic Substances: strong ionic forces that hold molecule together are overcome by strong attraction between ions & polar water molecule
- Polar Substances: most are soluble (with polarities similar to water)
  - Ethanol (used in alcoholic beverages) – soluble because of polar O-H bond (like in water)
  - Sugar – has many O-H bonds

Figure 15.2: Polar water molecules interacting with positive and negative ions of a salt.

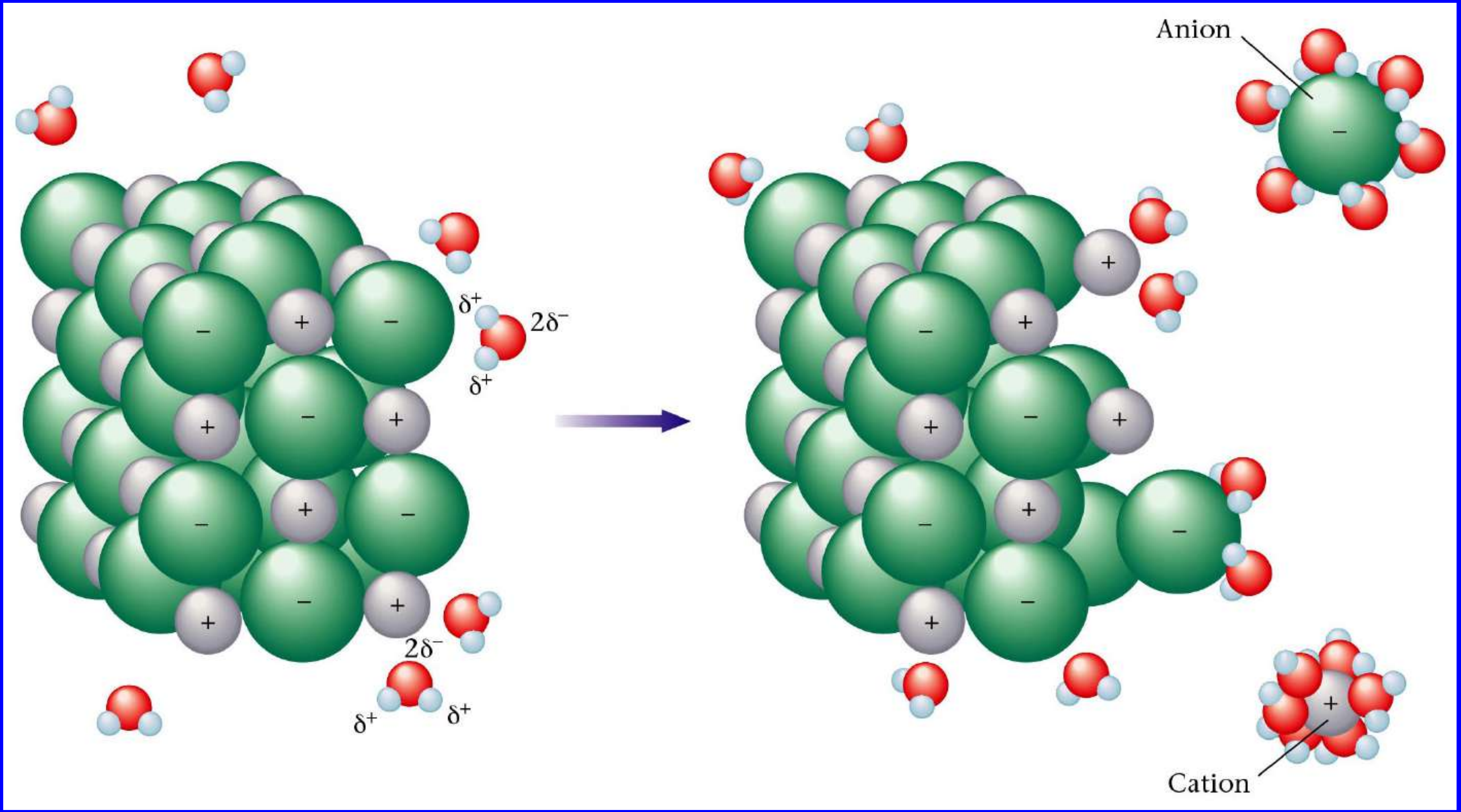


Figure 15.3: The ethanol molecule contains a polar O—H bond.

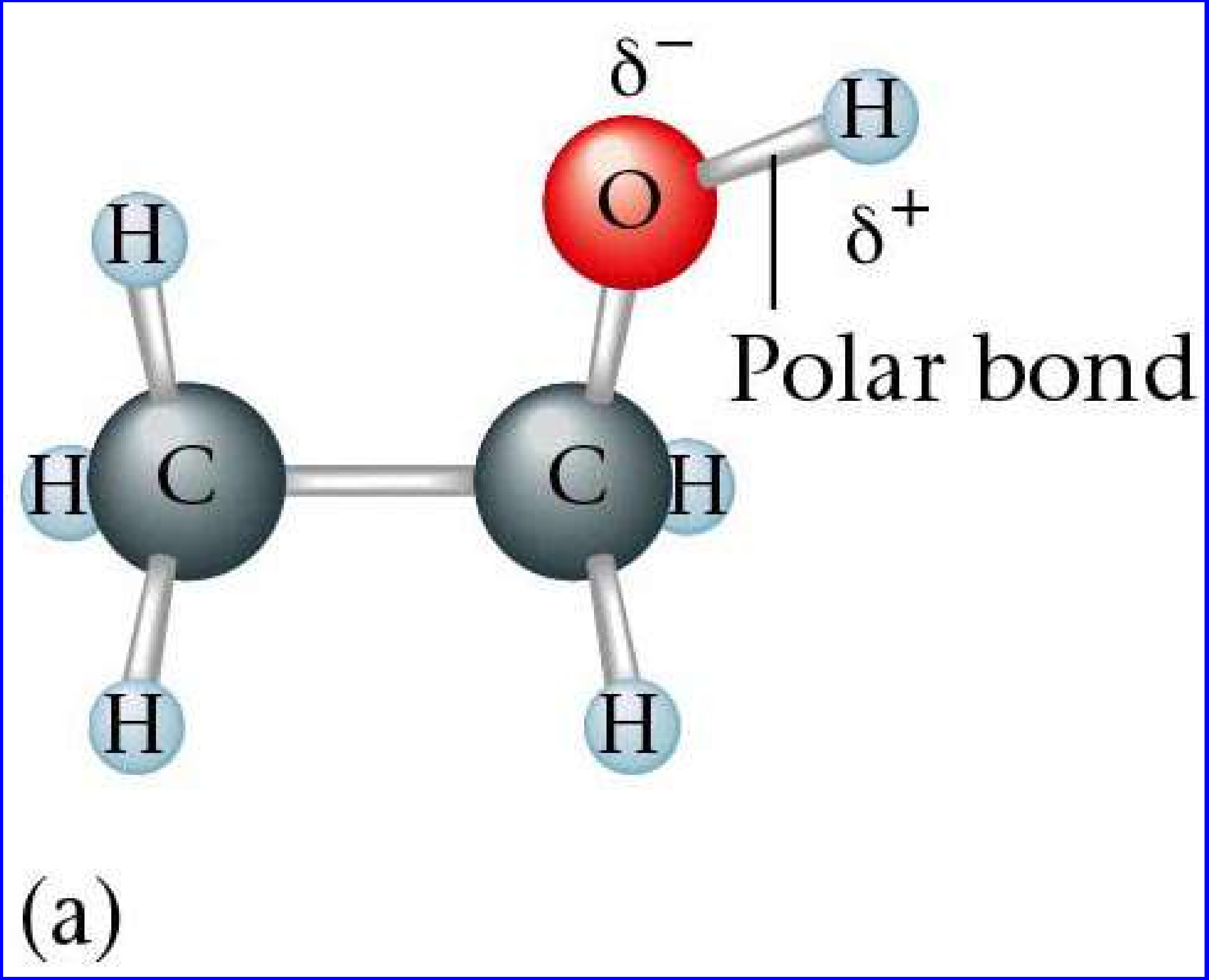


Figure 15.3: The polar water molecule interacts strongly with the polar O—H bond in ethanol.

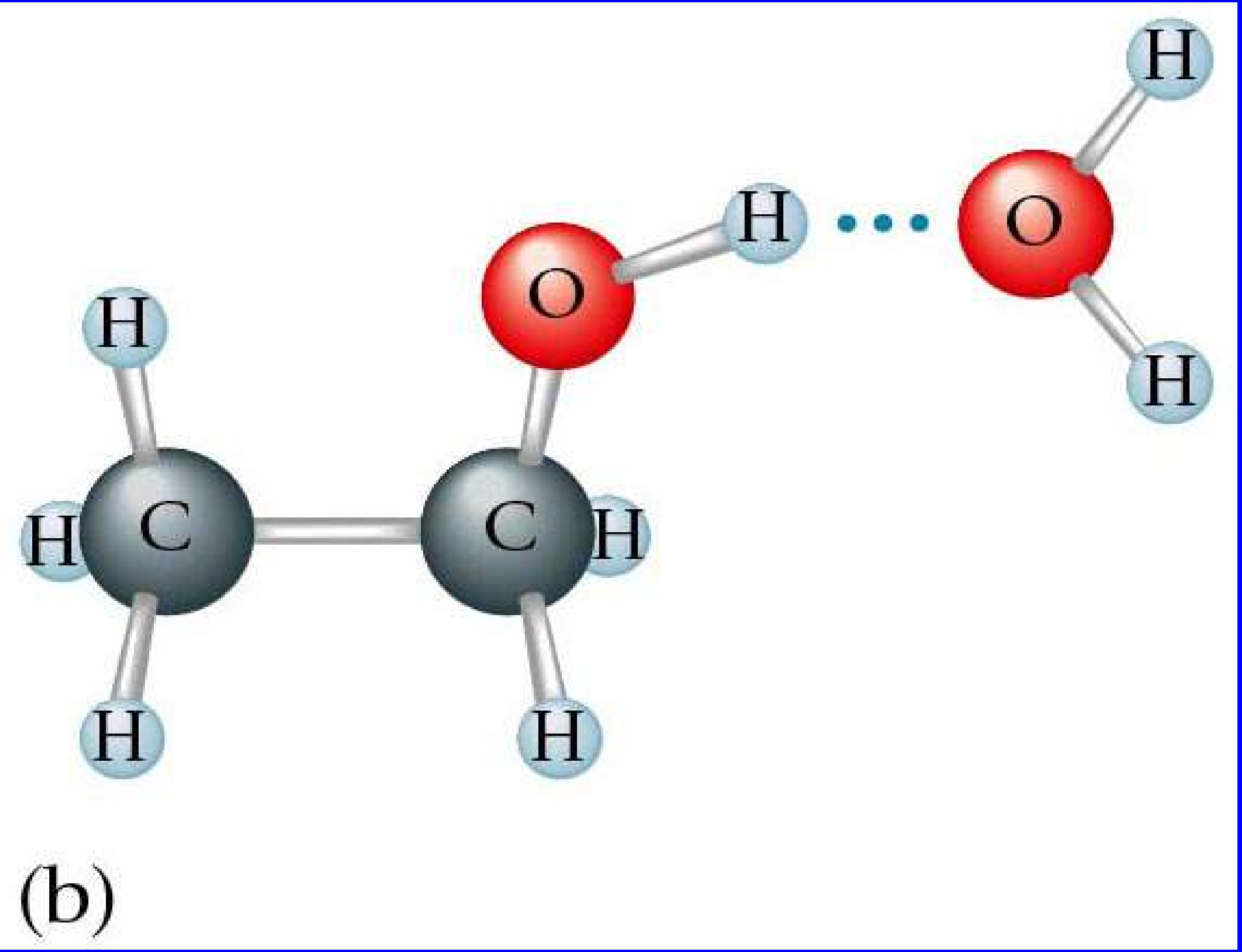
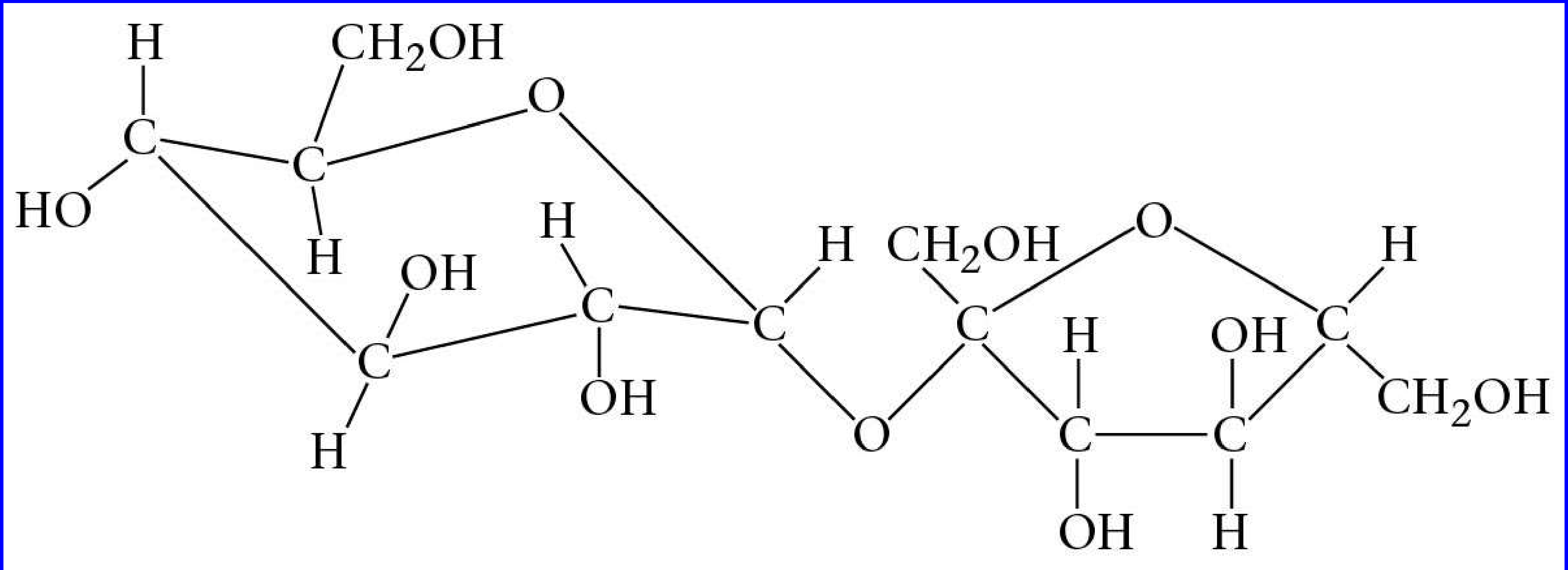


Figure 15.4: Structure of common table sugar.



Substances insoluble in water

- Nonpolar molecules are incompatible with polar water molecules
- Will float or sink depending on density
  - Oil & gasoline float on water

Figure 15.5: A molecule typical of those found in petroleum.

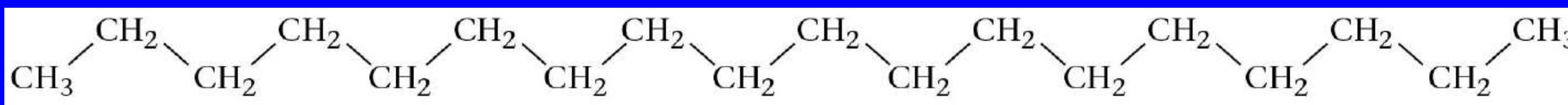
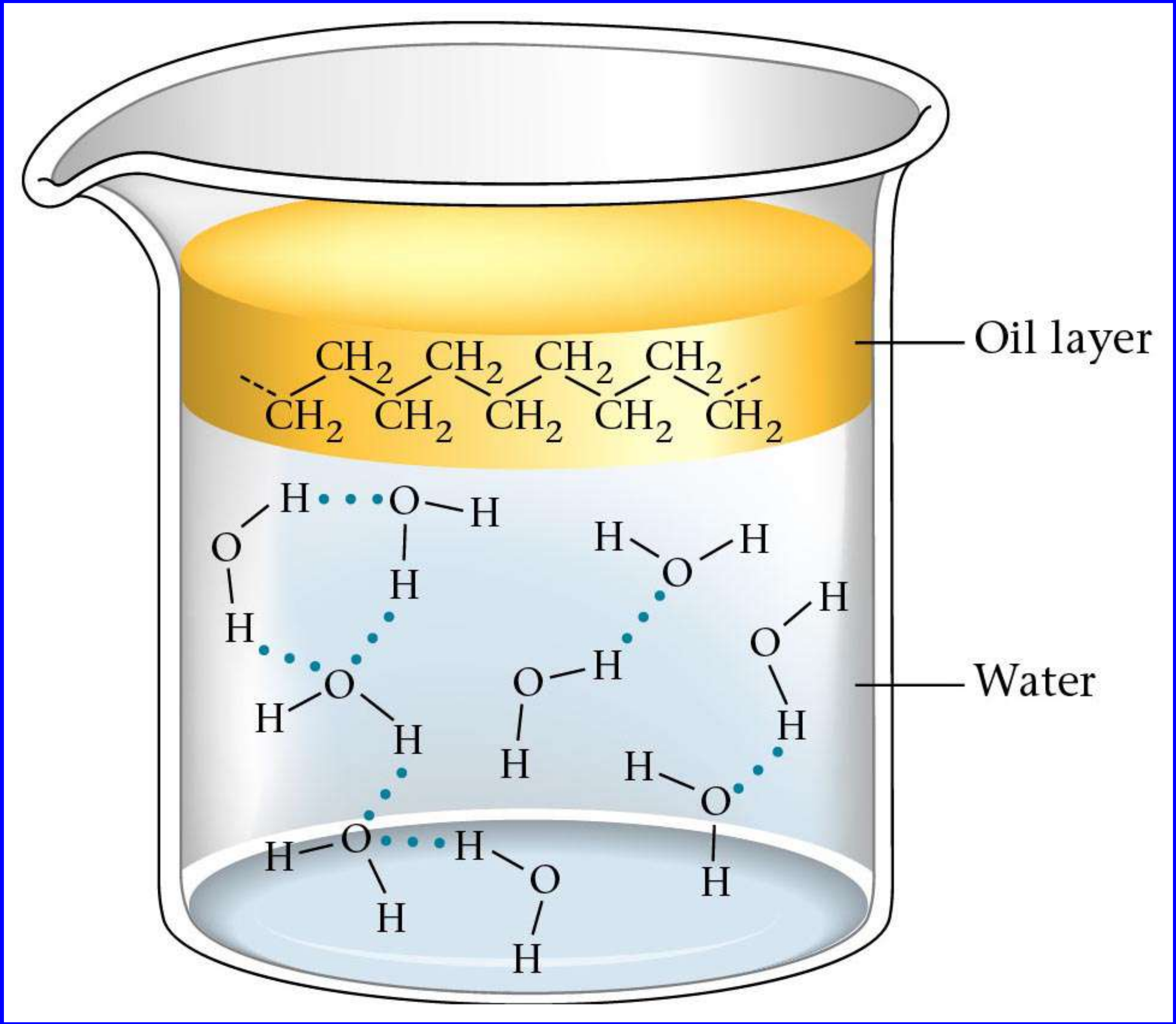


Figure 15.6: An oil layer floating on water.



How Substances Dissolve

- "Hole" must be made in water structure for each solute particle
- Water-water interactions must be replaced by similar water-solute interactions
  - Interactions occur between ions and polar water molecules
  - Hydrogen-bonding interactions occur between the O-H groups and water molecules
- "Like dissolves like" (polar-polar & nonpolar-nonpolar)

Solution Composition

- ***Saturated***: solution contains as much solute as will dissolve at that temperature
- ***Unsaturated***: a solution in which more solute can be dissolved than is dissolved already
- ***Supersaturated***: solution that contains more dissolved solid than a saturated solution will hold at that temperature (very unstable)
- ***Concentrated solution***: contains a relatively large amount of solute (strong coffee)
- ***Dilute solution***: contains a relatively small amount of solute (weak coffee)

Rate of Dissolution - Factors

- Surface area
  - Large surface area = faster dissolving
  - Sugar crystals dissolve faster than sugar cubes
- Stirring
  - Continuously exposes surface of solute to fresh solvent
- Temperature
  - Dissolve more rapidly at higher temperatures – solvent molecules move more rapidly = faster dissolving
  - Solids usually more soluble at higher temperatures
  - Gases less soluble at higher temperature

Solution Composition: Mass Percent

- Sometimes called weight percent
- Mass of solute present in a given mass of solution

mass % = (mass solute/mass solution) x 100%

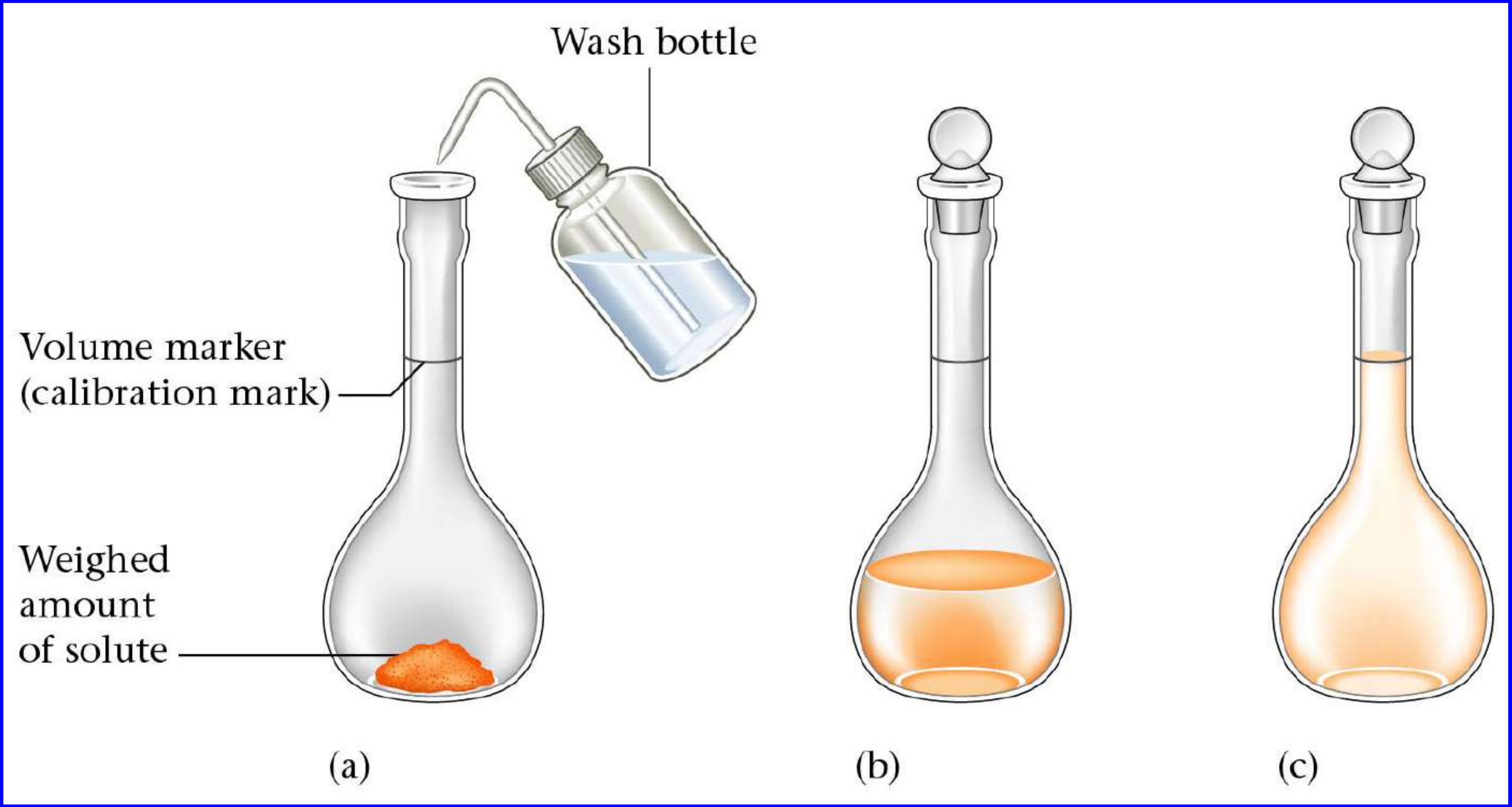
OR

mass %= [grams solute/(g solute + g solvent)] x 100%

Solution Composition: Molarity

- ***Molarity***: number of moles of solute per volume of solution in liters
  - Most commonly used expression of concentration
  - M = moles of solute/liters of solution = mol/L
- ***Standard solution***: solution whose concentration is accurately known
  - Used extensively in quantitative analysis
  - Water analysis, blood-alcohol levels

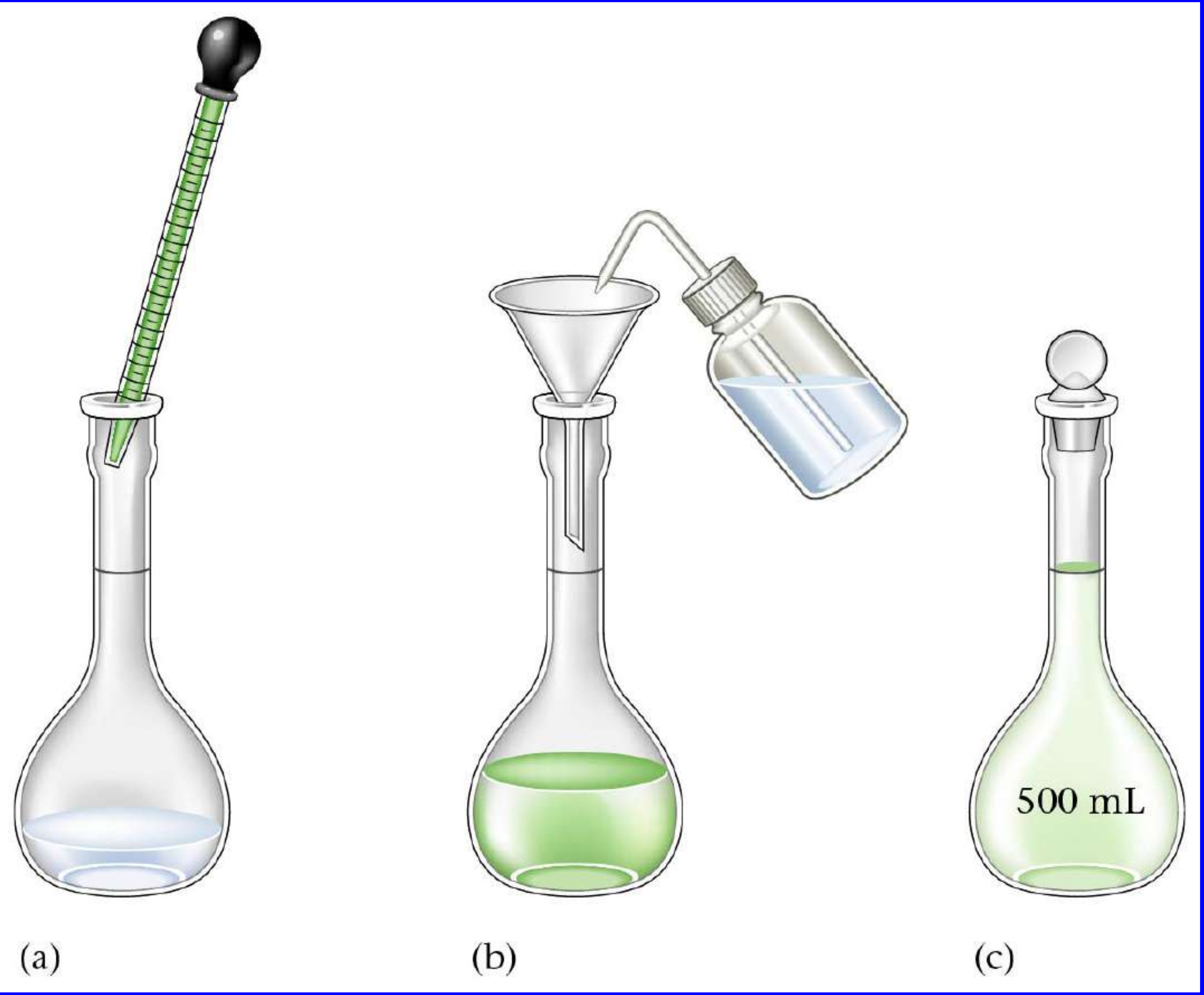
Figure 15.7: Steps involved in the preparation of a standard aqueous solution.



Dilution

- The process of adding more solvent to a solution
- $M_1 \times V_1 = M_2 \times V_2$ (yes Jaci, cross-multiply & divide!)
- ***Always add acid to water***! - never the other way around

Figure 15.8: Process of making 500 mL of a 1.00 *M* acetic acid solution.



Stoichiometry of Solution Reactions

- Step 1: Write balanced equation for reaction. If ions involved – write net ionic equation.
- Step 2: Calculate moles of reactants
- Step 3: Determine limiting reactant
- Step 4: Calculate moles of other products or reactants, as required
- Step 5: Convert to grams or other units, if required

Neutralization Reactions

- When just enough strong base is added to react with a strong acid in a solution, the acid has been neutralized
- One product is always water

Solution Composition: Normality

- Unit of concentration – used when dealing with acids and bases
- Focuses on H^+ and OH^- available
- Equivalent of an acid: amount of that acid that can furnish 1 mol of H^+ ions
- Equivalent of a base: amount of base that can furnish 1 mol of OH^- ions
- Equivalent weight: mass in grams of 1 equivalent of the acid or base

Normality

- The number of equivalents of solute per liter of solution

Normality = N = # of equivalents/1 L of solution

- Use in neutralization reactions

$$N_{\text{acid}} \times V_{\text{acid}} = N_{\text{base}} \times V_{\text{base}}$$

Boiling Point & Freezing Point of Solutions

- Presence of solute particles causes water to exist as liquid over wider temperature range
  - Freezes at lower temperature
  - Boils at higher temperature
- Colligative property
  - Depends on number of solute particles present
- Use this property to melt ice on roads (add salt) and in car antifreeze (ethylene glycol)

Figure 15.9: A bubble in the interior of liquid water surrounded by solute particles and water molecules.

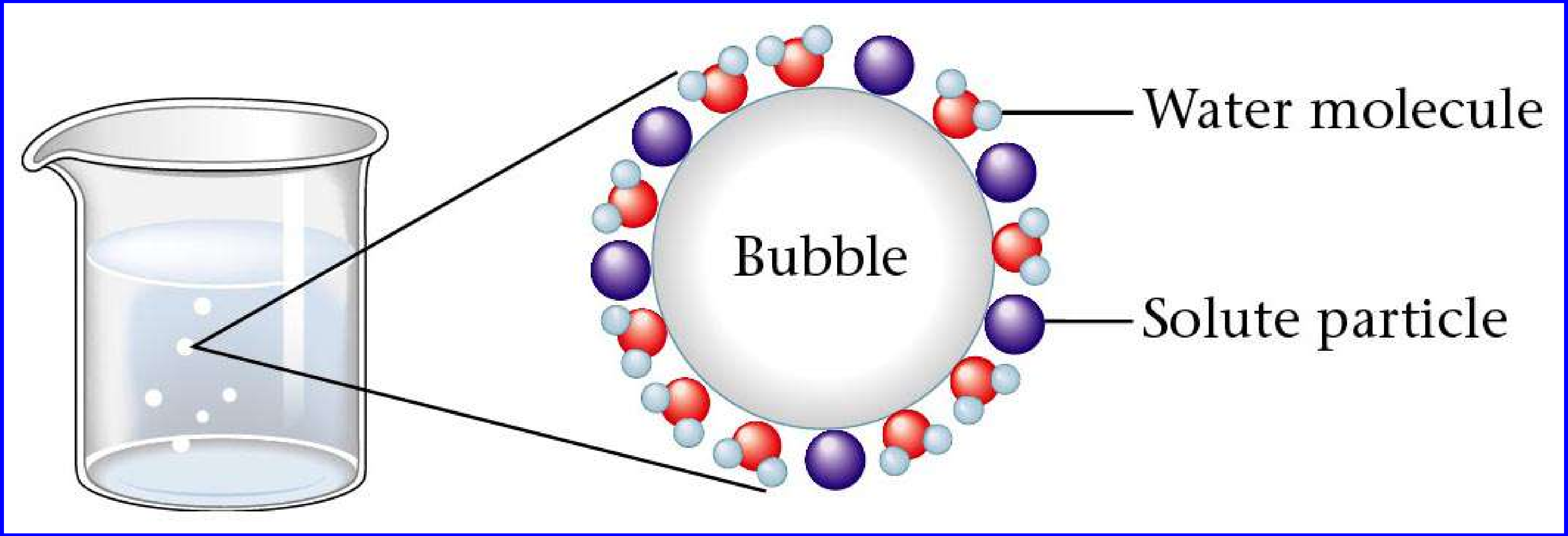


Figure 15.10: Pure water.

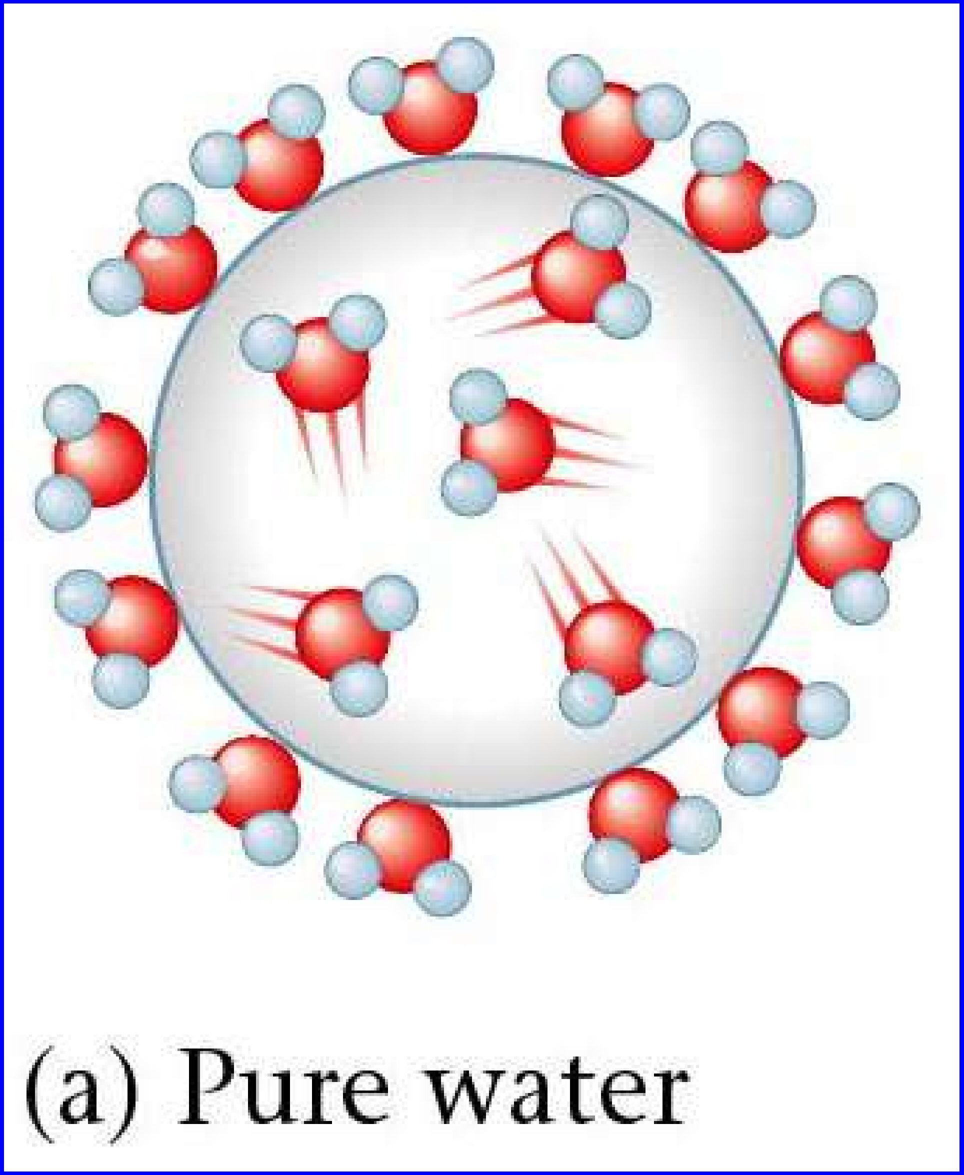
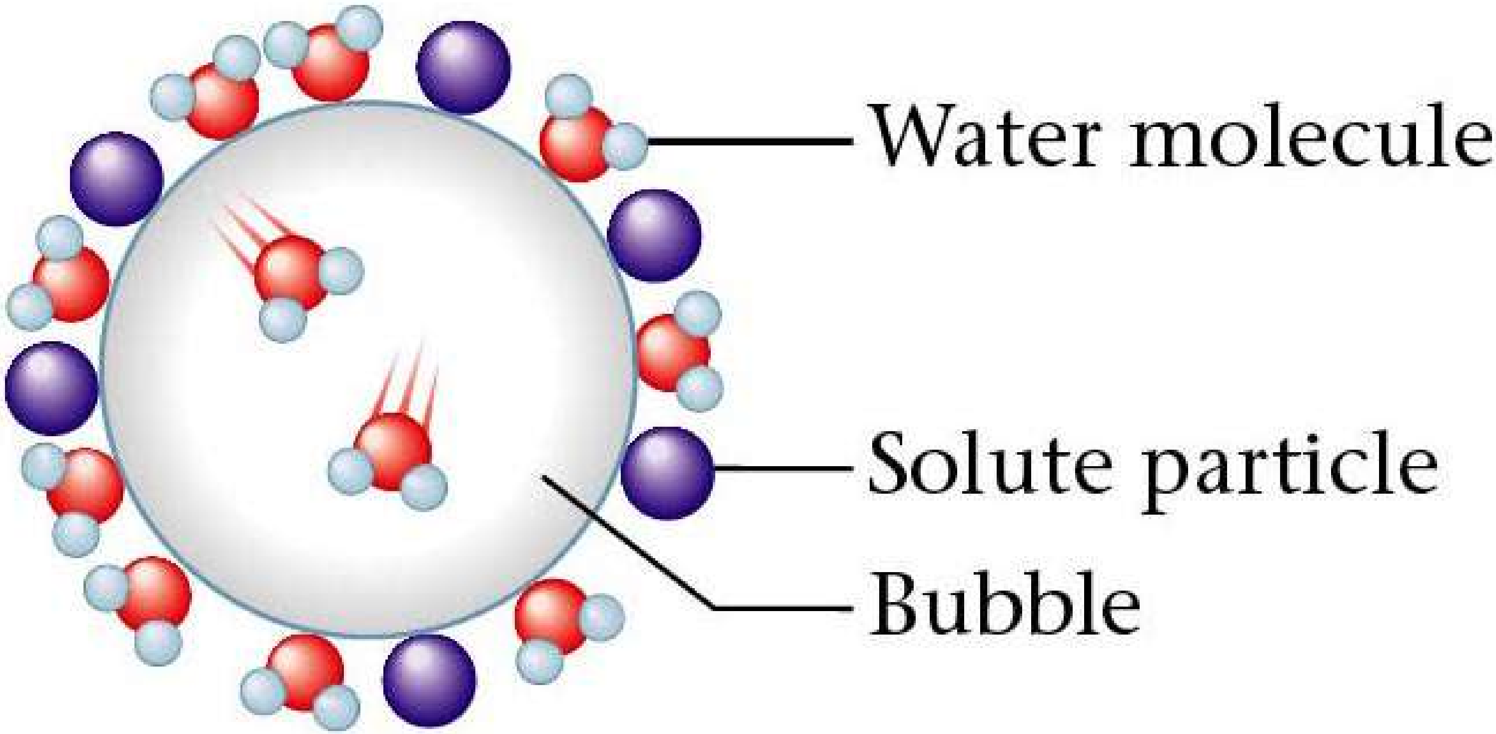


Figure 15.10: Solution (contains solute).



(b) Solution (contains solute)