Solutions

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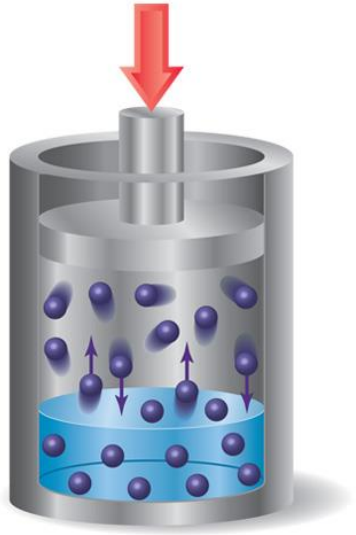
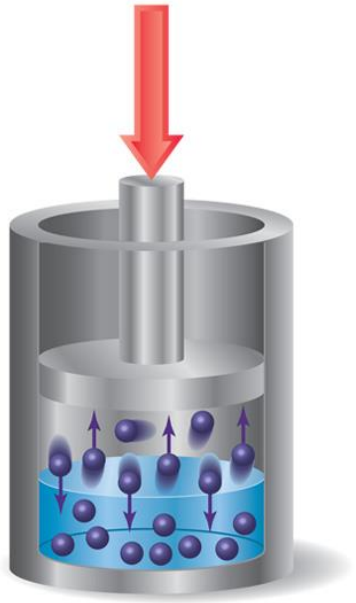
Effect of Pressure on Gas Solubility

- **The solubilities of solids and liquids are not affected appreciably by pressure.**
- **When the pressure of a gas is increased, as in (b), the rate at which gas molecules enter the solution increases.**
- **The concentration of solute molecules at equilibrium increases in proportion to the pressure.**
- **So the solubility of a gas increases with pressure.**



(a)



(b)

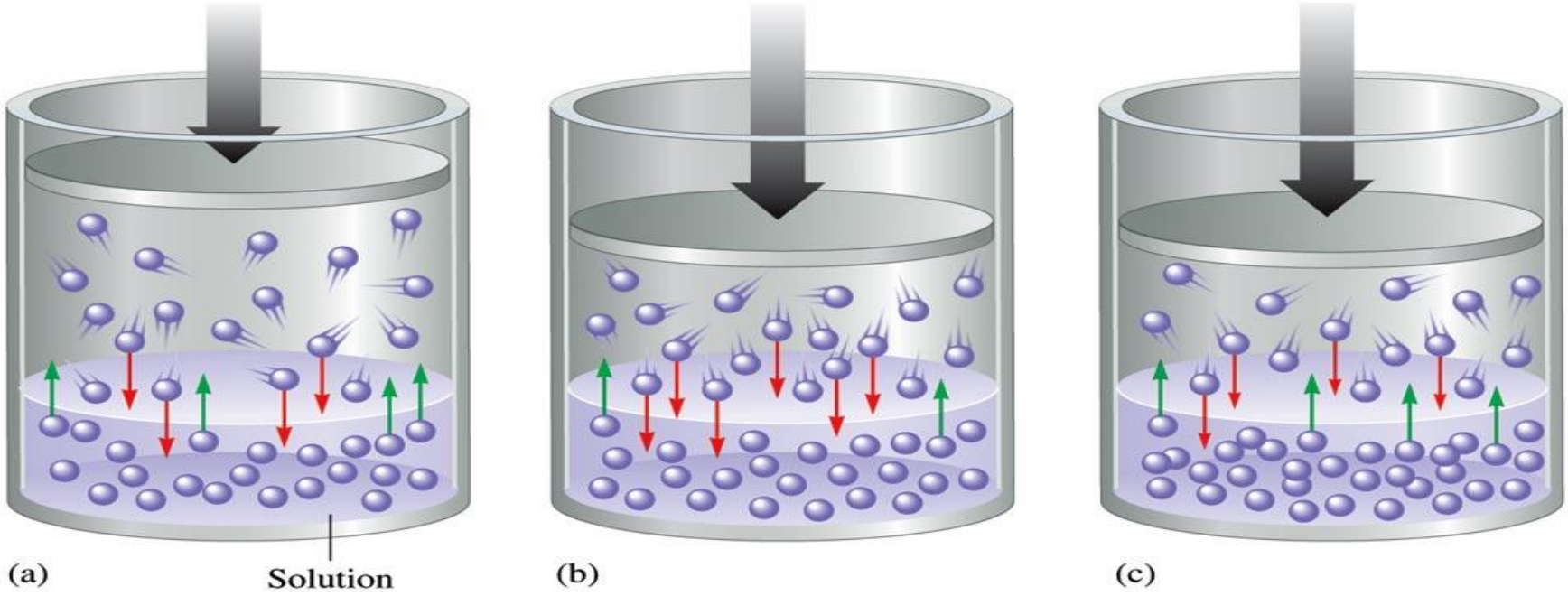
Pressure and Solubility of Gases

Solubility of a gas in a solvent depends on pressure and temperature

The solubility of a gas in a liquid is proportional to the pressure of the gas over the solution at constant temperature (***Henry's law***).

$$c = kP$$

c is the concentration (*M*) of the dissolved gas
P is the pressure of the gas over the solution
k is a constant (mol/L•atm) that depends only on temperature



Limitations:

(i) At moderate temperature and Pressure

(ii)Solubility in solvent is low

(iii)Gas react with solvent

(iv)Associate or Dissociate the molecules

SAMPLE EXERCISE A Henry's Law Calculation

Calculate the concentration of CO_2 in a soft drink that is bottled with a partial pressure of CO_2 of 4.0 atm over the liquid at 25°C. The Henry's law constant for CO_2 in water at this temperature is 3.1×10^{-2} mol/L-atm.

Solution

Analyze: We are given the partial pressure of CO_2, and the Henry's law constant, *k*, and asked to calculate the concentration of CO_2 in the solution.

Plan: With the information given, we can use Henry's law to calculate the solubility.

Solve: $S_{CO_2} = kP_{CO_2} = (3.1 \times 10^{-2}\ \text{mol/L-atm})(4.0\ \text{atm}) = 0.12\ \text{mol/L} = 0.12\ M$

Check: The units are correct for solubility, and the answer has two significant figures consistent with both the partial pressure of CO_2 and the value of Henry's constant.

PRACTICE EXERCISE

Calculate the concentration of CO_2 in a soft drink after the bottle is opened and equilibrates at 25°C under a CO_2 partial pressure of 3.0×10^{-4} atm.

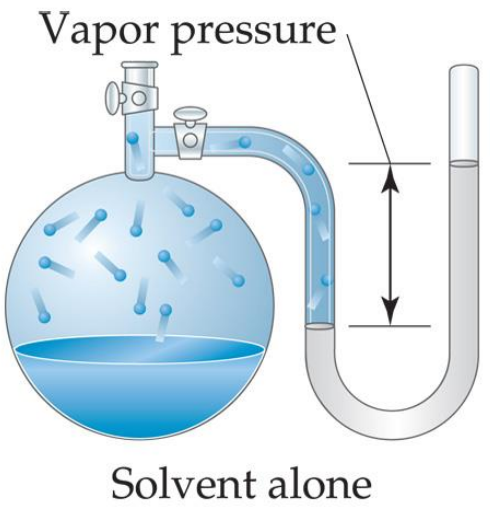
Answer: $9.3 \times 10^{-6}\ M$

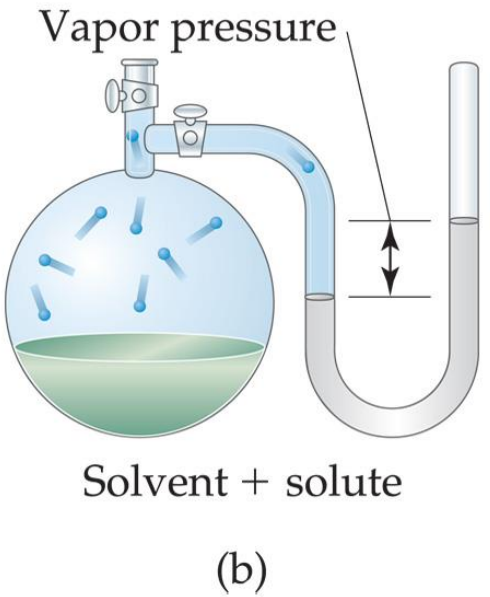
Vapor Pressure

When a liquid is heated, its molecules obtain sufficient kinetic energy to overcome the forces holding them in the liquid and they escape into the gaseous phase.

Pressure exerted by this vapor at a fixed temperature is call Vapor Pressure.

Because of solute-solvent intermolecular attraction, higher concentrations of nonvolatile solutes make it harder for solvent to escape to the vapor phase.





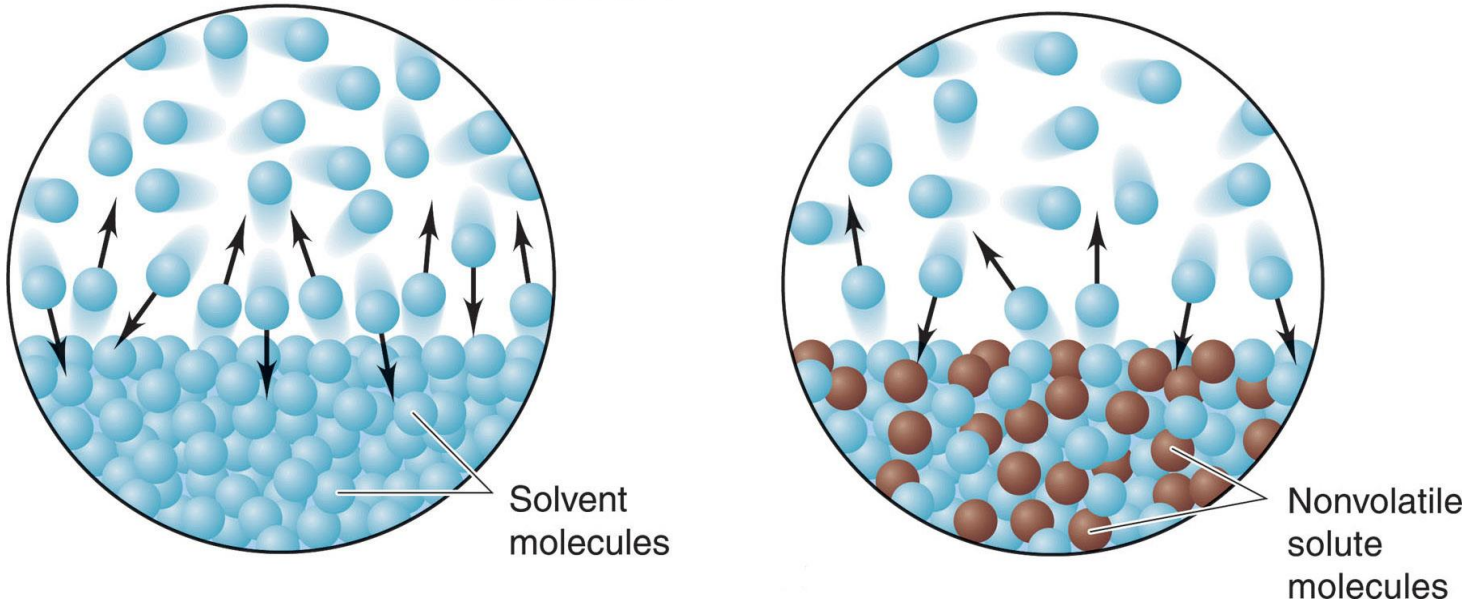
Colligative Properties

- Changes in colligative properties depend only on the *number* of solute particles present, not on the *identity* of the solute particles.

- Among colligative properties are
  - Vapor pressure lowering
  - Boiling point elevation
  - Melting point depression
  - Osmotic pressure

Vapor Pressure Lowering

The vapor pressure of a solution of a nonvolatile nonelectrolyte is always lower than the vapor pressure of the pure solvent.



An entropy argument!

Boiling Point Elevation

A solution boils at a higher temperature than the pure solvent.

This effect is explained by differences between the VP of the solution and VP of the pure solvent at a given temperature.

Depression of Freezing Point

- Freezing point: temperature at which a liquid becomes a solid
- The freezing point of a liquid solvent decreases when a solute is dissolved in it.
- Example
  - Water, pure = 0 degrees C.
  - Water + salt = a freezing point lower than 0 degrees C.

Osmotic Pressure

- Two solutions of different concentrations are separated by a semi-permeable membrane (allows water/solvent but notsolute to pass through)

The development of osmotic pressure

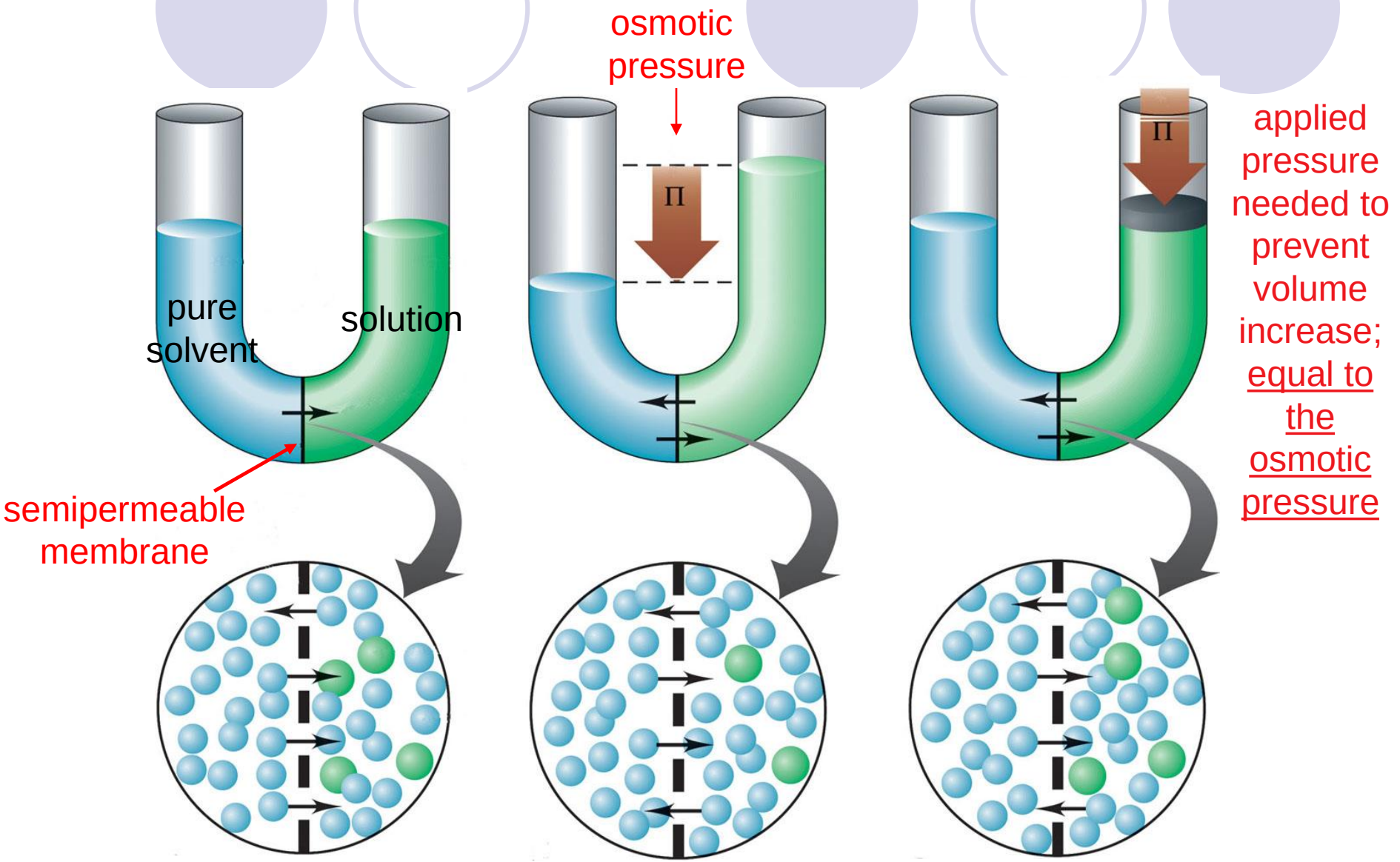


Figure 13.17