Definition

- Colligative properties = effect of solute on solvent due to the number of particles
- Examples:
  - **Freezing point depression**
  - **Boiling point elevation**
  - **Vapor pressure**
  - **Osmotic pressure**

The Nature of Colligative Properties

- Colligative properties are not affected by the properties of the solute, but,rather, only by the number of particles.
- Electrolytes dissociate producing more particles per mole than nonelectrolytes.

$$NaCl\,(s) \rightarrow Na^{+}\,(aq) + Cl^{-}(aq)$$
$$1\ mol\ (s) \rightarrow 2\ mol\ (aq)$$

  - Therefore electrolytes produce larger colligative affects than nonelectrolytes.

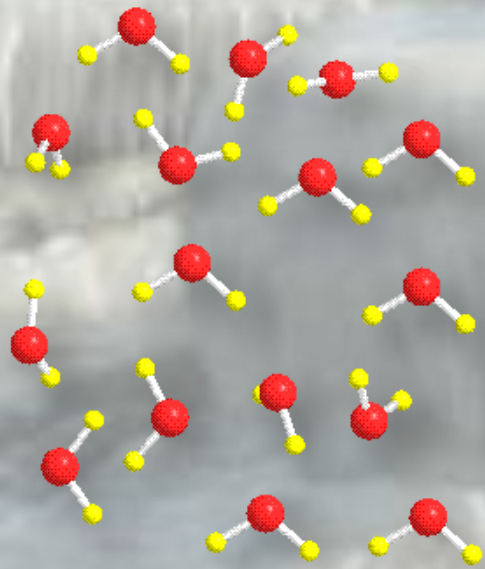
Freezing Point Depression

- The presence of dissolved solute lowers the freezing point of a solvent.
- Examples:
  - Putting salt on an icy sidewalk or roadway causes the ice to melt.
  - Antifreeze keeps the auto radiator from freezing.

Explaining Freezing Point Depression

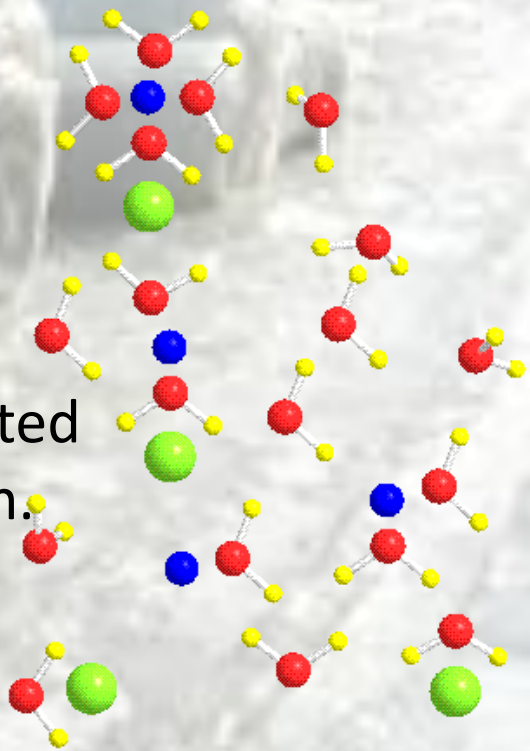
Water freezing

- When water freezes, positive hydrogens line up with negative oxygens.



Water freezing with solute

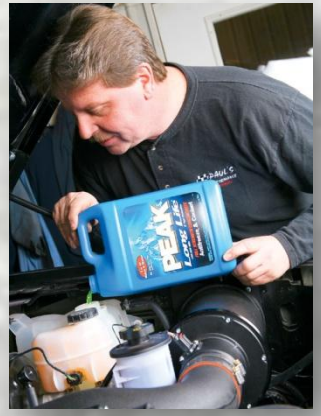
- Solute interferes with crystallization, lowering the freezing point.
- Na^+ (blue) is attracted to oxygen. Cl^- is attracted to hydrogen.



Boiling Point Elevation

- The presence of nonvolatile dissolved solute raises the boiling point of a more volatile solvent.

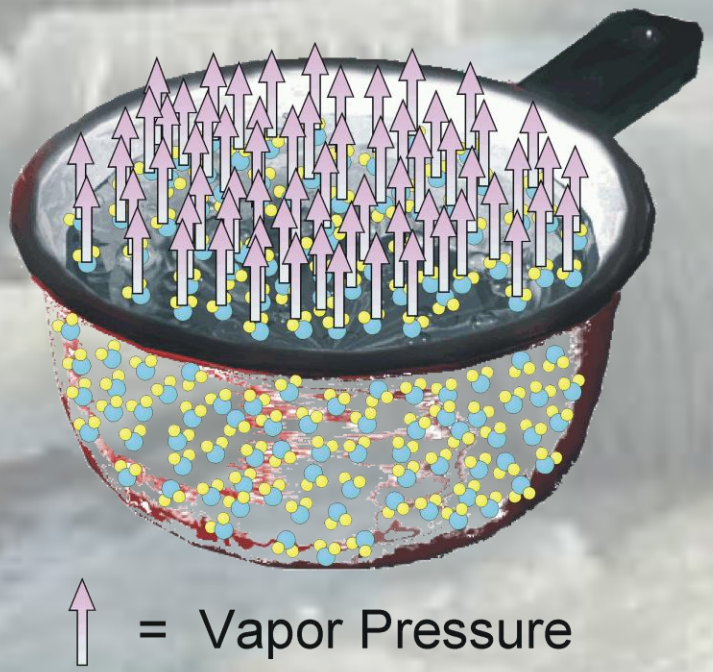
  - **Volatile** = vaporizes easily, has a high vapor pressure
- Example:
  - Adding coolant to the auto radiator.
  - Antifreeze keeps the water in the radiator from boiling as much as it keeps it from freezing.



Explaining Boiling Point Elevation

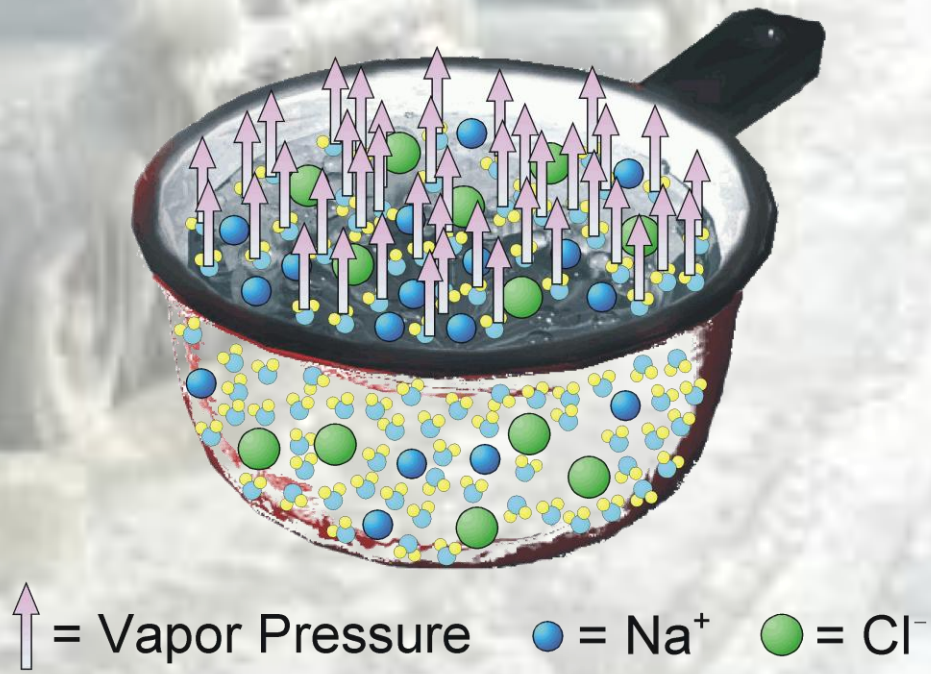
Water boiling

- Water boils when the vapor pressure equals the surrounding pressure.



Water boiling with solute

- Dissolved solute reduces the vapor pressure, raising the boiling point.



Getting Quantitative

- **1 mol of dissolved particles will elevate the boiling point of 1,000 g of water by 0.52°C and will depress the freezing point of 1,000 g of water by 1.86°C**

Freezing Point Depression and Boiling Point Elevation of Water

Freezing point depression ..... 1.86°C/mol

Boiling point elevation ..... 0.52°C/mol

Sample Problem 1

Find the boiling point of a solution containing 1,000 g of water and 2.5 mol of dissolved $BaCl_2$.

- **Step 1:** Determine the number of moles of solute particles.

  $2.5BaCl_2(s) \rightarrow 2.5Ba^{2+}(aq) + 5Cl^{-}(aq)$ $\quad mol = 7.5$

- **Step 2:** Multiply the boiling point elevation per mole by the number of moles of solute to find the boiling point elevation.

  $BPE = 0.52°C/mol \times 7.5\ mol = 3.9°C$

- **Step 3:** Add the boiling point elevation to 100°C.

  $BP = 100°C + 3.9°C = 103.9°C$

Sample Problem 2

Find the freezing point of a solution containing 1,000 g of water and 90. g of dissolved antifreeze ($C_2H_4O_2$).

- **Step 1:** Determine the number of moles of solute particles.

  C = 12 × 2 = 24
  H = 1 × 4 = 4
  O = 16 × 2 = 32
  60.

$$(90.\ g)\left(\frac{1\ mol}{60.\ g}\right) = 1.5\ mol$$

- **Step 2:** Multiply the freezing point depression per mole by the number of moles of solute to find the freezing point depression.

  FPD = 1.86°C/*mol* × 1.5 *mol* = 2.8°C

- **Step 3:** Subtract the freezing point depression from 0°C.

  FP = 0°C – 2.8°C = – 2.8°C