Chapter 9 – Solutions Practice Problems

Section 9.1 – Solutions

Goal: Identify the solute and solvent in a solution; describe the formation of a solution.

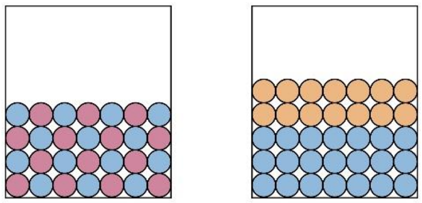
Summary:

- A solution forms when a **solute** dissolves in a **solvent**. The particles of the solute are evenly dispersed throughout the solvent. The solute and solvent may be a solid, liquid, or gas.
- The polar O-H bond leads to hydrogen bonding between water molecules.
- An ionic solute dissolves in water, a polar solvent, because the polar water molecules attract and pull the ions into solution, where they become hydrated.
- The expression *like dissolves like* means that a polar or an ionic solute dissolves in a polar solvent while a nonpolar solute dissolves in a nonpolar solvent.

Understanding the Concepts

Match the diagrams with the following:

a. A polar solute and a polar solvent
b. A nonpolar solute and a polar solvent
c. A nonpolar solute and a nonpolar solvent



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Describe the formation of an aqueous KI solution, when solid KI dissolves in water.

Describe the formation of an aqueous LiBr solution, when solid LiBr dissolves in water.

Practice Problems

1. Identify the solute and the solvent in each solution composed of the following:
   a. 10.0g of NaCl and 100.0g of H_2O
   b. 50.0 mL of ethanol, C_2H_5OH, and 10.0 mL H_2O
   c. 0.20 L of O_2 and 0.80 L of N_2

2. Water is a polar solvent and carbon tetrachloride (CCl_4) is a nonpolar solvent. In which solvent is each of the following more likely to be soluble?
   a. $CaCO_3$, ionic ___________
   b. Retinol (vitamin A), nonpolar ___________
   c. Sucrose (table sugar), polar ___________
   d. Cholesterol (lipid), nonpolar ___________

3. Water is a polar solvent and hexane is a nonpolar solvent. In which solvent is each of the following more likely to be soluble?
   a. Vegetable oil, nonpolar ___________
   b. Oleic acid (lipid), nonpolar ___________
   c. Niacin (vitamin B3), polar ___________
   d. $FeSO_4$ (iron supplement), ionic ___________

Section 9.2 – Electrolytes and Nonelectrolytes

Goal: Identify solutes as electrolytes or nonelectrolytes.

Summary:

- Substances that produce ions in water are called **electrolytes** because their solutions will conduct an electrical current.
- **Strong electrolytes** are completely dissociated, and conduct electricity strongly

$$NaCl(s) \xrightarrow{H_2O} Na^+(aq) + Cl^-(aq)$$

- **Weak electrolytes** only partially ionize, and conduct electricity weakly.

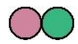
$$HF(aq) \rightleftharpoons H^+(aq) + F^-(aq)$$

- **Nonelectrolytes** are substances that dissolve in water to produce only molecules and cannot conduct electrical currents.

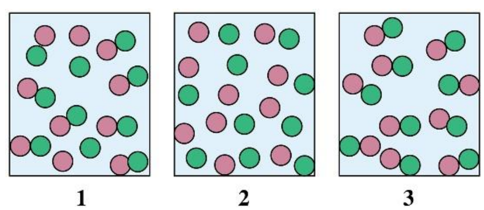
$$CH_3OH(l) \xrightarrow{H_2O} CH_3OH(aq)$$

- An **equivalent (Eq)** is the amount of an electrolyte that carries one mole of positive or negative charge.
  - One mole of Na^+ has 1Eq. One mole of Ca^{2+} has 2Eq.

Understanding the Concepts

Select the diagram that represents the solution formed by a solute  that is a:

a. Nonelectrolyte
b. Weak electrolyte
c. Strong electrolyte



Practice Problems

4. KF is a strong electrolyte, and HF is a weak electrolyte. How is the solution of KF different from that of HF?
   a. HF conducts electricity but KF does not.
   b. KF conducts electricity but HF does not.
   c. HF dissociates completely, KF dissociates partly.
   d. KF dissociates completely, HF does not dissociate at all.
   e. KF dissociates completely, HF dissociates to a few ions but mostly remains molecules.

5. NaOH is a strong electrolyte, and CH_3OH is a nonelectrolyte. How is the solution of NaOH different from that of CH_3OH?
   a. CH_3OH dissociates completely, NaOH doesn't dissociate at all.
   b. CH_3OH conducts electricity, NaOH does not.
   c. NaOH conducts electricity, CH_3OH does not.
   d. Both conduct electricity, NaOH conducts stronger than CH_3OH.

6. Write a balanced equation for the dissociation of each of the following **strong** electrolytes in water:
   a. KCl

   b. $CaCl_2$

   c. K_3PO_4

   d. $Fe(NO_3)_3$

7. Indicate whether aqueous solutions of each of the following solutes contain only ions, only molecules, or mostly molecules and a few ions:
   a. NH_4Cl, a strong electrolyte ______________________
   b. ethanol, C_2H_5OH, a nonelectrolyte ______________________
   c. HCN, hydrocyanic acid, a weak electrolyte ______________________

8. Classify the solute represented in each of the following equations as strong, weak, or nonelectrolyte:

   a. $CH_3OH(l) \xrightarrow{H_2O} CH_3OH(aq)$

   b. $MgCl_2(s) \xrightarrow{H_2O} Mg^{2+}(aq) + 2Cl^{-}(aq)$

   c. $HClO(aq) \rightleftarrows H^{+}(aq) + ClO^{-}(aq)$

9. Calculate the number of equivalents in each of the following:
   a. 1 mole of Mg^{2+}
   b. 0.5 mole of H^+
   c. 4 moles of Cl^-
   d. 2 moles of Fe^{3+}

10. An intravenous solution to replace potassium loss contains 40 mEq/L each of K^+ and Cl^-. How many moles of K^+ are in 1.5L of the solution.
    a. 27 moles
    b. 0.12 moles
    c. 0.060 moles
    d. 0.40 moles
    e. 60 moles

Section 9.3 – Solubility

Goal: Define solubility; distinguish between an unsaturated and a saturated solution. Identify an ionic compound as soluble or insoluble.

Summary:

- The **solubility** of a solute is the maximum amount of a solute that can dissolve in 100g of solvent.
- A solution that contains the maximum amount of dissolved solute is a **saturated solution**.
- An increase in temperature *increases* the solubility of most solids in water, but *decreases* the solubility of gases in water.

TABLE 9.7 Solubility Rules for Ionic Compounds in Water

An ionic compound is soluble in water if it contains one of the following:	
Positive Ions:	Li^+, Na^+, K^+, Rb^+, Cs^+, NH_4^+
Negative Ions:	NO_3^-, $C_2H_3O_2^-$
	Cl^-, Br^-, I^- except when combined with Ag^+, Pb^{2+}, or Hg_2^{2+}
	SO_4^{2-} except when combined with Ba^{2+}, Pb^{2+}, Ca^{2+}, Sr^{2+}, or Hg_2^{2+}
Ionic compounds that do not contain at least one of these ions are usually insoluble.	

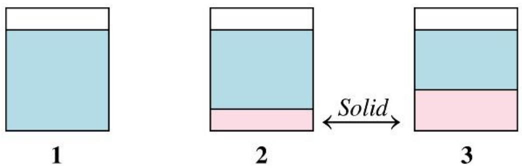
Example: Is $CdCl_2$ soluble in water?
Answer: Yes. Because Cl^- is listed on the table.

Understanding the Concepts

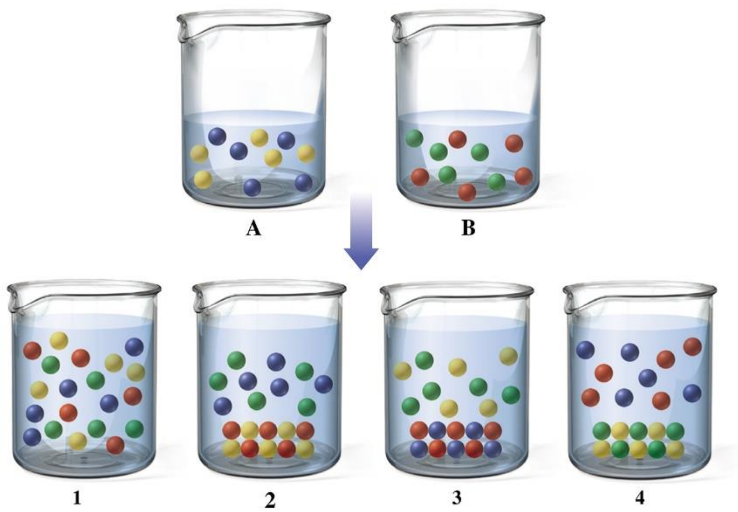
Explain the following observations:
a. More sugar dissolves in hot tea than in iced tea.
b. Champagne in a warm room goes flat.
c. A warm can of soda has more spray when opened than a cold one.

If diagram 1 represents all the solute (pink) is dissolved, how would heating or cooling the solution cause each of the following changes?
a. **2** to **3**

b. **2** to **1**



Use the following illustration of beakers and solutions for the next two problems:



Use the following types of ions: Na^+ Cl^- Ag^+ NO_3^-
Select the beaker (**1, 2, 3,** or **4**) that contains the products after the solutions in beaker **A** and **B** are mixed. Insoluble molecules are at the bottom of the beakers as "solid piles".

- If an insoluble ionic compound forms, write the ionic equation.

- If a reaction occurs, write the net ionic equation.

Use the following types of ions: K^+ NO_3^- NH_4^+ Br^-
Select the beaker (**1, 2, 3,** or **4**) that contains the products after the solutions in beaker **A** and **B** are mixed. Insoluble molecules are at the bottom of the beakers as "solid piles".

- If an insoluble ionic compound forms, write the ionic equation.

- If a reaction occurs, write the net ionic equation.

Practice Problems

	Solubility (g/100 g H_2O)	
Substance	**20 °C**	**50 °C**
KCl	34	43
$NaNO_3$	88	110
$C_{12}H_{22}O_{11}$ (sugar)	204	260

11. Use the chart above to determine whether each of the following solutions will be saturated or unsaturated at 20°C:
a. adding 25g of KCl to 100g of H_2O

b. adding 11g of $NaNO_3$ to 25g of H_2O

c. adding 400g of sugar to 125g of H_2O

12. Use the chart above. A solution containing 80g of KCl in 200g of H_2O at 50°C is cooled to 20°C.
a. How many grams of KCl remain in a solution at 20°C?

b. How many grams of KCL crystallized after cooling?

13. Use the Ionic Solubility Chart to predict whether each of the following ionic compounds is soluble in water:
a. LiCl
b. AgCl
c. $BaCO_3$
d. K_2O
e. $Fe(NO_3)_3$

14. Predict whether **each** of the following would be soluble or insoluble in water. (Use the Ionic Solubility Chart.)
1. LiCl
2. AgCl
3. $BaCO_3$
4. K_2O
5. $Fe(NO_3)_3$
6. Pbs
7. KI
8. Na_2S
9. Ag_2O
10. $CaSO_4$

15. Use the Ionic Solubility Chart to determine whether a solid forms when solutions containing the following ionic compounds are mixed. If so, write the ionic equation and the net ionic equation.
   a. KCl(*aq*) and Na_2S(*aq)*

   b. $AgNO_3$(*aq*) and K_2S(*aq*)

   c. $CaCl_2$(*aq*) and Na_2SO_4(*aq*)

   d. $CuCl_2$(*aq*) and Li_3PO_4(*aq*)

Section 9.4 – Solution Concetration and Reactions

Goal: Calculate the concentration of a solute in a solution; use concentration units to calculate the aount of solute or solution. Given the volume and concentration of a solution, calculate the amount of another reactant or product in a reaction.

Summary:

Calculating Concentration

The amount of solute dissolved in a certain amount of solution is called the **concentration** of the solution.

$$\text{mass percent} = \frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \text{ x } 100$$

$$\text{volume percent} = \frac{\text{volume of solute (mL)}}{\text{volume of solution (mL)}} \text{ x } 100$$

$$\text{mass/volume percent} = \frac{\text{mass of solute (g)}}{\text{volume of solution (mL)}} \text{ x } 100$$

$$\text{Molarity (M)} = \frac{\text{moles of solute}}{\text{volume of solution (L)}}$$

Example: What is the mass/volume percent (m/v) and the molarity (M) of 225 mL (0.225 L) of a LiCl solution that contains 17.1g of LiCl?

Answer:

$$\text{mass/volume percent} = \frac{\text{mass of solute (g)}}{\text{volume of solution (mL)}} \text{ x } 100$$

$$= \frac{\text{17.1 g LiCl}}{\text{225 mL}} \text{ x } 100$$

= 7.60% (m/v) LiCl solution

$$\text{Moles of LiCl} = \text{17.1 g LiCl x } \frac{\text{1 mole LiCl}}{\text{42.39 g LiCl}} = \text{0.403 moles of LiCl}$$

$$\text{Molarity (M)} = \frac{\text{moles of solute}}{\text{volume of solution (L)}} = \frac{\text{0.403 moles LiCl}}{\text{0.225 L solution}} = \mathbf{1.79\ M\ LiCl\ solution}$$

Using Concentration as a Conversion Factor

- When we need to calculate the amount of solute or solution, we use the mass/volume precent (m/v) or the molarity (M) as a conversion factor.
- For example, the concentration of a 4.50M HCl solutions means there are 4.50 moles of HCl in 1 L of HCl solution, which give the conversion factor:

$$\frac{4.50 \text{ moles HCl}}{1 \text{ L solution}}$$

Example: How many milliliters of a 4.50 M HCl solution will provide 1.13 moles of HCl?
Answer:

$$1.13 \cancel{\text{moles of HCl}} \times \frac{\cancel{1 \text{ L solution}}}{\cancel{4.50 \text{ moles HCl}}} \times \frac{1000 \text{ mL solution}}{\cancel{1 \text{ L solution}}} = 251 \text{ mL of HCl solution}$$

Calculating the quantity of a reactant or product for a chemical reaction in solution

When chemical reactions involve aqueous solutions of reactants or products, we use the balanced chemical equation, the molarity, and the volume to determine the moles or grams of the reactants or products.

Example How many grams of zinc metal will react with 0.315 L of a 1.20 M HCl solution.

$$Zn(s) + 2HCl(aq) \rightarrow H_2(g) + ZnCl_2(aq)$$

Answer: L → mol HCl → mol Zn → g Zn

$$0.315 \text{ L solution} \times \frac{\cancel{1.20 \text{ moles HCl}}}{\cancel{1 \text{ L solution}}} \times \frac{\cancel{1 \text{ mole Zn}}}{\cancel{2 \text{ moles of HCl}}} \times \frac{65.41 \text{ g Zn}}{\cancel{1 \text{ mole zinc}}} = 12.4 \text{ g of Zn}$$

Practice Problems

16. Calculate the mass percent (m/m) for the solute in 25g of KCl and 125g of H_2O.
    a. 20.0% (m/m)
    b. 0.17% (m/m)
    c. 17.0% (m/m)
    d. 5.0% (m/m)
    e. 0.20% (m/m)

17. Calculate the mass percent (m/m) for the solute in 12g of sucrose in 225g of tea solution.
    a. 0.053% (m/m)
    b. 0.95% (m/m)
    c. 95% (m/m)
    d. 5.3% (m/m)
    e. 19% (m/m)

18. Calculate the mass percent (m/m) for the solute in 8.0g of $CaCl_2$ in 80.0g of $CaCl_2$ solution.
    a. 0.05% (m/m)
    b. 5.1% (m/m)
    c. 91% (m/m)
    d. 0.10% (m/m)
    e. 10% (m/m)

19. Calculate the mass/volume percent (m/v) for the solute in 2.5g of LiCl in 40.0mL of LiCl solution.
    a. 6.3% (m/v)
    b. 16% (m/v)
    c. 5.9% (m/v)
    d. 0.059% (m/v)
    e. 0.063% (m/v)

20. Calculate the mass/volume percent (m/v) for the solute in 39g of sucrose in 355mL of a carbonated drink.
    a. 99% (m/v)
    b. 11% (m/v)
    c. 0.11% (m/v)
    d. 8.6% (m/v)
    e. 0.099% (m/v)

21. Calculate the grams or milliliters of solute needed to prepare 50g of a 5.0% (m/m) KCl solution.
    a. 250 g solute
    b. 250 mL solute
    c. 0.50 mL solute
    d. 2.5 g solute
    e. 2.5 mL solute

22. Calculate the grams or milliliters of solute needed to prepare 1250mL of a 4.0% (m/v) NH_4Cl solution.
    a. 50 g solute
    b. 50 mL solute
    c. 12.5 g solute
    d. 5000 mL solute
    e. 5000 g solute

23. Calculate the grams or milliliters of solute needed to prepare 250mL of a 10% (v/v) acetic acid solution.
    a. 25 g solute
    b. 4.0 mL solute
    c. 2500 mL solute
    d. 25 mL solute
    e. 2500 g solute

24. Champagne contains 22.5% (v/v) alcohol. If there are 750mL of champagne in the bottle, what is the volume, in milliliters, of alcohol?
    a. 3330 mL alcohol
    b. 16900 mL alcohol
    c. 32.1 mL alcohol
    d. 169 mL alcohol
    e. 7.50 mL alcohol

25. Calculate the grams of 25% (m/m) $LiNO_3$ solution that contains 5.0g of $LiNO_3$.
    a. 500 g solution
    b. 0.2 g solution
    c 1.3 g solution
    d. 20 g solution
    e. 5.0 g solution

26. Calculate the milliliters of 10.0% (m/v) KOH solution that contains 40.0g of KOH.
a. 4.00 mL solution
b. 25.0 mL solution
c. 0.250 mL solution
d. 4000 mL solution
e. 400 mL solution

27. Calculate the milliliters of 10.0% (v/v) formic acid solution that contains 2.0mL of formic acid.
a. 20 mL solution
b. 50 mL solution
c. 2.0 mL solution
d. 200 mL solution
e. 0.02 mL solution

28. A patient receives 250 mL of a 4.0% (m/v) amino acid solution twice a day. How many grams of amino acids are in 250 mL of solution?
a. 1000 g amino acids
b. 2.5 g amino acids
c. 4.0 g amino acids
d. 10 g amino acids
e. 0.40 g amino acids

29. Calculate the molarity of 0.500 mole of glucose in 0.200 L of a glucose solution.
a. 10 M
b. 2.5 M
c. 4.0 M
d. 0.10 M
e. 0.40 M

30. Calculate the molarity of 73.0 g of HCl in 2.00 L of a HCl solution.
a. 0.50 M
b. 0.027 M
c. 2.00 M
d. 36.5 M
e. 1.00 M

31. Calculate the molarity of 30.0 g of NaOH in 350 mL of a NaOH solution.
a. 4.61 M
b. 2.14 M
c. 0.00214 M
d. 0.477 M
e. 0.750 M

32. Calculate the grams of solute needed to prepare 2.00 L of a 6.00 M NaOH solution.
a. 12.0 g solute
b. 0.33 g solute
c. 516 g solute
d. 480 g solute
e. 3.00 g solute

33. Calculate the grams of solute needed to prepare 5.00 L of a 0.100 M $CaCl_2$ solution.
 a. 0.500 g solute
 b. 50.0 g solute
 c. 116 g solute
 d. 55.5 g solute
 e. 222 g solute

34. Calculate the grams of solute needed to prepare 175 mL of 3.00 M $NaNO_3$ solution.
 a. 4.96 g solute
 b. 44.6 g solute
 c. 111 g solute
 d. 162 g solute
 e. 0.525 g solute

35. Calculate the liters of a 4.00 M KCl solution to obtain 0.100 mole of KCl.
 a. 250 L solution
 b. 0.025 L solution
 c. 40 L solution
 d. 400 L solution
 e. 0.400 L solution

36. Calculate the milliliters of a 2.5 M K_2SO_4 solution to obtain 1.20 moles of K_2SO_4.
 a. 0.48 mL solution
 b. 2.08 mL solution
 c. 2083 mL solution
 d. 3000 mL solution
 e. 480 mL solution

Challenge Questions

37. How many milliliters of a 0.200 M NaOH solution are needed to react with 18.0 mL of a 0.500 M $NiCl_2$ solution?

$$NiCl_2(aq) + 2NaOH(aq) \rightarrow Ni(OH)_2(s) + 2NaCl(aq)$$

 a. 90.0 mL
 b. 1000 mL
 c. 3.6 mL
 d. 200 mL
 e. 0.090 mL

38. How many grams of $Ni(OH)_2$ are produced from the reaction of 35.0 mL of a 1.75 M NaOH solution and excess $NiCl_2$?

$$NiCl_2(aq) + 2NaOH(aq) \rightarrow Ni(OH)_2(s) + 2NaCl(aq)$$

 a. 2800 g
 b. 0.031 g
 c. 5.68 g
 d. 2.84 g
 e. 0.010 g

39. What is the molarity of 30.0 mL of a $NiCl_2$ solution that reacts completely with 10.0 mL of a 0.250 M NaOH solution?

$$NiCl_2(aq) + 2NaOH(aq) \rightarrow Ni(OH)_2(s) + 2NaCl(aq)$$

a. 83.3 M
b. 0.0417 M
c. 0.167 M
d. 0.0833 M
e. 41.7 M

40. How many milliliters of a 0.200 M HCl solution can react with 8.25 g of $CaCO_3$?

$$CaCO_3(s) + 2HCl(aq) \rightarrow CO_2(g) + H_2O(l) + CaCl_2(aq)$$

a. 412 mL
b. 17.1 mL
c. 0.412 mL
d. 82500 mL
e. 824 mL

Section 9.5 – Dilution of Solutions

Goal: Describe the dilution of a solution; calculate the unknown concentration or volume when a solution is diluted.

Summary:

In a **dilution**, a solvent such as water is added to a solution, which increases its volume and decreases its concentration.

$$C_1V_1 = C_2V_2$$

Example: Calculate the final concentration when 2.0 L of a 6.0 M HCl solution is added to water so that the final volume is 6.0 L.

Answer: V_1 = 2.0 L, C_1 = 6.0M HCl, V_2 = 6.0 L

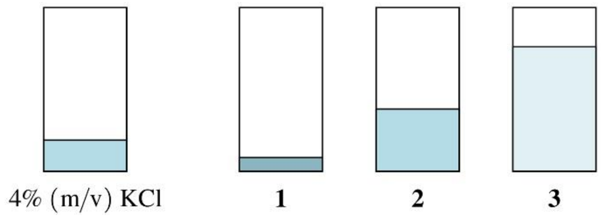
$$C_2 = \frac{C_1V_1}{V_2} = \frac{(6.0M)(2.0L)}{6.0L} = 2.0M\ HCl$$

Understanding the Concepts

Select the container that represents the dilution of a 4% (m/v) KCl solution to give each of the following:

a. a 2% (m/v) KCl solution

b. a 1% (m/v) KCl solution



Practice Problems

41. Calculate the final concentration when water is added to 0.25 L of a 6.0 M NaF solution to make 2.0 L of a diluted NaF solution.

a. 12 M
b. 1.5 M
c. 0.75 M
d. 8.0 M
e. 48 M

42. Calculate the final concentration when a 50.0 mL sample of an 8.0% (m/v) KBr solution is diluted with water so that the final volume is 200.0 mL.
    a. 0.67% (m/v)
    b. 1.3% (m/v)
    c. 2.0% (m/v)
    d. 46% (m/v)
    e. 32% (m/v)

43. Determine the final volume, in milliliters, when a 0.10 M HCl solution is prepared from 25 mL of a 6.0 M HCl solution.
    a. 0.42 mL
    b. 15 mL
    c. 420 mL
    d. 150 mL
    e. 1500 mL

44. Determine the final volume, in milliliters, when a 1.0% (m/v) $CaCl_2$ solution is prepared from 18 mL of a 4.0% (m/v) $CaCl_2$ solution.
    a. 288 mL
    b. 0.014 mL
    c. 0.22 mL
    d. 72 mL
    e. 4.5 mL

45. What initial volume of 6.00M KNO_3, in mL, is needed to make 20.0 mL of a 0.250M KNO_3 solution.
    a. 0.83 mL
    b. 30 mL
    c. 480 mL
    d. 0.075 mL
    e. 13.3 mL

46. A doctor orders 100 mL of 2.0% (m/v) ibuprofen. If you have 8.0% (m/v) ibuprofen on hand, how many milliliters do you need?
    a. 25 mL
    b. 400 mL
    c. 6.25 mL
    d. 1600 mL
    e. 0.160 mL

Section 9.6 – Properties of Solutions

Goal: Identify a mixture as a solution, a colloid, or a suspension. Describe how the number of particles in a solution affects the freezing point and the boiling point.

Summary:

Solutions are homogenous mixtures and the particles pass through both filters and semipermeable membranes.
Colloids contain particles that pass through most filters but do not settle out or pass through semipermeable membranes.
Suspensions have very large particles that settle out of solution.

The particles in a solution *lower the vapor pressure*, *raise the boiling point*, *and lower the freezing point.*
In **osmosis**, solvent (water) passes through a semipermeable membrane from a solution with a *lower solute concentration to a solution with a higher solute concentration.*

Calculating the boiling point/freezing point of a solution

The boiling point elevation and freezing point lowering is determined from the moles of particles in one kilogram of water.

Boiling point increases 0.51°C per mole of particles in 1.0 kg H_2O.
Freezing point decreases 1.86°C per mole of particles in 1.0 kg H_2O.

Example: What is the boiling point of a solution that contains 1.5 moles of the strong electrolyte KCl in 1.0 kg of water?

Answer: A solution of 1.5 moles of KCl in 1.0 kg of water contains 3.0 moles of particles (1.5 moles of K^+ and 1.5 moles of Cl^-) in 1.0 kg of water and has a boiling point change of:

$$3.0 \text{ moles of particles x } \frac{0.51°\text{C}}{1 \text{ mole of particles}} = 1.53°\text{C}$$

Practice Problems

47. Identify the following as characteristics of a solution, a colloid, or a suspension:
    a. a mixture that cannot be separated by a semipermeable membrane

    b. a mixture that settles out upon standing

    c. particles of this mixture will pass through a filter but not a semipermeable membrane

    d. the particles of solute in this solution are very large and visible

48. In each pair, identify the solution that will have a lower freezing point.
    a. 1.0 mole of glycerol (nonelectrolyte) and 2.0 moles of ethylene glycol (nonelectrolyte) each in 1.0 kg of water.
    b. 0.50 mole of KCl (strong electrolyte) and 0.50 mole of $MgCl_2$ (strong electrolyte) each in 1.0 kg of water.

49. In each pair, identify the solution that will have the higher boiling point.
    a. 1.50 moles of LiOH (strong electrolyte) and 3.00 moles of KOH (strong electrolyte) each in 1.0 kg of water.
    b. 0.40 mole of $Al(NO_3)_3$ (strong electrolyte) and 0.40 mole of CsCl (strong electrolyte) each in 1.0 kg of water.

50. Calculate the freezing point of 1.36 moles of methanol, CH_3OH, a nonelectrolyte, added to 1.00 kg of water. (Freezing point decreases 1.86°C per mole of particles in 1.0 kg H_2O.)
    a. 2.53°C
    b. 0.731°C
    c. -1.37°C
    d. -2.53°C
    e. -0.731°C

51. Calculate the freezing point of 640 g of the antifreeze propylene glycol, $C_3H_8O_2$, a nonelectrolyte, dissolved in 1.00 kg of water. (Freezing point decreases 1.86°C per mole of particles in 1.0 kg H_2O.)
a. 0.0029°C
b. -15.6°C
c. -1.86°C
d. 15.6°C
e. -0.0029°C

52. Calculate the freezing point of 111g of KCl, a strong electrolyte, dissolved in 1.00 kg of water. (Freezing point decreases 1.86°C per mole of particles in 1.0 kg H_2O.)
a. -5.54°C
b. 5.54°C
c. -2.77°C
d. 2.77°C
e. 1.86°C

53. Calculate the boiling point of 2.12 moles of glucose, $C_6H_{12}O_6$, a nonelectrolyte, added to 1.00 kg of water. (Boiling point increases 0.51°C per mole of particles in 1.0 kg H_2O).
a. 102.001°C
b. 101.081°C
c. 100.00°C
d. 98.919°C
e. 77.62°C

54. Calculate the boiling point of 110 g of sucrose, $C_{12}H_{22}O_{11}$, a nonelectrolyte, dissolved in 1.00 kg of water. (Boiling point increases 0.51°C per mole of particles in 1.0 kg H_2O).
a. 100.16°C
b. 100.57°C
c. 100.00°C
d. 99.84°C
e. 99.49°C

55. Calculate the boiling point of 145g of $NaNO_3$, a strong electrolyte, dissolved in 1.00 kg of water. (Boiling point increases 0.51°C per mole of particles in 1.0 kg H_2O).
a. 100.57°C
b. 92.1°C
c. 103.6°C
d. 98.26°C
e. 101.74°C