

## 9.E: Solutions (Exercises)

### 9.1: Solutions

#### Concept Review Exercises

1. What causes a solution to form?
2. How does the phrase *like dissolves like* relate to solutions?

#### Answers

1. Solutions form because a solute and a solvent have similar intermolecular interactions.
2. It means that substances with similar intermolecular interactions will dissolve in each other.

#### Exercises

1. Define *solution*.
2. Give several examples of solutions.
3. What is the difference between a solvent and a solute?
4. Can a solution have more than one solute in it? Can you give an example?
5. Does a solution have to be a liquid? Give several examples to support your answer.
6. Give at least two examples of solutions found in the human body.
7. Which substances will probably be soluble in water, a very polar solvent?
  - a. sodium nitrate ( $\text{NaNO}_3$ )
  - b. hexane ( $\text{C}_6\text{H}_{14}$ )
  - c. isopropyl alcohol [ $(\text{CH}_3)_2\text{CHOH}$ ]
  - d. benzene ( $\text{C}_6\text{H}_6$ )
8. Which substances will probably be soluble in toluene ( $\text{C}_6\text{H}_5\text{CH}_3$ ), a nonpolar solvent?
  - a. sodium nitrate ( $\text{NaNO}_3$ )
  - b. hexane ( $\text{C}_6\text{H}_{14}$ )
  - c. isopropyl alcohol [ $(\text{CH}_3)_2\text{CHOH}$ ]
  - d. benzene ( $\text{C}_6\text{H}_6$ )
9. The solubility of alcohols in water varies with the length of carbon chain. For example, ethanol ( $\text{CH}_3\text{CH}_2\text{OH}$ ) is soluble in water in any ratio, while only 0.0008 mL of heptanol ( $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ ) will dissolve in 100 mL of water. Propose an explanation for this behavior.
10. Dimethyl sulfoxide [ $(\text{CH}_3)_2\text{SO}$ ] is a polar liquid. Based on the information in Exercise 9, which do you think will be more soluble in it—ethanol or heptanol?

#### Answers

1. a homogeneous mixture
2. vinegar, dextrose IV, saline IV, coffee, tea, wine
3. A solvent is the majority component of a solution; a solute is the minority component of a solution.
4. yes. Coke or Pepsi has sugar, caffeine and carbon dioxide as solutes.
5. A solution does not have to be liquid; air is a gaseous solution, while some alloys are solid solutions (answers will vary).
6. Urine, plasma
7.
  - a. probably soluble
  - b. probably not soluble
  - c. probably soluble
  - d. probably not soluble

- 8.
- probably not soluble
  - probably soluble
  - probably not soluble
  - probably soluble
9. Small alcohol molecules have strong polar intermolecular interactions, so they dissolve in water. In large alcohol molecules, the nonpolar end overwhelms the polar end, so they do not dissolve very well in water.
10. Ethanol is a smaller molecule. It will be more soluble in water than heptanol.

## 9.2: Concentration

### Concept Review Exercises

- What are some of the units used to express concentration?
- Distinguish between the terms *solubility* and *concentration*.

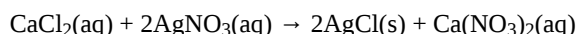
### Answers

- % m/m, % m/v, ppm, ppb, molarity, and Eq/L (answers will vary)
- Solubility is typically a limit to how much solute can dissolve in a given amount of solvent. Concentration is the quantitative amount of solute dissolved at any concentration in a solvent.

### Exercises

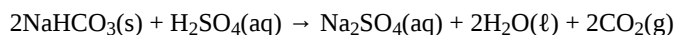
- Define *solubility*. Do all solutes have the same solubility?
- Explain why the terms *dilute* or *concentrated* are of limited usefulness in describing the concentration of solutions.
- If the solubility of sodium chloride (NaCl) is 30.6 g/100 mL of H<sub>2</sub>O at a given temperature, how many grams of NaCl can be dissolved in 250.0 mL of H<sub>2</sub>O?
- If the solubility of glucose (C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>) is 120.3 g/100 mL of H<sub>2</sub>O at a given temperature, how many grams of C<sub>6</sub>H<sub>12</sub>O<sub>6</sub> can be dissolved in 75.0 mL of H<sub>2</sub>O?
- How many grams of sodium bicarbonate (NaHCO<sub>3</sub>) can a 25.0°C saturated solution have if 150.0 mL of H<sub>2</sub>O is used as the solvent?
- If 75.0 g of potassium bromide (KBr) are dissolved in 125 mL of H<sub>2</sub>O, is the solution saturated, unsaturated, or supersaturated?
- Calculate the mass/mass percent of a saturated solution of NaCl. Use the data from Table 9.E. 1 "Solubilities of Various Solutes in Water at 25°C (Except as Noted)", assume that masses of the solute and the solvent are additive, and use the density of H<sub>2</sub>O (1.00 g/mL) as a conversion factor.
- Calculate the mass/mass percent of a saturated solution of MgCO<sub>3</sub>. Use the data from Table 9.E. 1 "Solubilities of Various Solutes in Water at 25°C (Except as Noted)", assume that masses of the solute and the solvent are additive, and use the density of H<sub>2</sub>O (1.00 g/mL) as a conversion factor.
- Only 0.203 mL of C<sub>6</sub>H<sub>6</sub> will dissolve in 100.000 mL of H<sub>2</sub>O. Assuming that the volumes are additive, find the volume/volume percent of a saturated solution of benzene in water.
- Only 35 mL of aniline (C<sub>6</sub>H<sub>5</sub>NH<sub>2</sub>) will dissolve in 1,000 mL of H<sub>2</sub>O. Assuming that the volumes are additive, find the volume/volume percent of a saturated solution of aniline in water.
- A solution of ethyl alcohol (C<sub>2</sub>H<sub>5</sub>OH) in water has a concentration of 20.56% v/v. What volume of C<sub>2</sub>H<sub>5</sub>OH is present in 255 mL of solution?
- What mass of KCl is present in 475 mL of a 1.09% m/v aqueous solution?
- The average human body contains 5,830 g of blood. What mass of arsenic is present in the body if the amount in blood is 0.55 ppm?

14. The Occupational Safety and Health Administration has set a limit of 200 ppm as the maximum safe exposure level for carbon monoxide (CO). If an average breath has a mass of 1.286 g, what is the maximum mass of CO that can be inhaled at that maximum safe exposure level?
15. Which concentration is greater—15 ppm or 1,500 ppb?
16. Express the concentration 7,580 ppm in parts per billion.
17. What is the molarity of 0.500 L of a potassium chromate solution containing 0.0650 mol of  $\text{K}_2\text{CrO}_4$ ?
18. What is the molarity of 4.50 L of a solution containing 0.206 mol of urea  $[(\text{NH}_2)_2\text{CO}]$ ?
19. What is the molarity of a 2.66 L aqueous solution containing 56.9 g of NaBr?
20. If 3.08 g of  $\text{Ca}(\text{OH})_2$  is dissolved in enough water to make 0.875 L of solution, what is the molarity of the  $\text{Ca}(\text{OH})_2$ ?
21. What mass of HCl is present in 825 mL of a 1.25 M solution?
22. What mass of isopropyl alcohol ( $\text{C}_3\text{H}_8\text{O}$ ) is dissolved in 2.050 L of a 4.45 M aqueous  $\text{C}_3\text{H}_8\text{O}$  solution?
23. What volume of 0.345 M NaCl solution is needed to obtain 10.0 g of NaCl?
24. How many milliliters of a 0.0015 M cocaine hydrochloride ( $\text{C}_{17}\text{H}_{22}\text{ClNO}_4$ ) solution is needed to obtain 0.010 g of the solute?
25. Aqueous calcium chloride reacts with aqueous silver nitrate according to the following balanced chemical equation:



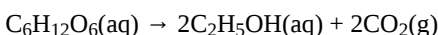
How many moles of  $\text{AgCl}(\text{s})$  are made if 0.557 L of 0.235 M  $\text{CaCl}_2$  react with excess  $\text{AgNO}_3$ ? How many grams of  $\text{AgCl}$  are made?

26. Sodium bicarbonate ( $\text{NaHCO}_3$ ) is used to react with acid spills. The reaction with sulfuric acid ( $\text{H}_2\text{SO}_4$ ) is as follows:



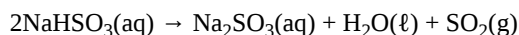
If 27.6 mL of a 6.25 M  $\text{H}_2\text{SO}_4$  solution were spilled, how many moles of  $\text{NaHCO}_3$  would be needed to react with the acid? How many grams of  $\text{NaHCO}_3$  is this?

27. The fermentation of glucose to make ethanol and carbon dioxide has the following overall chemical equation:



If 1.00 L of a 0.567 M solution of  $\text{C}_6\text{H}_{12}\text{O}_6$  were completely fermented, what would be the resulting concentration of the  $\text{C}_2\text{H}_5\text{OH}$  solution? How many moles of  $\text{CO}_2$  would be formed? How many grams is this? If each mole of  $\text{CO}_2$  had a volume of 24.5 L, what volume of  $\text{CO}_2$  is produced?

28. Aqueous sodium bisulfite gives off sulfur dioxide gas when heated:



If 567 mL of a 1.005 M  $\text{NaHSO}_3$  solution were heated until all the  $\text{NaHSO}_3$  had reacted, what would be the resulting concentration of the  $\text{Na}_2\text{SO}_3$  solution? How many moles of  $\text{SO}_2$  would be formed? How many grams of  $\text{SO}_2$  would be formed? If each mole of  $\text{SO}_2$  had a volume of 25.78 L, what volume of  $\text{SO}_2$  would be produced?

29. What is the concentration of a 1.0 M solution of  $\text{K}^+(\text{aq})$  ions in equivalents/liter?
30. What is the concentration of a 1.0 M solution of  $\text{SO}_4^{2-}(\text{aq})$  ions in equivalents/liter?
31. A solution having initial concentration of 0.445 M and initial volume of 45.0 mL is diluted to 100.0 mL. What is its final concentration?
32. A 50.0 mL sample of saltwater that is 3.0% m/v is diluted to 950 mL. What is its final mass/volume percent?

## Answers

1. Solubility is the amount of a solute that can dissolve in a given amount of solvent, typically 100 mL. The solubility of solutes varies widely.
2. The term *dilute* means relatively less solute and the term *concentrated* implies relatively more solute. Both are of limited usefulness because these are not accurate.

3. 76.5 g
4. 90.2 g
5. 12.6 g
6. unsaturated
7. 26.5%
8. 2.15%
9. 0.203%
10. 3.4%
11. 52.4 mL
12. 5.18 g
13. 0.00321 g
14.  $2.57 \times 10^{-4}$  g
15. 15 ppm
16. 7,580,000 ppb
17. 0.130 M
18. 0.0458 M
19. 0.208 M
20. 0.0475 M
21. 37.6 g
22. 548 g
23. 0.496 L
24. 20 mL
25. 0.262 mol; 37.5 g
26. 0.345 mol; 29.0 g
27. 1.13 M  $\text{C}_2\text{H}_5\text{OH}$ ; 1.13 mol of  $\text{CO}_2$ ; 49.7 g of  $\text{CO}_2$ ; 27.7 L of  $\text{CO}_2$
28. 0.503 M  $\text{Na}_2\text{SO}_3$ ; 0.285 mol  $\text{SO}_2$ ; 18.3 g  $\text{SO}_2$ ; 471 L  $\text{SO}_2$
29. 1.0 Eq/L
30. 2.0 Eq/L
31. 0.200 M
32. 0.16 % m/v

### 9.3: The Dissolution Process

#### Concept Review Exercise

1. Explain how the solvation process describes the dissolution of a solute in a solvent.

#### Answer

1. Each particle of the solute is surrounded by particles of the solvent, carrying the solute from its original phase.

#### Exercises

1. Describe what happens when an ionic solute like  $\text{Na}_2\text{SO}_4$  dissolves in a polar solvent.
2. Describe what happens when a molecular solute like sucrose ( $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ ) dissolves in a polar solvent.
3. Classify each substance as an electrolyte or a nonelectrolyte. Each substance dissolves in  $\text{H}_2\text{O}$  to some extent.
  - a.  $\text{NH}_4\text{NO}_3$

- b.  $\text{CO}_2$
  - c.  $\text{NH}_2\text{CONH}_2$
  - d.  $\text{HCl}$
4. Classify each substance as an electrolyte or a nonelectrolyte. Each substance dissolves in  $\text{H}_2\text{O}$  to some extent.
- a.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
  - b.  $\text{Ca}(\text{CH}_3\text{CO}_2)_2$
  - c.  $\text{I}_2$
  - d.  $\text{KOH}$
5. Will solutions of each solute conduct electricity when dissolved?
- a.  $\text{AgNO}_3$
  - b.  $\text{CHCl}_3$
  - c.  $\text{BaCl}_2$
  - d.  $\text{Li}_2\text{O}$
6. Will solutions of each solute conduct electricity when dissolved?
- a.  $\text{CH}_3\text{COCH}_3$
  - b.  $\text{N}(\text{CH}_3)_3$
  - c.  $\text{CH}_3\text{CO}_2\text{C}_2\text{H}_5$
  - d.  $\text{FeCl}_2$

## Answers

- 1. Each ion of the ionic solute is surrounded by particles of solvent, carrying the ion from its associated crystal.
- 2. Each sucrose molecule is surrounded by solvent molecules (attracted to each other via intermolecular forces of attraction).
- 3.
  - a. electrolyte
  - b. nonelectrolyte
  - c. nonelectrolyte
  - d. electrolyte
- 4.
  - a. nonelectrolyte
  - b. electrolyte
  - c. nonelectrolyte
  - d. electrolyte
- 5.
  - a. yes
  - b. no
  - c. yes
  - d. yes
- 6.
  - a. no
  - b. no
  - c. no
  - d. yes

## 9.4: Properties of Solutions

### Concept Review Exercises

- 1. What are the colligative properties of solutions?

2. Explain how the following properties of solutions differ from those of the pure solvent: vapor pressure, boiling point, freezing point, and osmotic pressure.

## Answers

1. Colligative properties are characteristics that a solution has that depend on the number, not the identity, of solute particles.
2. In solutions, the vapor pressure is lower, the boiling point is higher, the freezing point is lower, and the osmotic pressure is higher.

## Exercises

1. In each pair of aqueous systems, which will have the lower vapor pressure?
  - a. pure water or 1.0 M NaCl
  - b. 1.0 M NaCl or 1.0 M  $\text{C}_6\text{H}_{12}\text{O}_6$
  - c. 1.0 M  $\text{CaCl}_2$  or 1.0 M  $(\text{NH}_4)_3\text{PO}_4$
2. In each pair of aqueous systems, which will have the lower vapor pressure?
  - a. 0.50 M  $\text{Ca}(\text{NO}_3)_2$  or 1.0 M KBr
  - b. 1.5 M  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$  or 0.75 M  $\text{Ca}(\text{OH})_2$
  - c. 0.10 M  $\text{Cu}(\text{NO}_3)_2$  or pure water
3. In each pair of aqueous systems, which will have the higher boiling point?
  - a. pure water or a 1.0 M NaCl
  - b. 1.0 M NaCl or 1.0 M  $\text{C}_6\text{H}_{12}\text{O}_6$
  - c. 1.0 M  $\text{CaCl}_2$  or 1.0 M  $(\text{NH}_4)_3\text{PO}_4$
4. In each pair of aqueous systems, which will have the higher boiling point?
  - a. 0.50 M  $\text{Ca}(\text{NO}_3)_2$  or 1.0 M KBr
  - b. 1.5 M  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$  or 0.75 M  $\text{Ca}(\text{OH})_2$
  - c. 0.10 M  $\text{Cu}(\text{NO}_3)_2$  or pure water
5. Estimate the boiling point of each aqueous solution. The boiling point of pure water is 100.0°C.
  - a. 0.50 M NaCl
  - b. 1.5 M  $\text{Na}_2\text{SO}_4$
  - c. 2.0 M  $\text{C}_6\text{H}_{12}\text{O}_6$
6. Estimate the freezing point of each aqueous solution. The freezing point of pure water is 0.0°C.
  - a. 0.50 M NaCl
  - b. 1.5 M  $\text{Na}_2\text{SO}_4$
  - c. 2.0 M  $\text{C}_6\text{H}_{12}\text{O}_6$
7. Explain why salt (NaCl) is spread on roads and sidewalks to inhibit ice formation in cold weather.
8. Salt (NaCl) and calcium chloride ( $\text{CaCl}_2$ ) are used widely in some areas to minimize the formation of ice on sidewalks and roads. One of these ionic compounds is better, mole for mole, at inhibiting ice formation. Which is that likely to be? Why?
9. What is the osmolarity of each aqueous solution?
  - a. 0.500 M  $\text{NH}_2\text{CONH}_2$
  - b. 0.500 M NaBr
  - c. 0.500 M  $\text{Ca}(\text{NO}_3)_2$
10. What is the osmolarity of each aqueous solution?
  - a. 0.150 M KCl
  - b. 0.450 M  $(\text{CH}_3)_2\text{CHOH}$
  - c. 0.500 M  $\text{Ca}_3(\text{PO}_4)_2$
11. A 1.0 M solution of an unknown soluble salt has an osmolarity of 3.0 osmol. What can you conclude about the salt?

12. A 1.5 M NaCl solution and a 0.75 M  $\text{Al}(\text{NO}_3)_3$  solution exist on opposite sides of a semipermeable membrane. Determine the osmolarity of each solution and the direction of solvent flow, if any, across the membrane.

### Answers

1.
  - a. 1.0 M NaCl
  - b. 1.0 M NaCl
  - c. 1.0 M  $(\text{NH}_4)_3\text{PO}_4$
2.
  - a. 1.0 M KBr
  - b. 0.75 M  $\text{Ca}(\text{OH})_2$
  - c. 0.10 M  $\text{Cu}(\text{NO}_3)_2$
3.
  - a. 1.0 M NaCl
  - b. 1.0 M NaCl
  - c. 1.0 M  $(\text{NH}_4)_3\text{PO}_4$
4.
  - a. 1.0 M KBr
  - b. 0.75 M  $\text{Ca}(\text{OH})_2$
  - c. 0.10 M  $\text{Cu}(\text{NO}_3)_2$
5.
  - a. 100.5°C
  - b. 102.3°C
  - c. 101°C
6.
  - a. -1.9°C
  - b. -8.6°C
  - c. -3.8°C
7. NaCl lowers the freezing point of water, so it needs to be colder for the water to freeze.
8.  $\text{CaCl}_2$  splits up into 3 ions while NaCl splits up into 2 ions only.  $\text{CaCl}_2$  will be more effective.
9.
  - a. 0.500 osmol
  - b. 1.000 osmol
  - c. 1.500 osmol
10.
  - a. 0.300 osmol
  - b. 0.450 osmol
  - c. 2.50 osmol
11. It must separate into three ions when it dissolves.
12. Both NaCl and  $\text{Al}(\text{NO}_3)_3$  have 3.0 osmol. There will be no net difference in the solvent flow.

## 9.5: Chemical Equilibrium

### Concept Review Exercises

1. What is chemical equilibrium?
2. What does the equilibrium constant tell us?

## Answers

1. The rate of the forward reaction equals the rate of the reverse reaction.
2. The ratio of products and reactants when the system is at equilibrium.

## EXERCISES

1. If the reaction  $\text{H}_2 + \text{I}_2 \rightleftharpoons 2\text{HI}$  is at equilibrium, do the concentrations of HI,  $\text{H}_2$ , and  $\text{I}_2$  have to be equal?
2. Do the concentrations at equilibrium depend upon how the equilibrium was reached?
3. What does it mean if the  $K_{\text{eq}}$  is  $> 1$ ?
4. What does it mean if the  $K_{\text{eq}}$  is  $< 1$ ?
5. Does the equilibrium state depend on the starting concentrations?
6. Write an expression for the equilibrium constant  $K$  equation.
  - a.  $\text{PCl}_5(g) \rightleftharpoons \text{PCl}_3(g) + \text{Cl}_2(g)$
  - b.  $2\text{O}_3(g) \rightleftharpoons 3\text{O}_2(g)$
7. Benzene is one of the compounds used as octane enhancers in unleaded gasoline. It is manufactured by the catalytic conversion of acetylene to benzene:  $3\text{C}_2\text{H}_2(g) \rightarrow \text{C}_6\text{H}_6(g)$ . Which value of  $K$  would make this reaction most useful commercially? Explain your answer.
  - a.  $K \approx 0.01$
  - b.  $K \approx 1$
  - c.  $K \approx 10$ .
8. Tell whether the reactants or the products are favored at equilibrium:
  - a.  $2\text{NH}_3(g) \rightleftharpoons \text{N}_2(g) + 3\text{H}_2(g)$   $K = 172$
  - b.  $2\text{SO}_3(g) \rightleftharpoons 2\text{SO}_2(g) + \text{O}_2(g)$   $K = 0.230$
  - c.  $2\text{NO}(g) + \text{Cl}_2(g) \rightleftharpoons 2\text{NOCl}(g)$   $K = 4.6 \times 10^4$
  - d.  $\text{N}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{NO}(g)$   $K = 0.050$

## Answers

1. No, the concentrations are constant but the concentrations do not have to be equal.
2. No.
3. More products than reactants are present at equilibrium.
4. More reactants than products present at equilibrium.
5. No. The equilibrium ratio does not depend on the initial concentrations.
- 6.

$$\text{a. } K = \frac{[\text{PCl}_3][\text{Cl}_2]}{[\text{PCl}_5]}$$

$$\text{b. } K = \frac{[\text{O}_2]^3}{[\text{O}_3]^2}$$

7. The answer is c.  $K \approx 10$ .

Since  $K = \frac{[\text{C}_6\text{H}_6]^2}{[\text{C}_2\text{H}_2]^3}$  ( $K \approx 10$ ), this means that  $\text{C}_6\text{H}_6$  predominates over  $\text{C}_2\text{H}_2$ . In such a case, the reaction would be commercially feasible if the rate to equilibrium is suitable.

- 8.



- a. products
- b. reactants
- c. products
- d. reactants

## 9.6: Le Chatelier's Principle

### Concept Review Exercises

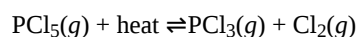
1. Define Le Chatelier's principle.
2. List the three factors types of changes that can disturb the equilibrium of a system.

### Answers

1. Le Chatelier's principle states that a system at equilibrium is disturbed, it will respond in a way to minimize the disturbance.
2. temperature, change in amount of substance, change in pressure through change in volume

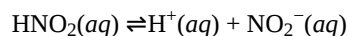
### EXERCISES

1. How will each change affect the reaction?



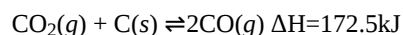
- a. Addition of  $\text{PCl}_5$
- b. Addition of  $\text{Cl}_2$
- c. Removal of  $\text{PCl}_3$
- d. Increasing temperature
- e. Decreasing temperature
- f. Decreasing volume

2. How will each change affect the reaction?



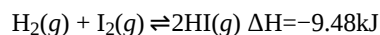
- a. Removal of  $\text{HNO}_2$
- b. Addition of  $\text{HCl}$  (i.e. adding more  $\text{H}^+$ )
- c. Increasing volume
- d. Decreasing volume
- e. Removal of  $\text{NO}_2^-$
- f. Addition of  $\text{OH}^-$  (which will react with and remove  $\text{H}^+$ )

3. How will each change affect the reaction?



- a. Addition of  $\text{CO}_2$
- b. Removal of  $\text{CO}_2$
- c. Increasing temperature
- d. Decreasing temperature
- e. Increasing volume
- f. Addition of  $\text{CO}$

4. How will each change affect the reaction?



- a. Addition of  $\text{H}_2$
- b. Removal of  $\text{H}_2$
- c. Increasing temperature

- d. Decreasing temperature
- e. Increasing volume
- f. Decreasing volume

## Answers

1.
  - a. shift right
  - b. shift left
  - c. shift right
  - d. shift right
  - e. shift left
  - f. shift left
2.
  - a. shift left
  - b. shift left
  - c. no effect
  - d. no effect
  - e. shift right
  - f. shift right
3.
  - a. shift right
  - b. shift left
  - c. shift right
  - d. shift left
  - e. shift right
  - f. shift left
4.
  - a. shift right
  - b. shift left
  - c. shift left
  - d. shift right
  - e. no effect
  - f. no effect

## 9.7: Osmosis and Diffusion

### Concept Review Exercises

1. What are some of the features of a semipermeable membrane?
2. What do the prefixes hyper, hypo, and iso mean?

### Answers

1. A semipermeable membrane allows some substances to pass through but not others.
2. hyper – higher; hypo – lower; iso - same

### EXERCISES

1. Two solutions are separated by a semipermeable membrane. Solution A contains 25.0 g of NaCl in 100.0 mL of water and solution B contains 35.0 g of NaCl in 100.0 mL of water.

- a. Which one has a higher concentration?
  - b. Which way will water molecules flow?
  - c. Which volume will increase?
  - d. Which volume will decrease?
  - e. What will happen to the concentration of solution A?
  - f. What will happen to the concentration of solution B?
2. Two solutions with different concentrations and compositions are separated by a semipermeable membrane. The left-hand solution is a .50 M solution of  $\text{MgSO}_4$ , while the right-hand solution contains  $\text{CaCl}_2$  at a concentration of .40 M. Determine the direction of the flow of solvent, left or right.
3. Given the following situations, wherein two tanks of different solutions are separated by a semipermeable membrane, determine the direction of the flow of solvent (water).
- a. Solution A contains a 0.40 M concentration of  $\text{CaCl}_2$ , while Solution B contains a 0.45 M concentration of KI
  - b. Solution A contains a 1.00 M concentration of  $\text{NH}_4\text{Cl}$ , while Solution B contains a 1.00 M concentration of  $\text{CH}_2\text{O}$
4. Cells are placed in a solution and the cells then undergo hemolysis. What can be said about the relative concentrations of solute in the cell and the solution?
5. Describe the relative concentrations inside and outside a red blood cell when crenation occurs.
6. A saltwater fish is placed in a freshwater tank. What will happen to the fish? Describe the flow of water molecules to explain the outcome.
7. What makes up the "head" region of a phospholipid? Is it hydrophobic or hydrophilic?
8. What makes up the "tail" region of a phospholipid? Is it hydrophobic or hydrophilic?

## Answers

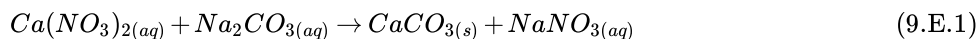
1. Two solutions are separated by a semipermeable membrane. Solution A contains 25.0 g of NaCl in 100.0 mL of water and solution B contains 35.0 g of NaCl in 100.0 mL of water.
- a. Solution B
  - b.  $A \rightarrow B$
  - c. B
  - d. A
  - e. increase
  - f. decrease
2. Water (solvent) flows from left to right.
- 3.
- a. Water flows from Solution B to Solution A.
  - b. Water flows from Solution B to Solution A.
4. Cells contain fluid with higher concentration than solution outside the cell.
5. Cells contain fluid with a lower concentration than the solution outside the cell.
6. Water molecules will flow from the tank water into the fish because the fish has a higher concentration of salt. If the fish absorbs too much water, it will die.
7. The "head" region is a phosphate group and it is hydrophilic.
8. The "tail" is a hydrocarbon tail and it is hydrophobic.

## Contributors

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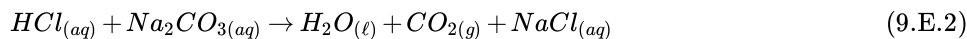
## Additional Exercises

1. Calcium nitrate reacts with sodium carbonate to precipitate solid calcium carbonate:



- Balance the chemical equation.
- How many grams of  $\text{Na}_2\text{CO}_3$  are needed to react with 50.0 mL of 0.450 M  $\text{Ca}(\text{NO}_3)_2$ ?
- Assuming that the  $\text{Na}_2\text{CO}_3$  has a negligible effect on the volume of the solution, find the osmolarity of the  $\text{NaNO}_3$  solution remaining after the  $\text{CaCO}_3$  precipitates from solution.

2. The compound HCl reacts with sodium carbonate to generate carbon dioxide gas:



- Balance the chemical equation.
  - How many grams of  $\text{Na}_2\text{CO}_3$  are needed to react with 250.0 mL of 0.755 M HCl?
  - Assuming that the  $\text{Na}_2\text{CO}_3$  has a negligible effect on the volume of the solution, find the osmolarity of the NaCl solution remaining after the reaction is complete.
- Estimate the freezing point of concentrated aqueous HCl, which is usually sold as a 12 M solution. Assume complete ionization into  $\text{H}^+$  and  $\text{Cl}^-$  ions.
  - Estimate the boiling point of concentrated aqueous  $\text{H}_2\text{SO}_4$ , which is usually sold as an 18 M solution. Assume complete ionization into  $\text{H}^+$  and  $\text{HSO}_4^-$  ions.
  - Seawater can be approximated by a 3.0% m/m solution of NaCl in water. Determine the molarity and osmolarity of seawater. Assume a density of 1.0 g/mL.
  - Human blood can be approximated by a 0.90% m/m solution of NaCl in water. Determine the molarity and osmolarity of blood. Assume a density of 1.0 g/mL.
  - How much water must be added to 25.0 mL of a 1.00 M NaCl solution to make a resulting solution that has a concentration of 0.250 M?
  - Sports drinks like Gatorade are advertised as capable of resupplying the body with electrolytes lost by vigorous exercise. Find a label from a sports drink container and identify the electrolytes it contains. You should be able to identify several simple ionic compounds in the ingredients list.
  - Occasionally we hear a sensational news story about people stranded in a lifeboat on the ocean who had to drink their own urine to survive. While distasteful, this act was probably necessary for survival. Why not simply drink the ocean water? (Hint: See Exercise 5 and Exercise 6 above. What would happen if the two solutions in these exercises were on opposite sides of a semipermeable membrane, as we would find in our cell walls?)

## Answers

1.

- $\text{Ca}(\text{NO}_3)_2(\text{aq}) + \text{Na}_2\text{CO}_3(\text{aq}) \rightarrow \text{CaCO}_3(\text{s}) + 2\text{NaNO}_3(\text{aq})$
- 2.39 g
- 1.80 osmol

2.

- $2\text{HCl}(\text{aq}) + \text{Na}_2\text{CO}_3(\text{aq}) \rightarrow \text{H}_2\text{O}(\ell) + \text{CO}_2(\text{g}) + 2\text{NaCl}(\text{aq})$
- 10.0 g
- 1.51 M

3.  $-45.6^{\circ}\text{C}$
4.  $118^{\circ}\text{C}$
5. 0.513 M; 1.026 osmol
6. molarity = 0.15 M; osmolarity = 0.31 M
7. 75.0 mL
8. magnesium chloride, calcium chloride (answers may vary)
9. The osmotic pressure of seawater is too high. Drinking seawater would cause water to go from inside our cells into the more concentrated seawater, ultimately killing the cells.

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