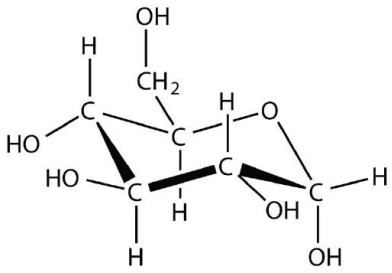
11.E: Solutions (Exercises)

Exercises (Definitions)

1. Define *solute* and *solvent*.
2. Define *saturated*, *unsaturated*, and *supersaturated*.
3. A solution is prepared by combining 2.09 g of CO_2 and 35.5 g of H_2O. Identify the solute and solvent.
4. A solution is prepared by combining 10.3 g of Hg(ℓ) and 45.0 g of Ag(s). Identify the solute and solvent.
5. Use Table 11.2.1 - Solubilities of Some Ionic Compounds, to decide if a solution containing 45.0 g of NaCl per 100 g of H_2O is unsaturated, saturated, or supersaturated.
6. Use Table 11.2.1 - Solubilities of Some Ionic Compounds, to decide if a solution containing 0.000092 g of AgCl per 100 g of H_2O is unsaturated, saturated, or supersaturated.
7. Would the solution in Exercise 5 be described as dilute or concentrated? Explain your answer.
8. Would the solution in Exercise 6 be described as dilute or concentrated? Explain your answer.
9. Identify a solute from Table 11.2.1 - Solubilities of Some Ionic Compounds, whose saturated solution can be described as dilute.
10. Identify a solute from Table 11.2.1 - Solubilities of Some Ionic Compounds, whose saturated solution can be described as concentrated.
11. Which solvent is Br_2 more likely soluble in—CH_3OH or C_6H_6?
12. Which solvent is NaOH more likely soluble in—CH_3OH or C_6H_6?
13. Compounds with the formula $C_nH_{2n+1}OH$ are soluble in H_2O when n is small but not when n is large. Suggest an explanation for this phenomenon.
14. Glucose has the following structure:



What parts of the molecule indicate that this substance is soluble in water?

Answers

1. The solvent is the majority component of a solution, whereas the solute is the minority component of a solution.
3. solute: CO_2; solvent: H_2O
5. supersaturated
7. concentrated because there is a lot of solute
9. AgCl or $CaCO_3$
11. C_6H_6
13. The nonpolar end dominates intermolecular forces when n is large.

Exercises (Quantitative Units of Concentration)

1. Differentiate between molarity and molality.

2. Differentiate between mass percentage and parts per thousand.

3. What is the molarity of a solution made by dissolving $13.4\ \text{g}$ of NaNO_3 in $345\ \text{mL}$ of solution?

4. What is the molarity of a solution made by dissolving $332\ \text{g}$ of $\text{C}_6\text{H}_{12}\text{O}_6$ in $4.66\ \text{L}$ of solution?

5. How many moles of MgCl_2 are present in $0.0331\ \text{L}$ of a 2.55M solution?

6. How many moles of NH_4Br are present in $88.9\ \text{mL}$ of a 0.228M solution?

7. What volume of $0.556\text{M}\ \text{NaCl}$ is needed to obtain $0.882\ \text{mol}$ of NaCl?

8. What volume of $3.99\text{M}\ \text{H}_2\text{SO}_4$ is needed to obtain $4.61\ \text{mol}$ of H_2SO_4?

9. What volume of $0.333\text{M}\ \text{Al(NO}_3)_3$ is needed to obtain $26.7\ \text{g}$ of $\text{Al(NO}_3)_3$?

10. What volume of $1.772\text{M}\ \text{BaCl}_2$ is needed to obtain $123\ \text{g}$ of BaCl_2?

11. What are the individual ion concentrations and the total ion concentration in $0.66\text{M}\ \text{Mg(NO}_3)_2$?

12. What are the individual ion concentrations and the total ion concentration in $1.04\text{M}\ \text{Al}_2\text{(SO}_4)_3$?

13. If the $\text{C}_2\text{H}_3\text{O}_2{}^-$ ion concentration in a solution is 0.554M, what is the concentration of $\text{Ca(C}_2\text{H}_3\text{O}_2)_2$?

14. If the Cl^- ion concentration in a solution is 2.61M, what is the concentration of FeCl_3?

Answers

1. Molarity is moles per liter, whereas molality is moles per kilogram of solvent.

3. 0.457M

5. $0.0844\ \text{mol}$

7. $1.59\ \text{L}$

9. $0.376\ \text{L}$

11. $\text{Mg}^{2+} = 0.66\text{M}$; $\text{NO}_3{}^- = 1.32\text{M}$; total: 1.98M

13. 0.277M

Exercises (Dilutions and Concentrations)

1. What is the difference between dilution and concentration?

2. What quantity remains constant when you dilute a solution?

3. A 1.88 M solution of NaCl has an initial volume of 34.5 mL. What is the final concentration of the solution if it is diluted to 134 mL?

4. A 0.664 M solution of NaCl has an initial volume of 2.55 L. What is the final concentration of the solution if it is diluted to 3.88 L?

5. If 1.00 mL of a 2.25 M H_2SO_4 solution needs to be diluted to 1.00 M, what will be its final volume?

6. If 12.00 L of a 6.00 M HNO_3 solution needs to be diluted to 0.750 M, what will be its final volume?

7. If 665 mL of a 0.875 M KBr solution are boiled gently to concentrate the solute to 1.45 M, what will be its final volume?

8. If 1.00 L of an LiOH solution is boiled down to 164 mL and its initial concentration is 0.00555 M, what is its final concentration?

9. How much water must be added to 75.0 mL of 0.332 M $FeCl_3(aq)$ to reduce its concentration to 0.250 M?

10. How much water must be added to 1.55 L of 1.65 M $Sc(NO_3)_3(aq)$ to reduce its concentration to 1.00 M?

Answers

1. Dilution is a decrease in a solution's concentration, whereas concentration is an increase in a solution's concentration.

3. 0.484 M

5. 2.25 mL

7. 401 mL

9. 24.6 mL

Exercises (Concentrations as Conversion Factors)

1. Using concentration as a conversion factor, how many moles of solute are in 3.44 L of 0.753 M $CaCl_2$?
2. Using concentration as a conversion factor, how many moles of solute are in 844 mL of 2.09 M $MgSO_4$?
3. Using concentration as a conversion factor, how many liters are needed to provide 0.822 mol of NaBr from a 0.665 M solution?
4. Using concentration as a conversion factor, how many liters are needed to provide 2.500 mol of $(NH_2)_2CO$ from a 1.087 M solution?
5. What is the mass of solute in 24.5 mL of 0.755 M $CoCl_2$?
6. What is the mass of solute in 3.81 L of 0.0232 M $Zn(NO_3)_2$?
7. What volume of solution is needed to provide 9.04 g of NiF_2 from a 0.332 M solution?
8. What volume of solution is needed to provide 0.229 g of CH_2O from a 0.00560 M solution?
9. What volume of 3.44 M HCl will react with 5.33 mol of $CaCO_3$?

   $2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$
10. What volume of 0.779 M NaCl will react with 40.8 mol of $Pb(NO_3)_2$?

    $Pb(NO_3)_2 + 2NaCl \rightarrow PbCl_2 + 2NaNO_3$
11. What volume of 0.905 M H_2SO_4 will react with 26.7 mL of 0.554 M NaOH?

    $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$
12. What volume of 1.000 M Na_2CO_3 will react with 342 mL of 0.733 M H_3PO_4?

    $3Na_2CO_3 + 2H_3PO_4 \rightarrow 2Na_3PO_4 + 3H_2O + 3CO_2$
13. It takes 23.77 mL of 0.1505 M HCl to titrate with 15.00 mL of $Ca(OH)_2$. What is the concentration of $Ca(OH)_2$? You will need to write the balanced chemical equation first.

14. It takes 97.62 mL of 0.0546 M NaOH to titrate a 25.00 mL sample of H_2SO_4. What is the concentration of H_2SO_4? You will need to write the balanced chemical equation first.
15. It takes 4.667 mL of 0.0997 M HNO_3 to dissolve some solid Cu. What mass of Cu can be dissolved?

    $Cu + 4HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2NO_2 + 2H_2O$
16. It takes 49.08 mL of 0.877 M NH_3 to dissolve some solid AgCl. What mass of AgCl can be dissolved?

    $AgCl(s) + 4NH_3(aq) \rightarrow Ag(NH_3)_4Cl(aq)$
17. What mass of 3.00% H_2O_2 is needed to produce 66.3 g of $O_2(g)$?

    $2H_2O_2(aq) \rightarrow 2H_2O(\ell) + O_2(g)$
18. A 0.75% solution of Na_2CO_3 is used to precipitate Ca^{2+} ions from solution. What mass of solution is needed to precipitate 40.7 L of solution with a concentration of 0.0225 M $Ca^{2+}(aq)$?

    $Na_2CO_3(aq) + Ca^{2+}(aq) \rightarrow CaCO_3(s) + 2Na^+(aq)$

Answers

1. 2.59 mol
3. 1.24 L
5. 2.40 g
7. 0.282 L
9. 3.10 L
11. 8.17 mL
13. 0.1192 M
15. 7.39 mg
17. 4.70 kg

Exercises (Colligative Properties of Solutions)

1. What are the three colligative properties that involve phase changes?
2. Which colligative property does not involve a phase change? Give an example of its importance.
3. If 45.0 g of C_6H_6 and 60.0 g of $C_6H_5CH_3$ are mixed together, what is the mole fraction of each component?
4. If 125 g of N_2 are mixed with 175 g of O_2, what is the mole fraction of each component?
5. If 36.5 g of NaCl are mixed with 63.5 g of H_2O, what is the mole fraction of each component?
6. An alloy of stainless steel is prepared from 75.4 g of Fe, 12.6 g of Cr, and 10.8 g of C. What is the mole fraction of each component?
7. A solution is made by mixing 12.0 g of $C_{10}H_8$ in 45.0 g of C_6H_6. If the vapor pressure of pure C_6H_6 is 76.5 torr at a particular temperature, what is the vapor pressure of the solution at the same temperature?
8. A solution is made by mixing 43.9 g of $C_6H_{12}C_6$ in 100.0 g of H_2O. If the vapor pressure of pure water is 26.5 torr at a particular temperature, what is the vapor pressure of the solution at the same temperature?
9. At 300°C, the vapor pressure of Hg is 32.97 torr. If 0.775 g of Au were dissolved into 3.77 g of Hg, what would be the vapor pressure of the solution?
10. At 300°C, the vapor pressure of Hg is 32.97 torr. What mass of Au would have to be dissolved in 5.00 g of Hg to lower its vapor pressure to 25.00 torr?
11. If 25.0 g of $C_6H_{12}O_6$ are dissolved in 100.0 g of H_2O, what is the boiling point of this solution?
12. If 123 g of $C_{10}H_{16}O$ are dissolved in 355 g of C_6H_6, what is the boiling point of this solution?
13. If 1 mol of solid CBr_4 is mixed with 2 mol of CCl_4, what is the boiling point of this solution?

14. A solution of $C_2H_2O_4$ in CH_3COOH has a boiling point of 123.40°C. What is the molality of the solution?
15. If 123 g of $C_{10}H_{16}O$ are dissolved in 355 g of C_6H_6, what is the freezing point of this solution?
16. If 25.0 g of $C_6H_{12}O_6$ are dissolved in 100.0 g of H_2O, what is the freezing point of this solution?
17. $C_8H_{17}OH$ is a nonvolatile solid that dissolves in C_6H_{12}. If 7.22 g of $C_8H_{17}OH$ is dissolved in 45.3 g of C_6H_{12}, what is the freezing point of this solution?
18. A solution of $C_2H_2O_4$ in CH_3COOH has a freezing point of 10.00°C. What is the molality of the solution?
19. If 25.0 g of $C_6H_{12}O_6$ are dissolved in H_2O to make 0.100 L of solution, what is the osmotic pressure of this solution at 25°C?
20. If 2.33 g of $C_{27}H_{46}O$ are dissolved in liquid CS_2 to make 50.00 mL of solution, what is the osmotic pressure of this solution at 298 K?
21. At 298 K, what concentration of solution is needed to have an osmotic pressure of 1.00 atm?
22. The osmotic pressure of blood is about 7.65 atm at 37°C. What is the approximate concentration of dissolved solutes in blood? (There are many different solutes in blood, so the answer is indeed an approximation.)

Answers

1. boiling point elevation, freezing point depression, vapor pressure depression
3. mole fraction C_6H_6: 0.469; mole fraction $C_6H_5CH_3$: 0.531
5. mole fraction NaCl: 0.157; mole fraction H_2O: 0.843
7. 65.8 torr
9. 27.26 torr
11. 100.71°C
13. 92.9°C
15. −5.65°C
17. −18.3°C
19. 33.9 atm
21. 0.0409 M

Exercises (Colligative Properties of Ionic Solutes)

1. Explain why we need to consider a van't Hoff factor for ionic solutes but not for molecular solutes.

2. NaCl is often used in winter to melt ice on roads and sidewalks, but calcium chloride $(CaCl_2)$ is also used. Which would be better (on a mole-by-mole basis), and why?

3. Calculate the boiling point of an aqueous solution of $NaNO_3$ made by mixing $15.6\ g$ of $NaNO_3$ with $100.0\ g$ of H_2O. Assume an ideal van't Hoff factor.

4. Many labs use a cleaning solution of KOH dissolved in C_2H_5OH. If $34.7\ g$ of KOH were dissolved in $88.0\ g$ of C_2H_5OH, what is the boiling point of this solution? The normal boiling point of C_2H_5OH is $78.4^\circ C$ and its $Kb = 1.19^\circ C/m$. Assume an ideal van't Hoff factor. $1,550\ g$ of H_2O ? Assume an ideal van't Hoff factor.

5. What is the freezing point of a solution made by dissolving $345\ g of CaCl_2$ in $1,550\ g$ of H_2O ? Assume an ideal van't Hoff factor.

6. A classic homemade ice cream can be made by freezing the ice cream mixture using a solution of $250\ g$ of $NaCl$ dissolved in $1.25\ kg$ of ice water. What is the temperature of this ice water? Assume an ideal van't Hoff factor.

7. Seawater can be approximated as a $3.5\% NaCl solution$ by mass; that is, $3.5\ g$ of $NaCl$ are combined with $96.5\ g H_2O$. What is

the osmotic pressure of seawater? Assume an ideal van't Hoff factor.

8. The osmotic pressure of blood is $7.65\ \text{atm}$ at 37°C. If blood were considered a solution of NaCl, what is the molar concentration of NaCl in blood? Assume an ideal van't Hoff factor.

9. What is the vapor pressure of an aqueous solution of $36.4\ \text{g}$ of KBr in $199.5\ \text{g}$ of H_2O if the vapor pressure of H_2O at the same temperature is 32.55 torr? What other solute(s) would give a solution with the same vapor pressure? Assume an ideal van't Hoff factor.

10. Assuming an ideal van't Hoff factor, what mole fraction is required for a solution of $\text{Mg}(\text{NO}_3)_2$ to have a vapor pressure of 20.00 torr at 25.0°C ? The vapor pressure of the solvent is 23.61 torr at this temperature.

Answers

1. Ionic solutes separate into more than one particle when they dissolve, whereas molecular solutes do not.

3. 101.9°C

5. -7.5°C

7. $30.3\ \text{atm}$

9. 30.86 torr; any two-ion salt should have the same effect.

Additional Exercises

1. One brand of ethyl alcohol (Everclear) is 95% ethyl alcohol, with the remaining 5% being water. What is the solvent and what is the solute of this solution?

2. Give an example of each type of solution from your own experience.

   a. A solution composed of a gas solute in a liquid solvent.
   b. A solution composed of a solid solute in a liquid solvent.
   c. A solution composed of a liquid solute in a liquid solvent.
   d. A solution composed of a solid solute in a solid solvent. (Hint: usually such solutions are made as liquids and then solidified.)

3. Differentiate between the terms saturated and concentrated.

4. Differentiate between the terms unsaturated and dilute.

5. What mass of FeCl_2 is present in $445\ \text{mL}$ of $0.0812\text{M}\ \text{FeCl}_2$ solution?

6. What mass of SO_2 is present in $26.8\ \text{L}$ of $1.22\text{M}\ \text{SO}_2$ solution?

7. What volume of $0.225\text{M}\ \text{Ca}(\text{OH})_2$ solution is needed to deliver $100.0\ \text{g}$ of $\text{Ca}(\text{OH})_2$?

8. What volume of $12.0\text{M}\ \text{HCl}$ solution is needed to obtain exactly $1.000\ \text{kg}$ of HCl ?

9. The World Health Organization recommends that the maximum fluoride ion concentration in drinking water is 1.0ppm. Assuming water has the maximum concentration, if an average person drinks $1,920\ \text{mL}$ of water per day, how many milligrams of fluoride ion are being ingested?

10. For sanitary reasons, water in pools should be chlorinated to a maximum level of 3.0ppm. In a typical 5,000 gal pool that contains $21,200\ \text{kg}$ of water, what mass of chlorine must be added to obtain this concentration?

11. Given its notoriety, you might think that uranium is very rare, but it is present at about 2-4 ppm of the earth's crust, which is more abundant than silver or mercury. If the earth's crust is estimated to have a mass of 8.50×10^{20} kg, what range of mass is thought to be uranium in the crust?

12. Chromium is thought to be an ultratrace element, with about 8.9ng present in a human body. If the average body mass is 75.0 kg, what is the concentration of chromium in the body in pptr?

13. What mass of $3.00\%\mathrm{H_2O_2}$ solution is needed to produce 35.7 g of $\mathrm{O_2(\,g)}$ at 295 K at 1.05 atm pressure?

$$2\mathrm{H_2O_2(aq)} \rightarrow 2\mathrm{H_2O}(\ell) + \mathrm{O_2(\,g)} \tag{11.E.1}$$

14. What volume of pool water is needed to generate 1.000 L$\mathrm{of^2_{Cl}(\,g)}$ at standard temperature and pressure if the pool contains 4.0ppmHOCl and the water is slightly acidic? The chemical reaction is as follows:

$$\mathrm{HOCl(aq) + HCl(aq) \rightarrow H_2O}(\ell) + \mathrm{Cl_2(\,g)} \tag{11.E.2}$$

Assume the pool water has a density of 1.00 g/mL.

15. A 0.500 m solution of $\mathrm{MgCl_2}$ has a freezing point of -2.60°C. What is the true van't Hoff factor of this ionic compound? Why is it less than the ideal value?

16. The osmotic pressure of a 0.050MLiCl solution at 25.0°C is 2.26 atm. What is the true van't Hoff factor of this ionic compound? Why is it less than the ideal value?

17. Order these solutions in order of increasing boiling point, assuming an ideal van't Hoff factor for each: 0.10 m$\mathrm{C_6H_{12}O_6}$, 0.06 mNaCl, 0.4 m$\mathrm{Au(NO_3)_3}$ and 0.4 m$\mathrm{Al_2(SO_4)_3}$.

18. Order these solutions in order of decreasing osmotic pressure, assuming an ideal van't Hoff factor: 0.1MHCl, 0.1M$\mathrm{CaCl_2}$, 0.05M$\mathrm{MgBr_2}$ and 0.07M $\mathrm{Ga(C_2H_3O_2)_3}$

Answers

1. solvent: ethyl alcohol; solute: water

3. Saturated means all the possible solute that can dissolve is dissolved, whereas concentrated implies that a lot of solute is dissolved.

5. 4.58 g

7. 6.00 L

9. 1.92mg

11. 1.7×10^{15} to 3.4×10^{15} kg

13. $2,530$ g

15. 2.80 ; it is less than 3 because not all ions behave as independent particles.

17. $0.10m\mathrm{C_6H_{12}O_6} < 0.06m\mathrm{NaCl} < 0.4m\mathrm{Au(NO_3)_3} < 0.4m\mathrm{Al_2(SO_4)_3}$