

9.E: Solutions (Exercises)

The following questions are related to the material covered in this chapter. For additional discussion on each topic, also check the links included in each heading.

Solubility

- Which of the following are likely to dissolve in water?
 - A polar molecule with hydrogen bonding
 - A non-polar molecule
 - An ionic compound
- Which of the following ionic compounds would you expect to dissolve in water?
 - NaCl
 - BaCO₃
 - Al₂S₃
 - Al(NO₃)₃
 - (NH₄)₃PO₄
- Classify each of the following as strong electrolyte, weak electrolyte, or non-electrolyte
 - NaCl
 - HCl
 - NaOH
 - CH₃OH
 - HC₂H₃O₂
- A solution of SrCl₂ is 0.664 M. What are the molarities of Sr²⁺ and Cl⁻ in this solution?

Answers

- a. Dissolves in water, b. Does not dissolve in water, c. Maybe, see solubility rules
- NaCl, Al(NO₃)₃, (NH₄)₃PO₄
- NaCl = strong, HCl = strong, NaOH = strong, CH₃OH = non-electrolyte, HC₂H₃O₂ = weak electrolyte
- 0.664 M Sr²⁺, 1.33 M Cl⁻

Dilutions and Concentrations

- What is the difference between dilution and concentration?
- What quantity remains constant when you dilute a solution?
- 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?
- 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?
- If 1.00 mL of a 2.25 M H₂SO₄ solution needs to be diluted to 1.00 M, what will be its final volume?
- If 12.00 L of a 6.00 M HNO₃ solution needs to be diluted to 0.750 M, what will be its final volume?
- 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?
- 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?
- How much water must be added to 75.0 mL of 0.332 M FeCl₃(aq) to reduce its concentration to 0.250 M?
- How much water must be added to 1.55 L of 1.65 M Sc(NO₃)₃(aq) to reduce its concentration to 1.00 M?

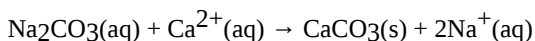
Answers

- Dilution is a decrease in a solution's concentration, whereas concentration is an increase in a solution's concentration.
-
- 0.484 M

- 4.
5. 2.25 mL
- 6.
7. 401 mL
- 8.
9. 24.6 mL

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 $(\text{NH}_2)_2\text{CO}$ 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 $\text{Zn}(\text{NO}_3)_2$?
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 ? $2\text{HCl} + \text{CaCO}_3 \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$
10. What volume of 0.779 M NaCl will react with 40.8 mol of $\text{Pb}(\text{NO}_3)_2$? $\text{Pb}(\text{NO}_3)_2 + 2\text{NaCl} \rightarrow \text{PbCl}_2 + 2\text{NaNO}_3$
11. What volume of 0.905 M H_2SO_4 will react with 26.7 mL of 0.554 M NaOH? $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$
12. What volume of 1.000 M Na_2CO_3 will react with 342 mL of 0.733 M H_3PO_4 ? $3\text{Na}_2\text{CO}_3 + 2\text{H}_3\text{PO}_4 \rightarrow 2\text{Na}_3\text{PO}_4 + 3\text{H}_2\text{O} + 3\text{CO}_2$
13. It takes 23.77 mL of 0.1505 M HCl to titrate with 15.00 mL of $\text{Ca}(\text{OH})_2$. What is the concentration of $\text{Ca}(\text{OH})_2$? 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? $\text{Cu} + 4\text{HNO}_3(\text{aq}) \rightarrow \text{Cu}(\text{NO}_3)_2(\text{aq}) + 2\text{NO}_2 + 2\text{H}_2\text{O}$
16. It takes 49.08 mL of 0.877 M NH_3 to dissolve some solid AgCl. What mass of AgCl can be dissolved? $\text{AgCl}(\text{s}) + 4\text{NH}_3(\text{aq}) \rightarrow \text{Ag}(\text{NH}_3)_4\text{Cl}(\text{aq})$
17. What mass of 3.00% H_2O_2 is needed to produce 66.3 g of $\text{O}_2(\text{g})$? $2\text{H}_2\text{O}_2(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g})$
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 $\text{Ca}^{2+}(\text{aq})$?



Answers

1. 2.59 mol
- 2.
3. 1.24 L
- 4.
5. 2.40 g
- 6.
7. 0.282 L
- 8.
9. 3.10 L
- 10.
11. 8.17 mL
- 12.
13. 0.1192 M
- 14.
15. 7.39 mg
- 16.

17. 4.70 kg

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 $\text{C}_6\text{H}_5\text{CH}_3$ 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 $\text{C}_6\text{H}_{12}\text{C}_6$ 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?

*For the following problems, you will want to access [table 9.5.1](#).

11. If 25.0 g of $\text{C}_6\text{H}_{12}\text{O}_6$ are dissolved in 0.100 kg of H_2O , what is the boiling point of this solution?
12. If 123 g of $\text{C}_{10}\text{H}_{16}\text{O}$ 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 $\text{C}_2\text{H}_2\text{O}_4$ in CH_3COOH has a boiling point of 123.40°C . What is the molality of the solution?
15. If 0.808 mol of $\text{C}_{10}\text{H}_{16}\text{O}$ are dissolved in 0.355 kg of C_6H_6 , what is the freezing point of this solution?
16. If 25.0 g of $\text{C}_6\text{H}_{12}\text{O}_6$ are dissolved in 100.0 g of H_2O , what is the freezing point of this solution?
17. $\text{C}_8\text{H}_{17}\text{OH}$ is a nonvolatile solid that dissolves in C_6H_{12} . If 7.22 g of $\text{C}_8\text{H}_{17}\text{OH}$ is dissolved in 45.3 g of C_6H_{12} , what is the freezing point of this solution?
18. A solution of $\text{C}_2\text{H}_2\text{O}_4$ in CH_3COOH has a freezing point of 10.00°C . What is the molality of the solution?
19. If 25.0 g of $\text{C}_6\text{H}_{12}\text{O}_6$ 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 $\text{C}_{27}\text{H}_{46}\text{O}$ 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
- 2.
3. mole fraction C_6H_6 : 0.469; mole fraction $\text{C}_6\text{H}_5\text{CH}_3$: 0.531
- 4.
5. mole fraction NaCl : 0.157; mole fraction H_2O : 0.843
- 6.
7. 65.8 torr
- 8.
9. 27.26 torr
- 10.
11. 100.71°C
- 12.
13. 92.9°C
- 14.
15. -6.11°C

- 16.
17. -18.3°C
- 18.
19. 33.9 atm
- 20.
21. 0.0409 M

? 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 mL of 0.0812 M FeCl_2 solution?
6. What mass of SO_2 is present in 26.8 L of 1.22 M SO_2 solution?
7. What volume of 0.225 M Ca(OH)_2 solution is needed to deliver 100.0 g of Ca(OH)_2 ?
8. What volume of 12.0 M HCl solution is needed to obtain exactly 1.000 kg of HCl?
9. The World Health Organization recommends that the maximum fluoride ion concentration in drinking water is 1.0 ppm. Assuming water has the maximum concentration, if an average person drinks 1,920 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 3.0 ppm. In a typical 5,000 gal pool that contains 21,200 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 8.9 ng present in a human body. If the average body mass is 75.0 kg, what is the concentration of chromium in the body in ppb?
13. What mass of 3.00% H_2O_2 solution is needed to produce 35.7 g of $\text{O}_2(\text{g})$ at 295 K at 1.05 atm pressure?
$$2\text{H}_2\text{O}_2(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\ell) + \text{O}_2(\text{g})$$
14. What volume of pool water is needed to generate 1.000 L of $\text{Cl}_2(\text{g})$ at standard temperature and pressure if the pool contains 4.0 ppm HOCl and the water is slightly acidic? The chemical reaction is as follows:
$$\text{HOCl}(\text{aq}) + \text{HCl}(\text{aq}) \rightarrow \text{H}_2\text{O}(\ell) + \text{Cl}_2(\text{g})$$
Assume the pool water has a density of 1.00 g/mL.
15. A 0.500 m solution of 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 0.050 M LiCl 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 $\text{C}_6\text{H}_{12}\text{O}_6$, 0.06 m NaCl, 0.4 m $\text{Au(NO}_3)_3$, and 0.4 m $\text{Al}_2(\text{SO}_4)_3$.

18. Order these solutions in order of decreasing osmotic pressure, assuming an ideal van 't Hoff factor: 0.1 M HCl, 0.1 M CaCl_2 , 0.05 M MgBr_2 , and 0.07 M $\text{Ga}(\text{C}_2\text{H}_3\text{O}_2)_3$

? Answers

1. solvent: ethyl alcohol; solute: water
- 2.
3. Saturated means all the possible solute that can dissolve is dissolved, whereas concentrated implies that a lot of solute is dissolved.
- 4.
5. 4.58 g
- 6.
7. 6.00 L
- 8.
9. 1.92 mg
- 10.
11. 1.7×10^{15} to 3.4×10^{15} kg
- 12.
13. 2,530 g
- 14.
15. 2.80; it is less than 3 because not all ions behave as independent particles.
- 16.
17. $0.10\text{ m C}_6\text{H}_{12}\text{O}_6 < 0.06\text{ m NaCl} < 0.4\text{ m Au}(\text{NO}_3)_3 < 0.4\text{ m Al}_2(\text{SO}_4)_3$

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