CHAPTER 9 Review

Reflecting on Chapter 9

Summarize this chapter in the format of your choice. Here are a few ideas to use as guidelines:

- Predict combinations of aqueous solutions that result in the formation of precipitates.
- Describe your experiences with a qualitative analysis of ions in solution.
- Represent a double-displacement reaction using its net ionic equation.
- Write balanced chemical equations and net ionic equations for double-displacement reactions.
- Apply your understanding of stoichiometry to solve quantitative problems involving solutions.
- Identify the origins of pollutants in drinking water, and the allowed concentrations of some of these pollutants.
- Examine the causes and effects of water hardness. Considered several methods for softening hard water.
- Compare the chemistry and the technology of water treatment and waste-water treatment.

Reviewing Key Terms

For each of the following terms, write a sentence that shows your understanding of its meaning.

general solubility guidelines
hard water
ion exchange
net ionic equation
precipitate
qualitative analysis
soft water
spectator ions
total ionic equation
waste-water treatment
water treatment

Knowledge/Understanding

1. In your own words, define the terms "spectator ion" and "net ionic equation."

2. Identify the spectator ions in the following skeleton equation. Then write the balanced ionic equation for the reaction.

$$Al(NO_3)_{3(aq)} + NH_4OH_{(aq)} \rightarrow Al(OH)_{3(s)} + NH_4NO_{3(aq)}$$

3. Hydrogen sulfide gas can be prepared by the reaction of sulfuric acid with sodium sulfide.

$$H_2SO_{4(aq)} + Na_2S_{(aq)} \rightarrow H_2S_{(g)} + Na_2SO_{4(aq)}$$

Write the net ionic equation for this reaction.

4. Each of the following combinations of reagents results in a double displacement reaction. In your notebook, complete the chemical equation. Then identify the spectator ions, and write the net ionic equation.

(a) copper(II) chloride$_{(aq)}$ + ammonium phosphate$_{(aq)}$ →

(b) aluminum nitrate$_{(aq)}$ + barium hydroxide$_{(aq)}$ →

(c) sodium hydroxide$_{(aq)}$ + magnesium chloride$_{(aq)}$ →

5. Use the general solubility guidelines to name three reagents that will combine with each ion below to form a precipitate. Assume that the reactions take place in aqueous solution. For each reaction, write the net ionic equation.

(a) bromide ion

(b) carbonate ion

(c) lead(II) ion

(d) iron(III) ion

6. The transition metals form insoluble sulfides, often with a characteristic colour. Write the net ionic equation for the precipitation of each ion by the addition of an aqueous solution of sodium sulfide.

(a) $Cr^{3+}_{(aq)}$ (**Note:** $Cr_2S_{3(s)}$ is brown-black.)

(b) $Ni^{2+}_{(aq)}$ (**Note:** $NiS_{(s)}$ is black.)

(c) $Mn^{4+}_{(aq)}$ (**Note:** $MnS_{2(s)}$ is green or red, depending on the arrangement of ions in the solid.)

7. Identify three cations and three anions that are commonly found in ground water. Suggest at least one likely source for each.

8. Briefly describe two steps in the primary treatment of waste water, one involving a physical change and the other involving a chemical change.

9. (a) Many liquid antacids contain magnesium hydroxide, $Mg(OH)_2$. Why must the bottle be shaken before a dose is poured?

(b) Stomach acid contains hydrochloric acid. Excess acid that backs up into the esophagus is the cause of "heartburn." Write the chemical equation and the net ionic equation for the reaction that takes place when someone with heartburn swallows a dose of liquid antacid.

10. Aqueous solutions of iron(III) chloride and ammonium sulfide react in a double displacement reaction.
    (a) Write the name and formula of the substance that precipitates.
    (b) Write the chemical equation for the reaction.
    (c) Write the net ionic equation.

Inquiry

11. A reference book states that the solubility of silver sulfate is 0.57 g in 100 mL of cold water. You decide to check this by measuring the mass of a silver salt precipitated from a known volume of saturated silver sulfate solution. Solubility data show that silver chloride is much less soluble than silver nitrate. Explain why you should not use barium chloride to precipitate the silver ions. Suggest a different reagent, and write the net ionic equation for the reaction.
12. The presence of copper(II) ions in solution can be tested by adding an aqueous solution of sodium sulfide. The appearance of a black precipitate indicates that the test is positive. A solution of copper(II) bromide is tested this way. What precipitate is formed? Write the net ionic equation for the reaction.
13. An old home-gardening "recipe" for fertilizer suggests adding 15 g of Epsom salts (magnesium sulfate heptahydrate, $MgSO_4 \cdot 7H_2O$) to 4 L of water. What will be the concentration of magnesium ions?
14. Calculate the concentration (in mol/L) of each aqueous solution.
    (a) 7.37 g of table sugar, $C_{12}H_{22}O_{11}$, dissolved in 125 mL of solution
    (b) 15.5 g of ammonium phosphate, $(NH_4)_3PO_4$, dissolved in 180 mL of solution
    (c) 76.7 g of glycerol, $C_3H_8O_3$, dissolved in 1.20 L of solution
15. 50.0 mL of 0.200 mol/L $Ca(NO_3)_{2(aq)}$ is mixed with 200 mL of 0.180 mol/L $K_2SO_{4(aq)}$. What is the concentration of sulfate ions in the final solution?
16. Suppose that 1.00 L of 0.200 mol/L $KNO_{3(aq)}$ is mixed with 2.00 L of 0.100 mol/L $Ca(NO_3)_{2(aq)}$. Determine the concentrations of the major ions in the solution.
17. Equal masses of each of the following salts are dissolved in equal volumes of water: sodium chloride, calcium chloride, and iron(III) chloride. Which salt produces the largest concentration of chloride ions?
18. Imagine that you are the chemist at a cement factory. You are responsible for analyzing the factory's waste water. If a 50.0 mL sample of waste water contains 0.090 g of $Ca^{2+}_{(aq)}$ and 0.029 g of $Mg^{2+}_{(aq)}$, calculate
    (a) the concentration of each ion in mol/L
    (b) the concentration of each ion in ppm
19. The concentration of calcium ions, Ca^{2+}, in blood plasma is about 2.5×10^{-3} mol/L. Calcium ions are important in muscle contraction and in regulating heartbeat. If the concentration of calcium ions falls too low, death is inevitable. In a television drama, a patient is brought to hospital after being accidentally splashed with hydrofluoric acid. The acid readily penetrates the skin, and the fluoride ions combine with the calcium ions in the blood. If the patient's volume of blood plasma is 2.8 L, what amount (in mol) of fluoride ions would completely combine with all the calcium ions in the patient's blood?
20. A double displacement reaction occurs in aqueous solution when magnesium phosphate reacts with lead(II) nitrate. If 20.0 mL of 0.750 mol/L magnesium phosphate reacts, what is the maximum mass of precipitate that can be formed?

Communication

21. Phosphate ions act as a fertilizer. They promote the growth of algae in rivers and lakes. They can enter rivers and lakes from fields that are improperly fertilized or from untreated waste water that contains phosphate detergents. How can the water be treated to remove the phosphate ions?
22. A chemist analyzes the sulfate salt of an unknown alkaline earth metal. The chemist adds 1.273 g of the salt to excess barium chloride solution. After filtering and drying, the mass of precipitate is found to be 2.468 g.
    (a) Use the formula MSO_4 to represent the unknown salt. Write the molecular and net ionic equations for the reaction.

(b) Calculate the amount (in mol) of MSO_4 used in the reaction.

(c) Determine the molar mass of the unknown salt.

(d) What is the likely identity of the unknown metal cation? What test might the chemist perform to help confirm this conclusion?

23. The same volume of solution is made using the same masses of two salts: rubidium carbonate and calcium carbonate. Which salt gives the larger concentration of aqueous carbonate ions?

24. A prospector asks you to analyze a bag of silver ore. You measure the mass of the ore and add excess nitric acid to it. Then you add excess sodium chloride solution. You filter and dry the precipitate. The mass of the ore is 856.1 g, and 1.092 g of silver chloride is collected.

(a) Why did you first treat the ore with excess nitric acid?

(b) Calculate the mass percent of silver in the ore. The ore that is extracted at a silver mine typically contains about 0.085% silver by mass. Should the prospector keep looking or begin celebrating?

Making Connections

25. Think about your activities yesterday. Which activity required the most use of water? Estimate the volume of water you used. Would it make sense to have two supplies of water to your home, one for drinking and a second of lower purity for every other activity that uses water? Give reasons for your answer.

26. List three different household wastes that are commonly discarded and have the potential to contaminate ground water if rain leaches through your local landfill site. What chemical(s) does each contain? For each waste, identify an alternative to dumping it in a landfill site.

27. Water is essential for crops. Improper irrigation over a number of years, however, can result in farmed land becoming laden with toxic chemical compounds. Research how this happens. Find out whether this is a concern to farmers near where you live.

Answers to Practice Problems and Short Answers to Section Review Questions:

Practice Problems: **1.(a)** insoluble **(b)** insoluble **(c)** soluble **2.(a)** soluble **(b)** soluble **(c)** insoluble **3.(a)** insoluble **(b)** soluble **(c)** insoluble

4.(a) $Na_2S_{(aq)} + FeSO_{4(aq)} \rightarrow Na_2SO_{4(aq)} + FeS_{(s)}$

(b) $NaOH_{(aq)} + Ba(NO_3)_{2(aq)} \rightarrow$ NR

(c) $2Cs_3PO_{4(aq)} + 3CaBr_{2(aq)} \rightarrow 6CsBr_{(aq)} + Ca_3(PO_4)_{2(s)}$

(d) $Na_2CO_{3(aq)} + H_2SO_{4(aq)} \rightarrow$ NR

(e) $NaNO_{3(aq)} + CuSO_{4(aq)} \rightarrow$ NR

(f) $NH_4I_{(aq)} + AgNO_{3(aq)} \rightarrow AgI_{(s)} + NH_4NO_{3(aq)}$

(g) $K_2CO_{3(aq)} + Fe(NO_3)_{2(aq)} \rightarrow FeCO_{3(s)} + 2KNO_{3(aq)}$

(h) $Al(NO_3)_{3(aq)} + Na_3PO_{4(aq)} \rightarrow AlPO_{4(s)} + 3NaNO_{3(aq)}$

(i) $KCl_{(aq)} + Fe(NO_3)_{2(aq)} \rightarrow$ NR

(j) $(NH_4)_2SO_{4(aq)} + BaCl_{2(aq)} \rightarrow BaSO_{4(s)} + 2NH_4Cl_{(aq)}$

(k) $Na_2S_{(aq)} + NiSO_{4(aq)} \rightarrow NiS_{(s)} + Na_2SO_{4(aq)}$

(l) $Pb(NO_3)_2 + 2KBr_{(aq)} \rightarrow PbBr_{2(s)} + 2KNO_{3(aq)}$

5.(a) spectator ions: $Na^+_{(aq)}$ and $Cl^-_{(aq)}$; net ionic equation: $CO_3^{2-}{}_{(aq)} + 2H^+_{(aq)} \rightarrow CO_{2(g)} + H_2O_{(l)}$ **(b)** spectator ions: $Na^+_{(aq)}$ and $SO_4^{2-}{}_{(aq)}$; net ionic equation: $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$ **6.(a)** spectator ions: $NH_4^+{}_{(aq)}$ and $SO_4^{2-}{}_{(aq)}$; net ionic equation: $Zn^{2+}_{(aq)} + PO_4^{3-}{}_{(aq)} \rightarrow Zn_3(PO_4)_{2(s)}$ **(b)** spectator ions: $Li^+_{(aq)}$ and $NO^{3-}_{(aq)}$; net ionic equation: $CO_3^{2-}{}_{(aq)} + 2H^+_{(aq)} \rightarrow CO_{2(g)} + H_2O_{(l)}$ **(c)** spectator ions: none; net ionic equation: $2H^+_{(aq)} + SO_4^{2-}{}_{(aq)} + Ba^{2-}{}_{(aq)} + 2OH^-_{(aq)} \rightarrow BaSO_{4(s)} + H_2O_{(l)}$

7. 300 mL **8.** concentration of $NH_4^+{}_{(aq)}$ is 0.40 mol/L; concentration of $PO_4^{3-}{}_{(aq)}$ is 0.13 mol/L **9.** 66.57% **10.** 30.47% **11.** 20.9 g of PbS **12.** 4.61 g PbI_2

13.(a) $3NaOH_{(aq)} + Al(NO_3)_{3(aq)} \rightarrow Al(OH)_{3(s)} + 3NaNO_{3(aq)}$

(b) 0.0975 g

Section Review: **9.1:** **2.** NaF less soluble, because F^- is smaller than I^-. **3.(a)** insoluble **(b)** soluble **(c)** soluble. **4.** all insoluble. **5.** Any reagent containing Cl^-, Br^-, or I^- will precipitate silver ion but leave calcium ion in solution. **6.** 1 = Ag^+, 2 = SO_4^{2+}, 3 = Ba^{2+}, 4 = Cl^-.

9.2: **2.(a)** $3Sn^{2+}_{(aq)} + 2PO_4^{3-}{}_{(aq)} \rightarrow Sn_3(PO_4)_{2(s)}$

(b) $Ni^{2+}_{(aq)} + CO_3^{2-(aq)} \rightarrow NiCO_{3(s)}$

(c) $2Cr^{3+}_{(aq)} + 3S^{2-}_{(aq)} \rightarrow Cr_2S_{3(s)}$ **3.(a)** $Cl^-_{(aq)}$ and $K^+_{(aq)}$ **(b)** $Cl^-_{(aq)}$ and $Na^+_{(aq)}$ **(c)** $NH_4^+{}_{(aq)}$ and $SO_4^{2-}{}_{(aq)}$.

6. copper(II) carbonate, $CuCO_3$; $Cu^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow CuCO_{3(s)}$; spectator ions: $SO_4^{2-}{}_{(aq)}$ and $Na^+_{(aq)}$. **9.3:** **1.** 0.300 mol/L nitrate ion. **2.** 0.636 g $Na_2CO_{3(s)}$. **3.** 114 mL. **4.** 1.09 mol/L $ZnCl_2$. **5.** 0.650 g Cu **6.** 3.4×10^{-2} L **7.** 0.267 L