Acid Water—A Hidden Menace

When purchasing a home with its own well, it is common practice to have the water in the well tested. Usually, the purpose of the tests is to indicate the presence of disease-causing microorganisms. Rarely is the water’s acidity measured.

Many people are unaware of their water’s pH value (see Chapter 16) until they are confronted with such phenomena as a blue ring materializing around a porcelain sink drain, a water heater suddenly giving out, or tropical fish that keep dying. Each of these could be traced to acidic water, which can also be a cause of lead poisoning.

The possibility of lead poisoning from home water supplies has gone largely unreported. Many older homes still have lead pipes in their plumbing, while most modern homes use copper piping. All pipe joints, however, are sealed with lead solder. Highly acidic water can leach out both the lead from the solder joints and copper from the pipes themselves, which turns the sink drain blue. In addition, people who are in the habit of filling their kettles in the morning without letting the tap run awhile first could be adding a number of unwanted chemicals to their tea or coffee.

Lead poisoning is of particular concern in young children. The absorption rate of lead in the intestinal tract of a child is much higher than that of an adult, and lead poisoning can permanently impair a child’s rapidly growing nervous system. The good news is that lead poisoning and other effects of acidic water in the home can be easily prevented. Here’s what you can do about it:

1. Monitor the pH of your water on a regular basis, especially if you have well water. This can easily be done with pH test kits (see photograph) that are sold in hardware or pet stores—many tropical fish are intolerant of water with a pH that is either too high (basic) or too low (acidic). The pH of most municipal water supplies should already be regulated, but it doesn’t hurt to check.

2. In the morning, let your water tap run for about half a minute before you fill your kettle or drink the water. If the water is acidic, the first flush of water will have the highest concentration of lead and copper ions.

3. Installing an alkali-injection pump is a low-cost, low-maintenance solution that can save your plumbing and lessen the risk of lead poisoning from your own water supply. The pump injects a small amount of an alkali (usually potassium carbonate or sodium carbonate) in your water-holding tank each time you activate your well’s pump. This effectively neutralizes the acidity of your water. The reaction below shows the neutralizing effect of potassium carbonate on well water that has been made acidic by acid rain.

\[
K_2CO_3(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + CO_2(g) + H_2O(l)
\]

Vocabulary
- chemical equation (241)
- formula equation (244)
- coefficient (243)
- precipitate (242)

8.1 Five observations that suggest a chemical reaction is taking place are the evolution of heat or light, the production of gas, a change in color, and the formation of a precipitate.

Vocabulary
- reversible reaction (246)
- word equation (243)

8.2 Synthesis reactions are represented by the general equation \( A + BX \rightarrow AX + B \) and \( Y + BX \rightarrow BY + X \).

Decomposition reactions are represented by the general equation \( AX \rightarrow A + X \).

Single-replacement reactions are represented by the following equations:

- combination reaction (263)
- composition reaction (256)
- decomposition reaction (259)
- electrolysis (259)
- synthesis reaction (256)

8.3 Activity series list the elements in order of their chemical reactivity and are useful in predicting whether a chemical reaction will occur.

Vocabulary
- activity series (265)

REVIEWING CONCEPTS

1. List four observations that indicate that a chemical reaction may be taking place.

2. List the three requirements for a correctly written chemical equation.

3. a. What is meant by the term coefficient in relation to a chemical equation? b. How does the presence of a coefficient affect the number of atoms of each type in the formula that it precedes?

4. Give an example of a word equation, a formula equation, and a chemical equation.

5. What quantitative information is revealed by a chemical equation?

6. What limitations are associated with the use of both word and formula equations?

7. Define each of the following:
   a. aqueous solution
   b. catalyst
   c. reversible reaction

8. Write formulas for each of the following compounds:
   a. potassium hydroxide
   b. calcium nitrate
   c. sodium carbonate
   d. carbon tetrachloride
   e. magnesium bromide
   f. sulfur dioxide
   g. ammonium sulfate
9. What four guidelines are useful in balancing an equation? (8-1)

10. How many atoms of each type are represented in each of the following?
   a. $3N_2$
   b. $2H_2O$
   c. $4NH_4$
   d. $3BaClO_3$
   e. $5Fe(NO_3)_2$
   f. $4MgF_2(SO_4)_2$
   g. $2(NH_4)_2SO_4$
   h. $6Al_2(SO_4)_3$
   i. $4CH_4$

11. Define and give general equations for the five basic types of chemical reactions introduced in Chapter 8. (8-1)

12. How are most decomposition reactions initiated? (8-2)

13. What is electrolysis? (8-2)

14. a. In what environment do many single-replacement reactions commonly occur? b. In general, how do single-replacement reactions compare with synthesis and decomposition reactions in terms of the amount of energy involved? (8-2)

15. a. What is meant by the activity of an element? b. How does this description differ for metals and nonmetals? (8-3)

16. a. What is an activity series of elements? b. What is the basis for the ordering of the elements in the activity series? (8-3)

17. a. What is the chemical principle upon which the activity series of metals is based? b. What is the significance of the distance between two metals in the activity series? (8-3)

### PROBLEMS

#### Chemical Equations

18. Write the chemical equation that relates to each of the following word equations. Include symbols for physical states in the equation. (Hint: See Sample Problem 8-1.)
   a. solid zinc sulfide + oxygen gas → solid zinc oxide + sulfur dioxide gas
   b. hydrochloric acid + aqueous magnesium hydroxide → aqueous magnesium chloride + water
   c. nitric acid + aqueous calcium hydroxide → aqueous calcium nitrate + water

19. Translate each of the following chemical equations into a sentence. (Hint: See Sample Problems 8-2.)
   a. $2ZnO + O_2 → 2ZnO_2$ (g)
   b. $Ca(OH)_2 + NaOH → Ca(OH)_2 (aq) + 2NaOH$
   c. $2AgNO_3 (aq) + NaOH (aq) → 2Ag(s) + NaNO_3 (aq)$

20. Balance each of the following:
   a. $H_2 + Cl_2 → HCl$
   b. $Fe + H_2O → Fe_2O_3 + H_2$
   c. $Pb(CH_3COO)_2 + H_2S → PbS + CH_3COOH$

21. The following equations are incorrect in some way. Identify and correct each error, and then balance each equation.
   a. $Li + O_2 → Li_2O$
   b. $H_2 + Cl_2 → H_2Cl_2$
   c. $MgCO_3 → MgO + CO_2$
   d. $Na + Cl_2 → NaCl + I$

22. Write chemical equations for each of the following sentences:
   a. Aluminum reacts with oxygen to produce aluminum oxide.
   b. Phosphoric acid, $H_3PO_4$, is produced through the reaction between tetraphosphorus decasulfide and water.
   c. Iron(II) oxide reacts with carbon monoxide to produce iron and carbon dioxide.

23. Carbon tetrachloride is used as an intermediate chemical in the manufacture of other chemicals. It is prepared in liquid form by reacting chlorine gas with methane gas. Hydrogen chloride gas is also formed in this reaction. Write the balanced chemical equation for the production of carbon tetrachloride. (Hint: See Sample Problems 8-3 and 8-4.)

24. For each of the following synthesis reactions, identify the missing reactant(s) or product(s), and then balance the resulting equation:
   a. $Mg + → MgO$
   b. $Li + → Fe_2O_3$
   c. $Li + Cl_2 → LiCl$
   d. $Ca + → CaCl_2$

#### Types of Chemical Reactions

25. Complete the following synthesis reactions by writing both word and chemical equations for each:
   a. sodium + oxygen →
   b. magnesium + fluorine →

26. Complete and balance the equation for each of the following decomposition reactions:
   a. $HgO →$
   b. $H_2O →$
   c. $AgNO_3 →$

27. Complete and balance the equations for each of the following single-replacement reactions:
   a. $Zn + Pb(NO_3)_2 →$
   b. $Al + H_2SO_4 →$
   c. $Ca + NaNO_3 →$

28. Complete and balance the equations for the following double-replacement reactions:
   a. $AgNO_3 (aq) + NaCl (aq) →$
   b. $Mg(NO_3)_2 (aq) + KOH (aq) →$
   c. $LiOH (aq) + Fe(NO_3)_2 (aq) →$

29. Complete and balance the equation for each of the following combustion reactions:
   a. $CH_4 + O_2 →$
   b. $C_2H_6 + O_2 →$
   c. $C_2H_2 + O_2 →$

30. Write and balance each of the following equations, and then identify each by type:
   a. hydrogen + iodine → hydrogen iodide
   b. lithium + hydrochloric acid → lithium chloride + hydrogen
   c. sodium carbonate → sodium oxide + carbon dioxide
   d. mercury(II) oxide → mercury + oxygen
   e. magnesium hydroxide → magnesium oxide + water

31. Identify the compound that can undergo decomposition to produce the following products, and then balance the final equation:
   a. magnesium oxide and water
   b. lead(II) oxide and water
   c. lithium chloride and oxygen
   d. barium chloride and oxygen

32. In each of the following combustion reactions, identify the missing reactant(s), product(s), or both, and then balance the resulting equation:
   a. $C_2H_6 + O_2 →$
   b. $S + O_2 →$
   c. $C_2H_5OH + →$

33. Complete and balance each of the following reactions observed to occur, and then identify each by type:
   a. zinc + sulfur →
   b. calcium + sodium nitrate →
   c. silver nitrate + potassium iodide →
   d. sodium iodide →
   e. toluene, $C_7H_8 + O_2 →$
   f. none, $C_4H_10 + O_2 →$

#### Activity Series

34. Based on the activity series of metals and halogens, which element within each pair is more likely to replace the other in a compound?
   a. K and Na
   b. Al and Ni
   c. Bi and Cr
   d. Cl and F
   e. Au and Ag
   f. Cl and I
   g. Fe and Sr
   h. I and F

35. Using the activity series in Table 8-3 on page 266, predict whether each of the possible reactions listed below will occur. For the reactions that will occur, write the products and balance the equation:
   a. Ni(s) + CuCl_2(aq) →
   b. Zn(s) + Pb(NO_3)_2(aq) →
   c. Cl_2(g) + KI(aq) →
   d. Cu(s) + FeSO_4(aq) →
   e. Ba(s) + H_2SO_4(aq) →

36. Use the activity series to predict whether each of the following reactions will occur, and write the chemical equations for those predicted to occur:
   a. Ca(s) + O_2(g) →
   b. Ni(s) + O_2(g) →
   c. Au(s) + O_2(g) →
37. Ammonia reacts with oxygen to yield nitrogen and water.

\[ 4\text{NH}_3(g) + 3\text{O}_2(g) \rightarrow 2\text{N}_2(g) + 6\text{H}_2\text{O}(l) \]

Given this chemical equation, as well as the number of moles of the reactant or product indicated below, determine the number of moles of all remaining reactants and products:

a. 3.0 mol \text{O}_2
b. 8.0 mol \text{NH}_3
c. 1.0 mol \text{N}_2
d. 0.40 mol \text{H}_2\text{O}

38. Complete the following synthesis reactions by writing both the word and chemical equation for each:

a. potassium + chlorine
b. hydrogen + iodine
c. magnesium + oxygen

39. Use the activity series to predict which metal, \text{Sn}, \text{Mn}, or \text{Pt}, would be the best choice as a container for an acid.

40. Aqueous sodium hydroxide is produced commercially by the electrolysis of aqueous sodium chloride. Hydrogen and chlorine gases are also produced. Write the balanced chemical equation for the production of sodium hydroxide. Include the physical states of the reactants and products.

41. Balance each of the following:

a. \text{Ca(OH)}_2 + (\text{NH}_4)_2\text{SO}_4 \rightarrow \text{CaSO}_4 + \text{NH}_3 + \text{H}_2\text{O}
b. \text{C}_2\text{H}_5\text{OH}(l) + \text{O}_2(g) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}(l)
c. \text{CuS} + \text{O}_2 \rightarrow \text{CuO} + \text{SO}_2
d. \text{Al} + \text{H}_2\text{SO}_4(aq) \rightarrow \text{Al}_2(\text{SO}_4)_3(aq) + \text{H}_2(g)

42. Use the activity series to predict whether each of the following reactions will occur, and write the balanced chemical equations for those predicted to occur:

a. \text{Al}(s) + \text{O}_2(g) \rightarrow 
b. \text{Pb}(s) + \text{ZnCl}_2(aq) \rightarrow 
c. \text{Zn}(\text{NO}_3)_2(aq) \rightarrow 

43. Complete and balance the equations for the following reactions, and identify the type of reaction each represents:

a. \text{NH}_3\text{S}(aq) + \text{ZnCl}_2(aq) \rightarrow 

44. Write and balance each of the following equations, and then identify each by type:

a. copper + chlorine \rightarrow copper(II) chloride
b. calcium chloride \rightarrow calcium chloride + oxygen
c. lithium + water \rightarrow lithium hydroxide + hydrogen
d. lead(II) carbonate \rightarrow lead(II) oxide + carbon dioxide

45. How many moles of \text{HCl} can be made from 6.15 mol of \text{H}_2 and an excess of \text{Cl}_2?

46. What product is missing in the following equation?

\[ \text{MgO} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \]

47. Balance the following equations:

a. \text{Pb(NO}_3)_2(aq) + \text{NaOH}(aq) \rightarrow 

b. \text{C}_2\text{H}_5\text{OH}(l) + \text{O}_2(g) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}(l)
c. \text{Al}_2(\text{SO}_4)_3(aq) \rightarrow 

48. Translate the following word equations into balanced chemical equations:

a. silver nitrate + potassium iodide \rightarrow nitric acid + nitrogen monoxide
b. aluminum + sulfur \rightarrow silicon tetrachloride + water

49. Inferring Relationships  Activity series are prepared by comparing single-displacement reactions between metals. Based on observations, the metals can be ranked by their ability to react. However, reactivity can be explained by the case with which atoms of metals lose electrons. Using information from the activity series, identify the locations in the periodic table of the most-reactive metals and the least-reactive metals. Based on your knowledge of electron configurations and periodic trends, infer possible explanations for their reactivity and position in the periodic table.

50. Analyzing Results  For the hypothetical elements \text{A}, \text{J}, \text{Q}, \text{Z}

\[ \text{A} + \text{Z} \rightarrow \text{AX} + \text{Z} \]

\[ \text{J} + \text{X} \rightarrow \text{JX} + \text{A} \]

Use the reaction information provided.

\[ \text{A} + \text{Z} \rightarrow \text{AX} + \text{Z} \]

\[ \text{J} + \text{X} \rightarrow \text{JX} + \text{A} \]

51. Find the common-reactions section for Group 1 metals in the Elements Handbook. Use this information to answer the following:

a. Write a balanced chemical equation for the formation of rubidium hydroxide from rubidum oxide.
b. Write a balanced chemical equation for the formation of cesium iodide.
c. Classify the reactions you wrote in (a) and (b).
d. Write word equations for the reactions you wrote in (a) and (b).

52. Find the common-reactions section for Group 13 in the Elements Handbook. Use this information to answer the following:

a. Write a balanced chemical equation for the formation of gallium bromide prepared from hydrobromic acid.
b. Write a balanced chemical equation for the formation of gallium oxide.
c. Classify the reactions you wrote in (a) and (b).
d. Write word equations for the reactions you wrote in (a) and (b).

53. Find the common-reactions section for Group 16 in the Elements Handbook. Use this information to answer the following:

a. Write a balanced chemical equation for the formation of selenium trioxide.
b. Write a balanced chemical equation for the formation of tellurium iodide.