21. a. What trend is there in the favored direction of proton-transfer reactions?
b. What determines the extent to which a proton-transfer reaction occurs?

22. a. What is meant by the term *amphoteric?*
b. Give an example of a substance or ion that has amphoteric characteristics.

23. For each reaction listed, identify the proton donor or acid and the proton acceptor or base. Label each conjugate acid-base pair.
a. $CH_3COOH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH_3COO^-(aq)$
b. $HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) + OH^-(aq)$
c. $HNO_3 + SO_4^{2-} \longrightarrow HSO_4^- + NO_3^-$

24. Using the information given in **Table 6,** determine the following relative to HF, H_2S, HNO_3, and CH_3COOH:
a. strongest acid
b. weakest acid
c. strongest conjugate base among the four conjugate bases produced by the acids listed
d. weakest conjugate base among the four conjugate bases produced by the acids listed

25. Explain why the conjugate base of a strong acid is a weak base and the conjugate acid of a strong base is a weak acid.

PRACTICE PROBLEMS

26. Complete the following neutralization reactions. Balance each reaction, and then write the overall ionic and net ionic equation for each.
a. $HCl(aq) + NaOH(aq) \longrightarrow$
b. $HNO_3(aq) + KOH(aq) \longrightarrow$
c. $Ca(OH)_2(aq) + HNO_3(aq) \longrightarrow$
d. $Mg(OH)_2(aq) + HCl(aq) \longrightarrow$

27. Write the formula equation, the overall ionic equation, and the net ionic equation for the neutralization reaction involving aqueous solutions of H_3PO_4 and $Mg(OH)_2$. Assume that the solutions are sufficiently dilute so that no precipitates form.

28. Write the balanced chemical equation for each of the following reactions between water and the non-metallic oxide to form an acid.
a. $CO_2(g) + H_2O(l) \longrightarrow$
b. $SO_3(g) + H_2O(l) \longrightarrow$
c. $N_2O_5(g) + H_2O(l) \longrightarrow$

29. Write the formula equation, the overall ionic equation, and the net ionic equation for a neutralization reaction that would form each of the following salts.
a. $RbClO_4$
b. $BaSO_4$
c. $CaCl_2$
d. K_2SO_4

30. Zinc reacts with 100.0 mL of 6.00 M cold, aqueous sulfuric acid through single replacement.
a. How many grams of zinc sulfate can be produced?
b. How many liters of hydrogen gas could be released at STP?

31. A 211 g sample of barium carbonate, $BaCO_3$, reacts with a solution of nitric acid to give barium nitrate, carbon dioxide and water. If the acid is present in excess, what mass and volume of dry carbon dioxide gas at STP will be produced?

32. A seashell that is composed largely of calcium carbonate reacts with a solution of HCl. As a result, 1500 mL of dry CO_2 gas at STP is produced. The other products are $CaCl_2$ and H_2O.
a. How many grams of $CaCO_3$ are consumed in the reaction?
b. What volume of 2.00 M HCl solution is used in this reaction?

33. *Acid precipitation* is the term generally used to describe rain or snow that is more acidic than it normally is. One cause of acid precipitation is the formation of sulfuric and nitric acids from various sulfur and nitrogen oxides produced in volcanic eruptions, forest fires, and thunderstorms. In a typical volcanic eruption, for example, 3.50×10^8 kg SO_2 may be produced. If this amount of SO_2 were converted to H_2SO_4 according to the two-step process given below, how many kilograms of H_2SO_4 would be produced from such an eruption?

$$SO_2 + \frac{1}{2}O_2 \longrightarrow SO_3$$
$$SO_3 + H_2O \longrightarrow H_2SO_4$$