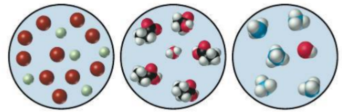
Exercises

Strong Electrolytes, Weak Electrolytes, and Nonelectrolytes

1. Using information from this chapter, indicate whether each of the following substances in aqueous solution is a nonelectrolyte, weak electrolyte, or strong electrolyte. **(a)** HC_6H_5O; **(b)** Li_2SO_4; **(c)** MgI_2; **(d)** $(CH_3CH_2)_2O$; **(e)** $Sr(OH)_2$.
2. Select the **(a)** best and **(b)** poorest electrical conductors from the following solutions, and explain the reason for your choices: 0.10 M NH_3; 0.10 M NaCl; 0.10 M CH_3COOH (acetic acid); 0.10 M CH_3CH_2OH (ethanol).
3. What response would you expect in the apparatus of Figure 5-4 if the solution tested were 1.0 M HCl? What response would you expect if the solution were both 1.0 M HCl and 1.0 M CH_3COOH?
4. $NH_3(aq)$ conducts electric current only weakly. The same is true for $CH_3COOH(aq)$. When these solutions are mixed, however, the resulting solution is a good conductor. How do you explain this?
5. Sketches **(a–c)** are molecular views of the solute in an aqueous solution. For each of the sketches, indicate whether the solute is a strong, weak, or nonelectrolyte; and which of these substances it is: sodium chloride, propionic acid, hypochlorous acid, ammonia, barium bromide, ammonium chloride, methanol.



(a) (b) (c)

6. After identifying the three substances represented by the sketches in Exercise 5, sketch molecular views of aqueous solutions of the remaining four substances listed.

Ion Concentrations

7. Determine the concentration of the ion indicated in each solution. **(a)** $[K^+]$ in 0.238 M KNO_3; **(b)** $[NO_3^-]$ in 0.167 M $Ca(NO_3)_2$; **(c)** $[Al^{3+}]$ in 0.083 M $Al_2(SO_4)_3$; **(d)** $[Na^+]$ in 0.209 M Na_3PO_4.
8. Which solution has the greatest $[SO_4^{2-}]$? **(a)** 0.075 M H_2SO_4; **(b)** 0.22 M $MgSO_4$; **(c)** 0.15 M Na_2SO_4; **(d)** 0.080 M $Al_2(SO_4)_3$; **(e)** 0.20 M $CuSO_4$.
9. A solution is prepared by dissolving 0.132 g $Ba(OH)_2 \cdot 8\,H_2O$ in 275 mL of water solution. What is $[OH^-]$ in this solution?
10. A solution is 0.126 M KCl and 0.148 M $MgCl_2$. What are $[K^+]$, $[Mg^{2+}]$, and $[Cl^-]$ in this solution?
11. Express the following data for cations in solution as molarities. **(a)** 14.2 mg Ca^{2+}/L; **(b)** 32.8 mg K^+/100 mL; **(c)** 225 μg Zn^{2+}/mL.
12. What molarity of NaF(aq) corresponds to a fluoride ion content of 0.9 mg F^-/L, the federal government's recommended limit for fluoride ion in drinking water?
13. Which of the following aqueous solutions has the highest concentration of K^+? **(a)** 0.0850 M K_2SO_4; **(b)** a solution containing 1.25 g KBr/100 mL; **(c)** a solution having 8.1 mg K^+/mL.
14. Which aqueous solution has the greatest $[H^+]$? **(a)** 0.011 M CH_3COOH; **(b)** 0.010 M HCl; **(c)** 0.010 M H_2SO_4; **(d)** 1.00 M NH_3. Explain your choice.
15. How many milligrams of MgI_2 must be added to 250.0 mL of 0.0876 M KI to produce a solution with $[I^-]$ = 0.1000 M?
16. If 18.2 mL H_2O evaporates from 1.00 L of a solution containing 15.5 mg K_2SO_4/mL, what is $[K^+]$ in the solution that remains?
17. Assuming the volumes are additive, what is the $[Cl^-]$ in a solution obtained by mixing 225 mL of 0.625 M KCl and 615 mL of 0.385 M $MgCl_2$?
18. Assuming the volumes are additive, what is the $[NO_3^-]$ in a solution obtained by mixing 275 mL of 0.283 M KNO_3, 328 mL of 0.421 M $Mg(NO_3)_2$, and 784 mL of H_2O?

Predicting Precipitation Reactions

19. Complete each of the following as a net ionic equation, indicating whether a precipitate forms. If no reaction occurs, so state.
    (a) $Na^+ + Br^- + Pb^{2+} + 2\,NO_3^- \longrightarrow$
    (b) $Mg^{2+} + 2\,Cl^- + Cu^{2+} + SO_4^{2-} \longrightarrow$
    (c) $Fe^{3+} + 3\,NO_3^- + Na^+ + OH^- \longrightarrow$
20. Complete each of the following as a net ionic equation. If no reaction occurs, so state.
    (a) $Ca^{2+} + 2\,I^- + 2\,Na^+ + CO_3^{2-} \longrightarrow$
    (b) $Ba^{2+} + S^{2-} + 2\,Na^+ + SO_4^{2-} \longrightarrow$
    (c) $2\,K^+ + S^{2-} + Ca^{2+} + 2\,Cl^- \longrightarrow$
21. Predict in each case whether a reaction is likely to occur. If so, write a net ionic equation.
    (a) $HI(aq) + Zn(NO_3)_2(aq) \longrightarrow$
    (b) $CuSO_4(aq) + Na_2CO_3(aq) \longrightarrow$
    (c) $Cu(NO_3)_2(aq) + Na_3PO_4(aq) \longrightarrow$
22. Predict in each case whether a reaction is likely to occur. If so, write a net ionic equation.
    (a) $AgNO_3(aq) + CuCl_2(aq) \longrightarrow$
    (b) $Na_2S(aq) + FeCl_2(aq) \longrightarrow$
    (c) $Na_2CO_3(aq) + AgNO_3(aq) \longrightarrow$

23. What reagent solution might you use to separate the cations in the following mixtures, that is, with one ion appearing in solution and the other in a precipitate? [*Hint:* Refer to Table 5.1, and consider water also to be a reagent.]
(a) $BaCl_2(s)$ and $MgCl_2(s)$
(b) $MgCO_3(s)$ and $Na_2CO_3(s)$
(c) $AgNO_3(s)$ and $Cu(NO_3)_2(s)$

24. What reagent solution might you use to separate the cations in each of the following mixtures? [*Hint:* Refer to Exercise 23.]
(a) $PbSO_4(s)$ and $Cu(NO_3)_2(s)$
(b) $Mg(OH)_2(s)$ and $BaSO_4(s)$
(c) $PbCO_3(s)$ and $CaCO_3(s)$

25. You are provided with $NaOH(aq)$, $K_2SO_4(aq)$, $Mg(NO_3)_2(aq)$, $BaCl_2(aq)$, $NaCl(aq)$, $Sr(NO_3)_2(aq)$, $AgNO_3(aq)$, and $BaSO_4(s)$. Write net ionic equations to show how you would use one or more of those reagents to obtain **(a)** $SrSO_4(s)$; **(b)** $Mg(OH)_2(s)$; **(c)** $KCl(aq)$.

26. Write net ionic equations to show how you would use one or more of the reagents in Exercise 25 to obtain **(a)** $BaSO_4(s)$; **(b)** $AgCl(s)$; **(c)** $KNO_3(aq)$.

Acid–Base Reactions

27. Complete each of the following as a *net ionic equation*. If no reaction occurs, so state.
(a) $Ba^{2+} + 2\,OH^- + CH_3COOH \longrightarrow$
(b) $H^+ + Cl^- + CH_3CH_2COOH \longrightarrow$
(c) $FeS(s) + H^+ + I^- \longrightarrow$
(d) $K^+ + HCO_3^- + H^+ + NO_3^- \longrightarrow$
(e) $Mg(s) + H^+ \longrightarrow$

28. Every antacid contains one or more ingredients capable of reacting with excess stomach acid (HCl). The essential neutralization products are CO_2 and/or H_2O. Write net ionic equations to represent the neutralizing action of the following popular antacids.
(a) Alka-Seltzer (sodium bicarbonate)
(b) Tums (calcium carbonate)
(c) milk of magnesia (magnesium hydroxide)
(d) Maalox (magnesium hydroxide, aluminum hydroxide)
(e) Rolaids $[NaAl(OH)_2CO_3]$

29. In this chapter, we described an acid as a substance capable of producing H^+ and a salt as the ionic compound formed by the neutralization of an acid by a base. Write ionic equations to show that sodium hydrogen sulfate has the characteristics of both a salt and an acid (sometimes called an *acid salt*).

30. A neutralization reaction between an acid and a base is a common method of preparing useful salts. Give net ionic equations showing how the following salts could be prepared in this way: **(a)** $(NH_4)_2HPO_4$; **(b)** NH_4NO_3; and **(c)** $(NH_4)_2SO_4$.

31. Which solutions would you use to precipitate Mg^{2+} from an aqueous solution of $MgCl_2$? Explain your choice. **(a)** $KNO_3(aq)$; **(b)** $NH_3(aq)$; **(c)** $H_2SO_4(aq)$; **(d)** $HC_2H_3O_2(aq)$.

32. Determine which of the following react(s) with HCl(aq) to produce a gas, and write a net ionic equation(s) for the reaction(s). **(a)** Na_2SO_4; **(b)** $KHSO_3$; **(c)** $Zn(OH)_2$; **(d)** $CaCl_2$.

Oxidation–Reduction (Redox) Equations

33. Assign oxidation states to the elements involved in the following reactions. Indicate which are redox reactions and which are not.
(a) $MgCO_3(s) + 2\,H^+(aq) \longrightarrow Mg^{2+}(aq) + H_2O(l) + CO_2(g)$
(b) $Cl_2(aq) + 2\,Br^-(aq) \longrightarrow 2\,Cl^-(aq) + Br_2(aq)$
(c) $Ag(s) + 2\,H^+(aq) + NO_3^-(aq) \longrightarrow Ag^+(aq) + H_2O(l) + NO_2(g)$
(d) $2\,Ag^+(aq) + CrO_4^{2-}(aq) \longrightarrow Ag_2CrO_4(s)$

34. Explain why these reactions cannot occur as written.
(a) $Fe^{3+}(aq) + MnO_4^-(aq) + H^+(aq) \longrightarrow Mn^{2+}(aq) + Fe^{2+}(aq) + H_2O(l)$
(b) $H_2O_2(aq) + Cl_2(aq) \longrightarrow ClO^-(aq) + O_2(g) + H^+(aq)$

35. Complete and balance these half-equations.
(a) $SO_3^{2-} \longrightarrow S_2O_3^{2-}$ (acidic solution)
(b) $HNO_3 \longrightarrow N_2O(g)$ (acidic solution)
(c) $Al(s) \longrightarrow Al(OH)_4^-$ (basic solution)
Indicate whether oxidation or reduction is involved.

36. Complete and balance these half-equations.
(a) $C_2O_4^{2-} \longrightarrow CO_2$ (acidic solution)
(b) $Cr_2O_7^{2-} \longrightarrow Cr^{3+}$ (acidic solution)
(c) $MnO_4^- \longrightarrow MnO_2$ (basic solution)
Indicate whether oxidation or reduction is involved.

37. Balance these equations for redox reactions occurring in acidic solution.
(a) $MnO_4^- + I^- \longrightarrow Mn^{2+} + I_2(s)$
(b) $BrO_3^- + N_2H_4 \longrightarrow Br^- + N_2(g)$
(c) $VO_4^{3-} + Fe^{2+} \longrightarrow VO^{2+} + Fe^{3+}$
(d) $UO^{2+} + NO_3^- \longrightarrow UO_2^{2+} + NO(g)$

38. Balance these equations for redox reactions occurring in acidic solution.
(a) $P_4(s) + NO_3^- \longrightarrow H_2PO_4^- + NO(g)$
(b) $S_2O_3^{2-} + MnO_4^- \longrightarrow SO_4^{2-} + Mn^{2+}$
(c) $HS^- + HSO_3^- \longrightarrow S_2O_3^{2-}$
(d) $Fe^{3+} + NH_3OH^+ \longrightarrow Fe^{2+} + N_2O(g)$

39. Balance these equations for redox reactions in basic solution.
(a) $MnO_2(s) + ClO_3^- \longrightarrow MnO_4^- + Cl^-$
(b) $Fe(OH)_3(s) + OCl^- \longrightarrow FeO_4^{2-} + Cl^-$
(c) $ClO_2 \longrightarrow ClO_3^- + Cl^-$
(d) $Ag(s) + CrO_4^{2-} \longrightarrow Ag^+ + Cr(OH)_3(s)$

40. Balance these equations for redox reactions occurring in basic solution.
(a) $CrO_4^{2-} + S_2O_4^{2-} \longrightarrow Cr(OH)_3(s) + SO_3^{2-}$
(b) $[Fe(CN)_6]^{3-} + N_2H_4 \longrightarrow [Fe(CN)_6]^{4-} + N_2(g)$
(c) $Fe(OH)_2(s) + O_2(g) \longrightarrow Fe(OH)_3(s)$
(d) $CH_3CH_2OH + MnO_4^- \longrightarrow CH_3COO^- + MnO_2(s)$

41. Balance these equations for disproportionation reactions.
(a) $Cl_2(g) \longrightarrow Cl^- + ClO_3^-$ (basic solution)
(b) $S_2O_4^{2-} \longrightarrow S_2O_3^{2-} + HSO_3^-$ (acidic solution)

42. Balance these equations for disproportionation reactions.
(a) $MnO_4^{2-} \longrightarrow MnO_2(s) + MnO_4^-$ (basic solution)
(b) $P_4(s) \longrightarrow H_2PO_2^- + PH_3(g)$ (basic solution)
(c) $S_8(s) \longrightarrow S^{2-} + S_2O_3^{2-}$ (basic solution)
(d) $As_2S_3 + H_2O_2 \longrightarrow AsO_4^{3-} + SO_4^{2-}$

43. Write a balanced equation for these redox reactions.
(a) The oxidation of nitrite ion to nitrate ion by permanganate ion, MnO_4^-, in acidic solution (MnO_4^- ion is reduced to Mn^{2+}).
(b) The reaction of manganese(II) ion and permanganate ion in basic solution to form solid manganese dioxide.
(c) The oxidation of ethanol by dichromate ion in acidic solution, producing chromium(III) ion, acetaldehyde (CH_3CHO), and water as products.

44. Write a balanced equation for the redox reactions.
(a) The reaction of aluminum metal with hydroiodic acid.
(b) The reduction of vanadyl ion (VO^{2+}) to vanadic ion (V^{3+}) in acidic solution with zinc metal as the reducing agent.
(c) The oxidation of methanol by chlorate ion in acidic solution, producing carbon dioxide gas, water, and chlorine dioxide gas as products.

45. The following reactions do not occur in aqueous solutions. Balance their equations by the half-equation method, as suggested in Are You Wondering 5-2.
(a) $CH_4(g) + NO(g) \longrightarrow CO_2(g) + N_2(g) + H_2O(g)$
(b) $H_2S(g) + SO_2(g) \longrightarrow S_8(s) + H_2O(g)$
(c) $Cl_2O(g) + NH_3(g) \longrightarrow N_2(g) + NH_4Cl(s) + H_2O(l)$

46. The following reactions do not occur in aqueous solutions. Balance their equations by the half-equation method, as suggested in Are You Wondering 5-2.
(a) $CH_4(g) + NH_3(g) + O_2(g) \longrightarrow HCN(g) + H_2O(g)$
(b) $NO(g) + H_2(g) \longrightarrow NH_3(g) + H_2O(g)$
(c) $Fe(s) + H_2O(l) + O_2(g) \longrightarrow Fe(OH)_3(s)$

Oxidizing and Reducing Agents

47. What are the oxidizing and reducing agents in the following redox reactions?
(a) $5\,SO_3^{2-} + 2\,MnO_4^- + 6\,H^+ \longrightarrow 5\,SO_4^{2-} + 2\,Mn^{2+} + 3\,H_2O$
(b) $2\,NO_2(g) + 7\,H_2(g) \longrightarrow 2\,NH_3(g) + 4\,H_2O(g)$
(c) $2\,[Fe(CN)_6]^{4-} + H_2O_2 + 2\,H^+ \longrightarrow 2\,[Fe(CN)_6]^{3-} + 2\,H_2O$

48. Thiosulfate ion, $S_2O_3^{2-}$, is a reducing agent that can be oxidized to different products, depending on the strength of the oxidizing agent and other conditions. By adding H^+, H_2O, and/or OH^- as necessary, write redox equations to show the oxidation of $S_2O_3^{2-}$ to
(a) $S_4O_6^{2-}$ by I_2 (iodide ion is another product)
(b) HSO_4^- by Cl_2 (chloride ion is another product)
(c) SO_4^{2-} by OCl^- in basic solution (chloride ion is another product)

Neutralization and Acid–Base Titrations

49. What volume of 0.0962 M NaOH is required to exactly neutralize 10.00 mL of 0.128 M HCl?

50. The exact neutralization of 10.00 mL of 0.1012 M $H_2SO_4(aq)$ requires 23.31 mL of NaOH. What must be the molarity of the NaOH(aq)?

$$H_2SO_4(aq) + 2\,NaOH(aq) \longrightarrow Na_2SO_4(aq) + 2\,H_2O(l)$$

51. How many milliliters of 2.155 M KOH are required to titrate 25.00 mL of 0.3057 M CH_3CH_2COOH (propionic acid)?

52. How many milliliters of 0.0750 M $Ba(OH)_2$ are required to titrate 200.0 mL of 0.0165 M HNO_3?

53. An NaOH(aq) solution cannot be made up to an exact concentration simply by weighing out the required mass of NaOH, because the NaOH is not pure. Also, water vapor condenses on the solid as it is being weighed. The solution must be standardized by titration. For this purpose, a 25.00 mL sample of an NaOH(aq) solution requires 28.34 mL of 0.1085 M HCl. What is the molarity of the NaOH(aq)?

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

54. Household ammonia, used as a window cleaner and for other cleaning purposes, is $NH_3(aq)$. The NH_3 present in a 5.00 mL sample is neutralized by 28.72 mL of 1.021 M HCl. The net ionic equation for the neutralization is

$$NH_3(aq) + H^+(aq) \longrightarrow NH_4^+(aq)$$

What is the molarity of NH_3 in the sample?

55. We want to determine the acetylsalicylic acid content of a series of aspirin tablets by titration with NaOH(aq). Each of the tablets is expected to contain about 0.32 g of $HC_9H_7O_4$. What molarity of NaOH(aq) should we use for titration volumes of about 23 mL? (This procedure ensures good precision and allows the titration of two samples with the contents of a 50 mL buret.)

$$HC_9H_7O_4(aq) + OH^-(aq) \longrightarrow C_9H_7O_4^-(aq) + H_2O(l)$$

56. For use in titrations, we want to prepare 20 L of HCl(aq) with a concentration known to four significant figures. This is a two-step procedure beginning with the preparation of a solution of about 0.10 M HCl. A sample of this dilute HCl(aq) is titrated with a NaOH(aq) solution of known concentration.
(a) How many milliliters of concentrated HCl(aq) (d = 1.19 g/mL; 38% HCl, by mass) must be diluted with water to 20.0 L to prepare 0.10 M HCl?
(b) A 25.00 mL sample of the approximately 0.10 M HCl prepared in part (a) requires 20.93 mL of 0.1186 M NaOH for its titration. What is the molarity of the HCl(aq)?
(c) Why is a titration necessary? That is, why not prepare a standard solution of 0.1000 M HCl simply by an appropriate dilution of the concentrated HCl(aq)?

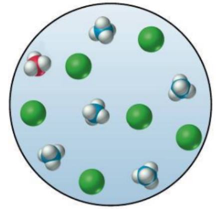
57. A 25.00 mL sample of 0.132 M HNO_3 is mixed with 10.00 mL of 0.318 M KOH. Is the resulting solution acidic, basic, or exactly neutralized?

58. A 7.55 g sample of $Na_2CO_3(s)$ is added to 125 mL of a vinegar that is 0.762 M CH_3COOH. Will the resulting solution still be acidic? Explain.

59. Refer to Example 5-9. Suppose the analysis of all vinegar samples uses 5.00 mL of the vinegar and 0.1000 M NaOH for the titration. What volume of the 0.1000 M NaOH would represent the legal minimum 4.0%, by mass, acetic acid content of the vinegar? That is, calculate the volume of 0.1000 M NaOH so that if a titration requires more than this volume, the legal minimum limit is met (less than this volume, and the limit is not met).

60. The electrolyte in a lead storage battery must have a concentration between 4.8 and 5.3 M H_2SO_4 if the battery is to be most effective. A 5.00 mL sample of a battery acid requires 49.74 mL of 0.935 M NaOH for its complete reaction (neutralization). Does the concentration of the battery acid fall within the desired range? [*Hint:* Keep in mind that the H_2SO_4 produces two H^+ ions per formula unit.]

61. Which of the following points in a titration is represented by the molecular view shown in the sketch?



(a) 20% of the necessary titrant added in the titration of $NH_4Cl(aq)$ with HCl(aq)
(b) 20% of the necessary titrant added in the titration of $NH_3(aq)$ with HCl(aq)
(c) the equivalence point in the titration of $NH_3(aq)$ with HCl(aq)
(d) 120% of the necessary titrant added in the titration of $NH_3(aq)$ with HCl(aq)

62. Using the sketch in Exercise 61 as a guide, sketch the molecular view of a solution in which
(a) HCl(aq) is titrated to the equivalence point with KOH(aq)
(b) $CH_3COOH(aq)$ is titrated halfway to the equivalence point with NaOH(aq).

Stoichiometry of Oxidation–Reduction Reactions

63. A $KMnO_4(aq)$ solution is to be standardized by titration against $As_2O_3(s)$. A 0.1078 g sample of As_2O_3 requires 22.15 mL of the $KMnO_4(aq)$ for its titration. What is the molarity of the $KMnO_4(aq)$?

$$5\,As_2O_3 + 4\,MnO_4^- + 9\,H_2O + 12\,H^+ \longrightarrow 10\,H_3AsO_4 + 4\,Mn^{2+}$$

64. Refer to Example 5-6. Assume that the only reducing agent present in a particular wastewater is SO_3^{2-}. If a 25.00 mL sample of this wastewater requires 31.46 mL of 0.02237 M $KMnO_4$ for its titration, what is the molarity of SO_3^{2-} in the wastewater?

65. An iron ore sample weighing 0.9132 g is dissolved in HCl(aq), and the iron is obtained as $Fe^{2+}(aq)$. This solution is then titrated with 28.72 mL of 0.05051 M $K_2Cr_2O_7$. What is the mass percent Fe in the ore sample?

$$6\,Fe^{2+} + 14\,H^+ + Cr_2O_7^{2-} \longrightarrow 6\,Fe^{3+} + 2\,Cr^{3+} + 7\,H_2O$$

66. The concentration of $Mn^{2+}(aq)$ can be determined by titration with $MnO_4^-(aq)$ in basic solution. A 50.00 mL sample of $Mn^{2+}(aq)$ requires 78.42 mL of 0.04997 M $KMnO_4$ for its titration. What is $[Mn^{2+}]$ in the sample?

$$Mn^{2+} + MnO_4^- \longrightarrow MnO_2(s) \quad \text{(not balanced)}$$

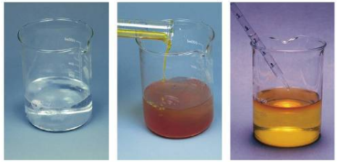
67. The titration of 5.00 mL of a saturated solution of sodium oxalate, $Na_2C_2O_4$, at 25 °C requires 25.8 mL of 0.02140 M $KMnO_4$ in acidic solution. What mass of $Na_2C_2O_4$ in grams would be present in 1.00 L of this saturated solution?

$$C_2O_4^{2-} + MnO_4^- \longrightarrow Mn^{2+} + CO_2(g) \quad \text{(not balanced)}$$

68. Refer to the Integrative Example. In the treatment of 1.00×10^2 L of a wastewater solution that is 0.0126 M CrO_4^{2-}, how many grams of **(a)** $Cr(OH)_3(s)$ would precipitate; **(b)** $Na_2S_2O_4$ would be consumed?

Integrative and Advanced Exercises

69. Write net ionic equations for the reactions depicted in photo **(a)** sodium metal reacts with water to produce hydrogen; photo **(b)** an excess of aqueous iron(III) chloride is added to the solution in **(a)**; and photo **(c)** the precipitate from **(b)** is collected and treated with an excess of HCl(aq).



(a) (b) (c)

(a) & (b) William H. Breazeale; (c) Tom Pantages

70. Following are some laboratory methods occasionally used for the preparation of small quantities of chemicals. Write a balanced equation for each.
(a) preparation of $H_2S(g)$: HCl(aq) is heated with FeS(s)
(b) preparation of $Cl_2(g)$: HCl(aq) is heated with $MnO_2(s)$; $MnCl_2(aq)$ and $H_2O(l)$ are other products
(c) preparation of $N_2(g)$: Br_2 and NH_3 react in aqueous solution; NH_4Br is another product
(d) preparation of chlorous acid: an aqueous suspension of solid barium chlorite is treated with dilute $H_2SO_4(aq)$

71. When concentrated $CaCl_2(aq)$ is added to $Na_2HPO_4(aq)$, a white precipitate forms that is 38.7% Ca by mass. Write a net ionic equation representing the probable reaction that occurs.

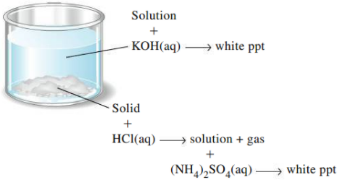
72. You have a solution that is 0.0250 M $Ba(OH)_2$ and the following pieces of equipment: 1.00, 5.00, 10.00, 25.00, and 50.00 mL pipets and 100.0, 250.0, 500.0, and 1000.0 mL volumetric flasks. Describe how you would use this equipment to produce a solution in which $[OH^-]$ is 0.0100 M.

73. Sodium hydroxide used to make standard NaOH(aq) solutions for acid–base titrations is invariably contaminated with some sodium carbonate. **(a)** Explain why, except in the most precise work, the presence of this sodium carbonate generally does not seriously affect the results obtained, for example, when NaOH(aq) is used to titrate HCl(aq). **(b)** Conversely, show that if Na_2CO_3 comprises more than 1% to 2% of the solute in NaOH(aq), the titration results are affected.

74. A 110.520 g sample of mineral water is analyzed for its magnesium content. The Mg^{2+} in the sample is first precipitated as $MgNH_4PO_4$, and this precipitate is then converted to $Mg_2P_2O_7$, which is found to weigh 0.0549 g. Express the quantity of magnesium in the sample in parts per million (that is, in grams of Mg per million grams of H_2O).

75. What volume of 0.248 M $CaCl_2$ must be added to 335 mL of 0.186 M KCl to produce a solution with a concentration of 0.250 M Cl^-? Assume that the solution volumes are additive.

76. An unknown white solid consists of two compounds, each containing a different cation. As suggested in the illustration, the unknown is partially soluble in water. The solution is treated with NaOH(aq) and yields a white precipitate. The part of the original solid that is insoluble in water dissolves in HCl(aq) with the evolution of a gas. The resulting solution is then treated with $(NH_4)_2SO_4(aq)$ and yields a white precipitate. **(a)** Is it possible that any of the cations Mg^{2+}, Cu^{2+}, Ba^{2+}, Na^+, or NH_4^+ were present in the original unknown? Explain your reasoning. **(b)** What compounds could be in the unknown mixture (that is, what anions might be present)?



77. Balance these equations for reactions in acidic solution.
(a) $IBr + BrO_3^- + H^+ \longrightarrow IO_3^- + Br^- + H_2O$
(b) $C_2H_5NO_3 + Sn \longrightarrow NH_2OH + CH_3CH_2OH + Sn^{2+}$
(c) $As_2S_3 + NO_3^- \longrightarrow H_3AsO_4 + S + NO$
(d) $H_5IO_6 + I_2 \longrightarrow IO_3^- + H^+ + H_2O$
(e) $S_2F_2 + H_2O \longrightarrow S_8 + H_2S_4O_6 + HF$

78. Balance these equations for reactions in basic solution.
(a) $Fe_2S_3 + H_2O + O_2 \longrightarrow Fe(OH)_3 + S$
(b) $O_2^- + H_2O \longrightarrow OH^- + O_2$
(c) $CrI_3 + H_2O_2 \longrightarrow CrO_4^{2-} + IO_4^-$
(d) $Ag + CN^- + O_2 + OH^- \longrightarrow [Ag(CN)_2]^- + H_2O$
(e) $B_2Cl_4 + OH^- \longrightarrow BO_2^- + Cl^- + H_2O + H_2$

79. A method of producing phosphine, PH_3, from elemental phosphorus, P_4, involves heating the P_4 with H_2O. An additional product is phosphoric acid, H_3PO_4. Write a balanced equation for this reaction.

80. Iron (Fe) is obtained from rock that is extracted from open pit mines and then crushed. The process used to obtain the pure metal from the crushed rock produces solid waste, called *tailings*, which are stored in disposal areas near the mines. The tailings pose a serious environmental risk because they contain sulfides, such as pyrite (FeS_2), which oxidize in air to produce metal ions and H^+ ions that can enter into surface water or ground water. The oxidation of FeS_2 to Fe^{3+} is described by the unbalanced chemical expression below.

$$FeS_2(s) + O_2(g) + H_2O(l) \longrightarrow Fe^{3+}(aq) + SO_4^{2-}(aq) + H^+(aq) \quad \text{(not balanced)}$$

Thus, the oxidation of pyrite produces Fe^{3+} and H^+ ions that can leach into surface or ground water. The leaching of H^+ ions causes the water to become very acidic. To prevent acidification of nearby ground or surface water, limestone ($CaCO_3$) is added to the tailings to neutralize the H^+ ions:

$$CaCO_3(s) + 2\,H^+(aq) \longrightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g)$$

(a) Balance the equation above for the reaction of FeS_2 and O_2. [*Hint:* Start with the half-equations $FeS_2(s) \rightarrow Fe^{3+}(aq) + SO_4{}^{2-}(aq)$ and $O_2(g) \rightarrow H_2O(l)$.] **(b)** What is the minimum amount of $CaCO_3(s)$ required, per kilogram of tailings, to prevent contamination if the tailings contain 3% S by mass? Assume that all the sulfur in the tailings is in the form FeS_2.

81. A sample of battery acid is to be analyzed for its sulfuric acid content. A 1.00 mL sample weighs 1.303 g. This 1.00 mL sample is diluted to 250.0 mL, and 10.00 mL of this diluted acid requires 34.12 mL of 0.00498 M $Ba(OH)_2$ for its titration. What is the mass percent of H_2SO_4 in the battery acid? (Assume that complete neutralization of the H_2SO_4 occurs.)

82. A piece of marble (assume it is pure $CaCO_3$) reacts with 2.00 L of 2.52 M HCl. After dissolution of the marble, a 10.00 mL sample of the resulting solution is withdrawn, added to some water, and titrated with 24.87 mL of 0.9987 M NaOH. What must have been the mass of the piece of marble? Comment on the precision of this method; that is, how many significant figures are justified in the result?

83. The reaction below can be used as a laboratory method of preparing small quantities of $Cl_2(g)$. If a 62.6 g sample that is 98.5% $K_2Cr_2O_7$ by mass is allowed to react with 325 mL of HCl(aq) with a density of 1.15 g/mL and 30.1% HCl by mass, how many grams of $Cl_2(g)$ are produced?

$$Cr_2O_7{}^{2-} + H^+ + Cl^- \longrightarrow Cr^{3+} + H_2O + Cl_2(g) \quad \text{(not balanced)}$$

84. Refer to Example 5-10. Suppose that the $KMnO_4(aq)$ were standardized by reaction with As_2O_3 instead of iron wire. If a 0.1304 g sample that is 99.96% As_2O_3 by mass had been used in the titration, how many milliliters of the $KMnO_4(aq)$ would have been required?

$$As_2O_3 + MnO_4{}^- + H^+ + H_2O \longrightarrow H_3AsO_4 + Mn^{2+} \quad \text{(not balanced)}$$

85. A new method under development for water treatment uses chlorine dioxide rather than chlorine. One method of producing ClO_2 involves passing $Cl_2(g)$ into a concentrated solution of sodium chlorite. $Cl_2(g)$ and sodium chlorite are the sole reactants, and NaCl(aq) and $ClO_2(g)$ are the sole products. If the reaction has a 97% yield, what mass of ClO_2 is produced per gallon of 2.0 M $NaClO_2(aq)$ treated in this way?

86. The active component in one type of calcium dietary supplement is calcium carbonate. A 1.2450 g tablet of the supplement is added to 65.00 mL of 0.4984 M HCl and allowed to react. After completion of the reaction, the excess HCl(aq) requires 38.45 mL of 0.2257 M NaOH for its titration to the equivalence point. What is the calcium content of the tablet, expressed in milligrams of Ca^{2+}?

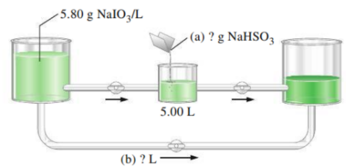
87. A 0.4324 g sample of a potassium hydroxide–lithium hydroxide mixture requires 28.28 mL of 0.3520 M HCl for its titration to the equivalence point. What is the mass percent lithium hydroxide in this mixture?

88. Chile saltpeter is a natural source of $NaNO_3$; it also contains $NaIO_3$. The $NaIO_3$ can be used as a source of iodine. Iodine is produced from sodium iodate in a two-step process occurring under acidic conditions:

$$IO_3{}^-(aq) + HSO_3{}^-(aq) \longrightarrow I^-(aq) + SO_4{}^{2-}(aq) \quad \text{(not balanced)}$$

$$I^-(aq) + IO_3{}^-(aq) \longrightarrow I_2(s) + H_2O(l) \quad \text{(not balanced)}$$

In the illustration, a 5.00 L sample of a $NaIO_3(aq)$ solution containing 5.80 g $NaIO_3$/L is treated with the stoichiometric quantity of $NaHSO_3$ (no excess of either reactant). Then, a further quantity of the initial $NaIO_3(aq)$ is added to the reaction mixture to bring about the second reaction. **(a)** How many grams of $NaHSO_3$ are required in the first step? **(b)** What additional volume of the starting solution must be added in the second step?



89. The active ingredients in a particular antacid tablet are aluminum hydroxide, $Al(OH)_3$, and magnesium hydroxide, $Mg(OH)_2$. A 5.00×10^2 mg sample of the active ingredients was dissolved in 50.0 mL of 0.500 M HCl. The resulting solution, which was still acidic, required 16.5 mL of 0.377 M NaOH for neutralization. What are the mass percentages of $Al(OH)_3$ and $Mg(OH)_2$ in the sample?

90. A compound contains only Fe and O. A 0.2729 g sample of the compound was dissolved in 50 mL of concentrated acid solution, reducing all the iron to Fe^{2+} ions. The resulting solution was diluted to 100 mL and then titrated with a 0.01621 M $KMnO_4$ solution. The unbalanced chemical expression for reaction between Fe^{2+} and $MnO_4{}^-$ is given below.

$$MnO_4{}^-(aq) + Fe^{2+}(aq) \longrightarrow Mn^{2+}(aq) + Fe^{3+}(aq) \quad \text{(not balanced)}$$

The titration required 42.17 mL of the $KMnO_4$ solution to reach the pink endpoint. What is the empirical formula of the compound?

91. Warfarin, $C_{19}H_{16}O_4$, is the active ingredient used in some anticoagulant medications. The amount of warfarin in a particular sample was determined as follows. A 13.96 g sample was first treated with an alkaline I_2 solution to convert $C_{19}H_{16}O_4$ to CHI_3. This treatment gives one mole of CHI_3 for every mole of $C_{19}H_{16}O_4$ that was initially present in the sample. The iodine in CHI_3 is then precipitated as AgI(s) by treatment with excess $AgNO_3$(aq):

$$CHI_3(aq) + 3\,AgNO_3(aq) + H_2O(l) \longrightarrow 3\,AgI(s) + 3\,HNO_3(aq) + CO(g)$$

If 0.1386 g solid AgI were obtained, then what is the percentage by mass of warfarin in the sample analyzed?

92. Copper refining traditionally involves "roasting" insoluble sulfide ores (CuS) with oxygen. Unfortunately, the process produces large quantities of $SO_2(g)$, which is a major contributor to pollution and acid rain. An alternative process involves treating the sulfide ore with HNO_3(aq), which dissolves the CuS without generating any SO_2. The unbalanced chemical expression for the reaction is given below.

$$CuS(s) + NO_3^-(aq) \longrightarrow Cu^{2+}(aq) + NO(g) + HSO_4^-(aq) \quad \text{(not balanced)}$$

What volume of concentrated nitric acid solution is required per kilogram of CuS? Assume that the concentrated nitric acid solution is 70% HNO_3 by mass and has a density of 1.40 g/mL.

93. Phosphorus is essential for plant growth, but an excess of phosphorus can be catastrophic in aqueous ecosystems. Too much phosphorus can cause algae to grow at an explosive rate and this robs the rest of the ecosystem of oxygen. Effluent from sewage treatment plants must be treated before it can be released into lakes or streams because the effluent contains significant amounts of $H_2PO_4^-$ and HPO_4^{2-}. (Detergents are a major contributor to phosphorus levels in domestic sewage because many detergents contain Na_2HPO_4.) A simple way to remove $H_2PO_4^-$ and HPO_4^{2-} from the effluent is to treat it with lime, CaO, which produces Ca^{2+} and OH^- ions in water. The OH^- ions convert $H_2PO_4^-$ and HPO_4^{2-} ions into PO_4^{3-} ions and, finally, Ca^{2+}, OH^-, and PO_4^{3-} ions combine to form a precipitate of $Ca_5(PO_4)_3OH(s)$.

(a) Write balanced chemical equations for the four reactions described above.
[*Hint*: The reactants are CaO and H_2O; $H_2PO_4^-$ and OH^-; HPO_4^{2-} and OH^-; Ca^{2+}, PO_4^{3-}, and OH^-.]

(b) How many kilograms of lime are required to remove the phosphorus from a 1.00×10^4 L holding tank filled with contaminated water, if the water contains 10.0 mg of phosphorus per liter?

Feature Problems

94. Sodium cyclopentadienide, NaC_5H_5, is a common reducing agent in the chemical laboratory, but there is a problem in using it: NaC_5H_5 is contaminated with tetrahydrofuran (THF), C_4H_8O, a solvent used in its preparation. The THF is present as $NaC_5H_5 \cdot (THF)_x$, and it is generally necessary to know exactly how much of this $NaC_5H_5 \cdot (THF)_x$ is present. This is accomplished by allowing a small amount of the $NaC_5H_5 \cdot (THF)_x$ to react with water,

$$NaC_5H_5 \cdot (C_4H_8O)_x + H_2O \longrightarrow NaOH(aq) + C_5H_5{-}H + x\,C_4H_8O$$

followed by titration of the NaOH(aq) with a standard acid. From the sample data tabulated below, determine the value of x in the formula $NaC_5H_5 \cdot (THF)_x$.

	Trial 1	Trial 2
Mass of $NaC_5H_5 \cdot (THF)_x$	0.242 g	0.199 g
Volume of 0.1001 M HCl required to titrate NaOH(aq)	14.92 mL	11.99 mL

95. Manganese is derived from pyrolusite ore, an impure manganese dioxide. In the procedure used to analyze a pyrolusite ore for its MnO_2 content, a 0.533 g sample is treated with 1.651 g oxalic acid ($H_2C_2O_4 \cdot 2\,H_2O$) in an acidic medium. Following this reaction, the excess oxalic acid is titrated with 0.1000 M $KMnO_4$, 30.06 mL being required. What is the mass percent MnO_2 in the ore?

$$H_2C_2O_4 + MnO_2 + H^+ \longrightarrow Mn^{2+} + H_2O + CO_2 \quad \text{(not balanced)}$$

$$H_2C_2O_4 + MnO_4^- + H^+ \longrightarrow Mn^{2+} + H_2O + CO_2 \quad \text{(not balanced)}$$

96. The Kjeldahl method is used in agricultural chemistry to determine the percent protein in natural products. The method is based on converting all the protein nitrogen to ammonia and then determining the amount of ammonia by titration. The percent nitrogen in the sample under analysis can be calculated from the quantity of ammonia produced. Interestingly, the majority of protein molecules in living matter contain just about 16% nitrogen.

A 1.250 g sample of meat is heated with concentrated sulfuric acid and a catalyst to convert all the nitrogen in the meat to $(NH_4)_2SO_4$. Then excess NaOH(aq) is added to the mixture, which is heated to expel $NH_3(g)$. All the nitrogen from the sample is found in the $NH_3(g)$, which is then absorbed in and neutralized by 50.00 mL of dilute H_2SO_4(aq). The excess H_2SO_4(aq) requires 32.24 mL of 0.4498 M NaOH for its titration. A separate 25.00 mL sample of the dilute H_2SO_4(aq) requires 22.24 mL of 0.4498 M NaOH for its titration. What is the percent protein in the meat?

97. Blood alcohol content (BAC) is often reported in weight–volume percent (w/v%). For example, a BAC of 0.10% corresponds to 0.10 g CH_3CH_2OH per 100 mL

A Method for Balancing Equations for Oxidation–Reduction Reactions That Occur in an Acidic or a Basic Aqueous Solution

1. Assign oxidation states to each element in the reaction and identify the species being oxidized and reduced.
2. Write separate, unbalanced equations for the oxidation and reduction half-reactions.
3. Balance the separate half-equations, in this order:
   - first with respect to the element being oxidized or reduced
   - then by adding electrons to one side or the other to account for the number of electrons produced (oxidation) or consumed (reduction)
4. Combine the half-reactions algebraically so that the total number of electrons cancels out.
5. Balance the net charge by either adding OH^- (for basic solutions) or H^+ (for acidic solutions).
6. Balance the O and H atoms by adding H_2O.
7. Check that the final equation is balanced with respect to each type of atom and with respect to charge.

of blood. Estimates of BAC can be obtained from breath samples by using a number of commercially available instruments, including the Breathalyzer for which a patent was issued to R. F. Borkenstein in 1958. The chemistry behind the Breathalyzer is described by the oxidation–reduction reaction below, which occurs in acidic solution:

$$\underset{\text{ethyl alcohol}}{CH_3CH_2OH(g)} + \underset{\text{(yellow-orange)}}{Cr_2O_7^{2-}(aq)} \longrightarrow CH_3COOH(aq) + \underset{\text{(green)}}{Cr^{3+}(aq)} \quad \text{(not balanced)}$$

A Breathalyzer instrument contains two ampules, each of which contains 0.75 mg $K_2Cr_2O_7$ dissolved in 3 mL of 9 M $H_2SO_4(aq)$. One of the ampules is used as reference. When a person exhales into the tube of the Breathalyzer, the breath is directed into one of the ampules, and ethyl alcohol in the breath converts $Cr_2O_7^{2-}$ into Cr^{3+}. The instrument compares the colors of the solutions in the two ampules to determine the breath alcohol content (BrAC), and then converts this into an estimate of BAC. The conversion of BrAC into BAC rests on the assumption that 2100 mL of air exhaled from the lungs contains the same amount of alcohol as 1 mL of blood. With the theory and assumptions described in this problem, calculate the molarity of $K_2Cr_2O_7$ in the ampules before and after a breath test in which a person with a BAC of 0.05% exhales 0.500 L of his breath into a Breathalyzer instrument.

98. In this problem, we describe an alternative method for balancing equations for oxidation-reduction reactions. The method is similar to the method given previously in Tables 5.5 and 5.6, but it places more emphasis on the assignment of oxidation states. (The method summarized in Tables 5.5 and 5.6 does not require you to assign oxidation states.) An emphasis on oxidation states is warranted because oxidation states are useful not only for keeping track of electrons but also for predicting chemical properties. The method is summarized in the table above.

The method offers a couple of advantages. First, the method applies to both acidic and basic environments because we balance charges by using either H^+ (for acidic environments) or OH^- (for basic environments). Second, the method is somewhat more efficient than the method we described previously because, in the method described here, we balance only once for charge and only once for hydrogen and oxygen. In the other method, we focus on the half-equations separately and must balance twice for charge and twice for hydrogen and oxygen.

Use the alternative method described above to balance the following oxidation-reduction equations.

(a) $Cr_2O_7^{2-}(aq) + Cl^-(aq) \longrightarrow Cr^{3+}(aq) + Cl_2(g)$ (acidic solution)

(b) $C_2O_4^{2-}(aq) + MnO_4^-(aq) \longrightarrow CO_3^{2-}(aq) + MnO_2(s)$ (basic solution)

Self-Assessment Exercises

99. In your own words, define or explain the terms or symbols **(a)** $\rightleftharpoons$ **(b)** [ ]; **(c)** spectator ion; **(d)** weak acid.

100. Briefly describe **(a)** half-equation method of balancing redox equations; **(b)** disproportionation reaction; **(c)** titration; **(d)** standardization of a solution.

101. Explain the important distinctions between **(a)** a strong electrolyte and strong acid; **(b)** an oxidizing agent and reducing agent; **(c)** precipitation reactions and neutralization reactions; **(d)** half-reaction and overall reaction.

102. The number of moles of hydroxide ion in 0.300 L of 0.0050 M $Ba(OH)_2$ is **(a)** 0.0015; **(b)** 0.0030; **(c)** 0.0050; **(d)** 0.010.

103. The highest $[H^+]$ will be found in an aqueous solution that is **(a)** 0.10 M HCl; **(b)** 0.10 M NH_3; **(c)** 0.15 M CH_3COOH; **(d)** 0.10 M H_2SO_4.

104. To precipitate Zn^{2+} from $Zn(NO_3)_2(aq)$, add **(a)** NH_4Cl; **(b)** $MgBr_2$; **(c)** K_2CO_3; **(d)** $(NH_4)_2SO_4$.

105. When treated with dilute HCl(aq), the solid that reacts to produce a gas is **(a)** $BaSO_3$; **(b)** ZnO; **(c)** NaBr; **(d)** Na_2SO_4.

106. An unknown solid compound dissolves readily when added to water, forming a solution that conducts electricity. A precipitate forms when $Ba(NO_3)_2(aq)$ is added to a solution of this compound, but not when $Cu(NO_3)_2(aq)$ is added. When the unknown solid is added to $CH_3COOH(aq)$, no gas is produced. When the solid is added to NaOH (aq), a gas with the pungent odor of ammonia is produced. What is the possible identity of the unknown solid?

107. What is the net ionic equation for the reaction that occurs when an aqueous solution of KI is added to an aqueous solution of $Pb(NO_3)_2$?

108. When aqueous sodium carbonate, Na_2CO_3, is treated with dilute hydrochloric acid, HCl, the products are sodium chloride, water, and carbon dioxide gas. What is the net ionic equation for this reaction?

109. Describe the synthesis of each of the following ionic compounds, starting from solutions of sodium and nitrate salts. Then write the net ionic equation for each synthesis.
(a) $Zn_3(PO_4)_2$;
(b) $Cu(OH)_2$;
(c) $NiCO_3$.

110. Consider the following redox reaction:

$$4\,NO(g) + 3\,O_2(g) + 2\,H_2O(l) \longrightarrow 4\,NO_3^-(aq) + 4\,H^+(aq)$$

(a) Which species is oxidized?
(b) Which species is reduced?
(c) Which species is the oxidizing agent?
(d) Which species is the reducing agent?
(e) Which species gains electrons?
(f) Which species loses electrons?

111. Balance the following oxidation–reduction equations.
(a) $Cl_2(aq) \longrightarrow Cl^-(aq) + ClO^-(aq)$ (basic solution)
(b) $C_2O_4^{2-}(aq) + MnO_4^-(aq) \longrightarrow Mn^{2+}(aq) + CO_2(g)$ (acidic solution)

112. In the equation

$$?\,Fe^{2+}(aq) + O_2(g) + 4\,H^+(aq) \longrightarrow ?\,Fe^{3+}(aq) + 2\,H_2O(l)$$

the missing coefficients **(a)** are each 2; **(b)** are each 4; **(c)** can have any values as long as they are the same; **(d)** must be determined by experiment.

113. What is the simplest ratio $a{:}b$ when the equation below is properly balanced?

$$a\,ClO^-(aq) + b\,I_2(aq) \xrightarrow[\text{solution}]{\text{acidic}} c\,Cl^-(aq) + d\,IO_3^-(aq)$$

(a) 2:5; **(b)** 5:2; **(c)** 1:5; **(d)** 5:1; **(e)** 2:3.

114. In the half-reaction in which NpO_2^+ is converted to Np^{4+}, the number of electrons appearing in the half-equation is **(a)** 1; **(b)** 2; **(c)** 3; **(d)** 4.

115. Which list of compounds contains a nonelectrolyte, a weak electrolyte, and a strong electrolyte? **(a)** CO_2, NaCl, $MnSO_4$; **(b)** H_2SO_4, CH_3COOH, CuCl; **(c)** SO_2, HF, $FeSO_4$; **(d)** $Ba(ClO_3)_2$, $K_2S_2O_3$, $NaMnO_4$; **(e)** none of these.

116. Which list of compounds contains a weak acid, a weak base, and a salt? **(a)** HCl, NH_3, Na_2SO_4; **(b)** HNO_2, NH_3, NH_4NO_2; **(c)** HCl, $Ca(OH)_2$, $CaSO_4$; **(d)** HNO_2, KOH, Cs_2CrO_4; **(e)** none of these.

117. Which list of compounds contains two soluble compounds and an insoluble one?
(a) $HgBr_2$, $MnSO_4$, $Na_2C_2O_4$;
(b) $Na_2S_2O_3$, NH_4Cl, CoI_2;
(c) MnS, $Cu(OH)_2$, Al_2O_3;
(d) $Pb(ClO_4)_2$, $Ca(NO_3)_2$, Hg_2SO_4;
(e) none of these.

118. Classify each of the following statements as true or false.
(a) Barium chloride, $BaCl_2$, is a weak electrolyte in aqueous solution.
(b) In the reaction $H^-(aq) + H_2O(l) \rightarrow H_2(g) + OH^-(aq)$, water acts as both an acid and an oxidizing agent.
(c) A precipitate forms when aqueous sodium carbonate, $Na_2CO_3(aq)$, is treated with excess aqueous hydrochloric acid, HCl(aq).
(d) Hydrofluoric acid, HF, is a strong acid in water.
(e) Compared with a 0.010 M solution of $NaNO_3$, a 0.010 M solution of $Mg(NO_3)_2$ is a better conductor of electricity.

119. Which of the following reactions are oxidation–reduction reactions?
(a) $H_2CO_3(aq) \longrightarrow H_2O(l) + CO_2(g)$
(b) $2\,Li(s) + 2\,H_2O(l) \longrightarrow 2\,LiOH(aq) + H_2(g)$
(c) $4\,Ag(s) + PtCl_4(aq) \longrightarrow 4\,AgCl(s) + Pt(s)$
(d) $2\,HClO_4(aq) + Ca(OH)_2(aq) \longrightarrow 2\,H_2O(l) + Ca(ClO_4)_2(aq)$

120. Similar to Figure 5-4(c), but using the formulas HAc, Ac^-, and H_3O^+, give a more accurate representation of $CH_3COOH(aq)$ in which ionization is 5% complete.

121. Appendix E describes a useful study aid known as concept mapping. Using the method presented in Appendix E, construct a concept map illustrating the different concepts introduced in Sections 5-4, 5-5, and 5-6.