Chemical Reactions

Section 9.1 Reactions and Equations

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Practice Problems

pages 284–287

Write skeleton equations for the following word equations.

1. Hydrogen and bromine gases react to yield hydrogen bromide.

hydrogen(g) + bromine(g) ⟶ hydrogen bromide(g)

$H_2(g) + Br_2(g) \rightarrow HBr(g)$

2. When carbon monoxide and oxygen react, carbon dioxide forms.

carbon monoxide(g) + oxygen(g) ⟶ carbon dioxide(g)

$CO(g) + O_2(g) \rightarrow CO_2(g)$

3. Challenge Write the word equation and the skeleton equation for the following reaction: when heated, solid potassium chlorate yields solid potassium chloride and oxygen gas.

Potassium chlorate(s) ⟶ potassium chloride(s) + oxygen(g)

$KClO_3(s) \rightarrow KCl(s) + O_2(g)$

Write chemical equations for each of the following reactions.

4. In water, iron(III) chloride reacts with sodium hydroxide, producing solid iron(III) hydroxide and sodium chloride.

$FeCl_3(aq) + 3NaOH(aq) \rightarrow Fe(OH)_3(s) + 3NaCl(aq)$

5. Liquid carbon disulfide reacts with oxygen gas, producing carbon dioxide gas and sulfur dioxide gas.

$CS_2(l) + 3O_2(g) \rightarrow CO_2(g) + 2SO_2(g)$

6. Challenge A piece of zinc metal is added to a solution of hydrogen sulfate. This reaction produces a gas and a solution of zinc sulfate.

$Zn(s) + H_2SO_4(aq) \rightarrow H_2(g) + ZnSO_4(aq)$

Section 9.1 Assessment

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7. Explain why it is important that a chemical equation be balanced.

Because mass is neither created nor destroyed in chemical reactions, the numbers of atoms of all elements must be equal on both sides of the reaction arrow.

8. List three types of physical evidence that indicate a chemical reaction has occurred.

Answers may include release or absorption of energy, change in color, change in odor, formation of a gas, or formation of a solid.

9. Compare and contrast a skeleton equation and a chemical equation.

The skeleton equation includes the formulas of reactants and products. The chemical equation gives the relative amounts of reactants and products.

10. Explain why it is important to reduce coefficients in a balanced equation to the lowest possible whole-number ratio.

Coefficients in the lowest ratio most clearly indicate the relative amounts of substances in a reaction.

11. Analyze When balancing a chemical equation, can you adjust the subscript in a formula? Explain.

No. Doing so changes the identity of the substance.

12. Assess Is the following equation balanced? If not, correct the coefficients to balance the equation.

$2K_2CrO_4(aq) + Pb(NO_3)_2(aq) \rightarrow 2KNO_3(aq) + PbCrO_4(s)$

No. The correct equation is $K_2CrO_4(aq) + Pb(NO_3)_2(aq) \rightarrow 2KNO_3(aq) + PbCrO_4(s)$

13. Evaluate Aqueous phosphoric acid and aqueous calcium hydroxide react to form solid calcium phosphate and water. Write a balanced chemical equation for this reaction.

$2H_3PO_4(aq) + 3Ca(OH)_2(aq) \rightarrow Ca_3(PO_4)_2(s) + 6H_2O(aq)$

Section 9.2 Classifying Chemical Reactions

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Practice Problems

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Write chemical equations for the following reactions. Classify each reaction into as many categories as possible.

14. The solids aluminum and sulfur react to produce aluminum sulfide.

$2Al(s) + 3S(s) \rightarrow Al_2S_3(s)$; synthesis

15. Water and dinitrogen pentoxide gas react to produce aqueous hydrogen nitrate.

$H_2O(l) + N_2O_5(g) \rightarrow 2HNO_3(aq)$; synthesis

16. The gases nitrogen dioxide and oxygen react to produce dinitrogen pentoxide gas.

$4NO_2(g) + O_2(g) \rightarrow 2N_2O_5(g)$; synthesis and combustion

17. Challenge Sulfuric acid (H_2SO_4) and sodium hydroxide solutions react to produce aqueous sodium sulfate and water.

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

Write chemical equations for the following decomposition reactions.

18. Aluminum oxide(s) decomposes when electricity is passed through it.

$2Al_2O_3(s) \rightarrow 4Al(s) + 3O_2(g)$

19. Nickel(II) hydroxide(s) decomposes to produce nickel(II) oxide(s) and water.

$Ni(OH)_2(s) \rightarrow NiO(s) + H_2O(l)$

20. Challenge Heating sodium hydrogen carbonate(s) produces sodium carbonate(aq) and water. Carbon dioxide gas is also produced.

$2NaHCO_3(s) \rightarrow Na_2CO_3(aq) + CO_2(g) + H_2O(l)$

Problem-Solving Lab

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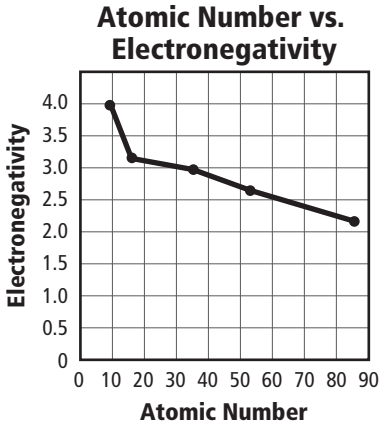
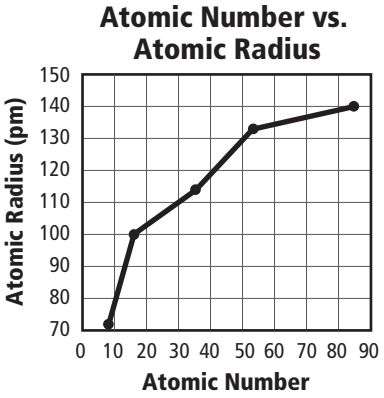
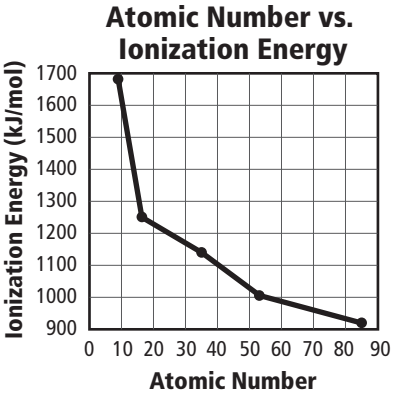
Properties of Halogens			
Halogen	**Atomic Radius (ppm)**	**Ionic Energy (kJ/mol)**	**Electronegativity**
Fluorine	72	1681	3.98
Chlorine	100	1251	3.16
Bromine	114	1140	2.96
Iodine	133	1008	2.66
Astatine	140	920	2.2

1. Make graphs Use the information in the data table to make three line graphs.

Student graphs should accurately reflect the data in the table.







2. Describe any periodic trends that you identify in the data.

With increasing atomic number, atomic radius increases, ionization energy decreases, and electronegativity decreases.

3. Relate any periodic trends that you identify among the halogens to the activity series of halogens shown in **Figure 9.13.**

These trends correlate with the decrease in reactivity down the period.

4. Predict the location of the element astatine in the activity series of halogens. Explain your answer.

Astatine is a group 17 element and follows the trends described for the halogens. Therefore, At would be at the bottom of the activity series on the basis of its periodic trends.

Practice Problems

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Predict if the following single-replacement reactions will occur. If a reaction occurs, write a balanced equation for the reaction.

21. $K(s) + ZnC_{l2}(aq) \rightarrow$

Yes. K is above Zn in the activity series.
$2K(s) + ZnCl_2(aq) \rightarrow Zn(s) + 2KCl(aq)$

22. $Cl_2(g) + HF(aq) \rightarrow$

No. Cl is below F in the activity series.

23. $Fe(s) + Na_3PO_4(aq) \rightarrow$

No. Fe is below Na in the activity series.

24. Challenge $Al(s) + Pb(NO_3)_2(aq) \rightarrow$

Yes. Al is above Pb in the activity series.
$2Al(s) + 3Pb(NO_3)_2(s) \rightarrow 3Pb(s) + 2Al(NO_3)_3(aq)$

Write the balanced chemical equations for the following double-replacement reactions.

LiI(aq) $AgNO_3(aq)$

25. The two substances at right react to produce solid silver iodide and aqueous lithium nitrate.

$LiI(aq) + AgNO_3(aq) \rightarrow AgI(s) + LiNO_3(aq)$

26. Aqueous barium chloride and aqueous potassium carbonate react to produce solid barium carbonate and aqueous potassium chloride.

$BaCl_2(aq) + K_2CO_3(aq) \rightarrow BaCO_3(s) + 2KCl(aq)$

27. Aqueous sodium oxalate and aqueous lead(II) nitrate react to produce solid lead(II) oxalate and aqueous sodium nitrate.

$Na_2C_2O_4(aq) + Pb(NO_3)_2(aq) \rightarrow$
$PbC_2O_4(s) + 2NaNO_3(aq)$

28. Challenge Acetic acid (CH_3COOH) and potassium hydroxide react to produce potassium acetate and water.

$CH_3COOH(aq) + KOH(aq) \rightarrow$
$CH_3COOK(aq) + H_2O(l)$

Section 9.2 Assessment

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29. Describe the four types of chemical reactions and their characteristics.

Synthesis: two substances react to yield a single product. Combustion: a substance reacts with oxygen, producing heat and light. Decomposition: a single compound breaks down into two or more elements or new compounds. Replacement: the atoms of one element replace the atoms of another element in a compound (single-replacement), or positive ions are exchanged between two compounds (double-replacement).

30. Explain how an activity series of metals is organized.

An activity series of metals orders metals by their reactivity with other metals. The most active metals are on the top of the list, and the least active metals are at the bottom of the list.

31. Compare and contrast single-replacement reactions and double-replacement reactions.

In a single-replacement reaction, atoms of one element replace atoms of another element in a compound. In a double-replacement reaction, two compounds dissolved in water exchange positive ions.

32. Describe the result of a double-replacement reaction.

Double-replacement reactions produce two different compounds, one being a solid precipitate, water, or gas.

33. Classify What type of reaction is most likely to occur when barium reacts with fluorine? Write the chemical equation for the reaction.

A synthesis reaction will likely occur.
$Ba + F_2 \rightarrow BaF_2$

34. Interpret Data Does the following reaction occur? Explain your answer.

$3Ni + 2AuBr_3 \rightarrow 3NiBr_2 + 2Au$

The reaction does occur because nickel is more reactive than gold.

Section 9.3 Reactions in Aqueous Solutions

pages 299–308

Practice Problems

pages 302–306

Write chemical, complete ionic, and net ionic equations for the following reactions that may produce precipitates. Use *NR* to indicate if no reaction occurs.

35. Aqueous solutions of potassium iodide and silver nitrate are mixed, forming the precipitate silver iodide.

chemical equation:
$KI(aq) + AgNO_3(aq) \rightarrow KNO_3(aq) + AgI(s)$

complete ionic equation: $\cancel{K^+}(aq) + I^-(aq) + Ag^+(aq) + \cancel{NO_3^-}(aq) \rightarrow \cancel{K^+}(aq) + \cancel{NO_3^-}(aq) + AgI(s)$

net ionic equation: $I^-(aq) + Ag^+(aq) \rightarrow AgI(s)$

36. Aqueous solutions of ammonium phosphate and sodium sulfate are mixed. No precipitate forms and no gas is produced.

chemical equation: $2(NH_4)_3PO_4(aq) + 3Na_2SO_4(aq) \rightarrow 3(NH_4)_2SO_4(aq) + 2Na_3PO_4(aq)$

complete ionic equation: $\cancel{6NH_4^+}(aq) + \cancel{2PO_4^{3-}}(aq) + \cancel{6Na^+}(aq) + \cancel{3SO_4^{2-}}(aq) \rightarrow \cancel{6NH_4^+}(aq) + \cancel{3SO_4^{2-}}(aq) + \cancel{6Na^+}(aq) + \cancel{2PO_4^{3-}}(aq)$

No reaction occurs; therefore, there is no net ionic equation.

37. Aqueous solutions of aluminum chloride and sodium hydroxide are mixed, forming the precipitate aluminum hydroxide.

chemical equation: $AlCl_3(aq) + 3NaOH(aq) \rightarrow Al(OH)_3(s) + 3NaCl(aq)$

complete ionic equation: $Al^{3+}(aq) + \cancel{3Cl^-}(aq) + \cancel{3Na^+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s) + \cancel{3Na^+}(aq) + \cancel{3Cl^-}(aq)$

net ionic equation:
$Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$

38. Aqueous solutions of lithium sulfate and calcium nitrate are mixed, forming the precipitate calcium sulfate.

chemical equation: $Li_2SO_4(aq) + Ca(NO_3)_2(aq) \rightarrow 2LiNO_3(aq) + CaSO_4(s)$

complete ionic equation:
$\cancel{2Li^+}(aq) + SO_4^{2-}(aq) + Ca^{2+}(aq) + \cancel{2NO_3^-}(aq) \rightarrow \cancel{2Li^+}(aq) + \cancel{2NO_3^-}(aq) + CaSO_4(s)$

net ionic equation:
$SO_4^{2-}(aq) + Ca^{2+}(aq) \rightarrow CaSO_4(s)$

39. Challenge When aqueous solutions of sodium carbonate and manganese(V) chloride are mixed, a precipitate forms. The precipitate is a compound containing manganese.

chemical equation: $5Na_2CO_3(aq) + 2MnCl_5(aq) \rightarrow 10NaCl(aq) + Mn_2(CO_3)_5(s)$

complete ionic equation: $\cancel{10Na^+}(aq) + 5CO_3^{2-}(aq) + 2Mn^{5+}(aq) + \cancel{10Cl^-}(aq) \rightarrow \cancel{10Na^+}(aq) + \cancel{10Cl^-}(aq) + Mn_2(CO_3)_5(s)$

net ionic equation:
$5CO_3^{2-}(aq) + 2Mn^{5+}(aq) \rightarrow Mn_2(CO_3)_5(s)$

40. Mixing sulfuric acid (H_2SO_4) and aqueous potassium hydroxide produces water and aqueous potassium sulfate.

chemical equation:
$H_2SO_4(aq) + 2KOH(aq) \rightarrow 2H_2O(l) + K_2SO_4(aq)$

complete ionic equation:
$2H^+(aq) + \cancel{SO_4^{2-}}(aq) + \cancel{2K^+}(aq) + 2OH^-(aq) \rightarrow 2H_2O(l) + \cancel{2K^+}(aq) + \cancel{SO_4^{2-}}(aq)$

net ionic equation: $2H^+(aq) + 2OH^-(aq) \rightarrow 2H_2O(l)$ **or** $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

41. Mixing hydrochloric acid (HCl) and aqueous calcium hydroxide produces water and aqueous calcium chloride.

chemical equation:
$2HCl(aq) + Ca(OH)_2(aq) \rightarrow 2H_2O(l) + CaCl_2(aq)$

complete ionic equation:
$2H^+(aq) + \cancel{2Cl^-}(aq) + \cancel{Ca^{2+}}(aq) + 2OH^-(aq) \rightarrow 2H_2O(l) + \cancel{Ca^{2+}}(aq) + \cancel{2Cl^-}(aq)$

net ionic equation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

42. Mixing nitric acid (HNO_3) and aqueous ammonium hydroxide produces water and aqueous ammonium nitrate.

chemical equation:
$HNO_3(aq) + NH_4OH(aq) \rightarrow H_2O(l) + NH_4NO_3(aq)$

complete ionic equation:
$H^+(aq) + \cancel{NO^{3-}}(aq) + \cancel{NH_4^+}(aq) + OH^-(aq) \rightarrow H_2O(l) + \cancel{NH_4^+}(aq) + \cancel{NO_3^-}(aq)$

net ionic equation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

43. Mixing hydrosulfuric acid (H_2S) and aqueous calcium hydroxide produces water and aqueous calcium sulfate.

chemical equation:
$H_2S(aq) + 1\ Ca(OH)_2(aq) \rightarrow 2H_2O(l) + CaS(aq)$

complete ionic equation:
$2H^+(aq) + \cancel{S^{2-}}(aq) + \cancel{Ca^{2+}}(aq) + 2OH^-(aq) \rightarrow 2H_2O(l) + \cancel{Ca^{2+}}(aq) + \cancel{S^{2-}}(aq)$

net ionic equation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

44. Challenge When benzoic acid (C_6H_5COOH) and magnesium hydroxide are mixed, water and magnesium benzoate are produced.

chemical equation: $2C_6H_5COOH(aq) + Mg(OH)_2(aq) \rightarrow Mg(C_6H_5COO)_2(aq) + 2H_2O(l)$

complete ionic equation: $\cancel{2C_6H_5COO^-(aq)} + 2H^+(aq) + \cancel{Mg^{2+}(aq)} + 2OH^-(aq) \rightarrow \cancel{2C_6H_5COO^-(aq)} + \cancel{Mg^{2+}(aq)} + 2H_2O(l)$

net ionic equation:
$2H^+(aq) + 2OH^-(aq) \rightarrow 2H_2O(l)$

45. Perchloric acid ($HClO_4$) reacts with aqueous potassium carbonate, forming carbon dioxide gas and water.

chemical equation: $2HClO_4(aq) + K_2CO_3(aq) \rightarrow H_2O(l) + CO_2(g) + 2KClO_4(aq)$

complete ionic equation:
$2H^+(aq) + \cancel{2ClO_4^-}(aq) + \cancel{2K^+}(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g) + \cancel{2K^+}(aq) + \cancel{2ClO_4^-}(aq)$

net ionic equation:
$2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$

46. Sulfuric acid (H_2SO_4) reacts with aqueous sodium cyanide, forming hydrogen cyanide gas and aqueous sodium sulfate.

chemical equation: $H_2SO_4(aq) + 2NaCN(aq) \rightarrow 2HCN(g) + Na_2SO_4(aq)$

complete ionic equation:
$2H^+(aq) + \cancel{SO_4^{2-}}(aq) + \cancel{2Na^+}(aq) + 2CN^-(aq) \rightarrow 2HCN(g) + \cancel{2Na^+}(aq) + \cancel{SO_4^{2-}}(aq)$

net ionic equation: $2H^+(aq) + 2CN^-(aq) \rightarrow 2HCN(g)$ **or** $H^+(aq) + CN^-(aq) \rightarrow HCN(g)$

47. Hydrobromic acid (HBr) reacts with aqueous ammonium carbonate, forming carbon dioxide gas and water.

chemical equation: $2HBr(aq) + (NH_4)_2CO_3(aq) \rightarrow H_2O(l) + CO_2(g) + 2NH_4Br(aq)$

complete ionic equation:
$2H^+(aq) + \cancel{2Br^-}(aq) + \cancel{2NH_4^+}(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g) + \cancel{2NH_4^+}(aq) + \cancel{2Br^-}(aq)$

net ionic equation:
$2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$

48. Nitric acid (HNO_3) reacts with aqueous potassium rubidium sulfide, forming hydrogen sulfide gas.

chemical equation: $2HNO_3(aq) + KRbS(aq) \rightarrow H_2S(g) + KRb(NO_3)_2(aq)$

complete ionic equation: $2H^+(aq) + 2NO_3^-(aq) + \cancel{K^+}(aq) + \cancel{Rb^+}(aq) + S^{2-}(aq) \rightarrow H_2S(g) + \cancel{K^+}(aq) + \cancel{Rb^+}(aq) + \cancel{2NO_3^-}(aq)$

net ionic equation: $2H^+(aq) + S^{2-}(aq) \rightarrow H_2S(g)$

49. Challenge Aqueous potassium iodide reacts with lead nitrate in solution, forming solid lead iodide.

chemical equation: $2KI(aq) + Pb(NO_3)_2(aq) \rightarrow 2KNO_3(aq) + PbI_2(s)$

complete ionic equation:
$\cancel{2K^+(aq)} + 2I^-(aq) + Pb^{2+}(aq) + \cancel{2NO_3^-(aq)} \rightarrow \cancel{2K^+(aq)} + \cancel{2NO_3^-(aq)} + PbI_2(s)$

net ionic equation: $Pb^{2+}(aq) + 2I^-(aq) \rightarrow PbI_2(s)$

Section 9.3 Assessment

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50. List three common types of products produced by reactions that occur in aqueous solutions.

precipitates, water, and gases

51. Describe solvents and solutes in an aqueous solution.

A solvent is the most plentiful substance in a solution, and a solute is the substance dissolved in the solvent.

52. Distinguish between a complete ionic equation and a net ionic equation.

In a complete ionic equation, all dissolved ionic compounds and highly ionized molecular compounds are shown as free ions. A net ionic equation includes only the particles that take part in the reaction.

53. Write complete ionic and net ionic equations for the reaction between sulfuric acid (H_2SO_4) and calcium carbonate ($CaCO_3$).

$H_2SO_4(aq) + CaCO_3(s) \rightarrow H_2O(I) + CO_2(g) + CaSO_4(s)$

Complete: $2H^+(aq) + SO_4^{2-}(aq) + CaCO_3(s) \rightarrow H_2O(l) + CO_2(g) + CaSO_4(s)$

Net: $2H^+(aq) + SO_4^{2-}(aq) + CaCO_3(s) \rightarrow H_2O(l) + CO_2(g) + CaSO_4(s)$

54. Analyze Complete and balance the following equation.

$CO_2(g) + HCl(aq) \rightarrow$

$CO_2(g) + 4HCl(aq) \rightarrow CCl_4(l) + 2H_2O(l)$

55. Predict What type of product would the following reaction be most likely to produce? Explain your reasoning.

$Ba(OH)_2(aq) + 2HCl(aq) \rightarrow$

water: The reactants would break down into these ions in solution: $Ba^+ + OH^- + H^+ + Cl^-$. The barium and chloride ions are spectator ions; so the ions that take part in the reaction are the OH^- and H^+ ions, which form water.

56. Formulate Equations A reaction occurs when nitric acid (HNO_3) is mixed with an aqueous solution of potassium hydrogen carbonate. Aqueous potassium nitrate is produced. Write the chemical and net ionic equations for the reaction.

Chemical: $HNO_3(aq) + KHCO_3(aq) \rightarrow H_2O(l) + CO_2(g) + KNO_3(aq)$

Net: $H^+(aq) + HCO_3^-(aq) \rightarrow H_2O(l) + CO_2(g)$

Chapter 9 Assessment

pages 312–315

Section 9.1

Mastering Concepts

57. Define *chemical equation*.

A chemical equation is a representation of a chemical reaction using chemical symbols, arrows, and numbers to indicate the reactants and products.

58. Distinguish between a chemical reaction and a chemical equation.

A chemical reaction occurs when reactants are converted into products. A chemical equation is a representation of a chemical reaction using chemical symbols. The chemical equation also indicates the physical state of the reactants and products.

59. Explain the difference between reactants and products.

Reactants are the initial components and products are the resultant components.

60. What do the arrows and coefficients in equations communicate?

Arrows separate reactants from products and specify direction of reaction. Coefficients specify the relative amount of the components.

61. Does a conversion of a substance into a new substance always indicate that a chemical reaction has occurred? Explain.

Yes. A chemical reaction is the process by which the atoms of one or more substances are rearranged to form different substances.

62. Write formulas for the following substances and designate their physical states.

a. nitrogen dioxide gas

$NO_2(g)$

b. liquid gallium

Ga(l)

c. barium chloride dissolved in water

$BaCl_2(aq)$

d. solid ammonium carbonate

$(NH_4)_2CO_3(s)$

63. Identify the reactants in the following reaction: When potassium is dropped into aqueous zinc nitrate, zinc and aqueous potassium nitrate form.

K(s) and $Zn(NO_3)_2(aq)$

64. Balance the reaction of hydrogen sulfide with atmospheric oxygen gas.

$H_2S(g) + O_2(g) \longrightarrow SO_2(g) + H_2O(g)$

$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g)$

65. Write word equations for the following skeleton equations.

a. $Cu(s) + O_2(g) \longrightarrow CuO(s)$

copper(s) + oxygen (g) → copper(II) oxide(s)

b. $K(s) + H_2O(l) \longrightarrow KOH(aq) + H_2(g)$

potassium(s) + water(l) → potassium hydroxide(aq) + hydrogen(g)

c. $CaCl_2(aq) + Na_2SO_4(aq) \longrightarrow CaSO_4(s) + NaCl(aq)$

calcium chloride(aq) + sodium sulfate(aq) → calcium sulfate(s) + sodium chloride(aq)

66. Balance the following reactions.

a. $(NH_4)_2Cr_2O_7(s) \longrightarrow Cr_2O_3(s) + N_2(g) + H_2O(g)$

$(NH_4)_2Cr_2O_7(s) \rightarrow Cr_2O_3(s) + N_2(g) + 4H_2O(g)$

b. $CO_2(g) + H_2O(l) \longrightarrow C_6H_{12}O_6(s) + O_2(g)$

$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$

Mastering Problems

67. Hydrogen iodide gas breaks down into hydrogen gas and iodine gas during a decomposition reaction. Write a skeleton equation for this reaction.

$HI(g) \rightarrow H_2(g) + I_2(g)$

68. Write skeleton equations for these reactions.

a. sodium carbonate(s) ⟶ sodium oxide(s) + carbon dioxide(g)

$Na_2CO_3(s) \rightarrow Na_2O(s) + CO_2(g)$

b. aluminum(s) + iodine(s) ⟶ aluminum iodide(s)

$Al(s) + I_2(s) \rightarrow AlI_3(s)$

c. iron(II) oxide(s) + oxygen(g) ⟶ iron(III) oxide(s)

$FeO(s) + O_2(g) \rightarrow Fe_2O_3(s)$

69. Write skeleton equations for these reactions.

a. butane $(C_4H_{10})(l)$ + oxygen(g) ⟶ carbon dioxide(g) + water(l)

$C_4H_{10}(l) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$

b. aluminum carbonate(s) ⟶ aluminum oxide(s) + carbon dioxide(g)

$Al_2(CO_3)_3(s) \rightarrow Al_2O_3(s) + CO_2(g)$

c. silver nitrate(aq) + sodium sulfide(aq) ⟶ silver sulfide(s) + sodium nitrate(aq)

$AgNO_3(aq) + Na_2S(aq) \rightarrow Ag_2S(s) + NaNO_3(aq)$

70. Write a skeleton equation for the reaction between lithium(s) and chlorine gas to produce lithium chloride(s).

$Li(s) + Cl_2(g) \rightarrow LiCl(s)$

71. Write skeleton equations for these reactions.

a. iron(s) + fluorine(g) ⟶ iron(III) fluoride(s)

$Fe(s) + F_2(g) \rightarrow FeF_3(s)$

b. sulfur trioxide(g) + water(l) ⟶ sulfuric acid(aq)

$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$

c. sodium(s) + magnesium iodide(aq) ⟶ sodium iodide(aq) + magnesium(s)

$Na(s) + MgI_2(aq) \rightarrow NaI(aq) + Mg(s)$

d. vanadium(s) + oxygen(g) ⟶ vanadium(V) oxide(s)

$V(s) + O_2(g) \rightarrow V_2O_5(s)$

72. Write skeleton equations for these reactions.

a. lithium(s) + gold(III) chloride(aq) ⟶ lithium chloride(aq) + gold(s)

$Li(s) + AuCl_3(aq) \rightarrow LiCl(aq) + Au(s)$

b. iron(s) + tin(IV) nitrate(aq) ⟶ iron(III) nitrate(aq) + tin(s)

$Fe(s) + Sn(NO_3)_4(aq) \rightarrow Fe(NO_3)_3(aq) + Sn(s)$

c. nickel(II) chloride(s) + oxygen(g) ⟶ nickel(II) oxide(s) + dichlorine pentoxide(g)

$NiCl_2(s) + O_2(g) \rightarrow NiO(s) + Cl_2O_5(g)$

d. lithium chromate(aq) + barium chloride(aq) ⟶ lithium chloride(aq) + barium chromate(s)

$Li_2CrO_4(aq) + BaCl_2(aq) \rightarrow LiCl(aq) + BaCrO_4(s)$

73. Balance the skeleton equations for the reactions described in Question 71.

a. $2Fe(s) + 3F_2(g) \rightarrow 2FeF_3(s)$

b. $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$

c. $2Na(s) + MgI_2(aq) \rightarrow 2NaI(aq) + Mg(s)$

d. $4V(s) + 5O_2(g) \rightarrow 2V_2O_5(s)$

74. Balance the skeleton equations for the reactions described in Question 72.

a. $3Li(s) + AuCl_3(aq) \rightarrow 3LiCl(aq) + Au(s)$

b. $4Fe(s) + 3Sn(NO_3)_4(aq) \rightarrow 4Fe(NO_3)_3(aq) + 3Sn(s)$

c. $NiCl_2(s) + 3O_2(g) \rightarrow NiO(s) + Cl_2O_5(g)$

d. $Li_2CrO_4(aq) + BaCl_2(aq) \rightarrow 2LiCl(aq) + BaCrO_4(s)$

75. Write chemical equations for these reactions.

a. When solid naphthalene ($C_{10}H_8$) burns in air, the products are gaseous carbon dioxide and liquid water.

$C_{10}H_8(s) + 12O_2(g) \rightarrow 10CO_2(g) + 4H_2O(l)$

b. Bubbling hydrogen sulfide gas through manganese(II) chloride dissolved in water results in the formation of the precipitate manganese(II) sulfide and hydrochloric acid.

$H_2S(g) + MnCl_2(aq) \rightarrow MnS(s) + 2HCl(aq)$

c. Solid magnesium reacts with nitrogen gas to produce solid magnesium nitride.

$3Mg(s) + N_2(g) \rightarrow Mg_3N_2(s)$

d. Heating oxygen difluoride gas yields oxygen gas and fluorine gas.

$2OF_2(g) \rightarrow O_2(g) + 2F_2(g)$

Section 9.2

Mastering Concepts

76. List each of the four types of chemical reactions and give an example for each type.

synthesis: reaction of hydrogen gas and oxygen gas to produce water

combustion: the combustion of methanol in oxygen produce carbon dioxide, water, and heat

decomposition: nitrogen monoxide decomposes into oxygen gas and nitrogen gas

replacement: copper replaces silver in silver nitrate

77. How would you classify a chemical reaction between two reactants that produces one product?

It is a synthesis reaction.

78. Under what conditions does a precipitate form in a chemical reaction?

when the reaction occurs in aqueous solution and the product of the reaction is insoluble.

79. Will a metal always replace another metal in a compound dissolved in water? Explain.

No. The most active metal will replace the least active metal, but the opposite will not occur.

80. In each of the following pairs, which element will replace the other in a reaction?

a. tin and sodium

Na replaces Sn

b. fluorine and iodine

F replaces I

c. lead and silver

Pb replaces Ag

d. copper and nickel

Ni replaces Cu

Mastering Problems

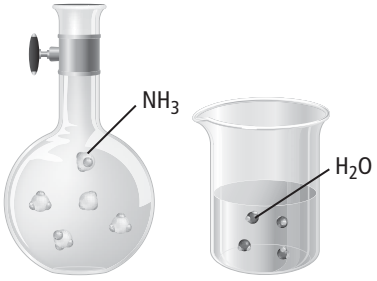
81. Classify each of the reactions represented by the chemical equations in Question 71.

a. single-replacement; b. single-replacement; c. combustion; d. double-replacement

82. Classify each of the reactions represented by the chemical equations in Question 72.

a. combustion; b. double-replacement; c. synthesis; d. decomposition

83. Use **Figure 9.22** to answer the following questions.



a. Write a chemical equation for the reaction between the two compounds shown in the figure.

$NH_3(g) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$

b. Classify this reaction.

single-replacement reaction

84. Write a balanced chemical equation for the combustion of liquid methanol (CH_3OH).

$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$

85. Write chemical equations for each of the following synthesis reactions.

a. boron + fluorine $\rightarrow$

$2B(s) + 3F_2(g) \rightarrow 2BF_3(g)$

b. germanium + sulfur $\rightarrow$

$Ge(s) + 2S(s) \rightarrow GeS_2(s)$

c. zirconium + nitrogen $\rightarrow$

$3Zr(s) + 2N_2(g) \rightarrow Zr_3N_4(s)$

d. tetraphosphorus decoxide + water $\rightarrow$ phosphoric acid

$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$

86. Combustion Write a chemical equation for the combustion of each of the following substances. If a compound contains carbon and hydrogen, assume that carbon dioxide gas and liquid water are produced.

a. solid barium

$2Ba(s) + O_2(g) \rightarrow 2BaO(s)$

b. solid boron

$4B(s) + 3O_2(g) \rightarrow 2B_2O_3(s)$

c. liquid acetone (C_3H_6O)

$C_3H_6O(l) + 4O_2(g) \rightarrow 3CO_2(g) + 3H_2O(l)$

d. liquid octane (C_8H_{18})

$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$

87. Write chemical equations for each of the following decomposition reactions. One or more products may be identified.

a. magnesium bromide $\rightarrow$

$MgBr_2(s) \rightarrow Mg(s) + Br_2(l)$

b. cobalt(II) oxide ⟶

$2CoO(s) \rightarrow 2Co(s) + O_2(g)$

c. titanium(IV) hydroxide ⟶ titanium(IV) oxide + water

$Ti(OH)_4(s) \rightarrow TiO_2(s) + 2H_2O(l)$

d. barium carbonate ⟶ barium oxide + carbon dioxide

$BaCO_3(s) \rightarrow BaO(s) + CO_2(g)$

88. Write chemical equations for the following single-replacement reactions that may occur in water. If no reaction occurs, write *NR* in place of the products.

a. nickel + magnesium chloride ⟶

$Ni(s) + MgCl_2(aq) \rightarrow NR$

b. calcium + copper(II) bromide ⟶

$Ca(s) + CuBr_2(aq) \rightarrow Cu(s) + CaBr_2(aq)$

c. potassium + aluminum nitrate ⟶

$3K(s) + Al(NO_3)_3(aq) \rightarrow Al(s) + 3KNO_3(aq)$

d. magnesium + silver nitrate ⟶

$Mg(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Mg(NO_3)_2(aq)$

Section 9.3

Mastering Concepts

89. Complete the following word equation.

Solute + Solvent ⟶

Solute + Solvent ⟶ Solution

90. Define each of the following terms: *solution, solvent,* and *solute*.

solution: a homogeneous mixture of a solute and a solvent; solvent: a substance that is in a larger amount in a solution; solute: a substance that is in a smaller amount in a solution

91. When reactions occur in aqueous solutions, what common types of products are produced?

solids, water, and gases

92. Compare and contrast chemical equations and ionic equations.

A chemical equation gives formulas and relative amounts of all substances. A complete ionic equation shows the particles as they exist in solution. A net ionic equation shows the particles that participate in the reaction.

93. What is a net ionic equation? How does it differ from a complete ionic equation?

A net ionic equation shows only the reactive particles. A complete ionic equation also shows ions that do not react (free ions from dissolved ionic compounds and highly ionized molecular compounds).

94. Define *spectator ion*.

A spectator ion is an ion that is present in solution but does not participate in the reaction.

95. Write the net ionic equation for a chemical reaction that occurs in an aqueous solution and produces water.

$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

Mastering Problems

96. Complete the following chemical equations.

a. $Na(s) + H_2O(l) \rightarrow$

$Na(s) + H_2O(l) \rightarrow NaOH(aq) + H_2(g)$

b. $K(s) + H_2O(l) \rightarrow$

$K(s) + H_2O(l) \rightarrow KOH(aq) + H_2(g)$

97. Complete the following chemical equation.

$CuCl_2(s) + Na_2SO_4(aq) \rightarrow$

$CuCl_2(s) + Na_2SO_4(aq) \rightarrow CuSO_4(aq) + 2NaCl(aq)$

98. Write a complete ionic and net ionic equation for the chemical reaction in Question 97.

ionic equation: $CuCl_2(s) + 2Na^+(aq) + SO_4^{2-}(aq) \rightarrow Cu^{2+}(aq) + SO_4^{2-}(aq) + 2Na^+(aq) + 2Cl^-(aq)$

net ionic equation: $CuCl_2(s) \rightarrow Cu^{2+}(aq) + 2Cl^-(aq)$

99. Write complete ionic and net ionic equations for each of the following reactions.

a. $K_2S(aq) + CoCl_2(aq) \longrightarrow 2KCl(aq) + CoS(s)$

Complete: $2K^+(aq) + S^{2-}(aq) + Co^{2+}(aq) + 2Cl^-(aq) \rightarrow 2K^+(aq) + 2Cl^-(aq) + CoS(s)$

Net: $S^{2-}(aq) + Co^{2+}(aq) \rightarrow CoS(s)$

b. $H_2SO_4(aq) + CaCO_3(s) \longrightarrow H_2O(l) + CO_2(g) + CaSO_4(s)$

Complete: $2H^+(aq) + SO_4{}^{2-}(aq) + CaCO_3(s) \rightarrow H_2O(l) + CO_2(g) + CaSO_4(s)$

Net: $2H^+(aq) + SO_4{}^{2-}(aq) + CaCO_3(s) \rightarrow H_2O(l) + CO_2(g) + CaSO_4(s)$

c. $2HClO(aq) + Ca(OH)_2(aq) \longrightarrow 2H_2O(l) + Ca(ClO)_2(aq)$

Complete: $2H^+(aq) + 2ClO^-(aq) + Ca^{2+}(aq) + 2OH^-(aq) \rightarrow 2H_2O(l) + Ca^{2+}(aq) + 2ClO^-(aq)$

Net: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

100. A reaction occurs when hydrosulfuric acid (H_2S) is mixed with an aqueous solution of iron(III) bromide. The reaction produces solid iron(III) sulfide and aqueous hydrogen bromide. Write the chemical and net ionic equations for the reaction.

Chemical: $3H_2S(aq) + 2FeBr_3(aq) \rightarrow 6HBr(aq) + Fe_2S_3(s)$

Net: $3S^{2-}(aq) + 2Fe^{3+}(aq) \rightarrow Fe_2S_3(s)$

101. Write complete ionic and net ionic equations for each of the following reactions.

a. $H_3PO_4(aq) + 3RbOH(aq) \longrightarrow 3H_2O(I) + Rb_3PO_4(aq)$

Complete: $3H^+(aq) + PO_4{}^{3-}(aq) + 3Rb^+(aq) + 3OH^-(aq) \rightarrow 3H_2O(l) + 3Rb^+(aq) + PO_4{}^{3+}(aq)$

Net: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

b. $HCl(aq) + NH_4OH(aq) \longrightarrow H_2O(I) + NH_4Cl(aq)$

Complete: $H^+(aq) + Cl^-(aq) + NH_4{}^+(aq) + OH^-(aq) \rightarrow H_2O(l) + NH_4{}^+(aq) + Cl^-(aq)$

Net: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

c. $2HI + (NH_4)_2S(aq) \longrightarrow H_2S(g) + 2NH_4I(aq)$

Complete: $2H^+(aq) + 2I^-(aq) + 2NH_4{}^+(aq) + S^{2-}(aq) \rightarrow H_2S(g) + 2NH_4{}^+(aq) + 2I^-(aq)$

Net: $2H^+(aq) + S^{2-}(aq) \rightarrow H_2S(g)$

d. $HNO_3(aq) + KCN(aq) \longrightarrow HCN(g) + KNO_3(aq)$

Complete: $H^+(aq) + NO_3{}^-(aq) + K^+(aq) + CN^-(aq) \rightarrow HCN(g) + K^+(aq) + NO_3{}^-(aq)$

Net: $H^+(aq) + CN^-(aq) \rightarrow HCN(g)$

102. Paper A reaction occurs when sulfurous acid (H_2SO_3) is mixed with an aqueous solution of sodium hydroxide. The reaction produces aqueous sodium sulfite, a chemical used in manufacturing paper. Write the chemical and net ionic equations for the reaction.

Chemical: $H_2SO_3(aq) + 2NaOH(aq) \rightarrow 2H_2O(l) + Na_2SO_3(aq)$

Net: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

Mixed Review

103. Photosynthesis Identify the products in the following reaction that occurs in plants: Carbon dioxide and water react to produce glucose and oxygen.

glucose and oxygen

104. How will aqueous solutions of sucrose and hydrogen chloride differ?

An aqueous sucrose solution contains water molecules and sucrose molecules. An aqueous hydrogen chloride solution contains water molecules, hydrogen ions, and chloride ions.

105. Write the word equation for each of these skeleton equations. C_6H_6 is the formula for benzene.

a. $C_6H_6(l) + O_2(g) \longrightarrow CO_2(g) + H_2O(l)$

benzene(l) + oxygen(g) → carbon dioxide(g) + water (l)

b. $CO(g) + O_2(g) \longrightarrow CO_2(g)$

carbon monoxide(g) + oxygen(g) → carbon dioxide(g)

c. $Cl_2(g) + NaBr(s) \longrightarrow NaCl(s) + Br_2(g)$

chlorine(g) + sodium bromide(s) → sodium chloride(s) + bromine(g)

d. $CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$

calcium carbonate(s) → calcium oxide(s) + carbon dioxide(g)

106. Classify each of the reactions represented by the chemical equations in Question 105.

a. combustion; b. synthesis or combustion; c. single-replacement; d. decomposition

107. Write skeleton equations for the following reactions.

a. ammonium phosphate(aq) + chromium(III) bromide(aq) ⟶ ammonium bromide(aq) + chromium(III) phosphate(s)

$(NH_4)_3PO_4(aq) + CrBr_3(aq) \rightarrow NH_4Br(aq) + CrPO_4(s)$

b. chromium(VI) hydroxide(s) ⟶ chromium(VI) oxide(s) + water(l)

$Cr(OH)_6(s) \rightarrow CrO_3(s) + H_2O(l)$

c. aluminum(s) + copper(I) chloride(aq) ⟶ aluminum chloride(aq) + copper(s)

$Al(s) + CuCl(aq) \rightarrow AlCl_3(aq) + Cu(s)$

d. potassium iodide(aq) + mercury(I) nitrate(aq) ⟶ potassium nitrate(aq) + mercury(I) iodide(s)

$KI(aq) + HgNO_3(aq) \rightarrow KNO_3(aq) + HgI(s)$

108. Balance the skeleton equations for the reactions described in Question 107.

a. $(NH_4)_3PO_4(aq) + CrBr_3(aq) \rightarrow 3NH_4Br(aq) + CrPO_4(s)$

b. $Cr(OH)_6(s) \rightarrow CrO_3(s) + 3H_2O(l)$

c. $Al(s) + 3CuCl(aq) \rightarrow AlCl_3(aq) + 3Cu(s)$

d. $KI(aq) + HgNO_3(aq) \rightarrow KNO_3(aq) + HgI(s)$

109. Classify each of the reactions represented by the chemical equations in Question 108.

a. double-replacement; b. decomposition; c. single-replacement; d. double-replacement

110. Predict whether each of the following reactions will occur in aqueous solutions. If you predict that a reaction will not occur, explain your reasoning. *Note: Barium sulfate and silver bromide precipitate in aqueous solutions.*

a. sodium hydroxide + ammonium sulfate ⟶

No reaction; products are soluble and no water or gas is formed.

b. niobium(V) sulfate + barium nitrate ⟶

reaction occurs

c. strontium bromide + silver nitrate ⟶

reaction occurs

111. Complete the missing information in the following skeleton equation and balance the chemical equation:

$NaOH(aq) + \_\_\_ \longrightarrow 3NaCl(aq) + Al(OH)_3(aq)$

$3NaOH(aq) + AlCl_3(s) \rightarrow 3NaCl(aq) + Al(OH)_3(aq)$

112. Precipitate Formation The addition of hydrochloric acid to beakers containing solutions of either sodium chloride (NaCl) or silver nitrate ($AgNO_3$) causes a white precipitate in one of the beakers.

a. Which beaker contains a precipitate?

the beaker with silver nitrate

b. What is the precipitate?

silver chloride

c. Write a chemical equation showing the reaction.

$HCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + HNO_3(aq)$

d. Classify the reaction.

double-replacement reaction

113. Write the skeleton equation and the balanced chemical equation for the reaction between iron and chlorine.

Skeleton equation: $Fe(s) + Cl_2(g) \rightarrow FeCl_3(s)$

Balanced chemical equation: $2Fe(s) + 3Cl_2(g) \rightarrow 2FeCl_3(s)$

114. Write a chemical equation representing the decomposition of water into two gaseous products. What are the products?

$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$; Hydrogen gas and oxygen gas

115. Distinguish between an ionic compound and a molecular compound dissolved in water. Do all molecular compounds ionize when dissolved in water? Explain.

When an ionic compound dissolves in water, it dissociates into ions and each ion is hydrated (or surrounded) by water molecules. A molecular compound dissolved in water might not dissociate into ions; it might remain molecular.

116. Classify the type of reactions that occur in aqueous solutions, and give an example to support your answer.

Reactions that occur in aqueous solutions can either form heterogeneous mixtures (precipitates) or homogeneous mixtures. Example of a heterogeneous mixture: $AgNO_3(aq) + HCl(aq) \rightarrow AgCl(s) + HNO_3(aq)$; example of a homogeneous mixture: $HBr(aq) + NaOH(aq) \rightarrow H_2O(l) + NaBr(aq)$

Think Critically

117. Explain how an equation can be balanced even if the number of reactant particles differs from the number of product particles.

The number of atoms of each element can be balanced while numbers of reactant and product molecules or other particles are different. For example, $2C_6H_6 + 15O_2 \rightarrow 12CO_2 + 6H_2O$ is balanced, but 17 molecules react and 18 molecules are produced.

118. Apply Describe the reaction of aqueous solutions of sodium sulfide and copper(II) sulfate, producing the precipitate copper(II) sulfide.

Sodium sulfide and copper(II) sulfate dissociate in water to form sodium ions, sulfide ions, copper(II) ions, and sulfate ions. The copper(II) ions and sulfide ions form the precipitate copper sulfide. Sodium ions and sulfate ions are spectator ions that remain dissolved in the solution.

119. Predict A piece of aluminum metal is placed in an aqueous KCl solution. Another piece of aluminum is placed in an aqueous $AgNO_3$ solution. Explain why a chemical reaction does or does not occur in each instance.

No reaction occurs when Al is placed in aqueous KCl because Al, being lower in the activity series, does not replace K. However, Al reacts with an aqueous $AgNO_3$ because Al is above Ag in the activity series.

120. Design an Experiment You suspect that the water in a lake close to your school might contain lead in the form of $Pb^{2+}(aq)$ ions. Formulate your suspicion as a hypothesis and design an experiment to test your theory. Write the net ionic equations for the reactions of your experiment. *(Hint: In aqueous solution, Pb^{2+} forms compounds that are solids with Cl^-, Br^-, I^-, and SO_4^{2-} ions.)*

Hypothesis: If lead is present, a reaction can be performed to precipitate a solid so it can be analyzed and confirmed as lead. Experiment: Allow a water sample to react with an excess amount of solution containing aqueous chloride, bromide, iodide, or sulfate ions. If the lead concentration is high, a lead-containing precipitate will form. Absence of precipitate leads to the conclusion that there is no lead in the sample. The presence of a precipitate requires further analysis to confirm that it is a lead precipitate.

121. Predict When sodium metal reacts with water, it produces sodium hydroxide, hydrogen gas, and heat. Write balanced chemical equations for Li, Na, and K reacting with water. Use **Figure 9.13** to predict the order of the amount of heat released from least to most amount of heat released.

$2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$

$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

$2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$

Sodium would release the least amount of heat, followed by potassium, then lithium.

122. Apply Write the chemical equations and net ionic equations for each of the following reactions that might occur in aqueous solutions. If a reaction does not occur, write *NR* in place of the products. Magnesium phosphate precipitates in an aqueous solution.

a. $KNO_3 + CsCl \rightarrow$

$KNO_3(aq) + CsCl(aq) \rightarrow KCl(aq) + CsNO_3(aq)$

$K^+(aq) + NO_3^-(aq) + Cs^+(aq) + Cl^-(aq) \rightarrow K^+(aq) + Cl^-(aq) + Cs^+(aq) + NO_3^-(aq)$

Ions remain in solution. No reaction occurs.

b. $Ca(OH)_2 + KCN \rightarrow$

$Ca(OH)_2(aq) + 2KCN(aq) \rightarrow Ca(CN)_2(aq) + 2KOH(aq)$

$Ca^{2+}(aq) + 2OH^-(aq) + 2K^+(aq) + 2CN^-(aq) \rightarrow Ca^{2+}(aq) + 2CN^-(aq) + 2K^+(aq) + 2OH^-(aq)$

Ions remain in solution. No reaction occurs.

c. $Li_3PO_4 + MgSO_4 \rightarrow$

Chemical: $2Li_3PO_4(aq) + 3MgSO_4(aq) \rightarrow 3Li_2SO_4(aq) + Mg_3(PO_4)_2(s)$

Net ionic: $2PO_4^{3-}(aq) + 3Mg^{2+}(aq) \rightarrow Mg_3(PO_4)_2(s)$

d. $HBrO + NaOH \rightarrow$

Chemical: $HBrO(aq) + NaOH(aq) \rightarrow H_2O(l) + NaBrO(aq)$

Net ionic: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

123. Analyze Explain why a nail exposed to air forms rust, whereas the same nail exposed to a pure nitrogen environment does not form rust.

A nail is composed of iron, Fe. Iron atoms react with oxygen gas to form rust iron (III) oxide. Iron atoms do not react with nitrogen gas.

124. Evaluate Write a balanced chemical equation for the reaction of aluminum and oxygen to produce aluminum oxide.

$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$

Challenge Problem

125. A single-replacement reaction occurs between copper and silver nitrate. When 63.5 g of copper reacts with 339.8 g of silver nitrate, 215.8 g of silver is produced. Write a balanced chemical equation for this reaction. What other product formed? What is the mass of the second product?

$2AgNO_3 + Cu \rightarrow Cu(NO_3)_2 + 2Ag$; 187.5 g of $Cu(NO_3)_2$

Cumulative Review

126. Complete the following problems in scientific notation. Round off to the correct number of significant figures. *(Chapter 2)*

a. $(5.31 \times 10^{-2}\ \text{cm}) \times (2.46 \times 10^{5}\ \text{cm})$

$1.31 \times 10^4\ cm^2$

b. $(6.42 \times 10^{-2}\ \text{g}) \div (3.21 \times 10^{-3}\ \text{g})$

2.00×10^1

c. $(9.87 \times 10^{4}\ \text{g}) - (6.2 \times 10^{3}\ \text{g})$

9.25×10^4 g

127. Distinguish between a mixture, a solution, and a compound. *(Chapter 3)*

A mixture is a physical blend of two or more pure substances in any proportion in which each substance retains its individual properties. A solution is a uniform mixture that may contain solids, liquids, or gases. A compound is a chemical combination of two or more different elements to form a substance with new properties. The components of mixtures and solutions can be separated by physical means. A compound can be broken down only by chemical means.

128. Data from chromium's four naturally occurring isotopes is provided in **Table 9.5.** Calculate chromium's atomic mass. *(Chapter 4)*

Chromium Isotope Data		
Isotope	**Percent Abundance**	**Mass (amu)**
Cr-50	4.5%	49.946
Cr-52	83.79%	51.941
Cr-53	9.50%	52.941
Cr-54	2.36%	53.939

$M_{avg} = 0.0435M_{50} + 0.8379M_{52} + 0.0950M_{53} + 0.0236M_{54}$

$M_{avg} = (0.0435 \times 49.946) + (0.8379 \times 51.941) \times (0.0950 \times 52.941) + (0.0236 \times 53.939)$ amu

$M_{avg} = 52.00$ amu

129. Differentiate between electron configuration and electron-dot structure. *(Chapter 5)*

Electron configuration is the arrangement of electrons in an atom. Electron-dot structure consist of the element's symbol and valence electrons.

130. Identify the elements by their electron configuration. *(Chapter 5)*

a. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^5$

Br

b. $[Ne]3s^2 3p^4$

S

c. $[Xe]6s^2$

Ba

131. Write the electron configuration for the element fitting each description. *(Chapter 6)*

a. metalloid in group 13

B: $[He]2s^2 2p^1$

b. nonmetal in group 15, period 3

P: $[Ne]3s^2 3p^3$

132. Describe the formation of positive and negative ions. *(Chapter 7)*

Positive ions form when atoms lose valence electrons. Negative ions form when valence electrons are added to an atom.

133. Write the formula for the compounds made from each of the following pairs of ions. *(Chapter 7)*

a. copper(I) and sulfite

Cu_2SO_3

b. tin(IV) and fluoride

SnF_4

c. gold(III) and cyanide

$Au(CN)_3$

d. lead(II) and sulfide

PbS

Additional Assessment

Writing in Chemistry

134. Kitchen Chemistry Make a poster describing types of chemical reactions that occur in the kitchen.

Answers will vary.

135. Mathematical Equations Write a report comparing and contrasting chemical equations and mathematical equations.

Student answers may include the following: chemical equations contain reaction arrows, while mathematical equations contain equal signs; chemical equations contain formulas for substances, while mathematical equations contain variables; because chemical equations contain formulas that represent kinds and numbers of atoms, they must be balanced; chemical equations may contain energy terms as well as formulas.

136. Balance Equations Create a flowchart describing how to balance a chemical equation.

Student flowcharts should be similar to Figure 9.6.

Document-Based Questions

Solubility *Scientists, in determining whether a precipitate will occur in a chemical reaction, will use a solubility rules chart.* ***Table 9.6*** *lists the solubility rules for ionic compounds in water.*

Data obtained from: Van Der Sluys, W.G. 2001, *J. Chem. Ed.* 78:111–115

Solubility Rules for Ionic Compound in Water

Ionic Compound	Rule
Soluble Salts	Group 1 cations and NH_4^+ ions form soluble salts.
	All nitrates are soluble.
	Most halides are soluble, except those of Pb^{2+}, Hg_2^{2+}, Ag^+, and Cu^+.
	Most sulfates are soluble, with the exceptions of those of Ba^{2+}, Sr^{2+}, and Pb^{2+}, Ag^+, Ca^{2+}, and Hg_2^{2+} form slightly soluble sulfates.
Insoluble Salts	Hydroxides, oxides, and sulfides are usually insoluble, except that those of group 1 ions and NH_4^+ are soluble and those of group 2 ions are slightly soluble.
	Chromates, phosphates, and carbonates are usually insoluble, except that those of group 1 ions and NH_4^+ are soluble.

Using the solubility rules provided in the table above complete the following chemical equations. Indicate whether a precipitate forms or not. Identify the precipitate. If no reaction occurs, write *NR*.

137. $Ca(NO_3)_2(aq) + Na_2CO_3(aq) \rightarrow$

$Ca(NO_3)_2(aq) + Na_2CO_3(aq) \rightarrow CaCO_3(s) + 2NaNO_3(aq)$

$CaCO_3(s)$ is the precipitate that forms.

138. $Mg(s) + NaOH(aq) \rightarrow$

$Mg(s) + NaOH(aq) \rightarrow$ NR

139. $PbS(s) + LiNO_3(aq) \rightarrow$

$PbS(s) + LiNO_3(aq) \rightarrow Li_2S(aq) + Pb(NO)_3(aq)$
No precipitate forms.

Standardized Test Practice Chapter 9

pages 316–317

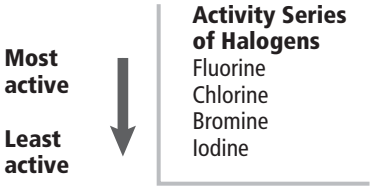
1. What type of reaction is described by the following equation?

$Cs(s) + H_2O(l) \rightarrow CsOH(aq) + H_2(g)$

a. synthesis
b. combustion
c. decomposition
d. single-replacement

d

Use the figure below to answer Question 2.



2. Which reaction between halogens and halide salts will occur?

a. $F_2(g) + FeI_2(aq) \rightarrow FeF_2(aq) + I_2(l)$
b. $I_2(s) + MnBr_2(aq) \rightarrow MnI_2(aq) + Br_2(g)$
c. $Cl_2(s) + SrF_2(aq) \rightarrow SrCl_2(aq) + F_2(g)$
d. $Br_2(l) + CoCl_2(aq) \rightarrow CoBr_2(aq) + Cl_2(g)$

a

3. Which is the electron configuration for iron?

a. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$
b. $[Ar]3d^6$
c. $1s^2 2p^6 3p^6 3d^6$
d. $[Ar]4s^2 4d^6$

a

4. Which is a description of a pattern displayed by elements in the periodic table?

a. repetition of their physical properties when arranged by increasing atomic radius
b. repetition of their chemical properties when arranged by increasing atomic mass
c. periodic repetition of their properties when arranged by increasing atomic number
d. periodic repetition of their properties when arranged by increasing atomic mass

c

5. When moving down a group on the periodic table, which two atomic properties follow the same trend?

a. atomic radius and ionization energy
b. ionic radius and atomic radius
c. ionization energy and ionic radius
d. ionic radius and electronegativity

d

Use the table below to answer Questions 6 to 8.

Physical Properties of Select Ionic Compounds

Compound	Name	State at 25°C	Soluble in Water?	Melting Point (°C)
$NaClO_3$	sodium chlorate	solid	yes	248
Na_2SO_4	sodium sulfate	solid	yes	884
$NiCl_2$	nickel(II) chloride	solid	yes	1009
$Ni(OH)_2$	nickel(II) hydroxide	solid	no	230
$AgNO_3$	silver nitrate	solid	yes	212

6. An aqueous solution of nickel(II) sulfate is mixed with aqueous sodium hydroxide. Will a visible reaction occur?

a. No, solid nickel(II) hydroxide is soluble in water.
b. No, solid sodium sulfate is soluble in water.
c. Yes, solid sodium sulfate will precipitate out of the solution.
d. Yes, solid nickel(II) hydroxide will precipitate out of the solution.

a

7. What happens when $AgClO_3(aq)$ and $NaNO_3(aq)$ are mixed?

a. No visible reaction occurs.
b. Solid $NaClO_3$ precipitates out of the solution.
c. NO_2 gas is released during the reaction.
d. Solid Ag metal is produced.

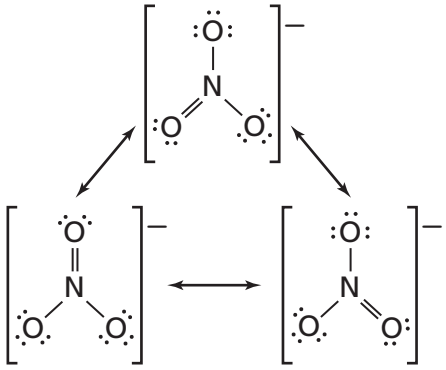
b

8. Finely ground nickel(II) hydroxide is placed in a beaker of water. It sinks to the bottom of the beaker and remains unchanged. An aqueous solution of hydrochloric acid (HCl) is then added to the beaker, and the $Ni(OH)_2$ disappears. Which equation best describes what occurred in the beaker?

a. $Ni(OH)_2(s) + HCl(aq) \rightarrow NiO(aq) + H_2(g) + HCl(aq)$
b. $Ni(OH)_2(s) + 2HCl(aq) \rightarrow NiCl_2(aq) + 2H_2O(l)$
c. $Ni(OH)_2(s) + 2H_2O(l) \rightarrow NiCl_2(aq) + 2H_2O(l)$
d. $Ni(OH)_2(s) + 2H_2O(l) \rightarrow NiCl_2(aq) + 3H_2O(l) + O_2(g)$

b

Use the diagram below to answer Questions 9 and 10.



9. What is the name for the multiple Lewis structures shown in the diagram?

resonance structures

10. Why do these structures form?

A pair of electrons can form a double bond in several different positions. This means that there are several equivalent Lewis structures for the same molecule.

11. Write the balanced chemical equation for the reaction of solid calcium with water to form calcium hydroxide in solution and hydrogen gas.

$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$

Use the partial chemical equation below to answer Questions 12 and 13.

$AlCl_3(aq) + Fe_2O_3(aq) \rightarrow$

12. What type of reaction will this be? Explain how you can tell from the reactants.

This will be a double-replacement reaction. There are two compounds reacting together. In the other types of reactions, a single element participates as one of the reactants.

13. Predict what the products of this reaction will be. Use evidence from the reaction to support your answer.

The products will be $FeCl_2$ and Al_2O_3. In a double-replacement reaction, the positive and negative ions exchange places, so that each positive ion forms a compound with a new negative ion.

14. What is the electron configuration for the ion P^{3-}? Explain how this configuration is different from the configuration for the neutral atom of phosphorus.

$1s^22s^22p^63s^23p^6$; This differs from the configuration of the neutral phosphorus atom because it has three extra valence electrons, completing its valence shell and making it resemble a noble gas in its configuration. A neutral atom of P has the configuration of $1s^22s^22p^63s^23p^3$.

15. Chloroform ($CHCl_3$) was one of the first anesthetics used in medicine. The chloroform molecule contains 26 valence electrons total. How many of these valence electrons are part of covalent bonds?

a. 26
b. 13
c. 8
d. 4
e. 2

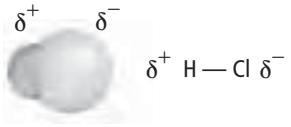
c

16. Which is NOT true of an atom obeying the octet rule?

a. obtains a full set of eight valence electrons
b. acquires the valence configuration of a noble gas
c. electron configuration is unusually stable
d. has an s^2p^6 valence configuration
e. will lose electrons

c

Use the figure below to answer Question 17.



17. Which statement does NOT correctly describe the model of HCl shown above?

a. A nonpolar bond exists between these atoms.
b. Chlorine has a stronger attraction for electrons than does hydrogen.
c. The electrons in the bond are shared unequally.
d. This compound dissolves in a polar substance.
e. Chlorine is the more electronegative atom.

a

18. The combustion of ethanol (C_2H_6O) produces carbon dioxide and water vapor. What equation best describes this process?

a. $C_2H_6O(l) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$
b. $C_2H_6O(l) \rightarrow 2CO_2(g) + 3H_2O(l)$
c. $C_2H_6O(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$
d. $C_2H_6O(l) \rightarrow 3O_2(l) + 2CO_2(g) + 3H_2O(l)$
e. $C_2H_6O(l) \rightarrow 2CO_2(g) + 3H_2O(g)$

c