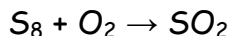# Chapter 8 – Chemical Reactions

Chapter 8: 1 – 7, 9 – 18, 20, 21, 24 – 26, 29 – 31, 46, 55, 69

Practice Problems

1. Write a skeleton equation for each chemical reaction. Include the appropriate symbols from Table 8.1 on page 206.
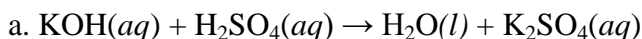
   a. Sulfur burns in oxygen to form sulfur dioxide.

      $S_8 + O_2 \rightarrow SO_2$

      b. Heating potassium chlorate in the presence of the catalyst manganese dioxide produces oxygen gas. Potassium chloride is left as a solid.

      $KClO_3 \xrightarrow{MnO_2} O_2 + KCl$ Note: the catalyst is written above the reaction arrow
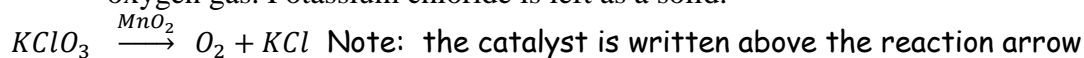
2. Write a sentence that describes each chemical reaction.

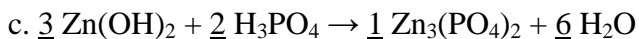   a. $KOH(aq) + H_2SO_4(aq) \rightarrow H_2O(l) + K_2SO_4(aq)$

      Potassium chloride reacts with sulfuric acid to produce water and potassium sulfate.

   b. $Na(s) + H_2O(l) \rightarrow NaOH(aq) + H_2(g)$
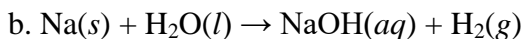
      Solid sodium metal reacts violently with water to yield sodium hydroxide and hydrogen gas.

3. Balance each equation, using the rules for balancing equations provided on pages 208, 209.
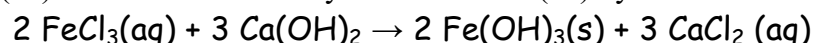
      a. $\underline{2} \ AgNO_3 + \underline{1} \ H_2S \rightarrow \underline{1} \ Ag_2S + \underline{2}HNO_3$

      b. $\underline{1} \ MnO_2 + \underline{4} \ HCl \rightarrow \underline{1} \ MnCl_2 + \underline{2} \ H_2O + \underline{1} \ Cl_2$

      c. $\underline{3} \ Zn(OH)_2 + \underline{2} \ H_3PO_4 \rightarrow \underline{1} \ Zn_3(PO_4)_2 + \underline{6} \ H_2O$
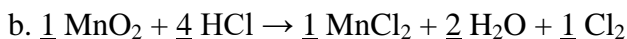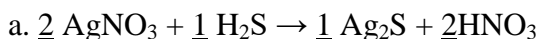
4. Rewrite these word equations as balanced chemical equations.

      a. hydrogen + sulfur $\rightarrow$ hydrogen sulfide

          $8 \ H_2(g) + S_8(s) \rightarrow 8 \ H_2S \ (g)$
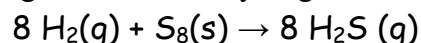
      b. iron(III) chloride + calcium hydroxide $\rightarrow$ iron(III) hydroxide + calcium chloride

          $2 \ FeCl_3(aq) + 3 \ Ca(OH)_2 \rightarrow 2 \ Fe(OH)_3(s) + 3 \ CaCl_2 \ (aq)$

5. Balance the equation. $\underline{3}$ CO + $\underline{1}$ Fe$_2$O$_3$ → $\underline{2}$ Fe + $\underline{3}$ CO$_2$
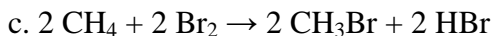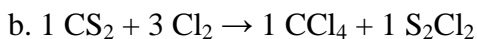
6. Write the balanced chemical equation for the reaction of carbon with oxygen to form carbon monoxide.

$$2\ C(s) + O_2(g) \rightarrow 2\ CO(g)$$

7. Balance each equation.

a. $\underline{1}$ FeCl$_3$ + $\underline{3}$ NaOH → $\underline{1}$ Fe(OH)$_3$ + $\underline{3}$ NaCl

b. $\underline{1}$ CS$_2$ + $\underline{3}$ Cl$_2$ → $\underline{1}$ CCl$_4$ + $\underline{1}$ S$_2$Cl$_2$

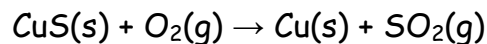c. $\underline{2}$ CH$_4$ + $\underline{2}$ Br$_2$ → $\underline{2}$ CH$_3$Br + $\underline{2}$ HBr
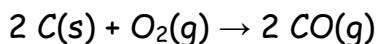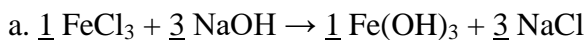
Section Review 8.1

9. Write balanced chemical equations for the following chemical reactions described below.
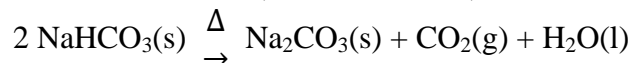
a. Pure copper can be produced by heating copper(II) sulfide in the presence of diatomic oxygen from the air. Sulfur dioxide gas is also produced in this reaction.
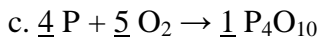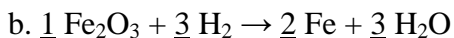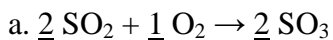
$$CuS(s) + O_2(g) \rightarrow Cu(s) + SO_2(g)$$

b. Water is formed by the explosive reaction between hydrogen gas and oxygen gas.

$$2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(g)$$
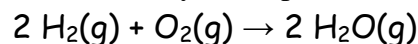
c. When baking soda (sodium hydrogen carbonate) is heated, it decomposes, forming the products sodium carbonate, carbon dioxide, and water.

$$2\ NaHCO_3(s) \xrightarrow{\Delta} Na_2CO_3(s) + CO_2(g) + H_2O(l)$$

10. Balance the following equations.

a. $\underline{2}$ SO$_2$ + $\underline{1}$ O$_2$ → $\underline{2}$ SO$_3$

b. $\underline{1}$ Fe$_2$O$_3$ + $\underline{3}$ H$_2$ → $\underline{2}$ Fe + $\underline{3}$ H$_2$O

c. $\underline{4}$ P + $\underline{5}$ O$_2$ → $\underline{1}$ P$_4$O$_{10}$

d. $\underline{2}$ Al + $\underline{1}$ N$_2$ → $\underline{2}$ AlN

11. Write formulas and other symbols for these substances.

   a. sulfur trioxide gas $SO_3(g)$

   b. potassium nitrate dissolved in water $KNO_3(aq)$

   c. heat supplied to a chemical reaction $\xrightarrow{\Delta}$

   d. metallic copper $Cu(s)$

   e. liquid mercury $Mg(l)$

   f. zinc chloride as a catalyst $\xrightarrow{ZnCl_2}$

12. How is the law of conservation of mass related to the balancing of a chemical equation?

   When balancing an equation, the number and kinds of atoms in the reactants equals those in the products, thus atoms and masses are conserved.

Practice Problems
13. Complete and balance these combination reactions.

   a. $\underline{2}$ Be $+ \underline{1}$ O$_2 \rightarrow$ **2 BeO**

   b. $\underline{1}$ SO$_2 + \underline{1}$ H$_2$O $\rightarrow$ **H$_2$SO$_3$**

> For 13a, Group A metals combine with nonmetals to form a compound that is the combination of a metal cation and nonmetal anion (Be^{2+}, O^{2-}).
>
> For 13b, some nonmetal oxides combine with water to form an acid.

14. Write and balance an equation for the formation of each compound from its elements.

   a. strontium iodide (SrI$_2$)
   Sr(s) + I$_2$(s) $\rightarrow$ SrI$_2$

   b. magnesium nitride (Mg$_3$N$_2$)
   3 Mg(s) + N$_2$(g) $\rightarrow$ Mg$_3$N$_2$(s)

> For 14a, b, Group A metals combine with nonmetals to form a compound that is the combination of a metal cation and nonmetal anion. To solve, write out the anions and cations that each element forms, then combine in the formula (14a [Sr^{2+}, I^-], 14b [Mg^{2+} and N^{3-}])

15. Complete and balance these decomposition reactions.

   a. $\underline{2}$ HI $\rightarrow$ **H$_2$(g) + I$_2$(s)**

   b. $\underline{1}$ Mg(ClO$_3$)$_2 \rightarrow \underline{1}$ MgCl$_2 +$ **3 O$_2$(g)**

16. Write the formula for the binary compound that decomposes to each set of products.

   a. **2 HBr** $\rightarrow \underline{1}$ H$_2 + \underline{1}$ Br$_2$

   b. **2 NaCl** $\rightarrow \underline{2}$ Na $+ \underline{1}$ Cl$_2$

17. Complete the equations for these single-replacement reactions that take place in aqueous solution. If a reaction does not occur (use the activity series on Table 8.2, p. 217), write "no reaction."
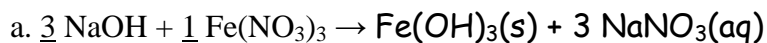
a. 1 Fe(s) + 1 Pb(NO$_3$)$_2$ (aq) → $Fe(NO_3)_2(aq) + Pb(s)$

b. 1 Cl$_2$(g) + 2 NaI(aq) → $2\ NaCl(aq) + I_2(s)$

c. 1 Ca(s) + 1 H$_2$O(l) → $CaO(s) + H_2(g)$
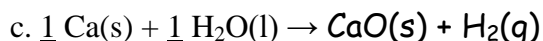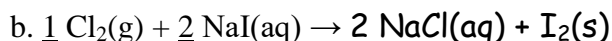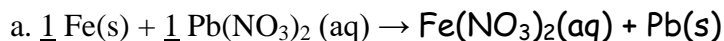
> 17a. Fe is more reactive than Pb, thus, it will replace it.
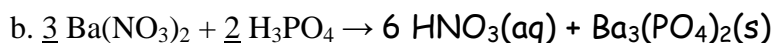> 17b. The activity of Cl is greater than that of I.
> 17c. Metals from Li to Na will replace H from water molecules.

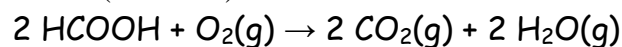18. Write the products for these double-replacement reactions. Then balance each equation.

a. 3 NaOH + 1 Fe(NO$_3$)$_3$ → $Fe(OH)_3(s) + 3\ NaNO_3(aq)$

   (Iron hydroxide is a precipitate)

b. 3 Ba(NO$_3$)$_2$ + 2 H$_3$PO$_4$ → $6\ HNO_3(aq) + Ba_3(PO_4)_2(s)$

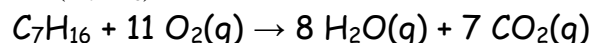   (Barium phosphate is a precipitate.)

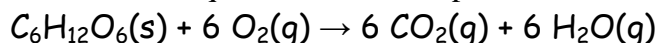20. Write a balanced equation for the complete combustion of each compound.
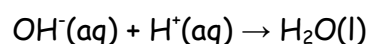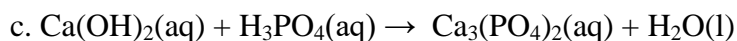
a. formic acid (HCOOH)
$$2\ HCOOH + O_2(g) → 2\ CO_2(g) + 2\ H_2O(g)$$

b. heptane (C$_7$H$_{16}$)
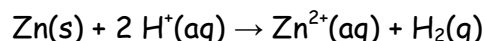$$C_7H_{16} + 11\ O_2(g) → 8\ H_2O(g) + 7\ CO_2(g)$$

21. Write a balanced equation for the complete combustion of glucose (C$_6$H$_{12}$O$_6$).
$$C_6H_{12}O_6(s) + 6\ O_2(g) → 6\ CO_2(g) + 6\ H_2O(g)$$

24. What three types of products drive double-replacement reactions?
(1) formation of a precipitate, (2) formation of a gas, (3) formation of water.

25. Write *balanced* net ionic equations for each reaction.

a. Pb(ClO$_4$)$_2$(aq) + NaI(aq) → PbI$_2$(s) + NaClO$_4$(aq)

$$Pb^{2+}(aq) + 2\ I^-(aq) → PbI_2(s)$$

b. Zn(s) + HCl(aq) → ZnCl$_2$(aq) + H$_2$(g)

$$Zn(s) + 2\ H^+(aq) → Zn^{2+}(aq) + H_2(g)$$

c. Ca(OH)$_2$(aq) + H$_3$PO$_4$(aq) → Ca$_3$(PO$_4$)$_2$(aq) + H$_2$O(l)

$$OH^-(aq) + H^+(aq) → H_2O(l)$$
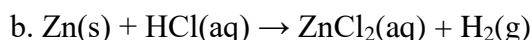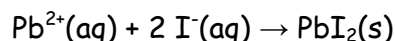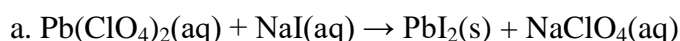
> Step 1. Balance the equation first.
> Step 2. Write the REACTANTS showing each as dissociated free ions.
> Step 3. Look at new pairings of cations and anions that provide an insoluble substance (solid, liquid or gas).
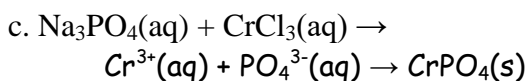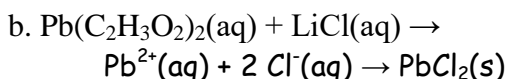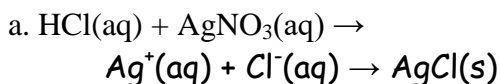> Step 4. Eliminate spectator ions and write the net ionic equation.

26. Identify the precipitate formed when solutions of these ionic compounds are mixed. Write a net ionic equation.

$$2\ NH_4Cl(aq) + Pb(NO_3)_2(aq) \rightarrow$$
$$Pb^{2+}(aq) + 2\ Cl^-(aq) \rightarrow PbCl_2(s)$$
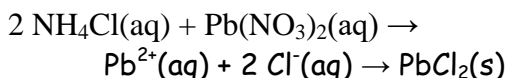
> Make sure you refer to solubility rules on page 227 in the textbook.

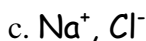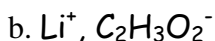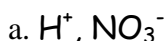## Section Review 8.3

29. Write a net ionic equation for each reaction.

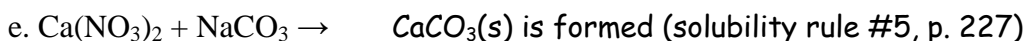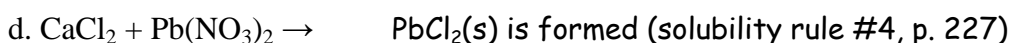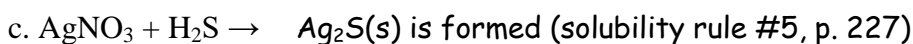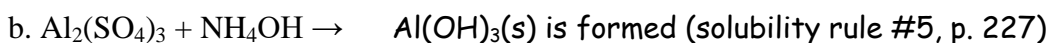> Refer to the steps above for writing net ionic equations, and follow the solubility rules on page 227.

a. $HCl(aq) + AgNO_3(aq) \rightarrow$
$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

b. $Pb(C_2H_3O_2)_2(aq) + LiCl(aq) \rightarrow$
$$Pb^{2+}(aq) + 2\ Cl^-(aq) \rightarrow PbCl_2(s)$$

c. $Na_3PO_4(aq) + CrCl_3(aq) \rightarrow$
$$Cr^{3+}(aq) + PO_4^{3-}(aq) \rightarrow CrPO_4(s)$$

30. Identify the spectator ions in each reaction in Problem 29.

a. H^+, NO_3^-

> Remember that spectator ions are those that do not get involved in the chemical reaction – they are merely spectators, and remain in their ionized form in the solution.

b. Li^+, $C_2H_3O_2^-$

c. Na^+, Cl^-

31. Identify the precipitate formed when solutions of these ionic compounds are mixed.

a. $H_2SO_4 + BaCl_2 \rightarrow$ $BaSO_4(s)$ is formed (solubility rule #3, p. 227)

b. $Al_2(SO_4)_3 + NH_4OH \rightarrow$ $Al(OH)_3(s)$ is formed (solubility rule #5, p. 227)

c. $AgNO_3 + H_2S \rightarrow$ $Ag_2S(s)$ is formed (solubility rule #5, p. 227)

d. $CaCl_2 + Pb(NO_3)_2 \rightarrow$ $PbCl_2(s)$ is formed (solubility rule #4, p. 227)

e. $Ca(NO_3)_2 + NaCO_3 \rightarrow$ $CaCO_3(s)$ is formed (solubility rule #5, p. 227)
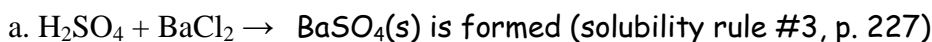
Chapter 8 Review

46. For each of the following pairs, predict which element as an atom would displace the other element as an ion from a compound in aqueous solution.

a. iron and sodium   sodium displaces iron

> Refer to Table 8.2, Activity Series of Metals, on p. 217.

b. silver and copper   copper displaces silver

c. zinc and hydrogen (in HCl)   zinc displaces hydrogen

55. Write a balanced chemical equation for each reaction. Use the necessary symbols from Table 8.1 to describe the reaction completely.

a. Bubbling chlorine gas through a solution of potassium iodide gives elemental iodine and a solution of potassium chloride.
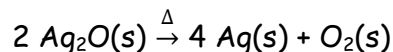
$Cl_2(g) + 2\ KI(aq) \rightarrow I_2(s) + 2\ KCl(aq)$
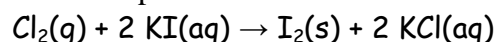
b. Bubbles of hydrogen gas and aqueous iron(III) chloride are produced when metallic iron is dropped into hydrochloric acid.
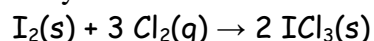
$2\ Fe(s) + 6\ HCl(aq) \rightarrow 2\ FeCl_3(aq) + 3\ H_2(g)$
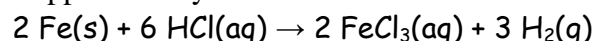
c. Solid tetraphosphorus decoxide reacts with water to produce phosphoric acid.

$P_4O_{10}(s) + 6\ H_2O(l) \rightarrow 4\ H_3PO_4(aq)$
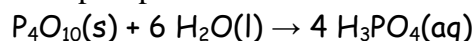
d. Solid silver oxide can be heated to give silver and oxygen gas.

$2\ Ag_2O(s) \overset{\Delta}{\rightarrow} 4\ Ag(s) + O_2(s)$

e. Iodine crystals react with chlorine gas to form solid iodine trichloride.

$I_2(s) + 3\ Cl_2(g) \rightarrow 2\ ICl_3(s)$

f. Mercury metal is produced by heating a mixture of mercury(II) sulfide and calcium oxide. Additional products are calcium sulfide and calcium sulfate.

$4\ HgS(aq) + 4\ CaO(s) \overset{\Delta}{\rightarrow} 4\ Hg(s) + 3\ CaS(s) + CaSO_4(s)$

69. The white solid calcium chloride ($CaCl_2$) is used as a drying agent. The maximum amount of water absorbed by different quantities of $CaCl_2$ is given in the table below.

$CaCl_2$ (g)	$CaCl_2$ (mol)	H_2O (g)	H_2O (mol)
17.3	0.156	5.62	0.312
48.8	0.439	15.8	0.878
124	1.12	40.3	2.24
337	3.03	109	6.06

a. Complete the table.

b. Plot the moles of water absorbed (y-axis) versus the moles of $CaCl_2$.

c. Based on your graph, how many molecules of water does each formula unit of $CaCl_2$ absorb?

Two water molecules are absorbed by each formula unit of $CaCl_2$.