Chapter 3

Synthesis, Decomposition, and Combustion Reactions

Section 3.1 Writing Chemical Equations

Solutions for Practice Problems

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Write a skeleton equation for each chemical reaction. Indicate the state of each reactant and product in the skeleton equation. Remember that the following seven elements are diatomic: hydrogen, $H_2(g)$; nitrogen, $N_2(g)$; oxygen, $O_2(g)$; fluorine, $F_2(g)$; chlorine, $Cl_2(g)$; bromine, $Br_2(\ell)$; and iodine, $I_2(s)$.

1. Practice Problem (page 115)

Gaseous hydrogen and oxygen react to form gaseous water.

What Is Required?

A skeleton equation that represents the chemical reaction is required.

What Is Given?

You are given the reactants: gaseous hydrogen and gaseous oxygen.
You are given the product: gaseous water.

Plan Your Strategy

Determine the chemical formula for each substance. Include the state.
Write the skeleton equation. Use an arrow to show the direction of the chemical change that is taking place. Use a plus sign to separate two or more reactants or products.

Act on Your Strategy

Gaseous hydrogen: $H_2(g)$
Gaseous oxygen: $O_2(g)$
Gaseous water: $H_2O(g)$

$H_2(g) + O_2(g) \rightarrow H_2O(g)$

Check Your Solution
The reactants are written on the left side of the arrow, and the product is written on the right side. The chemical formula for each substance is written correctly. The physical state of each reactant and product is shown.

2. Practice Problem (page 115)
Solid sodium metal reacts with liquid water to form an aqueous solution of sodium hydroxide and hydrogen gas.

What Is Required?
A skeleton equation that represents the chemical reaction is required.

What Is Given?
You are given the reactants: solid sodium metal and liquid water.
You are given the products: sodium hydroxide solution and hydrogen gas.

Plan Your Strategy
Determine the chemical formula for each substance. Include the state.
Write the skeleton equation. Use an arrow to show the direction of the chemical change that is taking place. Use a plus sign to separate two or more reactants or products.

Act on Your Strategy
Solid sodium metal: Na(s)
Liquid water: $H_2O(\ell)$
Aqueous solution of sodium hydroxide: NaOH(aq)
Hydrogen gas: $H_2(g)$

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

Check Your Solution
The reactants are written on the left side of the arrow, and the products are written on the right side. The chemical formula for each substance is written correctly. The physical state of each reactant and product is shown.

3. Practice Problem (page 115)
Solid potassium chlorate breaks down to form solid potassium chloride and oxygen gas.

What Is Required?
A skeleton equation that represents the chemical reaction is required.

What Is Given?
You are given the reactant: solid potassium chlorate.
You are given the products: solid potassium chloride and oxygen gas.

Plan Your Strategy
Determine the chemical formula for each substance. Include the state. Write the skeleton equation. Use an arrow to show the direction of the chemical change that is taking place. Use a plus sign to separate two or more reactants or products.

Act on Your Strategy
Solid potassium chlorate: $KClO_3(s)$
Solid potassium chloride: $KCl(s)$
Oxygen gas: $O_2(g)$

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

Check Your Solution
The reactant is written on the left side of the arrow, and the products are written on the right side. The chemical formula for each substance is written correctly. The physical state of each reactant and product is shown.

4. Practice Problem (page 115)
Solid copper reacts with oxygen gas to form solid copper(II) oxide.

What Is Required?
A skeleton equation that represents the chemical reaction is required.

What Is Given?
You are given the reactants: solid copper and oxygen gas.
You are given the product: solid copper(II) oxide.

Plan Your Strategy
Determine the chemical formula for each substance. Include the state. Write the skeleton equation. Use an arrow to show the direction of the chemical change that is taking place. Use a plus sign to separate two or more reactants or products.

Act on Your Strategy
Solid copper: $Cu(s)$
Oxygen gas: $O_2(g)$
Solid copper(II) oxide: $CuO(s)$

$Cu(s) + O_2(g) \rightarrow CuO(s)$

Check Your Solution
The reactants are written on the left side of the arrow, and the product is written on the right side. The chemical formula for each substance is written correctly. The physical state of each reactant and product is shown.

5. Practice Problem (page 115)

When aqueous solutions of silver nitrate and sodium chloride are combined, the reaction produces an aqueous solution of sodium nitrate and a precipitate of silver chloride.

What Is Required?

A skeleton equation that represents the chemical reaction is required.

What Is Given?

You are given the reactants: a solution of silver nitrate and a solution of sodium chloride.
You are given the products: a solution of sodium nitrate and a precipitate of silver chloride.

Plan Your Strategy

Determine the chemical formula for each substance. Include the state.
Write the skeleton equation. Use an arrow to show the direction of the chemical change that is taking place. Use a plus sign to separate two or more reactants or products.

Act on Your Strategy

Aqueous solution of silver nitrate: $AgNO_3(aq)$
Aqueous solution of sodium chloride: $NaCl(aq)$
Aqueous solution of sodium nitrate: $NaNO_3(aq)$
Precipitate of silver chloride: $AgCl(s)$

$AgNO_3(aq) + NaCl(aq) \rightarrow NaNO_3(aq) + AgCl(s)$

Check Your Solution

The reactants are written on the left side of the arrow, and the products are written on the right side. The chemical formula for each substance is written correctly. The physical state of each reactant and product is shown.

6. Practice Problem (page 115)

The complete combustion of propane gas, $C_3H_8(g)$, in the presence of oxygen gas forms gaseous water and carbon dioxide.

What Is Required?

A skeleton equation that represents the chemical reaction is required.

What Is Given?

You are given the reactants: propane gas, $C_3H_8(g)$, and oxygen gas.
You are given the products: gaseous water and carbon dioxide.

Plan Your Strategy
Determine the chemical formula for each substance. Include the state.
Write the skeleton equation. Use an arrow to show the direction of the chemical change that is taking place. Use a plus sign to separate two or more reactants or products.

Act on Your Strategy
Propane gas: $C_3H_8(g)$
Oxygen gas: $O_2(g)$
Gaseous water: $H_2O(g)$
Carbon dioxide gas: $CO_2(g)$

$C_3H_8(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$

Check Your Solution
The reactants are written on the left side of the arrow, and the products are written on the right side. The chemical formula for each substance is written correctly. The physical state of each reactant and product is shown.

7. Practice Problem (page 115)
Sulfur trioxide gas reacts with liquid water to form an aqueous solution of sulfuric acid.

What Is Required?
A skeleton equation that represents the chemical reaction is required.

What Is Given?
You are given the reactants: sulfur trioxide gas and liquid water.
You are given the product: solution of sulfuric acid.

Plan Your Strategy
Determine the chemical formula for each substance. Include the state.
Write the skeleton equation. Use an arrow to show the direction of the chemical change that is taking place. Use a plus sign to separate two or more reactants or products.

Act on Your Strategy
Sulfur trioxide gas: $SO_3(g)$
Liquid water: $H_2O(\ell)$
Aqueous solution of sulfuric acid: $H_2SO_4(aq)$

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

Check Your Solution
The reactants are written on the left side of the arrow, and the product is written on the right side. The chemical formula for each substance is written correctly. The physical state of each reactant and product is shown.

8. Practice Problem (page 115)
Solid ammonium chloride is formed when hydrogen chloride gas reacts with gaseous ammonia.

What Is Required?
A skeleton equation that represents the chemical reaction is required.

What Is Given?
You are given the reactants: hydrogen chloride gas and gaseous ammonia.
You are given the product: solid ammonium chloride.

Plan Your Strategy
Determine the chemical formula for each substance. Include the state.
Write the skeleton equation. Use an arrow to show the direction of the chemical change that is taking place. Use a plus sign to separate two or more reactants or products.

Act on Your Strategy
Hydrogen chloride gas: $HCl(g)$
Gaseous ammonia: $NH_3(g)$
Solid ammonium chloride: $NH_4Cl(s)$

$HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$

Check Your Solution
The reactants are written on the left side of the arrow, and the product is written on the right side. The chemical formula for each substance is written correctly. The physical state of each reactant and product is shown.

9. Practice Problem (page 115)
Solid aluminum and gaseous fluorine form when solid aluminum fluoride breaks down.

What Is Required?
A skeleton equation that represents the chemical reaction is required.

What Is Given?
You are given the reactant: solid aluminum fluoride.
You are given the products: solid aluminum and gaseous fluorine.

Plan Your Strategy
Determine the chemical formula for each substance. Include the state. Write the skeleton equation. Use an arrow to show the direction of the chemical change that is taking place. Use a plus sign to separate two or more reactants or products.

Act on Your Strategy
Solid aluminum fluoride: $AlF_3(s)$
Solid aluminum: Al(s)
Gaseous fluorine: $F_2(g)$

$AlF_3(s) \rightarrow Al(s) + F_2(g)$

Check Your Solution
The reactant is written on the left side of the arrow, and the products are written on the right side. The chemical formula for each substance is written correctly. The physical state of each reactant and product is shown.

10. Practice Problem (page 115)
Liquid mercury reacts with oxygen gas to form solid mercury(II) oxide.

What Is Required?
A skeleton equation that represents the chemical reaction is required.

What Is Given?
You are given the reactants: liquid mercury and oxygen gas.
You are given the product: solid mercury(II) oxide.

Plan Your Strategy
Determine the chemical formula for each substance. Include the state. Write the skeleton equation. Use an arrow to show the direction of the chemical change that is taking place. Use a plus sign to separate two or more reactants or products.

Act on Your Strategy
Liquid mercury**:** $Hg(\ell)$
Oxygen gas: $O_2(g)$
Solid mercury(II) oxide: HgO(s)

$Hg(\ell) + O_2(g) \rightarrow HgO(s)$

Check Your Solution
The reactants are written on the left side of the arrow, and the product is written on the right side. The chemical formula for each substance is written correctly. The physical state of each reactant and product is shown.

Section 3.1 Writing Chemical Equations

Solutions for Practice Problems

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Write a balanced chemical equation for each reaction in Practice Problems 11−20.

11. Practice Problem (page 120)

$NO(g) + O_2(g) \rightarrow NO_2(g)$

What Is Required?

A balanced chemical equation that represents the chemical reaction is required.

What Is Given?

You are given a skeleton equation with the reactants $NO(g)$ and $O_2(g)$ and the product $NO_2(g)$.

Plan Your Strategy

Count the atoms of each element in the reactants and products.
Insert coefficients in front of the reactant and product species until the number of each kind of atom is the same in the reactants and in the products.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom is the same in the reactants and products.

Act on Your Strategy

Skeleton equation:
$NO(g) + O_2(g) \rightarrow NO_2(g)$
Reactants: 1 N, 3 O
Products: 1 N, 2 O
Insert the coefficient 2 in front of $NO(g)$ and $NO_2(g)$.
Balanced chemical equation:
$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$
The ratio of the coefficients is 2:1:2. This is the lowest possible ratio.
Reactants: 2 N, 4 O
Products: 2 N, 4 O

Check Your Solution

The chemical formula for each substance is written correctly. The number of atoms of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

12. Practice Problem (page 120)

$Mg(s) + AlCl_3(aq) \rightarrow Al(s) + MgCl_2(aq)$

What Is Required?

A balanced chemical equation that represents the chemical reaction is required.

What Is Given?

You are given a skeleton equation with the reactants Mg(s) and $AlCl_3(aq)$ and the products Al(s) and $MgCl_2(aq)$.

Plan Your Strategy

Count the atoms and ions of each element in the reactants and products.
Insert coefficients in front of the reactant and product species until the number of each kind of atom or ion is the same in the reactants and in the products.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy

Skeleton equation:
$Mg(s) + AlCl_3(aq) \rightarrow Al(s) + MgCl_2(aq)$
Reactants 1 Mg, 1 Al^{3+}, 3 Cl^-
Products: 1 Al, 1 Mg^{2+}, 2 Cl^-
Insert the coefficient 2 in front $AlCl_3(aq)$ and the coefficient 3 in front of $MgCl_2(aq)$ to balance the Cl^-.
Insert the coefficient 3 in front of Mg(s) and the coefficient 2 in front of Al(s) to balance the Mg and Al.
Balanced chemical equation:
$3Mg(s) + 2AlCl_3(aq) \rightarrow 2Al(s) + 3MgCl_2(aq)$
The ratio of the coefficients is 3:2:2:3. This is the lowest possible ratio.
Reactants: 3 Mg, 2 Al^{3+}, 6 Cl^-
Products: 3 Mg, 2 Al^{3+}, 6 Cl^-

Check Your Solution

The chemical formula for each substance is written correctly. The number of atoms and ions of each element are equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$3Mg(s) + 2AlCl_3(aq) \rightarrow 2Al(s) + 3MgCl_2(aq)$

13. Practice Problem (page 120)

$NaOH(aq) + CuCl_2(aq) \rightarrow NaCl(aq) + Cu(OH)_2(s)$

What Is Required?

A balanced chemical equation that represents the chemical reaction is required.

What Is Given?

You are given a skeleton equation with the reactants $NaOH(aq)$ and $CuCl_2(aq)$ and the products $NaCl(aq)$ and $Cu(OH)_2(s)$.

Plan Your Strategy

Count the atoms and ions of each element in the reactants and products.
Consider the polyatomic OH^- ion as a single unit.
Insert coefficients in front of the reactant and product species until the number of each kind of atom or ion is the same in the reactants and in the products.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each atom and ion is the same in the reactants and products.

Act on Your Strategy

Skeleton equation:
$NaOH(aq) + CuCl_2(aq) \rightarrow NaCl(aq) + Cu(OH)_2(s)$
Reactants: 1 Na^+, 1 OH^-, 1 Cu^{2+}, 2 Cl^-
Products: 1 Na^+, 2 OH^-, 1 Cu^{2+}, 1 Cl^-
Insert the coefficient 2 in front of $NaOH(aq)$ and the coefficient 2 in front of $NaCl(aq)$ to balance the Cl^-. This also balances the OH^-.
Balanced chemical equation:
$2NaOH(aq) + CuCl_2(aq) \rightarrow 2NaCl(aq) + Cu(OH)_2(s)$
The ratio of the coefficients is 2:1:2:1. This is the lowest possible ratio.
Reactants: 2 Na^+, 2OH^-, 1 Cu^{2+}, 2 Cl^-
Products: 2 Na^+, 2OH^-, 1 Cu^{2+}, 2 Cl^-

Check Your Solution

The chemical formula for each substance is written correctly. The number of atoms and ions of each element and the number of polyatomic ions are equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$2NaOH(aq) + CuCl_2(aq) \rightarrow 2NaCl(aq) + Cu(OH)_2(s)$

14. Practice Problem (page 120)

$C_2H_4(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$

What Is Required?

A balanced chemical equation that represents the chemical reaction is required.

What Is Given?
You are given a skeleton equation with the reactants $C_2H_4(g)$ and $O_2(g)$ and the products $CO_2(g)$ and $H_2O(g)$.

Plan Your Strategy
Count the atoms of each element in the reactants and products.
Insert coefficients in front of the reactant and product species until the number of each kind of atom is the same in the reactants and in the products.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom is the same in the reactants and products.

Act on Your Strategy
Skeleton equation:
$C_2H_4(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$
Insert the coefficient 2 in front of $CO_2(g)$ to balance the C:
$C_2H_4(g) + O_2(g) \rightarrow 2CO_2(g) + H_2O(g)$
Insert the coefficient 2 in front of $H_2O(g)$ to balance the H:
$C_2H_4(g) + O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$
Insert the coefficient 3 in front of $O_2(g)$ to balance the O:
$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$
Balanced chemical equation:
$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$
The ratio of the coefficients is 1:3:2:2. This is the lowest possible ratio.
Reactants: 2 C, 4 H, 6 O
Products: 2 C, 4 H, 6 O

Check Your Solution
The chemical formula for each substance is written correctly. The number of atoms of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$

15. Practice Problem (page 120)
$Cu(s) + AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + Ag(s)$

What Is Required?
A balanced chemical equation that represents the chemical reaction is required.

What Is Given?
You are given a skeleton equation with the reactants $Cu(s)$ and $AgNO_3(aq)$ and the products $Cu(NO_3)_2(aq)$ and $Ag(s)$.

Plan Your Strategy
Count the atoms and ions of each element in the reactants and products.
Consider the polyatomic NO_3^- ion as a single unit.
Insert coefficients in front of the reactant and product species until the number of each kind of atom or ion is the same in the reactants and in the products.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy
Skeleton equation:
$Cu(s) + AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + Ag(s)$
Reactants: 1 Cu, 1 Ag^+, 1 NO_3^-
Products: 1 Cu^{2+}, 1 Ag, 2 NO_3^-
Insert the coefficient 2 in front of $AgNO_3(aq)$ to balance the NO_3^-.
Insert the coefficient 2 in front of Ag(s) to balance the Ag.
Balanced chemical equation:
$Cu(s) + 2AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2Ag(s)$
The ratio of coefficients is 1:2:1:2. This is the lowest possible ratio.
Reactants: 1 Cu, 2 Ag^+, 2 NO_3^-
Products: 1 Cu, 2 Ag^+, 2 NO_3^-

Check Your Solution
The chemical formula for each substance is written correctly. The number of atoms and ions of each element and the number of polyatomic ions are equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$Cu(s) + 2AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2Ag(s)$

16. Practice Problem (page 120)
$Al(s) + MnO_2(s) \rightarrow Al_2O_3(s) + Mn(s)$

What Is Required?
A balanced chemical equation that represents the chemical reaction is required.

What Is Given?
You are given a skeleton equation with the reactants Al(s) and $MnO_2(s)$ and the products $Al_2O_3(s)$ and Mn(s).

Plan Your Strategy
Count the atoms and ions of each element in the reactants and products.
Insert coefficients in front of the reactant and product species until the number of each kind of atom or ion is the same in the reactants and in the products.

Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products

Act on Your Strategy
Skeleton equation:
$Al(s) + MnO_2(s) \rightarrow Al_2O_3(s) + Mn(s)$
Reactants: 1 Al, 1 Mn^{4+}, 2 O^{2-}
Products: 2 Al, 1 Mn, 3 O^{2-}
Insert the coefficient 3 in front of $MnO_2(s)$ and the coefficient 2 in front of $Al_2O_3(s)$ to balance the O.
Insert the coefficient 4 in front of Al(s) and the coefficient 3 in front of Mn(s) to balance these two elements.
Balanced chemical equation:
$4Al(s) + 3MnO_2(s) \rightarrow 2Al_2O_3(s) + 3Mn(s)$
The ratio of the coefficients is 4:3:2:3. This is the lowest possible ratio.
Reactants: 4 Al, 3 Mn^{4+}, 6 O^{2-}
Products: 4 Al, 3 Mn^{4+}, 6 O^{2-}

Check Your Solution
The chemical formula for each substance is written correctly. The number of atoms and ions of each element are equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$4Al(s) + 3MnO_2(s) \rightarrow 2Al_2O_3(s) + 3Mn(s)$

17. Practice Problem (page 120)
Propane, $C_3H_8(g)$, burns in the presence of oxygen gas to form carbon dioxide gas and water vapour.

What Is Required?
A balanced chemical equation that represents the chemical reaction is required.

What Is Given?
You are given the reactants: propane and oxygen gas.
You are given the products: carbon dioxide gas and water vapour.

Plan Your Strategy
Write the chemical formulas for oxygen gas, carbon dioxide gas, and water vapour.
Write a skeleton equation for the reaction.
Count the atoms of each element in the reactants and products.
Insert coefficients in front of the reactant and product species until the number of each kind of atom is the same in the reactants and in the products.

Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom is the same in the reactants and products.

Act on Your Strategy
Chemical formulas: oxygen gas, $O_2(g)$; carbon dioxide gas, $CO_2(g)$; water vapour, $H_2O(g)$
Skeleton equation:
$C_3H_8(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$
Reactants; 3 C, 8 H, 2 O
Products: 1 C, 2 H, 3 O
Insert the coefficient 3 in front of $CO_2(g)$ to balance the C:
$C_3H_8(g) + O_2(g) \rightarrow 3CO_2(g) + H_2O(g)$
Insert the coefficient 4 in front of $H_2O(g)$ to balance the H:
$C_3H_8(g) + O_2(g) \rightarrow 3\ CO_2(g) + 4H_2O(g)$
Insert the coefficient 5 in front of $O_2(g)$ to balance the O:
$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$
Balanced chemical equation:
$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$
The ratio of the coefficients is 1:5:3:4. This is the lowest possible ratio.
Reactants; 3 C, 8 H, 10 O
Products: 3 C, 8 H, 10 O

Check Your Solution
The chemical formula for each substance is written correctly. The number of atoms of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

18. Practice Problem (page 120)
Gaseous ammonia and oxygen react to form nitrogen dioxide gas and liquid water.

What Is Required?
A balanced chemical equation that represents the chemical reaction is required.

What Is Given?
You are given the reactants: ammonia gas and oxygen gas.
You are given the products: nitrogen dioxide gas and liquid water.

Plan Your Strategy
Write the chemical formulas for ammonia gas, oxygen gas, nitrogen dioxide gas, and liquid water.
Write the skeleton equation for the reaction.

Count the atoms of each element in the reactants and products.
Insert coefficients in front of the reactant and product species until the number of each kind of atom is the same in the reactants and in the products.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom is the same in the reactants and products.

Act on Your Strategy
Chemical formulas: ammonia, $NH_3(g)$; oxygen gas, $O_2(g)$; nitrogen dioxide gas, $NO_2(g)$; liquid water, $H_2O(\ell)$
Skeleton equation:
$NH_3(g) + O_2(g) \rightarrow NO_2(g) + H_2O(\ell)$
Reactants: 1 N, 3 H, 2 O
Products: 1 N, 2 H, 3 O
Insert the coefficient 2 in front of $NH_3(g)$ and the coefficient 3 in front of $H_2O(\ell)$ to balance the H:
$2NH_3(g) + O_2(g) \rightarrow NO_2(g) + 3H_2O(\ell)$.
Insert the coefficient 2 in front of $NO_2(g)$ to balance the N:
$2NH_3(g) + O_2(g) \rightarrow 2NO_2(g) + 3H_2O(\ell)$.
Insert the coefficient $\frac{7}{2}$ in front of $O_2(g)$ to balance the O:

$$2NH_3(g) + \frac{7}{2}O_2(g) \rightarrow 2NO_2(g) + 3H_2O(\ell).$$

Since there is a fraction for one of the coefficients, multiply each coefficient by 2 to clear the fraction.
Balanced chemical equation:
$4NH_3(g) + 7O_2(g) \rightarrow 4NO_2(g) + 6H_2O(\ell)$
The ratio of the coefficients is 4:7:4:6. This is the lowest possible ratio.
Reactants: 4 N, 12 H, 14 O
Products: 4 N, 12 H, 14 O

Check Your Solution
The chemical formula for each substance is written correctly. The number of atoms of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$4NH_3(g) + 7O_2(g) \rightarrow 4NO_2(g) + 6H_2O(\ell)$

19. Practice Problem (page 120)
Aqueous solutions of potassium sulfide and cobalt(II) chloride react to form a solution of potassium chloride and a precipitate of cobalt(II) sulfide.

What Is Required?
A balanced chemical equation that represents the chemical reaction is required.

What Is Given?
You are given the reactants: potassium sulfide solution and cobalt(II) chloride solution.
You are given the products: potassium chloride solution and cobalt(II) sulfide precipitate.

Plan Your Strategy
Write the chemical formulas for potassium sulfide solution, cobalt(II) chloride solution, potassium chloride solution, and solid cobalt(II) sulfide.
Write the skeleton equation for the reaction.
Count the ions of each element in the reactants and products.
Insert coefficients in front of the reactant and product species until the number of each kind of atom or ion is the same in the reactants and in the products.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of ion is the same in the reactants and products.

Act on Your Strategy
Chemical formulas: potassium sulfide solution, $K_2S(aq)$; cobalt(II) chloride solution, $CoCl_2(aq)$; potassium chloride solution, $KCl(aq)$; solid cobalt(II) sulfide, $CoS(s)$
Skeleton equation:
$K_2S(aq) + CoCl_2(aq) \rightarrow KCl(aq) + CoS(s)$
Reactants: 2 K, 1 S^{2-}, 1 Co^{2+}, 2 Cl^-
Products: 1 K, 1 S^{2-}, 1 Co^{2+}, 1 Cl^-
Insert the coefficient 2 in front of $KCl(aq)$ to balance the K^+ and Cl^-.
Balanced chemical equation:
$K_2S(aq) + CoCl_2(aq) \rightarrow 2KCl(aq) + CoS(s)$
The ratio of the coefficients is 1:1:2:1. This is the lowest possible ratio.
Reactants: 2 K, 1 S^{2-}, 1 Co^{2+}, 2 Cl^-
Products: 2 K, 1 S^{2-}, 1 Co^{2+}, 2 Cl^-

Check Your Solution
The chemical formula for each substance is written correctly. The number of ions of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$K_2S(aq) + CoCl_2(aq) \rightarrow 2KCl(aq) + CoS(s)$

20. Practice Problem (page 120)

Carbon dioxide gas, liquid water, and an aqueous solution of sodium chloride form when hydrogen chloride gas is bubbled through a solution of sodium carbonate.

What Is Required?

A balanced chemical equation that represents the chemical reaction is required.

What Is Given?

You are given the reactants: hydrogen chloride gas and a solution of sodium carbonate.
You are given the products: carbon dioxide gas, liquid water, and an aqueous solution of sodium chloride.

Plan Your Strategy

Count the atoms and ions of each element in the reactants and products.
Consider the polyatomic CO_3^{2-} ion as a single unit.
Insert coefficients in front of the reactant and product species until the number of each kind of atom or ion is the same in the reactants and in the products.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy

Skeleton equation:
$HCl(g) + Na_2CO_3(aq) \rightarrow CO_2(g) + H_2O(\ell) + NaCl(aq)$
Reactants: 1 H, 1 Cl, 2 Na^{2+}, 1 CO_3^{2-}
Products: 2 H, 1 Na^{2+}, 1 Cl^-, 1 C, 3 O
Insert the coefficient 2 in front of NaCl(aq) to balance the Na^+.
Insert the coefficient 2 in front of the HCl(g) to balance the Cl.
Balanced chemical equation:
$2HCl(g) + Na_2CO_3(aq) \rightarrow CO_2(g) + H_2O(\ell) + 2NaCl(aq)$
The ratio of the coefficients is 2:1:1:1:2. This is the lowest possible ratio.
Reactants: 2 H, 2 Cl, 2 Na^{2+}, 1 CO_3^{2-}
Products: 2 H, 2 Cl^-, 2 Na^{2+}, 1 C, 3 O

Check Your Solution

The chemical formula for each substance is written correctly. The number of atoms and ions of each element are equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$2HCl(g) + Na_2CO_3(aq) \rightarrow CO_2(g) + H_2O(\ell) + 2NaCl(aq)$

Section 3.1 Writing Chemical Equations

Solutions for Selected Review Questions

Student Edition page 121

11. Review Question (page 121)

Write a balanced chemical equation for each chemical reaction.

a. Solid potassium reacts with gaseous chlorine to form solid potassium chloride.

b. Aluminum foil is placed in an aqueous solution of copper(II) sulfate, producing solid copper metal and a solution of aluminum sulfate.

c. Nitrogen gas and hydrogen gas react to form gaseous ammonia.

d. An aqueous solution of calcium chloride reacts with fluorine gas to form an aqueous solution of calcium fluoride and chlorine gas.

a. Solid potassium reacts with gaseous chlorine to form solid potassium chloride.

What Is Required?

You need to write a balanced chemical equation that represents the chemical reaction.

What Is Given?

You are given the reactants: solid potassium and chlorine gas.
You are given the product: solid potassium chloride.

Plan Your Strategy

Write the chemical formulas for each reactant and product.
Write the skeleton equation for the reaction.
Count the atoms of each element in the reactants and products.
Insert coefficients in front of the reactant and product species until the number of each kind of atom or ion is the same in the reactants and in the products.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy

Chemical formulas: solid potassium, K(s); chlorine gas, $Cl_2(g)$; solid potassium chloride, KCl(s)
Skeleton equation: $K(s) + Cl_2(g) \rightarrow KCl(s)$
Balance Cl: $K(s) + Cl_2(g) \rightarrow 2KCl(s)$
Balance K: $2K(s) + Cl_2(g) \rightarrow 2KCl(s)$
Balanced chemical equation: $2K(s) + Cl_2(g) \rightarrow 2KCl(s)$
The ratio of the coefficients is 2:1:2. This is the lowest possible ratio.
Reactants: 2 K, 2 Cl
Products: $2\ K^+$, $2\ Cl^-$

Check Your Solution

The chemical formula for each substance is written correctly. The number of atoms of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$2K(s) + Cl_2(g) \rightarrow 2KCl(s)$

b. Aluminum foil is placed in an aqueous solution of copper(II) sulfate, producing solid copper metal and a solution of aluminum sulfate.

What Is Required?

You need to write a balanced chemical equation that represents the chemical reaction.

What Is Given?

You are given the reactants: solid aluminum and a solution of copper(II) sulfate.
You are given the products: solid copper metal and a solution of aluminum sulfate.

Plan Your Strategy

Write the chemical formulas for the reactants and products.
Write the skeleton equation for the reaction.
Count the atoms of each element in the reactants and products.
Insert coefficients in front of the reactant and product species until the number of each kind of atom or ion is the same in the reactants and in the products.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy

Chemical formulas: solid aluminum, Al(s); solution of copper(II) sulfate, $CuSO_4(aq)$; solid copper, Cu(s); solution of aluminum sulfate, $Al_2(SO_4)_3(aq)$
Skeleton equation: $Al(s) + CuSO_4(aq) \rightarrow Cu(s) + Al_2(SO_4)_3(aq)$
Balance the SO_4^{2-}: $Al(s) + 3CuSO_4(aq) \rightarrow Cu(s) + Al_2(SO_4)_3(aq)$
Balance Al: $2Al(s) + 3CuSO_4(aq) \rightarrow Cu(s) + Al_2(SO_4)_3(aq)$
Balance Cu: $2Al(s) + 3CuSO_4(aq) \rightarrow 3Cu(s) + Al_2(SO_4)_3(aq)$
Balanced chemical equation: $2Al(s) + 3CuSO_4(aq) \rightarrow 3Cu(s) + Al_2(SO_4)_3(aq)$
The ratio of the coefficients is 2:3:3:1. This is the lowest possible ratio.
Reactants: 2 Al, 3 Cu^{2+}, 3 SO_4^{2-}
Products: 2 Al^{3+}, 3 Cu, 3 SO_4^{2-}

Check Your Solution

The chemical formula for each substance is written correctly. The number of atoms of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$2Al(s) + 3CuSO_4(aq) \rightarrow 3Cu(s) + Al_2(SO_4)_3(aq)$

c. Nitrogen gas and hydrogen gas react to form gaseous ammonia.

What Is Required?

You need to write a balanced chemical equation that represents the chemical reaction.

What Is Given?

You are given the reactants: nitrogen gas and hydrogen gas.
You are given the product: gaseous ammonia.

Plan Your Strategy

Write the chemical formulas for each reactant and product.
Write the skeleton equation for the reaction.
Count the atoms of each element in the reactants and products.
Insert coefficients in front of the reactant and product species until the number of each kind of atom is the same in the reactants and in the products.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom is the same in the reactants and products.

Act on Your Strategy

Chemical formulas: nitrogen gas, $N_2(g)$; hydrogen gas, $H_2(g)$; ammonia gas, $NH_3(g)$
Skeleton equation: $N_2(g) + H_2(g) \rightarrow NH_3(g)$
Balance N: $N_2(g) + H_2(g) \rightarrow 2NH_3(g)$
Balance H: $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
Balanced chemical equation: $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
The ratio of the coefficients is 1:3:2. This is the lowest possible ratio.
Reactants: 2 N, 6 H
Products: 2 N, 6 H

Check Your Solution

The chemical formula for each substance is written correctly. The number of atoms of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

d. An aqueous solution of calcium chloride reacts with fluorine gas to form an aqueous solution of calcium fluoride and chlorine gas.

What Is Required?

You need to write a balanced chemical equation that represents the chemical reaction.

What Is Given?

You are given the reactants: a solution of calcium chloride and fluorine gas.
You are given the products: a solution of calcium fluoride and chlorine gas.

Plan Your Strategy

Write the chemical formulas for the reactants and products.
Write the skeleton equation for the reaction.
Count the atoms of each element in the reactants and products.
Insert coefficients in front of the reactant and product species until the number of each kind of atom or ion is the same in the reactants and in the products.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy

Chemical formulas: calcium chloride solution, $CaCl_2(aq)$; fluorine gas, $F_2(g)$; calcium fluoride solution, $CaF_2(aq)$; chlorine gas, $Cl_2(g)$
Skeleton equation: $CaCl_2(aq) + F_2(g) \rightarrow CaF_2(aq) + Cl_2(g)$
Balanced chemical equation: $CaCl_2(aq) + F_2(g) \rightarrow CaF_2(aq) + Cl_2(g)$
The ratio of the coefficients is 1:1:1:1. This is the lowest possible ratio.
Reactants: 1 Ca^{2+}, 2 Cl^-, 2 F
Products: 1 Ca^{2+}, 2 Cl, 2 F^-

Check Your Solution

The chemical formula for each substance is written correctly. The number of atoms and ions of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$CaCl_2(aq) + F_2(g) \rightarrow CaF_2(aq) + Cl_2(g)$.

12. Review Question (page 121)

Barium hydroxide can react with phosphoric acid to form barium hydrogen phosphate and water: $Ba(OH)_2(s) + H_3PO_4(aq) \rightarrow BaHPO_4(s) + H_2O(\ell)$.
a. Identify the polyatomic ions in the reactants.
b. Can each polyatomic ion be treated as a unit when balancing the equation? Explain why or why not.
c. Write the balanced chemical equation.

a. The polyatomic ions are the hydroxide ion, OH^-, and the phosphate ion, PO_4^{3-}.
b. A polyatomic ion can be balanced as a unit when it appears on both sides of the equation.
c. Balanced chemical equation:

What Is Required?

You need to write a balanced chemical equation that represents the chemical reaction.

What Is Given?

You are given the reactants: solid barium hydroxide and a solution of phosphoric acid.
You are given the products: solid barium hydrogen phosphate and liquid water.

Plan Your Strategy

Write the chemical formulas for the reactants and products.
Write the skeleton equation for the reaction.
Count the atoms of each element in the reactants and products.
Insert coefficients in front of the reactant and product species until the number of each kind of atom or ion is the same in the reactants and in the products.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy

Chemical formulas: solid barium hydroxide, $Ba(OH)_2(s)$; solution of phosphoric acid, $H_3PO_4(aq)$; solid barium hydrogen phosphate, $BaHPO_4(s)$; liquid water, $H_2O(\ell)$
Skeleton equation: $Ba(OH)_2(s) + H_3PO_4(aq) \rightarrow BaHPO_4(s) + H_2O(\ell)$
Reactants: 1 Ba^{2+}, 2 OH^-, 3 H, 1 PO_4^{3-}
Products: 1 Ba^{2+}, 1 HPO_4^{2-}, 2 H, 1 O
Insert a 2 in front of the $H_2O(\ell)$ to balance the H.
Balanced chemical equation: $Ba(OH)_2(s) + H_3PO_4(aq) \rightarrow BaHPO_4(s) + 2H_2O(\ell)$
The ratio of the coefficients is 1:1:1:2. This is the lowest possible ratio.
Reactants: 1 Ba^{2+}, 2 OH^-, 3 H, 1 PO_4^{3-}
Products: 1 Ba^{2+}, 1 HPO_4^{2-}, 4 H, 2 O

Check Your Solution

The chemical formula for each substance is written correctly. The number of atoms and ions of the elements is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$Ba(OH)_2(s) + H_3PO_4(aq) \rightarrow BaHPO_4(s) + 2H_2O(\ell)$.

14. Review Question (page 121)

Your friend has written the following balanced equation for the reaction in which aluminum and chlorine form aluminum(III) chloride:
$Al(s) + Cl(g) \rightarrow AlCl(s)$
Is this correct? If not, how would you suggest that your friend correct it?

The equation is not correct. The chemical formulas for chlorine gas and aluminum chloride are incorrect and the equation is not balanced.
The correct balanced chemical equation for this reaction is:
$2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$

Section 3.2 Synthesis Reactions and Decomposition Reactions

Solutions for Practice Problems

Student Edition page 127

21. Practice Problem (page 127)

Predict the product that is likely to form in a reaction between lithium and oxygen, and write a balanced chemical equation for the reaction.

What Is Required?

You need to predict the product and write a balanced chemical equation for the reaction between lithium and oxygen.

What Is Given?

You are given the reactants: lithium and oxygen.

Plan Your Strategy
Identify the types of elements involved and predict the product that will form.
Write the chemical formula for the product and write a balanced equation for the reaction.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy
You know this will be a synthesis reaction between a univalent metal and a non-metal to form a binary ionic compound.
The product is predicted to be lithium oxide, $Li_2O(s)$.
Skeleton equation: $Li(s) + O_2(g) \rightarrow Li_2O(s)$
Reactants: 1 Li, 2 O
Products: 2 Li^+, 1 O^{2-}
Balanced chemical equation: $4Li(s) + O_2(g) \rightarrow 2Li_2O(s)$
The ratio of the coefficients is 4:1:2. This is the lowest possible ratio.
Reactants: 4 Li, 2 O
Products: 4 Li^+, 2 O^{2-}

Check Your Solution
The overall charge on the compound lithium oxide is zero and the equation is balanced. The product is what would be expected in a synthesis reaction.
The balanced chemical equation for this reaction is:
$4Li(s) + O_2(g) \rightarrow 2Li_2O(s)$

22. Practice Problem (page 127)
Predict the product that is likely to form in a reaction between strontium and fluorine, and write a balanced chemical equation for the reaction.

What Is Required?
You need to predict the product and write a balanced chemical equation for the reaction between strontium and fluorine.

What Is Given?
You are given the reactants: strontium and fluorine.

Plan Your Strategy
Identify the types of elements involved and predict the product that will form.
Write the chemical formula for the product and write a balanced chemical equation for the reaction.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy
You know this will be a synthesis reaction between a univalent metal and a non-metal to form a binary ionic compound.
The product is predicted to be strontium fluoride, $SrF_2(s)$.
Skeleton equation: $Sr(s) + F_2(g) \rightarrow SrF_2(s)$
Reactants: 1 Sr, 2 F
Products: 1 Sr^{2+}, 2 F^-
Balanced chemical equation: $Sr(s) + F_2(g) \rightarrow SrF_2(s)$
The ratio of the coefficients is 1:1:1. This is the lowest possible ratio.
The skeleton and balanced equations are the same.

Check Your Solution
The overall charge on the compound strontium fluoride is zero and the equation is balanced. The product is what would be expected in a synthesis reaction.
The balanced chemical equation for this reaction is:
$Sr(s) + F_2(g) \rightarrow SrF_2(s)$

23. Practice Problem (page 127)
Predict the product that is likely to form in a reaction between iron and bromine, and write a balanced chemical equation for the reaction.

What Is Required?
You need to predict the product and write a balanced chemical equation for the reaction between iron and bromine.

What Is Given?
You are given the reactants: iron and bromine.

Plan Your Strategy
Identify the types of elements involved and predict the most likely product that will form.
Determine whether the metal involved, iron, is multivalent and, if so, determine its possible charges.
Write the chemical formula for the products and write balanced chemical equations for the reactions.
Check to make sure that the ratio of the coefficients in each equation is the lowest possible ratio.
Check each equation to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy
You know this will be a synthesis reaction between a multivalent metal and a non-metal to form a binary ionic compound.
The possible charges on multivalent iron are Fe^{2+} and Fe^{3+}.

The predicted products are solid iron(II) bromide, $FeBr_2(s)$, and solid iron(III) bromide, $FeBr_3(s)$.
Skeleton equations:
$Fe(s) + Br_2(\ell) \rightarrow FeBr_2(s)$
$Fe(s) + Br_2(\ell) \rightarrow FeBr_3(s)$
Balanced chemical equation for solid iron(II) bromide:
$Fe(s) + Br_2(g) \rightarrow FeBr_2(s)$
Reactants: 1 Fe, 2 Br
Products: 1 Fe^{2+}, 2 Br^-
Balanced chemical equation for solid iron(III) bromide:
$2Fe(s) + 3Br_2(\ell) \rightarrow 2FeBr_3(s)$
Reactants: 2 Fe, 6 Br
Products: 2 Fe^{3+}, 6 Br^-

Check Your Solution
The overall charges on the compounds iron(II) bromide and iron(III) bromide are zero and each equation is balanced. The products are what would be expected in synthesis reactions.
The balanced chemical equation for solid iron(II) bromide is:
$Fe(s) + Br_2(\ell) \rightarrow FeBr_2(s)$
The balanced chemical equation for solid iron(III) bromide is:
$2Fe(s) + 3Br_2(\ell) \rightarrow 2FeBr_3(s)$

24. Practice Problem (page 127)
Predict the product that is likely to form in a reaction between phosphorus and hydrogen, forming gaseous phosphorus trihydride, and write a balanced chemical equation for the reaction.

What Is Required?
You need to write the balanced chemical equation for the reaction between phosphorus and hydrogen, forming gaseous phosphorus trihydride.

What Is Given?
You are given the reactants: phosphorus and hydrogen.
You are given the product: phosphorus trihydride.

Plan Your Strategy
Identify the types of elements involved in the reaction.
Write the chemical formula for the products and write a balanced chemical equation for the reaction.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom is the same in the reactants and products.

Act on Your Strategy
You know this will be a synthesis reaction between two non-metals to form a binary molecular compound.
The product is phosphorus trihydride, $PH_3(g)$.
Skeleton equation: $P(s) + H_2(g) \rightarrow PH_3(g)$
Reactants: 1 P, 2 H
Products: 1 P, 3 H
Balanced chemical equation: $2P(s) + 3H_2(g) \rightarrow 2PH_3(g)$
The ratio of the coefficients is 2:3:2. This is the lowest possible ratio.
Reactants: 2 P, 6 H
Products: 2 P, 6 H

Check Your Solution
The equation is balanced. The product is what would be expected in a synthesis reaction.
The balanced chemical equation for this reaction is:
$2P(s) + 3H_2(g) \rightarrow 2PH_3(g)$

25. Practice Problem (page 127)
Predict the product that is likely to form in a reaction between calcium and iodine, and write a balanced chemical equation for the reaction.

What Is Required?
You need to predict the product and write a balanced chemical equation for the reaction between calcium and iodine.

What Is Given?
You are given the reactants: calcium and iodine.

Plan Your Strategy
Identify the types of elements involved and predict the product that will form.
Write the chemical formula for the product and write a balanced chemical equation for the reaction.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy
You know this will be a synthesis reaction between a univalent metal and a non-metal to form a binary ionic compound.
The product is predicted to be solid calcium iodide, $CaI_2(s)$.
Skeleton equation: $Ca(s) + I_2(g) \rightarrow CaI_2(s)$

Reactants: 1 Ca, 2 I
Products: 1 Ca^{2+}, 2 I^-
Balanced chemical equation: $Ca(s) + I_2(g) \rightarrow CaI_2(s)$
The ratio of the coefficients is 1:1:1. This is the lowest possible ratio.
The skeleton and balanced equations are the same.

Check Your Solution
The overall charge on the compound calcium iodide is zero and the equation is balanced. The product is what would be expected in a synthesis reaction.
The balanced chemical equation for this reaction is:
$Ca(s) + I_2(g) \rightarrow CaI_2(s)$

26. Practice Problem (page 127)
Predict the product that is likely to form in a reaction between tin and oxygen, and write a balanced chemical equation for the reaction.

What Is Required?
You need to predict the most likely product and write a balanced chemical equation for the reaction between tin and oxygen.

What Is Given?
You are given the reactants: tin and oxygen.

Plan Your Strategy
Identify the types of elements involved and predict the most likely product that will form.
Determine whether the metal involved, tin, is multivalent and, if so, determine its possible charges.
Write the chemical formula for the products and write Balanced chemical equations for the reactions.
Check to make sure that the ratio of the coefficients in each equation is the lowest possible ratio.
Check each equation to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy
You know this will be a synthesis reaction between a multivalent metal and a non-metal to form a binary ionic compound.
The possible charges on multivalent tin are Sn^{2+} and Sn^{4+}.
The predicted products are solid tin(II) oxide, SnO(s), and solid tin(IV) oxide, SnO_2 (s).
Skeleton equations:
$Sn(s) + O_2(g) \rightarrow SnO(s)$
$Sn(s) + O_2(g) \rightarrow SnO_2(s)$
Balanced chemical equation for solid tin(II) oxide: $2Sn(s) + O_2(g) \rightarrow 2SnO(s)$

Reactants: 2 Sn, 2 O
Products: 2 Sn^{2+}, 2 O^{2-}
Balanced chemical equation for solid tin(IV) oxide: $Sn(s) + O_2(g) \rightarrow SnO_2(s)$
Reactants: 1 Sn, 2 O
Products: 1 Sn^{4+}, 2 O^{2-}

Check Your Solution
The overall charges on the compounds tin(II) oxide and tin(IV) oxide are zero and each equation is balanced. The products are what would be expected in synthesis reactions.
The balanced chemical equation for solid tin(II) oxide is:
$2Sn(s) + O_2(g) \rightarrow 2SnO(s)$
The balanced chemical equation for solid tin(IV) oxide is:
$Sn(s) + O_2(g) \rightarrow SnO_2(s)$

27. Practice Problem (page 127)
Predict the product that is likely to form in a reaction between bismuth and sulfur, and write a balanced chemical equation for the reaction.

What Is Required?
You need to predict the product and write a balanced chemical equation for the reaction between bismuth and sulfur.

What Is Given?
You are given the reactants: bismuth and sulfur.

Plan Your Strategy
Identify the types of elements involved and predict the most likely product that will form.
Determine whether the metal involved, bismuth, is multivalent and, if so, determine its possible charges.
Write the chemical formula for the products and write Balanced chemical equations for the reactions.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy
You know this will be a synthesis reaction between a multivalent metal and a non-metal to form a binary ionic compound.
The possible charges on multivalent bismuth are Bi^{3+} and Bi^{5+}.
The predicted products are solid bismuth(III) sulfide, $Bi_2S_3(s)$, and solid bismuth(V) sulfide, $Bi_2S_5(s)$.

Skeleton equations:
$Bi(s) + S(s) \rightarrow Bi_2S_3(s)$
$Bi(s) + S(s) \rightarrow Bi_2S_5(s)$
Balanced chemical equation for solid bismuth(III) sulfide:
$2Bi(s) + 3S(s) \rightarrow Bi_2S_3(s)$
Reactants: 2 Bi, 3 S
Products: 2 Bi^{3+}, 3 S^{2-}
Balanced chemical equation for solid bismuth(V) sulfide:
$2Bi(s) + 5S(s) \rightarrow Bi_2S_5(s)$
Reactants: 2 Bi, 5 S
Products: 2 Bi^{5+}, 5 S^{2-}

Check Your Solution
The overall charges on the compounds bismuth((III) sulfide and bismuth(V) sulfide are zero and each equation is balanced. The products are what would be expected in synthesis reactions.
The balanced chemical equation for bismuth((III) sulfide is:
$2Bi(s) + 3S(s) \rightarrow Bi_2S_3(s)$
The balanced chemical equation for bismuth(V) sulfide is:
$2Bi(s) + 5S(s) \rightarrow Bi_2S_5(s)$

28. Practice Problem (page 127)
Predict the product that is likely to form in a reaction between aluminum and iodine, and write a balanced chemical equation for the reaction.

What Is Required?
You need to predict the product and write a balanced chemical equation for the reaction between aluminum and iodine.

What Is Given?
You are given the reactants: aluminum and iodine.

Plan Your Strategy
Identify the types of elements involved and predict the product that will form.
Write the chemical formula for the product and write a balanced chemical equation for the reaction.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy
You know this will be a synthesis reaction between a univalent metal and a non-metal to form a binary ionic compound.
The product is predicted to be solid aluminum iodide, $AlI_3(s)$.
Skeleton equation: $Al(s) + I_2(s) \rightarrow AlI_3(s)$

Reactants: 1 Al, 2 I
Products: 1 Al^{3+}, 3 I^-
Balanced chemical equation: $2Al(s) + 3I_2(s) \rightarrow 2AlI_3(s)$
The ratio of the coefficients is 2:3:2. This is the lowest possible ratio.
Reactants: 2 Al, 6 I
Products: 2 Al^{3+}, 6 I^-

Check Your Solution
The overall charge on the compound aluminum iodide is zero and the equation is balanced. The product is what would be expected in a synthesis reaction.
The balanced chemical equation for this reaction is:
$2Al(s) + 3 I_2(s) \rightarrow 2AlI_3(s)$

29. Practice Problem (page 127)
Predict the product that is likely to form in a reaction between silver and oxygen, and write a balanced chemical equation for the reaction.

What Is Required?
You need to predict the product and write a balanced chemical equation for the reaction between silver and oxygen.

What Is Given?
You are given the reactants: silver and oxygen.

Plan Your Strategy
Identify the types of elements involved and predict the product that will form.
Write the chemical formula for the product and write a balanced chemical equation for the reaction.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy
You know this will be a synthesis reaction between a univalent metal and a non-metal to form a binary ionic compound.
The product is predicted to be solid silver oxide, $Ag_2O(s)$.
Skeleton equation: $Ag(s) + O_2(g) \rightarrow Ag_2O(s)$
Reactants: 1 Ag, 2 O
Products: 2 Ag^+, O^{2-}
Balanced chemical equation: $4Ag(s) + O_2(g) \rightarrow 2Ag_2O(s)$
The ratio of the coefficients is 4:1:3. This is the lowest possible ratio.
Reactants: 4 Ag, 2 O
Products: 4 Ag^+, 2 O^{2-}

Check Your Solution
The overall charge on the compound silver oxide is zero and the equation is balanced. The product is what would be expected in a synthesis reaction.
The balanced chemical equation for this reaction is:
$4Ag(s) + O_2(g) \rightarrow 2Ag_2O(s)$

30. Practice Problem (page 127)
Predict the product that is likely to form in a reaction between nitrogen and oxygen, forming nitrogen dioxide, and write a balanced chemical equation for the reaction.

What Is Required?
You need to write a balanced chemical equation for the reaction between nitrogen and oxygen forming nitrogen dioxide.

What Is Given?
You are given the reactants: nitrogen and oxygen.
You are given the product: nitrogen dioxide.

Plan Your Strategy
Write the chemical formula for the product and write a balanced chemical equation for the reaction.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom is the same in the reactants and products.

Act on Your Strategy
You know this will be a synthesis reaction between two non-metals to form a binary molecular compound.
The product is nitrogen dioxide, $NO_2(g)$.
Skeleton equation: $N_2(g) + O_2(g) \rightarrow NO_2(g)$
Reactants: 2 N, 2 O
Products: 1 N, 2 O
Balanced chemical equation: $N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$
The ratio of the coefficients is 1:2:2. This is the lowest possible ratio.
Reactants: 2 N, 4 O
Products: 2 N, 4 O

Check Your Solution
The equation is balanced. The product is what would be expected in a synthesis reaction.
The balanced chemical equation for this reaction is:
$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$

Section 3.2 Synthesis Reactions and Decomposition Reactions

Solutions for Practice Problems

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31. Practice Problem (page 134)

Determine the products that are likely to form in the decomposition of potassium bromide, and write a balanced chemical equation for the reaction.

What Is Required?

You need to determine the products that are likely to form when potassium bromide decomposes and write a balanced chemical equation for the reaction.

What Is Given?

You are given the type of reaction: decomposition.
You are given the reactant: potassium bromide.

Plan Your Strategy

Identify the type of compound that is decomposing.
Determine the types of products that usually form in this type of reaction.
Write a word equation for the reaction.
Write and balance a chemical equation for the reaction.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy

A binary compound is decomposing.
The products of the decomposition of a binary compound are two elements.
Word equation: potassium bromide → potassium + bromine
Skeleton equation: $KBr(\ell) \rightarrow K(\ell) + Br_2(\ell)$
Reactants: 1 K^+, 1 Br^-
Products: 1 K, 2 Br
Balanced chemical equation: $2KBr(\ell) \rightarrow 2K(\ell) + Br_2(\ell)$
The ratio of the coefficients is 2:2:1. This is the lowest possible ratio.
Reactants: 2 K^+, 2 Br^-
Products: 2 K, 2 Br

Check Your Solution

Each chemical formula is correct, and the chemical equation is balanced. The products are what you would expect to be produced from the decomposition of a metal halide.

The balanced chemical equation for this reaction is:

$2KBr(\ell) \rightarrow 2K(\ell) + Br_2(\ell)$

32. Practice Problem (page 134)

Determine the products that are likely to form in the decomposition of aluminum oxide, and write a balanced chemical equation for the reaction.

What Is Required?

You need to determine the products that are likely to form when aluminum oxide decomposes and write a balanced chemical equation for the reaction.

What Is Given?

You are given the type of reaction: decomposition.
You are given the reactant: aluminum oxide.

Plan Your Strategy

Identify the type of compound that is decomposing.
Determine the types of products that usually form in this type of reaction.
Write a word equation for the reaction.
Write and balance a chemical equation for the reaction.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy

A binary compound is decomposing.
The products of the decomposition of a binary compound are the two elements.
Word equation: aluminum oxide → aluminum + oxygen
Skeleton equation: $Al_2O_3(\ell) \rightarrow Al(\ell) + O_2(g)$
Reactants: 2 Al^{3+}, 3 O^{2-}
Products: 1 Al, 2 O
Balanced chemical equation: $2Al_2O_3(\ell) \rightarrow 4Al(\ell) + 3O_2(g)$
The ratio of the coefficients is 2:4:3. This is the lowest possible ratio.
Reactants: 4 Al^{3+}, 6 O^{2-}
Products: 4 Al, 6 O

Check Your Solution

Each chemical formula is correct, and the chemical equation is balanced. The products are what you would expect to be produced from the decomposition of a metal halide.
The balanced chemical equation for this reaction is:
$2Al_2O_3(\ell) \rightarrow 4Al(\ell) + 3O_2(g)$

33. Practice Problem (page 134)

Determine the products that are likely to form in the decomposition of magnesium hydroxide, and write a balanced chemical equation for the reaction.

What Is Required?

You need to determine the products that are likely to form when magnesium hydroxide decomposes write a balanced chemical equation for the reaction.

What Is Given?

You are given the type of reaction: decomposition.
You are given the reactant: magnesium hydroxide.

Plan Your Strategy

Identify the type of compound that is decomposing.
Determine the types of products that usually form in this type of reaction.
Write a word equation for the reaction.
Write and balance a chemical equation for the reaction.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy

A metal hydroxide is decomposing.
A metal oxide and water are the usual products that form when a metal hydroxide decomposes.
Word equation: magnesium hydroxide → magnesium oxide + water
Skeleton equation: $Mg(OH)_2(s) \rightarrow MgO(s) + H_2O(g)$
Reactants: 1 Mg^{2+}, 2 OH^-
Products: 1 Mg^{2+}, 1 O^{2-}, 2 H, 1 O
Balanced chemical equation: $Mg(OH)_2(s) \rightarrow MgO(s) + H_2O(g)$
The ratio of the coefficients is 1:1:1. This is the lowest possible ratio.
The skeleton and balanced equations are the same.

Check Your Solution

Each chemical formula is correct, and the chemical equation is balanced. The products are what you would expect to be produced from the decomposition of a metal hydroxide.
The balanced chemical equation for this reaction is:
$Mg(OH)_2(s) \rightarrow MgO(s) + H_2O(g)$

34. Practice Problem (page 134)

Determine the products that are likely to form in the decomposition of calcium nitrate, and write a balanced chemical equation for the reaction.

What Is Required?

You need to determine the products that are likely to form when calcium nitrate decomposes and write a balanced chemical equation for the reaction.

What Is Given?

You are given the type of reaction: decomposition.
You are given the reactant: calcium nitrate.

Plan Your Strategy

Identify the type of compound that is decomposing.
Determine the types of products that usually form in this type of reaction.
Write a word equation for the reaction.
Write and balance a chemical equation for the reaction.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy

A metal nitrate is decomposing.
A metal nitrite and oxygen are the usual products that form when a metal nitrate decomposes.
Word equation: calcium nitrate → calcium nitrite + oxygen
Skeleton equation: $Ca(NO_3)_2(s) \rightarrow Ca(NO_2)_2(s) + O_2(g)$
Reactants: 1 Ca^{2+}, 2 NO_3^-
Products: 1 Ca^{2+}, 2 NO_2^-, 2 O
Balanced chemical equation: $Ca(NO_3)_2(s) \rightarrow Ca(NO_2)_2(s) + O_2(g)$
The ratio of the coefficients is 1:1:1. This is the lowest possible ratio.
The skeleton and balanced equations are the same.

Check Your Solution

Each chemical formula is correct, and the chemical equation is balanced. The products are what you would expect to be produced from the decomposition of a metal nitrate.
The balanced chemical equation for this reaction is:
$Ca(NO_3)_2(s) \rightarrow Ca(NO_2)_2(s) + O_2(g)$

35. Practice Problem (page 134)

Determine the products that are likely to form in the decomposition of copper(II) carbonate, and write a balanced chemical equation for the reaction.

What Is Required?

You need to determine the products that are likely to form when copper(II) carbonate decomposes and write a balanced chemical equation for the reaction.

What Is Given?

You are given the type of reaction: decomposition.
You are given the reactant: copper(II) carbonate.

Plan Your Strategy

Identify the type of compound that is decomposing.
Determine the types of products that usually form in this type of reaction.
Write a word equation for the reaction.
Write and balance a chemical equation for the reaction.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy

A metal carbonate is decomposing.
A metal oxide and carbon dioxide are the usual products that form when a metal carbonate decomposes.
Word equation: copper(II) carbonate → copper(II) oxide + carbon dioxide
Skeleton equation: $CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$
Reactants: 1 Cu^{2+}, 1 CO_3^{2-}
Products: 1 Cu^{2+}, 1 O^{2-}, 1 C, 2 O
Balanced chemical equation: $CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$
The ratio of the coefficients is 1:1:1. This is the lowest possible ratio.
The skeleton and balanced equations are the same.

Check Your Solution

Each chemical formula is correct, and the chemical equation is balanced. The products are what you would expect to be produced from the decomposition of a metal carbonate.
The balanced chemical equation for this reaction is:
$CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$

36. Practice Problem (page 134)

Determine the products that are likely to form in the decomposition of chromium(III) chloride, and write a balanced chemical equation for the reaction.

What Is Required?

You need to determine the products that are likely to form when chromium(III) chloride decomposes and write a balanced chemical equation for the reaction.

What Is Given?

You are given the type of reaction: decomposition.
You are given the reactant: chromium(III) chloride.

Plan Your Strategy

Identify the type of compound that is decomposing.
Determine the types of products that usually form in this type of reaction.
Write a word equation for the reaction.
Write and balance a chemical equation for the reaction.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy

A binary compound is decomposing.
The products of the decomposition of a binary compound are the two elements.
Word equation: chromium(III) chloride → chromium + chlorine
Skeleton equation: $CrCl_3(\ell) \rightarrow Cr(\ell) + Cl_2(g)$
Reactants: 1 Cr^{3+}, 3 Cl^-
Products: 1 Cr, 2 Cl
Balanced chemical equation: $2CrCl_3(\ell) \rightarrow 2Cr(\ell) + 3Cl_2(g)$
The ratio of the coefficients is 2:2:3. This is the lowest possible ratio.
Reactants: 2 Cr^{3+}, 6 Cl^-
Products: 2 Cr, 6 Cl

Check Your Solution

Each chemical formula is correct, and the chemical equation is balanced. The products are what you would expect to be produced from the decomposition of a metal halide.
The balanced chemical equation for this reaction is:
$2CrCl_3(\ell) \rightarrow 2Cr(\ell) + 3Cl_2(g)$

37. Practice Problem (page 134)

Determine the products that are likely to form in the decomposition of barium carbonate, and write a balanced chemical equation for the reaction.

What Is Required?

You need to determine the products that are likely to form when barium carbonate decomposes and write a balanced chemical equation for the reaction.

What Is Given?

You are given the type of reaction: decomposition.
You are given the reactant: barium carbonate.

Plan Your Strategy

Identify the type of compound that is decomposing.
Determine the types of products that usually form in this type of reaction.
Write a word equation for the reaction.
Write and balance a chemical equation for the reaction.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy

A metal carbonate is decomposing.
A metal oxide and carbon dioxide are the usual products that form when a metal carbonate decomposes.
Word equation: barium carbonate → barium oxide + carbon dioxide
Skeleton equation: $BaCO_3(s) \rightarrow BaO(s) + CO_2(g)$
Reactants: 1 Ba^{2+}, 1 CO_3^{2-}
Products: 1 Ba^{2+}, 1 O^{2-}, 1 C, 2 O
Balanced chemical equation: $BaCO_3(s) \rightarrow BaO(s) + CO_2(g)$
The ratio of the coefficients is 1:1:1. This is the lowest possible ratio.
Reactants: 1 Ba^{2+}, 1 CO_3^{2-}
Products: 1 Ba^{2+}, 1 O^{2-}, 1 C, 2 O
The skeleton and balanced equations are the same.

Check Your Solution

Each chemical formula is correct, and the chemical equation is balanced. The products are what you would expect to be produced from the decomposition of a metal carbonate.
The balanced chemical equation for this reaction is:
$BaCO_3(s) \rightarrow BaO(s) + CO_2(g)$

38. Practice Problem (page 134)

Determine the products that are likely to form in the decomposition of rubidium nitrate, and write a balanced chemical equation for the reaction.

What Is Required?

You need to determine the products that are likely to form when rubidium nitrate decomposes and write a balanced chemical equation for the reaction.

What Is Given?

You are given the type of reaction: decomposition.
You are given the reactant: rubidium nitrate.

Plan Your Strategy

Identify the type of compound that is decomposing.
Determine the types of products that usually form in this type of reaction.
Write a word equation for the reaction.
Write and balance a chemical equation for the reaction.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy

A metal nitrate is decomposing.
A metal nitrite and oxygen are the usual products that form when a metal nitrate decomposes.
Word equation: rubidium nitrate → rubidium nitrite + oxygen
Skeleton equation: $RbNO_3(s) \rightarrow RbNO_2(s) + O_2(g)$
Reactants: 1 Rb^+, 1 NO_3^-
Products: 1 Rb^+, 1 NO_2^-, 2 O
Balanced chemical equation: $2RbNO_3(s) \rightarrow 2RbNO_2(s) + O_2(g)$
The ratio of the coefficients is 2:2:1. This is the lowest possible ratio.
Reactants: 2 Rb^+, 2 NO_3^-
Products: 2 Rb^+, 2 NO_2^-, 2 O

Check Your Solution

Each chemical formula is correct, and the chemical equation is balanced. The products are what you would expect to be produced from the decomposition of a metal nitrate.
The balanced chemical equation for this reaction is:
$2RbNO_3(s) \rightarrow 2RbNO_2(s) + O_2(g)$

39. Practice Problem (page 134)

Determine the products that are likely to form in the decomposition of lithium hydroxide, and write a balanced chemical equation for the reaction.

What Is Required?

You need to determine the products that are likely to form when lithium hydroxide decomposes and write a balanced chemical equation for the reaction.

What Is Given?

You are given the type of reaction: decomposition.
You are given the reactant: lithium hydroxide.

Plan Your Strategy

Identify the type of compound that is decomposing.
Determine the types of products that usually form in this type of reaction.
Write a word equation for the reaction.
Write and balance a chemical equation for the reaction.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy

A metal hydroxide is decomposing.
A metal oxide and water are the usual products that form when a metal hydroxide decomposes.
Word equation: lithium hydroxide → lithium oxide + water
Skeleton equation: $LiOH(s) \rightarrow Li_2O(s) + H_2O(g)$
Reactants: 1 Li^+, 1 OH^-
Products: 2 Li^+, 1 O^{2-}, 2 H, 1 O
Balanced chemical equation: $2LiOH(s) \rightarrow Li_2O(s) + H_2O(g)$
The ratio of the coefficients is 2:1:1. This is the lowest possible ratio.
Reactants: 2 Li^+, 2 OH^-
Products: 2 Li^+, 1 O^{2-}, 2 H, 1 O

Check Your Solution

Each chemical formula is correct, and the chemical equation is balanced. The products are what you would expect to be produced from the decomposition of a metal hydroxide.
The balanced chemical equation for this reaction is:
$2LiOH(s) \rightarrow Li_2O(s) + H_2O(g)$

40. Practice Problem (page 134)

Determine the products that are likely to form in the decomposition of magnesium chloride, and write a balanced chemical equation for the reaction.

What Is Required?

You need to determine the products that are likely to form when magnesium chloride decomposes and write a balanced chemical equation for the reaction.

What Is Given?

You are given the type of reaction: decomposition.
You are given the reactant: magnesium chloride.

Plan Your Strategy

Identify the type of compound that is decomposing.
Determine the types of products that usually form in this type of reaction.
Write a word equation for the reaction.
Write and balance a chemical equation for the reaction.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom and ion is the same in the reactants and products.

Act on Your Strategy

A binary compound is decomposing.
The products of the decomposition of a binary compound are the two elements.
Word equation: magnesium chloride → magnesium + chlorine
Skeleton equation: $MgCl_2(\ell) \rightarrow Mg(\ell) + Cl_2(g)$
Reactants: 1 Mg^{2+}, 2 Cl^-
Products: 1 Mg, 2 Cl
Balanced chemical equation: $MgCl_2(\ell) \rightarrow Mg(\ell) + Cl_2(g)$
The ratio of the coefficients is 1:1:1. This is the lowest possible ratio.
The skeleton and balanced equations are the same.

Check Your Solution

Each chemical formula is correct, and the chemical equation is balanced. The products are what you would expect to be produced from the decomposition of a metal halide.
The balanced chemical equation for this reaction is:
$MgCl_2(\ell) \rightarrow Mg(\ell) + Cl_2(g)$

Section 3.2 Synthesis Reactions and Decomposition Reactions

Solutions for Selected Review Questions

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7. Review Question (page 136)

Predict whether each compound would form an acid or a base in a reaction with water.

a. dinitrogen trioxide
b. lithium oxide
c. sulfur trioxide
d. calcium oxide

a. acid
b. base
c. acid
d. base

15. Review Question (page 136)

If you wanted to generate lithium oxide, what are two decomposition reactions you could try?

Heat solid lithium carbonate: $Li_2CO_3(s) \rightarrow Li_2O(s) + CO_2(g)$
Heat solid lithium hydroxide: $2LiOH(s) \rightarrow Li_2O(s) + H_2O(g)$

Section 3.3 Combustion Reactions

Solutions for Practice Problems

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41. Practice Problem (page 141)

Write the chemical equation for the complete combustion of heptane, $C_7H_{16}(\ell)$.

What Is Required?

You need to write a balanced chemical equation for the complete combustion of heptane.

What Is Given?

You are given the reactant: heptane
You are given the type of reaction: complete combustion

Plan Your Strategy

Identify the reactants.
Identify the product.
Write the balanced equation.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom is the same in the reactants and products.

Act on Your Strategy

Reactants: heptane, $C_7H_{16}(\ell)$, and oxygen, $O_2(g)$
Products: carbon dioxide, $CO_2(g)$, and water vapour, $H_2O(g)$

Skeleton equation:
$C_7H_{16}(\ell) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$
Reactants: 7 C, 16 H, 2 O
Products: 1 C, 2 H, 3 O
Insert the coefficient 7 in front of the $CO_2(g)$ to balance the C:
$C_7H_{16}(\ell) + O_2(g) \rightarrow 7CO_2(g) + H_2O(g)$
Insert the coefficient 8 in front of the $H_2O(g)$ to balance the H:
$C_7H_{16}(\ell) + O_2(g) \rightarrow 7CO_2(g) + 8H_2O(g)$
Insert the coefficient 11 in front of the $O_2(g)$ to balance the O.
Balanced equation:
$C_7H_{16}(\ell) + 11O_2(g) \rightarrow 7CO_2(g) + 8H_2O(g)$
The ratio of the coefficients is 1:11:7:8. This is the lowest possible ratio.
Reactants: 7 C,16 H, 22 O
Products: 7 C, 16 H, 22 O

Check Your Solution
The products are correct for the complete combustion of a hydrocarbon. The chemical formula for each substance is written correctly. The number of atoms of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$C_7H_{16}(\ell) + 11O_2(g) \rightarrow 7CO_2(g) + 8H_2O(g)$

42. Practice Problem (page 141)
Write the balanced equation for the complete combustion of nonane, $C_9H_{20}(\ell)$.

What Is Required?
You need to write a balanced chemical equation for the complete combustion of nonane.

What Is Given?
You are given the reactant: nonane
You are given the type of reaction: complete combustion

Plan Your Strategy
Identify the reactants.
Identify the products.
Write the balanced equation.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom is the same in the reactants and products.

Act on Your Strategy
Reactants: nonane, $C_9H_{20}(\ell)$, and oxygen, $O_2(g)$
Products: carbon dioxide, $CO_2(g)$, and water vapour, $H_2O(g)$

Skeleton equation:
$C_9H_{20}(\ell) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$
Reactants: 9 C, 20 H, 2 O
Products: 1 C, 2 H, 3 O
Insert the coefficient 9 in front of the $CO_2(g)$ to balance the C:
$C_9H_{20}(\ell) + O_2(g) \rightarrow 9CO_2(g) + H_2O(g)$
Insert the coefficient 10 in front of the $H_2O(g)$ to balance the H:
$C_9H_{20}(\ell) + O_2(g) \rightarrow 9CO_2(g) + 10H_2O(g)$
Insert the coefficient 14 in front of the $O_2(g)$ to balance the O.
Balanced equation:
$C_9H_{20}(\ell) + 14O_2(g) \rightarrow 9CO_2(g) + 10H_2O(g)$
The ratio of the coefficients is 1:14:9:10. This is the lowest possible ratio.
Reactants: 9 C, 20 H, 28 O
Products: 9 C, 20 H, 28 O

Check Your Solution
The products are correct for the complete combustion of a hydrocarbon. The chemical formula for each substance is written correctly. The number of atoms of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$C_9H_{20}(\ell) + 14O_2(g) \rightarrow 9CO_2(g) + 10H_2O(g)$

43. Practice Problem (page 141)
Write the balanced equation for the complete combustion of ethyne, $C_2H_2(g)$.

What Is Required?
You need to write a balanced chemical equation for the complete combustion of ethyne.

What Is Given?
You are given the reactant: ethyne
You are given the type of reaction: complete combustion

Plan Your Strategy
Identify the reactants.
Identify the products.
Write the balanced equation.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom is the same in the reactants and products.

Act on Your Strategy
Reactants: ethyne, $C_2H_2(g)$, and oxygen, $O_2(g)$
Products: carbon dioxide, $CO_2(g)$, and water vapour, $H_2O(g)$
Skeleton equation:
$C_2H_2(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$
Reactants: 2 C, 2 H, 2 O
Products: 1 C, 2 H, 3 O
Insert the coefficient 2 in front of the $CO_2(g)$ to balance the C:
$C_2H_2(\ell) + O_2(g) \rightarrow 2CO_2(g) + H_2O(g)$
Insert the coefficient $\frac{5}{2}$ in front of the $O_2(g)$ to balance the O:

$$C_2H_2(\ell) + \frac{5}{2}O_2(g) \rightarrow 2CO_2(g) + H_2O(g)$$

Multiply each coefficient by 2 to clear the fraction.
Balanced equation:
$2C_2H_2(\ell) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(g)$
The ratio of the coefficients is 2:5:4:2. This is the lowest possible ratio.
Reactants: 4 C, 4 H, 10 O
Products: 4 C, 4 H, 10 O

Check Your Solution
The products are correct for the complete combustion of a hydrocarbon. The chemical formula for each substance is written correctly. The number of atoms of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$2C_2H_2(\ell) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(g)$

44. Practice Problem (page 141)
Write the balanced equation for the complete combustion of benzene, $C_6H_6(\ell)$.

What Is Required?
You need to write a balanced chemical equation for the complete combustion of benzene.

What Is Given?
You are given the reactant: benzene
You are given the type of reaction: complete combustion

Plan Your Strategy
Identify the reactants.
Identify the products.
Write the balanced equation.

Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom is the same in the reactants and products.

Act on Your Strategy
Reactants: benzene, $C_6H_6(\ell)$, and oxygen, $O_2(g)$
Products: carbon dioxide, $CO_2(g)$, and water vapour, $H_2O(g)$
Skeleton equation:
$C_6H_6(\ell) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$
Reactants: 6 C, 6 H, 2 O
Products: 1 C, 2 H, 3 O
Insert the coefficient 6 in front of the $CO_2(g)$ to balance the C:
$C_6H_6(\ell) + O_2(g) \rightarrow 6CO_2(g) + H_2O(g)$
Insert the coefficient 3 in front of the $H_2O(g)$ to balance the H:
$C_6H_6(\ell) + O_2(g) \rightarrow 6CO_2(g) + 3H_2O(g)$
Insert the coefficient $\frac{15}{2}$ in front of the $O_2(g)$ to balance the O:

$$C_6H_6(\ell) + \frac{15}{2}O_2(g) \rightarrow 6CO_2(g) + 3H_2O(g)$$

Multiply each coefficient by 2 to clear the fraction.
Balanced equation:
$2C_6H_6(\ell) + 15O_2(g) \rightarrow 12CO_2(g) + 6H_2O(g)$
The ratio of the coefficients is 2:15:12:6. This is the lowest possible ratio.
Reactants: 12 C, 12 H, 30 O
Products: 12 C,12 H, 30 O

Check Your Solution
The products are correct for the complete combustion of a hydrocarbon. The chemical formula for each substance is written correctly. The number of atoms of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$2C_6H_6(\ell) + 15O_2(g) \rightarrow 12CO_2(g) + 6H_2O(g)$

45. Practice Problem (page 141)
Write the balanced equation for the complete combustion of octane, $C_8H_{18}(\ell)$.

What Is Required?
You need to write a balanced chemical equation for the complete combustion of octane.

What Is Given?
You are given the reactant: octane
You are given the type of reaction: complete combustion

Plan Your Strategy
Identify the reactants.
Identify the products.
Write the balanced equation.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom is the same in the reactants and products.

Act on Your Strategy
Reactants: octane, $C_8H_{18}(\ell)$, and oxygen, $O_2(g)$
Products: carbon dioxide, $CO_2(g)$, and water vapour, $H_2O(g)$
Skeleton equation:
$C_8H_{18}(\ell) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$
Reactants: 8 C, 18 H, 2 O
Products: 1 C, 2 H, 3 O
Insert the coefficient 8 in front of the $CO_2(g)$ to balance the C:
$C_8H_{18}(\ell) + O_2(g) \rightarrow 8CO_2(g) + H_2O(g)$
Insert the coefficient 9 in front of the $H_2O(g)$ to balance the H:
$C_8H_{18}(\ell) + O_2(g) \rightarrow 8CO_2(g) + 9H_2O(g)$
Insert the coefficient $\frac{25}{2}$ in front of the $O_2(g)$ to balance the O:

$$C_8H_{18}(\ell) + \frac{25}{2}O_2(g) \rightarrow 8CO_2(g) + 9H_2O(g)$$

Multiply each coefficient by 2 to clear the fraction.
Balanced equation:
$2C_8H_{18}(\ell) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$
The ratio of the coefficients is 2:25:16:18. This is the lowest possible ratio.
Reactants: 16 C, 36 H, 50 O
Products: 16 C, 36 H, 50 O

Check Your Solution
The products are correct for complete combustion of a hydrocarbon. The chemical formula for each substance is written correctly. The number of atoms of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$2C_8H_{18}(\ell) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$

46. Practice Problem (page 141)
Write the balanced equation for the incomplete combustion of octane:
$2C_8H_{18}(\ell) + 17O_2(g) \rightarrow \_\_CO(g) + \_\_H_2O(g)$.

What Is Required?
You need to write a balanced chemical equation for the incomplete combustion of octane based upon the given partial equation.

What Is Given?
You are given the reactant: octane
You are given the type of reaction: incomplete combustion
You are given a partial chemical equation:
$2C_8H_{18}(\ell) + 17O_2(g) \rightarrow \_\_CO(g) + \_\_H_2O(g)$.
You know the products: $CO(g)$ and $H_2O(g)$

Plan Your Strategy
Identify the information that is missing in the given partial chemical equation.
Begin balancing the equation from the known information in the partial equation.
Complete the balancing of the equation knowing what products could form.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom is the same in the reactants and products.

Act on Your Strategy
For the equation to balance, the coefficient in front of $H_2O(g)$ must be 18. This leads to the conclusion that the second product must contain the remaining oxygen. The other product must contain 34 – 18 = 16 oxygen atoms. The missing product is $16CO(g)$. This balances the carbon atoms.
Balanced equation: $2C_8H_{18}(\ell) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(g)$
The ratio of the coefficients is 2:17:16:18. This is the lowest possible ratio.
Reactants: 16 C, 36 H, 34 O
Products: 16 C, 36 H, 34 O

Check Your Solution
The chemical formula for each substance is written correctly. The number of atoms of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$2C_8H_{18}(\ell) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(g)$

47. Practice Problem (page 141)
Write the balanced equation for the incomplete combustion of pentane:
$2C_5H_{12}(\ell) + 11O_2(g) \rightarrow \_\_ + 12H_2O(g)$.

What Is Required?
You need to write a balanced chemical equation for the incomplete combustion of pentane based upon the given partial equation.

What Is Given?
You are given the reactant: pentane
You are given the type of reaction: incomplete combustion

You are given a partial chemical equation:
$2C_5H_{12}(\ell) + 11O_2(g) \rightarrow \_\_ + 12H_2O(g)$
You know the possible products are C(s) and CO(g).

Plan Your Strategy
Identify the information that is missing in the given partial chemical equation.
Begin balancing the equation from the known information in the partial equation.
Complete the balancing of the equation.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom is the same in the reactants and products.

Act on Your Strategy
For the equation to balance, the unknown product must contain 10 C atoms and 10 O atoms. The missing product is 10CO(g).
Balanced equation: $2C_5H_{12}(\ell) + 11O_2(g) \rightarrow 10CO(g) + 12H_2O(g)$
The ratio of the coefficients is 2:11:10:12. This is the lowest possible ratio.
Reactants: 10 C, 24 H, 22 O
Products: 10 C, 24 H, 22 O

Check Your Solution
The chemical formula for each substance is written correctly. The number of atoms of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$2C_5H_{12}(\ell) + 11O_2(g) \rightarrow 10CO(g) + 12H_2O(g)$

48. Practice Problem (page 141)
Write the balanced equation for the incomplete combustion of propane:
$C_3H_8(g) + 2O_2(g) \rightarrow \_\_\_ + \_\_H_2O(g)$

What Is Required?
You need to write a balanced chemical equation for the incomplete combustion of propane based upon the given partial equation.

What Is Given?
You are given the reactant: propane
You are given the type of reaction: incomplete combustion
You are given a partial chemical equation:
$C_3H_8(g) + 2O_2(g) \rightarrow \_\_\_ + \_\_H_2O(g)$
You know the possible products: C(s) and CO(g)

Plan Your Strategy
Identify the information that is missing in the given partial chemical equation.
Begin balancing the equation from the known information in the partial equation.
Identify the coefficient required in front of $H_2O(g)$.
Complete the balancing of the equation.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom is the same in the reactants and products.

Act on Your Strategy
The possible products that could balance the equation are C(s) and CO(g).
For the equation to balance, the number coefficient in front of $H_2O(g)$ must be 4 to balance the H atoms. This number supplies enough O atoms to balance the equation. The other product must be C(s).
Balanced equation:
$C_3H_8(g) + 2O_2(g) \rightarrow 3C(s) + 4H_2O(g)$
The ratio of the coefficients is 1:2:3:4. This is the lowest possible ratio.
Reactants: 3 C, 8 H, 4 O
Products: 3 C, 8 H, 4 O

Check Your Solution
The chemical formula for each substance is written correctly. The number of atoms of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$C_3H_8(g) + 2O_2(g) \rightarrow 3C(s) + 4H_2O(g)$

49. Practice Problem (page 141)
Write the balanced equation for the incomplete combustion of heptane:
$4C_7H_{16}(\ell) + 37O_2(g) \rightarrow$ ___$CO_2(g)$ + __$CO(g)$ + __$H_2O(g)$.

What Is Required?
You need to write a balanced chemical equation for the incomplete combustion of heptane based upon the given partial equation.

What Is Given?
You are given the reactant: heptane
You are given the type of reaction: incomplete combustion.
You are given a partial chemical equation:
$4C_7H_{16}(\ell) + 37O_2(g) \rightarrow$ ___$CO_2(g)$ + __$CO(g)$ + __$H_2O(g)$
You know the identity of the products.

Plan Your Strategy
Identify the information that is missing in the given partial chemical equation.
Begin balancing the equation from the known information in the partial equation.
Identify the coefficient required in front of $H_2O(g)$.
Complete the balancing of the equation.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom is the same in the reactants and products.

Act on Your Strategy
For the equation to balance, the product must contain 64 H atoms. The coefficient in front of H_2O is 32. This accounts for 32 O atoms in the products. There are 2×37 O atoms in the reactants. The remainder of the O atoms, 74 – 32 = 42 O must be shared between CO_2 and CO.
Balanced equation: $4C_7H_{16}(\ell) + 37O_2(g) \rightarrow 14CO_2(g) + 14CO(g) + 32H_2O(g)$
The ratio of the coefficients is 4:37:14:14:32. This is the lowest possible ratio.
Reactants: 28 C, 64 H, 74O
Products: 28 C, 64 H, 74 O

Check Your Solution
The chemical formula for each substance is written correctly. The number of atoms of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio.
The balanced chemical equation for this reaction is:
$4C_7H_{16}(\ell) + 37O_2(g) \rightarrow 14CO_2(g) + 14CO(g) + 32H_2O(g)$

50. Practice Problem (page 141)
Write two balanced equations for the incomplete combustion of cyclohexane:
a. $C_6H_{12}(\ell) + 6O_2(g) \rightarrow$ ___ $+ 6H_2O(g)$
b. $C_6H_{12}(\ell) + 3O_2(g) \rightarrow$ ___ $+ 6H_2O(g)$

What Is Required?
You need to write a balanced chemical equation for the incomplete combustion of cyclohexane based upon the given partial equations.

What Is Given?
You are given the reactant: cyclohexane
You are given the type of reaction: incomplete combustion
You are given two partial chemical equations:
a. $C_6H_{12}(\ell) + 6O_2(g) \rightarrow$ ___ $+ 6H_2O(g)$
b. $C_6H_{12}(\ell) + 3O_2(g) \rightarrow$ ___ $+ 6H_2O(g)$
You know the possible products: C(s) and CO(g)

Plan Your Strategy
Identify the information that is missing in the given partial chemical equation.
Begin balancing the equation from the known information in the partial equation.
Complete the balancing of the equation.
Check to make sure that the ratio of the coefficients is the lowest possible ratio.
Check to make sure that the number of each kind of atom is the same in the reactants and products.

Act on Your Strategy
The possible products that could balance the equations are C(s) and CO(g).
a. For the equation to balance, the product must contain 6 C atoms and 6 O atoms. The product is 6CO(g).
Balanced equation:
$C_6H_{12}(\ell) + 6O_2(g) \rightarrow 6CO(g) + 6H_2O(g)$
The ratio of the coefficients is 1:6:6:6. This is the lowest possible ratio.
Reactants: 6 C, 12 H, 12 O
Products: 6 C, 12 H, 12 O
b. For the equation to balance, 6 C are needed. The product is 6C(s).
Balanced equation:
$C_6H_{12}(\ell) + 3O_2(g) \rightarrow 6C(s) + 6H_2O(g)$
The ratio of the coefficients is 1:3:6:6. This is the lowest possible ratio.
Reactants: 6 C, 12 H, 6 O
Products: 6 C, 12 H, 6 O

Check Your Solution
The chemical formula for each substance is written correctly. The number of atoms of each element is equal on both sides of the equation. The coefficients are written in the lowest possible ratio. The balanced chemical equations for the two reactions:
a. $C_6H_{12}(\ell) + 6O_2(g) \rightarrow 6CO(g) + 6H_2O(g)$
b. $C_6H_{12}(\ell) + 3O_2(g) \rightarrow 6C(s) + 6H_2O(g)$

Section 3.3 Combustion Reactions

Solutions for Selected Review Questions

Student Edition page 145

5. Review Question (page 145)
Identify the missing product in the following balanced chemical equation for the complete combustion of pentane:
$C_5H_{12}(\ell) + 8O_2(g) \rightarrow$ _____ $+ 6H_2O(g)$

Since the combustion is complete, the missing product is $CO_2(g)$. 5 C atoms are required on the right side of the equation to balance the reaction.
$C_5H_{12}(\ell) + 8O_2(g) \rightarrow 5CO_2(g) + 6H_2O(g)$

6. Review Question (page 145)

Write a balanced chemical equation for the complete combustion of each hydrocarbon.

a. ethene, $C_2H_4(g)$
b. decane, $C_{10}H_{22}(\ell)$
c. butene, $C_4H_8(g)$
d. hexane, $C_6H_{14}(\ell)$

a. $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$
b. $2C_{10}H_{22}(\ell) + 31O_2(g) \rightarrow 20CO_2(g) + 22H_2O(g)$
c. $C_4H_8(g) + 6O_2(g) \rightarrow 4CO_2(g) + 4H_2O(g)$
d. $2C_6H_{14}(\ell) + 19O_2(g) \rightarrow 12CO_2(g) + 14H_2O(g)$

12. Review Question (page 145)

Why is it not possible to balance a chemical equation representing incomplete combustion without having additional information about the reaction?

The products vary depending upon the temperature and amount of oxygen available. Either or both CO(g) and C(s) may form. $CO_2(g)$ may be produced. $H_2O(g)$ will be produced.

14. Review Question (page 145)

What causes a candle flame to appear yellow?

Glowing particles of carbon give the flame a yellow colour.

15. Review Question (page 145)

Classify each reaction as a synthesis or combustion reaction, or both. Give reasons for your classifications.

a. $2Ca(s) + O_2(g) \rightarrow 2CaO(s)$
b. $2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g)$
c. $6K(s) + N_2(g) \rightarrow 2K_3N(s)$

a. The reaction is a synthesis reaction (also combustion of a metal), since two elements combine to form a compound. It is also a combustion reaction, since oxygen combines with the metal (could also be called oxidation). This combustion is different from hydrocarbon combustion.
b. The reaction is complete combustion of a hydrocarbon, since the products are $CO_2(g)$ and $H_2O(g)$.
c. The reaction is a synthesis reaction, since two elements combine to form a compound.