# 3.2 COMBUSTION, SYNTHESIS, AND DECOMPOSITION REACTIONS

## PRACTICE

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### Understanding Concepts

1. Reactants: a substance for fuel, and oxygen; conditions: three things must be present - fuel, oxygen, and heat; products: common oxides of the elements making up the substance that is burned.
2. $CO_{2(g)}$; $H_2O_{(g)}$; $SO_{2(g)}$; $NO_{2(g)}$; $Fe_2O_{3(s)}$
3. Carbon dioxide and water are products of the combustion of carbon compounds that have had a significant effect on the atmosphere, including making it warmer than it would otherwise be. This phenomenon is known as the "greenhouse effect."

   Gaseous oxides of nitrogen and sulfur are released from sources such as automobiles and coal-burning power plants. These oxides join the naturally produced oxides in the atmosphere, react with water vapour to form acids, and are responsible for the increased acidity of precipitation known as "acid rain."

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### Understanding Concepts

4. (a) Decomposition — the product is a simpler elemental compound and an element.
   (b) Synthesis — the product is a more complex compound.
   (c) Synthesis — the product is a more complex compound.
5. (a) $2\ Al_{(s)} + 3\ F_{2(g)} \rightarrow 2\ AlF_{3(s)}$ synthesis
   (b) $2\ KCl_{(s)} \rightarrow 2\ K_{(s)} + Cl_{2(g)}$ decomposition
   (c) $S_{8(s)} + 8\ O_{2(g)} \rightarrow 8\ SO_{2(g)}$ synthesis (combustion)
   (d) $CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2(g)} + 2\ H_2O_{(g)}$ combustion
   (e) $2\ Al_2O_{3(s)} \rightarrow 4\ Al_{(s)} + 3\ O_{2(g)}$ decomposition
   (f) $2\ Hg_{(l)} + O_{2(g)} \rightarrow 2\ HgO_{(s)}$ synthesis (combustion)
   (g) $2\ FeBr_{3(s)} \rightarrow 2\ Fe_{(s)} + 3\ Br_{2(g)}$ decomposition
6.

| Reaction Type | Reactants |
|---|---|
| Synthesis | element + element<br>element + compound<br>compound + compound |
| Decomposition | binary compound<br>complex compound |
| Combustion | metal + oxygen<br>nonmetal + oxygen<br>fossil fuel |

7. (a) $2\ Na_{(s)} + Cl_{2(g)} \rightarrow 2\ NaCl_{(s)}$ synthesis
   (b) $2\ CuO_{(s)} \rightarrow 2\ Cu_{(s)} + O_{2(g)}$ decomposition
   (c) $Cu_{(s)} + Cl_{2(aq)} \rightarrow CuCl_{2(s)}$ synthesis
8. (a) $2\ Li_2O_{(s)} \rightarrow 4\ Li_{(s)} + O_{2(g)}$
   $2\ MgO_{(s)} \rightarrow 2\ Mg_{(s)} + O_{2(g)}$
   $ZnCl_{2(s)} \rightarrow Zn_{(s)} + Cl_{2(g)}$
   $Mg(OH)_{2(s)} \rightarrow MgO_{(s)} + H_2O_{(l)}$

9. **Evaluation**
   (a) The experimental design is not sufficient to identify all of the elements of the white powder. However, there is sufficient evidence to indicate that the white powder could be a metal carbonate of some sort. Carbonates will decompose when heated to produce a metal oxide and carbon dioxide gas.
   To identify the elements of the metal oxide, the melting point of the white powder could be determined and matched against known melting points of ionic solids.
   To identify the gas, the gas could be bubbled into a limewater solution. Carbon dioxide gas is indicated if limewater solution turns milky. The limewater undergoes a chemical change to form an insoluble white precipitate. Carbon dioxide gas is also indicated if a flaming splint, held at the mouth of the test tube, is extinguished.
   **Synthesis**
   (b) A thermal decomposition reaction of the general form AB → A + B
   (c) Calcium carbonate → calcium oxide + carbon dioxide
   $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$
10. The student is to use the Internet to investigate a vehicle exhaust pollutant, and to describe the chemical reactions that produce it and its harmful effects on living organisms. Also, the student is to develop a list of suggestions for reducing the production of this pollutant, and to discuss the pros and cons of implementing these suggestions from the perspective of a car manufacturer and from the perspective of an environmentalist.
   GO TO www.science.nelson.com, Chemistry 11, Teacher Centre
11. The student is to use the Internet to investigate the properties of diesel fuel and gasoline, and the products of their combustion. Also, the student is to determine which fuel poses the greater threat to the environment.
   GO TO www.science.nelson.com, Chemistry 11, Teacher Centre
12. The student is to use the Internet to research the chemical compositions of natural gas and propane, for use as alternative fuels for vehicles. Also, the student is to compare the products of combustion with those of gasoline.
   GO TO www.science.nelson.com, Chemistry 11, Teacher Centre

## SECTION 3.2 QUESTIONS

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### Understanding Concepts

1. (a) The warning signs at gas stations are there to insure that people refrain from any activity that could result in the occurrence of a gasoline-related chemical reaction, such as a fire or an explosion.
   (b) A combustion reaction is the concern.
   (c) The necessary conditions for this reaction to proceed are fuel, oxygen, and heat.
2. (a) Butane — combustion reaction. Butane is a fuel.
   Butane + oxygen → carbon dioxide + water
   $2\ C_4H_{10(g)} + 13\ O_{2(g)} \rightarrow 8\ CO_{2(g)} + 10\ H_2O_{(g)}$
   Calcium carbonate — thermal decomposition reaction. Carbonates will decompose when heated to produce a metal oxide and carbon dioxide gas.
   Calcium carbonate → calcium oxide + carbon dioxide
   $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$
   Li and Br — synthesis reaction. Two substances combine to form a single product.
   Lithium + bromine → lithium bromide
   $Li_{(s)} + Br_{(l)} \rightarrow LiBr_{(s)}$
   Bluestone — decomposition reaction. Compounds consisting of more than two elements often decompose to form simpler compounds. When a hydrated salt is heated, the products are the anhydrous salt and water.
   Copper(II) sulfate pentahydrate → copper(II) sulfate + water
   $CuSO_4 \cdot 5\ H_2O_{(s)} \rightarrow CuSO_{4(s)} + 5\ H_2O_{(g)}$

### Making Connections

3. (a) $2\ C_8H_{18(g)} + 25\ O_{2(g)} \rightarrow 16\ CO_{2(g)} + 18\ H_2O_{(g)}$ — a combustion reaction.
   Gasoline often contains trace amounts of elemental sulfur, and when the gas is burned, the sulfur combines with oxygen to produce sulfur dioxide.

$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$ synthesis (combustion)

$2\ SO_{2(g)} + O_{2(g)} \rightarrow 2\ SO_{3(g)}$ synthesis (combustion)

$SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)}$ synthesis

(b) Sulfur trioxide is a byproduct of the combustion of gasoline in car engines. In the atmosphere it reacts with condensed water on dust particles, producing sulfuric acid. Atmospheric sulfuric acid is one of the acids that is responsible for the increased acidity of precipitation known as acid rain.

4. (a) Nitrogen monoxide decomposes into nitrogen and oxygen.

$$2\ NO_{(g)} \xrightarrow{Pt/Pd} N_{2(g)} + O_{2(g)}$$

(b) The platinum/palladium catalytic converter built into today's automobiles catalyzes the decomposition of nitrogen monoxide — which is a combustion engine exhaust pollutant — into harmless nitrogen and oxygen.

## 3.3 SINGLE DISPLACEMENT REACTIONS

### PRACTICE

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### Understanding Concepts

1. In single displacement reactions, like displaces like – a metallic element takes the place of a metal in a compound; a nonmetallic element takes the place of a nonmetal in a compound.
2. An "activity series" is a list of elements arranged in order of their reactivity, based upon empirical evidence gathered from single displacement reactions.
3. (a) $Zn_{(s)} + CuCl_{2(aq)} \rightarrow Cu_{(s)} + ZnCl_{2(aq)}$

   (b) $Br_{2(aq)} + CaCl_{2(aq)} \rightarrow NR$

   (c) $Pb_{(s)} + 2\ HCl_{(aq)} \rightarrow H_{2(g)} + PbCl_{2(aq)}$

   (d) $Cl_{2(aq)} + 2\ NaI_{(aq)} \rightarrow 2\ NaCl_{(aq)} + I_{2(s)}$

   (e) $Ca_{(s)} + 2\ H_2O_{(l)} \rightarrow H_{2(g)} + Ca(OH)_{2(aq)}$

   (f) $Au_{(s)} + ZnSO_{4(aq)} \rightarrow NR$

   (g) $Sn_{(s)} + 2\ AgNO_{3(aq)} \rightarrow 2\ Ag_{(s)} + Sn(NO_3)_{2(aq)}$

   (h) $2\ Al_{(s)} + 3\ H_2O_{(l)} \rightarrow 3\ H_{2(g)} + Al_2O_{3(aq)}$

   (i) $Br_{2(aq)} + MgI_{2(aq)} \rightarrow MgBr_{2(aq)} + I_{2(s)}$

   (j) $2\ Al_{(s)} + 3\ ZnSO_{4(aq)} \rightarrow 3\ Zn_{(s)} + Al_2(SO_4)_{3(aq)}$
4. Generally speaking, the more reactive elements will replace the less reactive elements. Thus, within the metal group, the more reactive metal elements are the ones with low electronegativity values and they will replace metal elements with higher electronegativity values. For example, lithium has an electronegativity value of 1.0 and will replace potassium, which has an electronegativity value of 0.8. (It should be noted that there are a number of exceptions to this generalization.)

   Within the nonmetal group, the more reactive nonmetal elements are the ones with high electronegativity values and they will replace nonmetal elements with lower electronegativity values. For example, fluorine has an electronegativity value of 4.0 and will replace chlorine, which has an electronegativity value of 3.0. (Again, it should be noted that there are a number of exceptions to this generalization.)
5. As you move from left to right within the same period, the elements of the periodic table show a general increase in electronegativity values. The most reactive metals are the ones with lower electronegativity values and are positioned at the left of a period. Thus, as you move from left to right within the same period, the metals become more electronegative and therefore less reactive. However, the most reactive nonmetals are the ones with high electronegativity values and are positioned at the right of a period. Thus, as you move from left to right within the same period, the nonmetals become more electronegative and therefore more reactive.