

## 10.2: General Types of Chemical Reactions

### Learning Objectives

- To classify a given chemical reaction into a variety of types.

Although there are untold millions of possible chemical reactions, most can be classified into a small number of general reaction types. Classifying reactions has two purposes: it helps us to recognize similarities among them, and it enables us to predict the products of certain reactions. A particular reaction may fall into more than one of the categories that we will define in this book.

### Combination (composition) Reactions

A combination (composition) reaction is a chemical reaction that makes a single substance from two or more reactants. There may be more than one molecule of product in the balanced chemical equation, but there is only one substance produced. For example, the equation



is a combination reaction that produces  $\text{Fe}_2\text{O}_3$  from its constituent elements—Fe and  $\text{O}_2$ . Combination reactions do not have to combine elements, however. The chemical equation



shows a combination reaction in which  $\text{Fe}_2\text{O}_3$  combines with three molecules of  $\text{SO}_3$  to make  $\text{Fe}_2(\text{SO}_4)_3$ .

#### ✓ Example 10.2.1

Which equations are combination reactions?

- $\text{Co(s)} + \text{Cl}_2\text{(g)} \rightarrow \text{CoCl}_2\text{(s)}$
- $\text{CO(g)} + \text{Cl}_2\text{(g)} \rightarrow \text{COCl}_2\text{(g)}$
- $\text{N}_2\text{H}_4\text{(l)} + \text{O}_2\text{(g)} \rightarrow \text{N}_2\text{(g)} + 2\text{H}_2\text{O(l)}$

#### Solution

- This is a combination reaction.
- This is a combination reaction. (The compound  $\text{COCl}_2$  is called phosgene and, in the past, was used as a gassing agent in chemical warfare.)
- This is not a combination reaction.

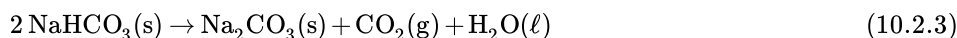
#### ? Exercise 10.2.1

Which equations are combination reactions?

- $\text{P}_4\text{(s)} + 6\text{Cl}_2\text{(g)} \rightarrow 4\text{PCl}_3\text{(g)}$
- $\text{SO}_3\text{(l)} + \text{H}_2\text{O(l)} \rightarrow \text{H}_2\text{SO}_4\text{(l)}$
- $\text{NaOH(s)} + \text{HCl(g)} \rightarrow \text{NaCl(s)} + \text{H}_2\text{O(l)}$

### Decomposition Reactions

A decomposition reaction is the reverse of a combination reaction. In a decomposition reaction, a single substance is converted into two or more products. There may be more than one molecule of the reactant, but there is only one substance initially. For example, the equation



is a decomposition reaction that occurs when  $\text{NaHCO}_3$  is exposed to heat. Another example is the decomposition of  $\text{KClO}_3$ :



This reaction was once commonly used to generate small amounts of oxygen in the chemistry lab.

The decomposition reaction of  $\text{NaHCO}_3$  is the reaction that occurs when baking soda is poured on a small kitchen fire. The intent is that the  $\text{H}_2\text{O}$  and  $\text{CO}_2$  produced by the decomposition will smother the flames.

## Combustion Reactions

A combustion reaction occurs when a substance combines with molecular oxygen to make oxygen-containing compounds of other elements in the reaction. One example is the burning of acetylene ( $\text{C}_2\text{H}_2$ ) in torches:



Oxygen (in its elemental form) is a crucial reactant in combustion reactions, and it is also present in the products.

*Energy in the form of heat is usually given off as a product in a combustion reaction as well.*

### ✓ Example 10.2.2

Identify each type of reaction.

- $2\text{K}(\text{s}) + \text{S}(\text{s}) + 2\text{O}_2(\text{g}) \rightarrow \text{K}_2\text{SO}_4(\text{s})$
- $(\text{NH}_4)_2\text{Cr}_2\text{O}_7(\text{s}) \rightarrow \text{N}_2(\text{g}) + \text{Cr}_2\text{O}_3(\text{s}) + 4\text{H}_2\text{O}(\ell)$
- $\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\ell)$

#### Solution

- Multiple reactants are combining to make a single product, so this reaction is a combination reaction.
- A single substance reacts to make several products, so we have a decomposition reaction.
- Oxygen reacts with a compound to make carbon dioxide (an oxide of carbon) and water (an oxide of hydrogen). This is a combustion reaction.

### ? Exercise 10.2.2

Identify each type of reaction.

- $\text{C}_2\text{H}_5\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O}$
- $2\text{Ca}(\text{s}) + \text{O}_2(\text{g}) \rightarrow 2\text{CaO}(\text{s})$
- $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$

## Summary

There are several recognizable types of chemical reactions: combination, decomposition, and combustion reactions are examples.

## Concept Review Exercises

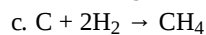
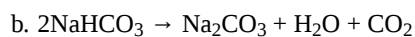
- What is the difference between a combination reaction and a combustion reaction?
- Give the distinguishing characteristic(s) of a decomposition reaction.
- How do we recognize a combustion reaction?

## Answers

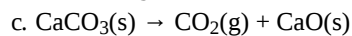
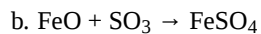
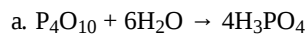
- A combination reaction produces a certain substance; a combustion reaction is a vigorous reaction, usually a combination with oxygen, that is accompanied by the production of light and/or heat.
- In a decomposition reaction, a single substance reacts to make multiple substances as products.
- A combustion reaction is typically a vigorous reaction accompanied by light and/or heat, usually because of reaction with oxygen.

## Exercises

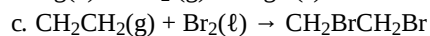
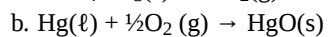
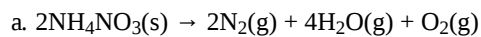
- Identify each type of reaction.
  - $\text{C}_6\text{H}_5\text{CH}_3 + 9\text{O}_2 \rightarrow 7\text{CO}_2 + 4\text{H}_2\text{O}$



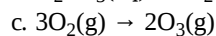
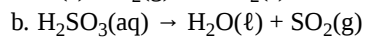
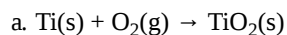
2. Identify each type of reaction.



3. Identify each type of reaction.



4. Identify each type of reaction.



## Answers

1.
  - a. combustion
  - b. decomposition
  - c. combination
3.
  - a. decomposition
  - b. combustion or combination
  - c. combination

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