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CONTENT 17.3

17.3 Classifying Reactions

READ

Chemical reactions may be classified into different groups according to the reactants and products. The five major groups of chemical reactions are summarized below.

Addition reactions - when two or more substances combine to form a new compound.

- *General equation*: $A + B \rightarrow AB$
- *Example*: When rust forms, iron reacts with oxygen to form iron oxide (rust).
  $4Fe\ (s) + 3O_2\ (g) \rightarrow 2\ Fe_2O_3\ (s)$

Decomposition reactions - when a single compound is broken down to produce two or more smaller compounds.

- *General equation*: $AB \rightarrow A + B$
- *Example*: Water can be broken down into hydrogen and oxygen gases.
  $2H_2O\ (l) \rightarrow 2H_2\ (g) + O_2\ (g)$

Single displacement reactions - when one element replaces a similar element in a compound.

- *General equation*: $A + BX \rightarrow AX + B$
- *Example*: When iron is added to a solution of copper chloride, iron replaces copper in the solution and copper falls out of the solution.
  $Fe\ (s) + CuCl_2\ (aq) \rightarrow Cu\ (s) + FeCl_2\ (aq)$

Double displacement reactions - when ions from two compounds in solution exchange places to produce two new compounds.

- *General equation*: $AX + BY \rightarrow AY + BX$
- *Example*: When carbon dioxide gas is bubbled into lime water, a precipitate of calcium carbonate is formed along with water.
  $CO_2\ (g) + CaO_2H_2\ (aq) \rightarrow CaCO_3\ (s) + H_2O\ (l)$

Combustion reactions - when a carbon compound reacts with oxygen gas to produce carbon dioxide and water vapor. Energy is released from the reaction.

- *General equation*: Carbon Compound + $O_2 \rightarrow CO_2 + H_2O$ + energy
- *Example*: The combustion of methane gas.
  $CH_4\ (g) + 2O_2 \rightarrow CO_2\ (g) + 2H_2O\ (g)$

EXAMPLE

Classify the following reaction as addition, decomposition, single displacement, double displacement, or combustion. Explain your answer.

$Mg\ (s) + CuSO_4\ (s) \rightarrow MgSO_4\ (aq) + Cu\ (s)$

Answer: Displacement. Magnesium replaces copper in the compound.

PRACTICE

Classify the reactions below as either: addition, decomposition, single displacement, double displacement, or combustion. Explain your answers.

1. CO_2 (g) + H_2O (l) → H_2CO_3 (aq)
2. Cl_2 (g) + 2KI (aq) → 2KCl (aq) + I_2 (g)
3. H_2O_2 (l) → H_2O (l) + O_2 (g)
4. $MnSO_4$ (s) → MnO (s) + SO_3 (g)
5. $C_6H_{12}O_6$ (s) + $6O_2$ (g) → $6CO_2$ (g) + $6H_2O$ (g)
6. $CaCl_2$ (aq) + $2AgNO_3$ (aq) → $Ca(NO_3)_2$ (aq) + 2AgCl (s)
7. 2NaCl (aq) + $CuSO_4$ (aq) → Na_2SO_4 (aq) + $CuCl_2$ (s)
8. $CaCl_2$ (aq) + 2Na (s) → Ca (s) + 2NaCl (aq)
9. $CaCO_3$ (s) → CaO (s) + CO_2 (g)
10. C_3H_8 (g) + $5O_2$ (g) → $3CO_2$ (g) + $4H_2O$ (g)

Answer the following questions.

11. You mix two clear solutions. Instantly, you see a bright yellow precipitate form. What type of reaction did you just observe? Explain your answer.
12. What type of reaction occurs when you strike a match?
13. Solid sodium reacts violently with chlorine gas. The product formed in the reaction is sodium chloride, also known as table salt. What type of reaction is this? Explain your answer.
14. Hydrogen-powered cars burn hydrogen gas to produce water and energy. The reaction is:

    $2H_2$ (g) + O_2 (g) → $2H_2O$ (g) + Energy

    While this reaction can be classified as an addition reaction, it is sometimes referred to as combustion. What characteristics does this reaction share with other combustion reactions? How is it different?

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CHALLENGE! 17.3

17.3 Predicting Chemical Equations

READ CPO Science

Chemical reactions cause chemical changes. Elements and compounds enter into a reaction, and new substances are formed as a result. Often, we know the types of substances that entered the reaction and can tell what types of substance(s) were formed. Sometimes, though, it might be helpful if we could predict the products of the chemical reaction—know in advance what would be formed and how much of it would be produced.

For certain chemical reactions, this is possible, using our knowledge of oxidation numbers, types of chemical reactions, and how equations are balanced. In this skill sheet, you will practice writing a complete balanced equation for chemical reactions when only the identities of the reactants are known.

Review: Chemical equations

Recall that chemical equations show the process of a chemical reaction. The equation reads from left to right with the reactants separated from the products by an arrow that indicates "yields" or "produces."

In the chemical equation:

$$2Li + BaCl_2 \rightarrow 2LiCl + Ba$$

Two atoms of lithium combine with one molecule of barium chloride to yield two molecules of lithium chloride and one atom of barium. The equation fully describes the chemical change for this reaction.

For reactions such as the one above, a single displacement reaction, we are often able to predict the products in advance and write a completely balanced equation for the chemical change. Here are the steps involved:

1. Predict the replacements for the reaction.

In single displacement reactions, one element is replaced by a similar element in a compound. The pattern for this replacement is easily predictable: if the element doing the replacing forms a positive ion, it replaces the element in the compound that forms a positive ion. If the substance doing the replacing forms a negative ion, it replaces the element in the compound that forms a negative ion.

For the reaction described above, we could predict that the lithium would replace the barium in the compound barium chloride since both lithium and barium have positive oxidation numbers. The resulting product would pair lithium (1+) and chlorine (1-): the positive/negative combination required for ionic compounds.

2. Determine the chemical formula for the products.

Once you have determined which elements will be swapped to form the products, you can use oxidation numbers and the fact that the sum of the oxidation numbers for an ionic compound must equal zero in order to determine the chemical formula for the reaction products.

3. Balance the chemical equation

Once you have determined the nature and formulas of the products for a chemical reaction, the final step is to write a balanced equation for the reaction.

CHALLENGE! 17.3

EXAMPLE

- If beryllium (Be) combines with potassium iodide (KI) in a chemical reaction, what are the products?

  Solution:

  First, we decide which element of KI will be replaced by the beryllium. Since beryllium has an oxidation number of 2+, it replaces the element in KI that also has a positive oxidation number—the potassium (K^{1+}). It will therefore combine with the iodine to form a new compound.

  Because beryllium has an oxidation number of 2+ and iodine's oxidation number is 1–, it is necessary for two atoms of iodine to combine with one atom of beryllium to form an electrically neutral compound. The resulting chemical formula for beryllium iodide is BeI_2.

  In single-displacement reactions, the component of the compound that has been replaced by the uncombined reactant now stands alone and uncombined. The resulting products of this chemical reaction, therefore, are BeI_2 and K. Balancing the equation give us:

$$Be + 2KI \rightarrow BeI_2 + 2K$$

PRACTICE

Predict replacements

1. If Na^{1+} were to combine with $CaCl_2$, what component of $CaCl_2$ would be replaced by the Na^{1+}?
2. If Fe^{2+} were to combine with K_2Br, what component of K_2Br would be replaced by the Fe^{2+}?
3. If Mg^{2+} were to combine with $AlCl_3$, what component of $AlCl_3$ would be replaced by the Mg^{2+}?

Predict product formulas

For the following combinations of reactants, predict the formulas of the products:

4. $Li + AlCl_3$
5. $K + CaO$
6. $F_2 + KI$

Predicting chemical equations for displacement reactions

Write complete balanced equations for the following combinations of reactants.

7. Ca and K_2S
8. Mg and Fe_2O_3
9. Li and NaCl