

A chemical equation is a written expression of an actual chemical reaction in which certain atoms, ions, or molecules become rearranged in a specific way. Therefore, the equation must represent exactly what happens in the reaction.

Recall that atoms are never created or destroyed in chemical reactions. A balanced chemical equation shows that all of the atoms present in reactants are still present in products.

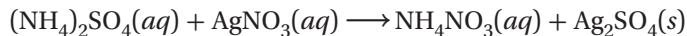
Problem-Solving TIPS

- First, identify reactants and products. (You may find it helpful to write a word equation first.)
- Using correct formulas and symbols, write an unbalanced equation for the reaction.
- Balance atoms one element at a time by inserting coefficients.
- Identify elements that appear in only one reactant and one product, and balance the atoms of those elements first.
- If a polyatomic ion appears on both sides of the equation, treat it as a single unit.
- Double-check to be sure that the number of atoms of each element is the same on both sides of the equation.

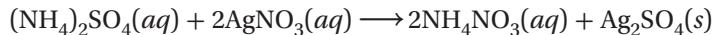
Sample

When an aqueous solution of ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4(aq)$, is combined with an aqueous solution of silver nitrate, $\text{AgNO}_3(aq)$, a precipitate of solid silver sulfate, $\text{Ag}_2\text{SO}_4(s)$, forms, leaving ammonium nitrate, $\text{NH}_4\text{NO}_3(aq)$, in solution. Balance the equation for this reaction.

As before, first write an equation with correct formulas for all reactants and products.

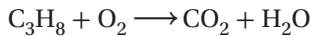


If you compare the number of silver atoms on each side, you can see that the equation is not balanced. This equation may look very complex, but it is really fairly simple. In many reactions involving polyatomic ions such as sulfate, nitrate, and ammonium, the ions do not change. In the equation above, you can see that NO_3 is present on both sides, as are SO_4 and NH_4 . You can balance the equation by treating the groups as if they were single atoms. To balance the NH_4 groups, place a 2 in front of NH_4NO_3 . This gives you two ammonium groups on the left and two on the right. Now, because you have two nitrate groups on the right, place a 2 in front of AgNO_3 to give two nitrate groups on the left. Finally, check silver atoms and sulfate groups, and you find that they balance.



Practice

1. When propane burns completely in air, the reaction forms carbon dioxide and water vapor. Balance the equation for this reaction.



2. Balance the following chemical equations:

- a. $\text{KI}(aq) + \text{Cl}_2(g) \longrightarrow \text{KCl}(aq) + \text{I}_2(s)$
- b. $\text{Al}(s) + \text{H}_2\text{SO}_4(aq) \longrightarrow \text{Al}_2(\text{SO}_4)_3(aq) + \text{H}_2(g)$

CHAPTER 8 Summary

BIG IDEA Chemical equations use chemical formulas with coefficients to show how a reaction satisfies the law of conservation of mass.

SECTION 1 Describing Chemical Reactions

- Four observations that suggest a chemical reaction is taking place are the evolution of energy as heat and light, the production of gas, a change in color, and the formation of a precipitate.
- A balanced chemical equation represents, with symbols and formulas, the identities and relative amounts of reactants and products in a chemical reaction.

KEY TERMS

chemical equation
precipitate
coefficient
word equation
formula equation
reversible reaction

SECTION 2 Types of Chemical Reactions

- Synthesis reactions are represented by the general equation $A + X \longrightarrow AX$.
- Decomposition reactions are represented by the general equation $AX \longrightarrow A + X$.
- Single-displacement reactions are represented by the general equations $A + BX \longrightarrow AX + B$ and $Y + BX \longrightarrow BY + X$.
- Double-displacement reactions are represented by the general equation $AX + BY \longrightarrow AY + BX$.
- In a combustion reaction, a substance combines with oxygen, releasing energy in the form of heat and light.

KEY TERMS

synthesis reaction
decomposition reaction
electrolysis
single-displacement reaction
double-displacement reaction
combustion reaction

SECTION 3 Activity Series of the Elements

- Activity series list the elements in order of their chemical reactivity and are useful in predicting whether a chemical reaction will occur.
- Chemists determine activity series through experiments.

KEY TERMS

activity series

**SECTION 1****Describing Chemical Reactions** **REVIEWING MAIN IDEAS**

1. List four observations that indicate that a chemical reaction may be taking place.
2. List the three requirements for a correctly written chemical equation.
3.
 - a. What is meant by the term *coefficient* in relation to a chemical equation?
 - b. How does the presence of a coefficient affect the number of atoms of each type in the formula that the coefficient precedes?
4. Give an example of a word equation, a formula equation, and a chemical equation.
5. What quantitative information is revealed by a chemical equation?
6. What limitations are associated with the use of both word and formula equations?
7. Define each of the following terms:
 - a. aqueous solution
 - b. catalyst
 - c. reversible reaction
8. Write formulas for each of the following compounds:
 - a. potassium hydroxide
 - b. calcium nitrate
 - c. sodium carbonate
 - d. carbon tetrachloride
 - e. magnesium bromide
9. What four guidelines are useful in balancing an equation?
10. How many atoms of each type are represented in each of the following?

a. 3N_2	f. $5\text{Fe}(\text{NO}_3)_2$
b. $2\text{H}_2\text{O}$	g. $4\text{Mg}_3(\text{PO}_4)_2$
c. 4HNO_3	h. $2(\text{NH}_4)_2\text{SO}_4$
d. $2\text{Ca}(\text{OH})_2$	i. $6\text{Al}_2(\text{SeO}_4)_3$
e. $3\text{Ba}(\text{ClO}_3)_2$	j. $4\text{C}_3\text{H}_8$

PRACTICE PROBLEMS

11. Write the chemical equation that relates to each of the following word equations. Include symbols for physical states in the equation.
 - a. solid zinc sulfide + oxygen gas \longrightarrow
solid zinc oxide + sulfur dioxide gas
 - b. aqueous hydrochloric acid + aqueous barium hydroxide \longrightarrow aqueous barium chloride + water
 - c. aqueous nitric acid + aqueous calcium hydroxide \longrightarrow aqueous calcium nitrate + water
12. Translate each of the following chemical equations into a sentence.
 - a. $2\text{ZnS}(s) + 3\text{O}_2(g) \longrightarrow 2\text{ZnO}(s) + 2\text{SO}_2(g)$
 - b. $\text{CaH}_2(s) + 2\text{H}_2\text{O}(l) \longrightarrow \text{Ca}(\text{OH})_2(aq) + 2\text{H}_2(g)$
 - c. $\text{AgNO}_3(aq) + \text{KI}(aq) \longrightarrow \text{AgI}(s) + \text{KNO}_3(aq)$
13. Balance each of the following:
 - a. $\text{H}_2 + \text{Cl}_2 \longrightarrow \text{HCl}$
 - b. $\text{Al} + \text{Fe}_2\text{O}_3 \longrightarrow \text{Al}_2\text{O}_3 + \text{Fe}$
 - c. $\text{Pb}(\text{CH}_3\text{COO})_2 + \text{H}_2\text{S} \longrightarrow \text{PbS} + \text{CH}_3\text{COOH}$
14. Identify and correct each error in the following equations, and then balance each equation.
 - a. $\text{Li} + \text{O}_2 \longrightarrow \text{LiO}_2$
 - b. $\text{H}_2 + \text{Cl}_2 \longrightarrow \text{H}_2\text{Cl}_2$
 - c. $\text{MgCO}_3 \longrightarrow \text{MgO}_2 + \text{CO}_2$
 - d. $\text{NaI} + \text{Cl}_2 \longrightarrow \text{NaCl} + \text{I}$
15. Write balanced chemical equations for each of the following sentences:
 - a. Aluminum reacts with oxygen to produce aluminum oxide.
 - b. Phosphoric acid, H_3PO_4 , is produced through the reaction between tetraphosphorus decoxide and water.
 - c. Iron(III) oxide reacts with carbon monoxide to produce iron and carbon dioxide.
16. Carbon tetrachloride is used as an intermediate chemical in the manufacture of other chemicals. It is prepared in liquid form by reacting chlorine gas with methane gas. Hydrogen chloride gas is also formed in this reaction. Write the balanced chemical equation for the production of carbon tetrachloride. (Hint: See Sample Problems C and D.)

17. For each of the following synthesis reactions, identify the missing reactant(s) or product(s) and then balance the resulting equation.
- $Mg + \underline{\hspace{2cm}} \rightarrow MgO$
 - $\underline{\hspace{2cm}} + O_2 \rightarrow Fe_2O_3$
 - $Li + Cl_2 \rightarrow \underline{\hspace{2cm}}$
 - $Ca + \underline{\hspace{2cm}} \rightarrow CaI_2$

SECTION 2**Types of Chemical Reactions** **REVIEWING MAIN IDEAS**

18. Define and give general equations for the five basic types of chemical reactions.
19. How are most decomposition reactions initiated?
20. A substance is decomposed by an electric current. What is the name of this type of reaction?
21. **a.** In what environment do many single-displacement reactions commonly occur?
b. In general, how do single-displacement reactions compare with synthesis and decomposition reactions in terms of the amount of energy involved?

PRACTICE PROBLEMS

22. Complete each of the following synthesis reactions by writing both a word equation and a chemical equation.
- sodium + oxygen $\rightarrow \underline{\hspace{2cm}}$
 - magnesium + fluorine $\rightarrow \underline{\hspace{2cm}}$
23. Complete and balance the equations for the following decomposition reactions:
- $HgO \xrightarrow[\text{electricity}]{\Delta} \underline{\hspace{2cm}}$
 - $H_2O(l) \xrightarrow[\text{electricity}]{\Delta} \underline{\hspace{2cm}}$
 - $Ag_2O \xrightarrow[\text{electricity}]{\Delta} \underline{\hspace{2cm}}$
 - $CuCl_2 \xrightarrow[\text{electricity}]{\Delta} \underline{\hspace{2cm}}$
24. Complete and balance the equations for the following single-displacement reactions:
- $Zn + Pb(NO_3)_2 \rightarrow \underline{\hspace{2cm}}$
 - $Al + Hg(CH_3COO)_2 \rightarrow \underline{\hspace{2cm}}$
 - $Al + NiSO_4 \rightarrow \underline{\hspace{2cm}}$
 - $Na + H_2O \rightarrow \underline{\hspace{2cm}}$
25. Complete and balance the equations for the following double-displacement reactions:
- $AgNO_3(aq) + NaCl(aq) \rightarrow \underline{\hspace{2cm}}$
 - $Mg(NO_3)_2(aq) + KOH(aq) \rightarrow \underline{\hspace{2cm}}$
 - $LiOH(aq) + Fe(NO_3)_3(aq) \rightarrow \underline{\hspace{2cm}}$

26. Complete and balance the equations for the following combustion reactions:
- $CH_4 + O_2 \rightarrow \underline{\hspace{2cm}}$
 - $C_3H_6 + O_2 \rightarrow \underline{\hspace{2cm}}$
 - $C_5H_{12} + O_2 \rightarrow \underline{\hspace{2cm}}$
27. Write and balance each of the following equations, and then identify each by type.
- hydrogen + iodine \rightarrow hydrogen iodide
 - lithium + hydrochloric acid \rightarrow lithium chloride + hydrogen
 - sodium carbonate \rightarrow sodium oxide + carbon dioxide
 - mercury(II) oxide \rightarrow mercury + oxygen
 - magnesium hydroxide \rightarrow magnesium oxide + water

28. Identify the compound that could undergo decomposition to produce the following products, and then balance the final equation.
- magnesium oxide and water
 - lead(II) oxide and water
 - lithium chloride and oxygen
 - barium chloride and oxygen
 - nickel chloride and oxygen
29. In each of the following combustion reactions, identify the missing reactant(s), product(s), or both and then balance the resulting equation.
- $C_3H_8 + \underline{\hspace{2cm}} \rightarrow \underline{\hspace{2cm}} + H_2O$
 - $\underline{\hspace{2cm}} + 8O_2 \rightarrow 5CO_2 + 6H_2O$
 - $C_2H_5OH + \underline{\hspace{2cm}} \rightarrow \underline{\hspace{2cm}} + \underline{\hspace{2cm}}$
30. Complete and balance the equations for the following reactions, and then identify each by type.
- zinc + sulfur $\rightarrow \underline{\hspace{2cm}}$
 - silver nitrate + potassium iodide $\rightarrow \underline{\hspace{2cm}}$
 - toluene, C_7H_8 + oxygen $\rightarrow \underline{\hspace{2cm}}$
 - nonane, C_9H_{20} + oxygen $\rightarrow \underline{\hspace{2cm}}$

SECTION 3**Activity Series of the Elements** **REVIEWING MAIN IDEAS**

31. **a.** What is meant by the *activity* of an element?
b. How does this description differ for metals and nonmetals?

- 32.** a. What is an activity series of elements?
b. What is the basis for the ordering of the elements in the activity series?

33. What chemical principle is the basis for the activity series of metals?

PRACTICE PROBLEMS

- 34.** Based on the activity series of metals and halogens, in **Figure 3.1**, which element within each pair is more likely to replace the other in a compound?

 - a. K and Na
 - b. Al and Ni
 - c. Bi and Cr
 - d. Cl and F
 - e. Au and Ag
 - f. Cl and I
 - g. Fe and Sr
 - h. I and F

35. Using the activity series in **Figure 3.1**, predict whether each of the possible reactions listed below will occur. For the reactions that will occur, write the products and balance the equation.

 - a. $\text{Ni}(s) + \text{CuCl}_2(aq) \rightarrow$ _____
 - b. $\text{Zn}(s) + \text{Pb}(\text{NO}_3)_2(aq) \rightarrow$ _____
 - c. $\text{Cl}_2(g) + \text{KI}(aq) \rightarrow$ _____
 - d. $\text{Cu}(s) + \text{FeSO}_4(aq) \rightarrow$ _____
 - e. $\text{Ba}(s) + \text{H}_2\text{O}(l) \rightarrow$ _____

36. Use the activity series in **Figure 3.1** to predict whether each of the following synthesis reactions will occur, and write the chemical equations for those predicted to occur.

 - a. $\text{Ca}(s) + \text{O}_2(g) \rightarrow$ _____
 - b. $\text{Ni}(s) + \text{O}_2(g) \rightarrow$ _____
 - c. $\text{Au}(s) + \text{O}_2(g) \rightarrow$ _____

Mixed Review



REVIEWING MAIN IDEAS

- 37.** Ammonia reacts with oxygen to yield nitrogen and water.



Given this chemical equation, as well as the number of moles of the reactant or product indicated below, determine the number of moles of all remaining reactants and products.

- a.** 3.0 mol O₂ **c.** 1.0 mol N₂
b. 8.0 mol NH₃ **d.** 0.40 mol H₂O

- 38.** Complete the following synthesis reactions by writing both the word and chemical equation for each:

 - potassium + chlorine \longrightarrow _____
 - hydrogen + iodine \longrightarrow _____
 - magnesium + oxygen \longrightarrow _____

39. Use the activity series in **Figure 3.1** to predict which metal—Sn, Mn, or Pt—would be the best choice as a container for an acid.

40. Aqueous sodium hydroxide is produced commercially by the electrolysis of aqueous sodium chloride. Hydrogen and chlorine gases are also produced. Write the balanced chemical equation for the production of sodium hydroxide. Include the physical states of the reactants and products.

41. Balance each of the following:

 - $\text{Ca}(\text{OH})_2 + (\text{NH}_4)_2\text{SO}_4 \longrightarrow \text{CaSO}_4 + \text{NH}_3 + \text{H}_2\text{O}$
 - $\text{C}_2\text{H}_6 + \text{O}_2 \longrightarrow \text{CO}_2 + \text{H}_2\text{O}$
 - $\text{Cu}_2\text{S} + \text{O}_2 \longrightarrow \text{Cu}_2\text{O} + \text{SO}_2$
 - $\text{Al} + \text{H}_2\text{SO}_4 \longrightarrow \text{Al}_2(\text{SO}_4)_3 + \text{H}_2$

42. Use the activity series in **Figure 3.1** to predict whether each of the following reactions will occur, and write the balanced chemical equations for those predicted to occur.

 - $\text{Al}(s) + \text{O}_2(g) \longrightarrow$ _____
 - $\text{Pb}(s) + \text{ZnCl}_2(s) \longrightarrow$ _____

43. Complete and balance the equations for the following reactions, and identify the type of reaction that each equation represents.

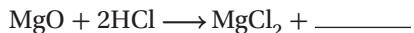
 - $(\text{NH}_4)_2\text{S}(aq) + \text{ZnCl}_2(aq) \longrightarrow$ _____ + $\text{ZnS}(s)$
 - $\text{Al}(s) + \text{Pb}(\text{NO}_3)_2(aq) \longrightarrow$ _____
 - $\text{Ba}(s) + \text{H}_2\text{O}(l) \longrightarrow$ _____
 - $\text{Cl}_2(g) + \text{KBr}(aq) \longrightarrow$
 - $\text{NH}_3(g) + \text{O}_2(g) \xrightarrow{\text{Pt}} \text{NO}(g) + \text{H}_2\text{O}(l)$
 - $\text{H}_2\text{O}(l) \longrightarrow \text{H}_2(g) + \text{O}_2(g)$

44. Write and balance each of the following equations, and then identify each by type.

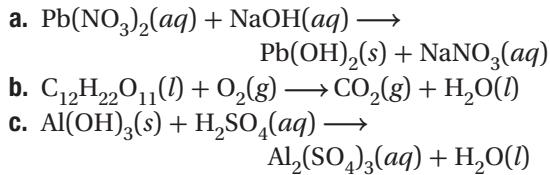
 - copper + chlorine \longrightarrow copper(II) chloride
 - calcium chlorate \longrightarrow
calcium chloride + oxygen
 - lithium + water \longrightarrow
lithium hydroxide + hydrogen
 - lead(II) carbonate \longrightarrow

45. How many moles of HCl can be made from 6.15 mol H₂ and an excess of Cl₂?

46. What product is missing in the following equation?



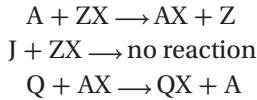
47. Balance the following equations:



CRITICAL THINKING

48. **Inferring Relationships** Activity series are prepared by comparing single-displacement reactions between metals. Based on observations, the metals can be ranked by their ability to react. However, reactivity can be explained by the ease with which atoms of metals lose electrons. Using information from the activity series, identify the locations in the periodic table of the most-reactive metals and the least-reactive metals. Using your knowledge of electron configurations and periodic trends, infer possible explanations for the metals' reactivity and position in the periodic table.

49. **Analyzing Results** Formulate an activity series for the hypothetical elements A, J, Q, and Z by using the following reaction information:



USING THE HANDBOOK

50. Find the common-reactions section for Group 1 metals in the *Elements Handbook* in Appendix A. Use this information to answer the following:

- a. Write a balanced chemical equation for the formation of rubidium hydroxide from rubidium oxide.
b. Write a balanced chemical equation for the formation of cesium iodide.
c. Classify the reactions you wrote in (a) and (b).
d. Write word equations for the reactions you wrote in (a) and (b).

51. Find the common-reactions section for Group 13 in the *Elements Handbook* (Appendix A). Use this information to answer the following:

- a. Write a balanced chemical equation for the formation of gallium bromide prepared from hydrobromic acid.
b. Write a balanced chemical equation for the formation of gallium oxide.
c. Classify the reactions you wrote in (a) and (b).
d. Write word equations for the reactions you wrote in (a) and (b).

RESEARCH AND WRITING

52. Trace the evolution of municipal water fluoridation. What advantages and disadvantages are associated with this practice?

53. Research how a soda-acid fire extinguisher works, and write the chemical equation for the reaction. Check your house and other structures for different types of fire extinguishers, and ask your local fire department to verify the effectiveness of each type of extinguisher.

ALTERNATIVE ASSESSMENT

54. **Performance Assessment** For one day, record situations that show evidence of a chemical change. Identify the reactants and the products, and determine whether there is proof of a chemical reaction. Classify each of the chemical reactions according to the common reaction types discussed in the chapter.