

CHAPTER 6

Chemical Reactions: An Introduction

1. The types of evidence for a chemical reaction mentioned in the text are: a change in color, formation of a solid, evolution of a gas, and absorption or evolution of heat. Other bits of evidence that might also be observed include appearance or disappearance of a characteristic odor, or separation of the reaction mixture into layers of visibly different composition.
2. Most of these products contain a peroxide, which decomposes releasing oxygen gas.
3. The oven cleaner is a more or less clear liquid (sodium hydroxide) when applied, but turns into a thick, opaque, soapy layer after reacting with oils and greases on the oven walls. Chapter 21 discusses the formation of a soap by reaction of a fat or oil with sodium hydroxide.
4. Bubbling takes place as the hydrogen peroxide chemically decomposes into water and oxygen gas.
5. The container of a flashlight battery usually consists of zinc, which is one of the substances involved in the chemical reaction in the battery that generates the electricity. The fact that the zinc decays until the battery leaks is a sign that a chemical reaction has taken place.
6. The appearance of the black color actually signals the breakdown of starches and sugars in the bread to elemental carbon. You may also see steam coming from the bread (water produced by the breakdown of the carbohydrates).
7. The substances to the left of the arrow are called the “reactants,” whereas those to the right of the arrow are termed the “products.” The arrow indicates a chemical reaction has occurred.
8. atoms
9. the same as
10. Balancing an equation ensures that no atoms are created or destroyed during the reaction. The total mass after the reaction must be the same as the total mass before the reaction.
11. In many reactions, the physical state of the reactants or products may influence whether or not the reaction takes place. For example, some metallic elements do not react with cold water, but will react vigorously with steam.
12. For solids we use (*s*), for liquids we use (*l*), and for gases we use (*g*).
13. $\text{Zn}(s) + \text{CuSO}_4(aq) \rightarrow \text{ZnSO}_4(aq) + \text{Cu}(s)$
14. $\text{H}_2\text{O}_2(aq) \rightarrow \text{H}_2(g) + \text{O}_2(g)$
15. $\text{H}_2(g) + \text{O}_2(g) \rightarrow \text{H}_2\text{O}(g)$

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16. $\text{N}_2\text{H}_4(l) \rightarrow \text{N}_2(g) + \text{H}_2(g)$
17. $\text{KI}(aq) + \text{H}_2\text{O}(l) \rightarrow \text{KOH}(aq) + \text{I}_2(s) + \text{H}_2(g)$
18. $\text{C}_3\text{H}_8(g) + \text{O}_2(g) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}(g)$
 $\text{C}_3\text{H}_8(g) + \text{O}_2(g) \rightarrow \text{CO}(g) + \text{H}_2\text{O}(g)$
19. $\text{B}_2\text{O}_3(s) + \text{Mg}(s) \rightarrow \text{B}(g) + \text{MgO}(s)$
20. $\text{CaCO}_3(s) + \text{HCl}(aq) \rightarrow \text{CaCl}_2(aq) + \text{H}_2\text{O}(l) + \text{CO}_2(g)$
21. $\text{P}_4(s) + \text{Cl}_2(g) \rightarrow \text{PCl}_3(s)$
22. $\text{SiO}_2(s) + \text{C}(s) \rightarrow \text{Si}(s) + \text{CO}(g)$
23. $\text{NH}_4\text{NO}_3(s) \rightarrow \text{N}_2\text{O}(g) + \text{H}_2\text{O}(g)$
24. $\text{Fe}(s) + \text{H}_2\text{O}(g) \rightarrow \text{FeO}(s) + \text{H}_2(g)$
25. $\text{C}_2\text{H}_2(g) + \text{O}_2(g) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}(g)$
26. $\text{SO}_2(g) + \text{H}_2\text{O}(l) \rightarrow \text{H}_2\text{SO}_3(aq)$
 $\text{SO}_3(g) + \text{H}_2\text{O}(l) \rightarrow \text{H}_2\text{SO}_4(aq)$
27. $\text{BaO}(s) + \text{Al}(s) \rightarrow \text{Ba}(s) + \text{Al}_2\text{O}_3(s)$
 $\text{CaO}(s) + \text{Al}(s) \rightarrow \text{Ca}(s) + \text{Al}_2\text{O}_3(s)$
 $\text{SrO}(s) + \text{Al}(s) \rightarrow \text{Sr}(s) + \text{Al}_2\text{O}_3(s)$
28. $\text{NO}(g) + \text{O}_3(g) \rightarrow \text{NO}_2(g) + \text{O}_2(g)$
29. $\text{CH}_4(g) + \text{Cl}_2(g) \rightarrow \text{CCl}_4(l) + \text{HCl}(g)$
30. $\text{P}_4(s) + \text{O}_2(g) \rightarrow \text{P}_2\text{O}_5(s)$
31. $\text{CaO}(s) + \text{H}_2\text{O}(g) \rightarrow \text{Ca}(\text{OH})_2(s)$
32. $\text{Xe}(g) + \text{F}_2(g) \rightarrow \text{XeF}_4(s)$
33. $\text{SnO}_2(s) + \text{C}(s) \rightarrow \text{Sn}(l) + \text{CO}(g)$
34. $\text{NH}_3(g) + \text{O}_2(g) \rightarrow \text{HNO}_3(aq) + \text{H}_2\text{O}(l)$
35. The subscripts in a formula really define what compound is present, since the subscripts represent in what proportions the elements combine to form the compound. Changing the subscripts would be changing the identity of the compound.
36. We cannot change the identities or formulas of the reactants or products in a chemical equation when balancing the equation. The proposed equation has incorrectly changed one of the products from water to hydrogen gas.

37. a. $\text{FeCl}_3 + \text{KOH} \rightarrow \text{Fe(OH)}_3 + \text{KCl}$
 Balance chlorine: $\text{FeCl}_3 + \text{KOH} \rightarrow \text{Fe(OH)}_3 + 3\text{KCl}$
 Balance potassium: $\text{FeCl}_3 + 3\text{KOH} \rightarrow \text{Fe(OH)}_3 + 3\text{KCl}$
 Balanced equation: $\text{FeCl}_3(aq) + 3\text{KOH}(aq) \rightarrow \text{Fe(OH)}_3(s) + 3\text{KCl}(aq)$
- b. $\text{Pb(C}_2\text{H}_3\text{O}_2)_2 + \text{KI} \rightarrow \text{PbI}_2 + \text{KC}_2\text{H}_3\text{O}_2$
 Balance iodine: $\text{Pb(C}_2\text{H}_3\text{O}_2)_2 + 2\text{KI} \rightarrow \text{PbI}_2 + \text{KC}_2\text{H}_3\text{O}_2$
 Balance potassium: $\text{Pb(C}_2\text{H}_3\text{O}_2)_2 + 2\text{KI} \rightarrow \text{PbI}_2 + 2\text{KC}_2\text{H}_3\text{O}_2$
 Balanced equation: $\text{Pb(C}_2\text{H}_3\text{O}_2)_2(aq) + 2\text{KI}(aq) \rightarrow \text{PbI}_2(s) + 2\text{KC}_2\text{H}_3\text{O}_2(aq)$
- c. $\text{P}_4\text{O}_{10} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_4$
 Balance phosphorus: $\text{P}_4\text{O}_{10} + \text{H}_2\text{O} \rightarrow 4\text{H}_3\text{PO}_4$
 Balance hydrogen: $\text{P}_4\text{O}_{10} + 6\text{H}_2\text{O} \rightarrow 4\text{H}_3\text{PO}_4$
 Balanced equation: $\text{P}_4\text{O}_{10}(s) + 6\text{H}_2\text{O}(l) \rightarrow 4\text{H}_3\text{PO}_4(aq)$
- d. $\text{Li}_2\text{O} + \text{H}_2\text{O} \rightarrow \text{LiOH}$
 Balance lithium: $\text{Li}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{LiOH}$
 Balanced equation: $\text{Li}_2\text{O}(s) + \text{H}_2\text{O}(l) \rightarrow 2\text{LiOH}(aq)$
- e. $\text{MnO}_2 + \text{C} \rightarrow \text{Mn} + \text{CO}_2$
 The equation is already balanced.
- f. $\text{Sb} + \text{Cl}_2 \rightarrow \text{SbCl}_3$
 This equation is more difficult to balance than it may appear. The problem arises in the fact that there are two Cl atoms on the left side of the equation, whereas there are three Cl atoms on the right side of the equation. To balance the chlorine atoms, we need to know the smallest whole number into which both 2 and 3 divide. This number is 6: we need to adjust the coefficients of Cl_2 and SbCl_3 so that there will be 6 chlorine atoms on each side of the equation.
 Balance chlorine: $\text{Sb} + 3\text{Cl}_2 \rightarrow 2\text{SbCl}_3$
 Balance antimony: $2\text{Sb} + 3\text{Cl}_2 \rightarrow 2\text{SbCl}_3$
 Balanced equation: $2\text{Sb}(s) + 3\text{Cl}_2(g) \rightarrow 2\text{SbCl}_3(s)$
- g. $\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + \text{H}_2$
 Balance hydrogen: $\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 3\text{H}_2$
 Balanced equation: $\text{CH}_4(g) + \text{H}_2\text{O}(g) \rightarrow \text{CO}(g) + 3\text{H}_2(g)$
- h. $\text{FeS} + \text{HCl} \rightarrow \text{FeCl}_2 + \text{H}_2\text{S}$
 Balance chlorine: $\text{FeS} + 2\text{HCl} \rightarrow \text{FeCl}_2 + \text{H}_2\text{S}$
 Balanced equation: $\text{FeS}(s) + 2\text{HCl}(aq) \rightarrow \text{FeCl}_2(aq) + \text{H}_2\text{S}(g)$

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38. a. $\text{Zn}(s) + \text{CuO}(s) \rightarrow \text{ZnO}(s) + \text{Cu}(l)$
The equation is already balanced.
- b. $\text{P}_4(s) + \text{F}_2(g) \rightarrow \text{PF}_3(g)$
balance phosphorus: $\text{P}_4(s) + \text{F}_2(g) \rightarrow 4\text{PF}_3(g)$
balance fluorine: $\text{P}_4(s) + 6\text{F}_2(g) \rightarrow 4\text{PF}_3(g)$
balanced equation: $\text{P}_4(s) + 6\text{F}_2(g) \rightarrow 4\text{PF}_3(g)$
- c. $\text{Xe}(g) + \text{F}_2(g) \rightarrow \text{XeF}_4(s)$
balance fluorine: $\text{Xe}(g) + 2\text{F}_2(g) \rightarrow \text{XeF}_4(s)$
balanced equation: $\text{Xe}(g) + 2\text{F}_2(g) \rightarrow \text{XeF}_4(s)$
- d. $\text{NH}_4\text{Cl}(g) + \text{Mg}(\text{OH})_2(s) \rightarrow \text{NH}_3(g) + \text{H}_2\text{O}(g) + \text{MgCl}_2(s)$
balance chlorine: $2\text{NH}_4\text{Cl}(g) + \text{Mg}(\text{OH})_2(s) \rightarrow \text{NH}_3(g) + \text{H}_2\text{O}(g) + \text{MgCl}_2(s)$
balance nitrogen: $2\text{NH}_4\text{Cl}(g) + \text{Mg}(\text{OH})_2(s) \rightarrow 2\text{NH}_3(g) + \text{H}_2\text{O}(g) + \text{MgCl}_2(s)$
balance oxygen: $2\text{NH}_4\text{Cl}(g) + \text{Mg}(\text{OH})_2(s) \rightarrow 2\text{NH}_3(g) + 2\text{H}_2\text{O}(g) + \text{MgCl}_2(s)$
balanced equation: $2\text{NH}_4\text{Cl}(g) + \text{Mg}(\text{OH})_2(s) \rightarrow 2\text{NH}_3(g) + 2\text{H}_2\text{O}(g) + \text{MgCl}_2(s)$
- e. $\text{SiO}(s) + \text{Cl}_2(g) \rightarrow \text{SiCl}_4(l) + \text{O}_2(g)$
balance oxygen: $2\text{SiO}(s) + \text{Cl}_2(g) \rightarrow \text{SiCl}_4(l) + \text{O}_2(g)$
balanced silicon: $2\text{SiO}(s) + \text{Cl}_2(g) \rightarrow 2\text{SiCl}_4(l) + \text{O}_2(g)$
balance chlorine: $2\text{SiO}(s) + 4\text{Cl}_2(g) \rightarrow 2\text{SiCl}_4(l) + \text{O}_2(g)$
balanced equation: $2\text{SiO}(s) + 4\text{Cl}_2(g) \rightarrow 2\text{SiCl}_4(l) + \text{O}_2(g)$
- f. $\text{Cs}_2\text{O}(s) + \text{H}_2\text{O}(l) \rightarrow \text{CsOH}(aq)$
balance cesium: $\text{Cs}_2\text{O}(s) + \text{H}_2\text{O}(l) \rightarrow 2\text{CsOH}(aq)$
balanced equation: $\text{Cs}_2\text{O}(s) + \text{H}_2\text{O}(l) \rightarrow 2\text{CsOH}(aq)$
- g. $\text{N}_2\text{O}_3(g) + \text{H}_2\text{O}(l) \rightarrow \text{HNO}_2(aq)$
balance hydrogen: $\text{N}_2\text{O}_3(g) + \text{H}_2\text{O}(l) \rightarrow 2\text{HNO}_2(aq)$
balanced equation: $\text{N}_2\text{O}_3(g) + \text{H}_2\text{O}(l) \rightarrow 2\text{HNO}_2(aq)$
- h. $\text{Fe}_2\text{O}_3(s) + \text{H}_2\text{SO}_4(l) \rightarrow \text{Fe}_2(\text{SO}_4)_3(s) + \text{H}_2\text{O}(g)$
balance sulfate ions: $\text{Fe}_2\text{O}_3(s) + 3\text{H}_2\text{SO}_4(l) \rightarrow \text{Fe}_2(\text{SO}_4)_3(s) + \text{H}_2\text{O}(g)$
balance hydrogen: $\text{Fe}_2\text{O}_3(s) + 3\text{H}_2\text{SO}_4(l) \rightarrow \text{Fe}_2(\text{SO}_4)_3(s) + 3\text{H}_2\text{O}(g)$
balanced equation: $\text{Fe}_2\text{O}_3(s) + 3\text{H}_2\text{SO}_4(l) \rightarrow \text{Fe}_2(\text{SO}_4)_3(s) + 3\text{H}_2\text{O}(g)$
39. a. $\text{K}_2\text{SO}_4(aq) + \text{BaCl}_2(aq) \rightarrow \text{BaSO}_4(s) + \text{KCl}(aq)$
Balance chlorine: $\text{K}_2\text{SO}_4(aq) + \text{BaCl}_2(aq) \rightarrow \text{BaSO}_4(s) + 2\text{KCl}(aq)$
Balanced equation: $\text{K}_2\text{SO}_4(aq) + \text{BaCl}_2(aq) \rightarrow \text{BaSO}_4(s) + 2\text{KCl}(aq)$

- b. $\text{Fe}(s) + \text{H}_2\text{O}(g) \rightarrow \text{FeO}(s) + \text{H}_2(g)$
The equation is already balanced.
- c. $\text{NaOH}(aq) + \text{HClO}_4(aq) \rightarrow \text{NaClO}_4(aq) + \text{H}_2\text{O}(l)$
The equation is already balanced.
- d. $\text{Mg}(s) + \text{Mn}_2\text{O}_3(s) \rightarrow \text{MgO}(s) + \text{Mn}(s)$
Balance oxygen: $\text{Mg}(s) + \text{Mn}_2\text{O}_3(s) \rightarrow 3\text{MgO}(s) + \text{Mn}(s)$
Balance magnesium: $3\text{Mg}(s) + \text{Mn}_2\text{O}_3(s) \rightarrow 3\text{MgO}(s) + \text{Mn}(s)$
Balance manganese: $3\text{Mg}(s) + \text{Mn}_2\text{O}_3(s) \rightarrow 3\text{MgO}(s) + 2\text{Mn}(s)$
Balanced equation: $3\text{Mg}(s) + \text{Mn}_2\text{O}_3(s) \rightarrow 3\text{MgO}(s) + 2\text{Mn}(s)$
- e. $\text{KOH}(s) + \text{KH}_2\text{PO}_4(aq) \rightarrow \text{K}_3\text{PO}_4(aq) + \text{H}_2\text{O}(l)$
Balance potassium: $2\text{KOH}(s) + \text{KH}_2\text{PO}_4(aq) \rightarrow \text{K}_3\text{PO}_4(aq) + \text{H}_2\text{O}(l)$
Balance hydrogen: $2\text{KOH}(s) + \text{KH}_2\text{PO}_4(aq) \rightarrow \text{K}_3\text{PO}_4(aq) + 2\text{H}_2\text{O}(l)$
Balanced equation: $2\text{KOH}(s) + \text{KH}_2\text{PO}_4(aq) \rightarrow \text{K}_3\text{PO}_4(aq) + 2\text{H}_2\text{O}(l)$
- f. $\text{NO}_2(g) + \text{H}_2\text{O}(l) + \text{O}_2(g) \rightarrow \text{HNO}_3(aq)$
Balance hydrogen: $\text{NO}_2(g) + \text{H}_2\text{O}(l) + \text{O}_2(g) \rightarrow 2\text{HNO}_3(aq)$
Balance nitrogen: $2\text{NO}_2(g) + \text{H}_2\text{O}(l) + \text{O}_2(g) \rightarrow 2\text{HNO}_3(aq)$
Balance oxygen: $2\text{NO}_2(g) + \text{H}_2\text{O}(l) + \frac{1}{2}\text{O}_2(g) \rightarrow 2\text{HNO}_3(aq)$
Balanced equation: $4\text{NO}_2(g) + 2\text{H}_2\text{O}(l) + \text{O}_2(g) \rightarrow 4\text{HNO}_3(aq)$
- g. $\text{BaO}_2(s) + \text{H}_2\text{O}(l) \rightarrow \text{Ba}(\text{OH})_2(aq) + \text{O}_2(g)$
Balance oxygen: $\text{BaO}_2(s) + \text{H}_2\text{O}(l) \rightarrow \text{Ba}(\text{OH})_2(aq) + \frac{1}{2}\text{O}_2(g)$
Balanced equation: $2\text{BaO}_2(s) + 2\text{H}_2\text{O}(l) \rightarrow 2\text{Ba}(\text{OH})_2(aq) + \text{O}_2(g)$
- h. $\text{NH}_3(g) + \text{O}_2(g) \rightarrow \text{NO}(g) + \text{H}_2\text{O}(l)$
Balance hydrogen: $2\text{NH}_3(g) + \text{O}_2(g) \rightarrow \text{NO}(g) + 3\text{H}_2\text{O}(l)$
Balance nitrogen: $2\text{NH}_3(g) + \text{O}_2(g) \rightarrow 2\text{NO}(g) + 3\text{H}_2\text{O}(l)$
Balance oxygen: $2\text{NH}_3(g) + \frac{5}{2}\text{O}_2(g) \rightarrow 2\text{NO}(g) + 3\text{H}_2\text{O}(l)$
Balanced equation: $4\text{NH}_3(g) + 5\text{O}_2(g) \rightarrow 4\text{NO}(g) + 6\text{H}_2\text{O}(l)$
40. a. $\text{Na}_2\text{SO}_4(aq) + \text{CaCl}_2(aq) \rightarrow \text{CaSO}_4(s) + 2\text{NaCl}(aq)$
- b. $3\text{Fe}(s) + 4\text{H}_2\text{O}(g) \rightarrow \text{Fe}_3\text{O}_4(s) + 4\text{H}_2(g)$
- c. $\text{Ca}(\text{OH})_2(aq) + 2\text{HCl}(aq) \rightarrow \text{CaCl}_2(aq) + 2\text{H}_2\text{O}(l)$
- d. $\text{Br}_2(g) + 2\text{H}_2\text{O}(l) + \text{SO}_2(g) \rightarrow 2\text{HBr}(aq) + \text{H}_2\text{SO}_4(aq)$
- e. $3\text{NaOH}(s) + \text{H}_3\text{PO}_4(aq) \rightarrow \text{Na}_3\text{PO}_4(aq) + 3\text{H}_2\text{O}(l)$
- f. $2\text{NaNO}_3(s) \rightarrow 2\text{NaNO}_2(s) + \text{O}_2(g)$

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- g. $2\text{Na}_2\text{O}_2(s) + 2\text{H}_2\text{O}(l) \rightarrow 4\text{NaOH}(aq) + \text{O}_2(g)$
- h. $4\text{Si}(s) + \text{S}_8(s) \rightarrow 2\text{Si}_2\text{S}_4(s)$
41. a. $\text{Fe}_3\text{O}_4(s) + 4\text{H}_2(g) \rightarrow 3\text{Fe}(l) + 4\text{H}_2\text{O}(g)$
- b. $\text{K}_2\text{SO}_4(aq) + \text{BaCl}_2(aq) \rightarrow \text{BaSO}_4(s) + 2\text{KCl}(aq)$
- c. $2\text{HCl}(aq) + \text{FeS}(s) \rightarrow \text{FeCl}_2(aq) + \text{H}_2\text{S}(g)$
- d. $\text{Br}_2(g) + 2\text{H}_2\text{O}(l) + \text{SO}_2(g) \rightarrow 2\text{HBr}(aq) + \text{H}_2\text{SO}_4(aq)$
- e. $\text{CS}_2(l) + 3\text{Cl}_2(g) \rightarrow \text{CCl}_4(l) + \text{S}_2\text{Cl}_2(g)$
- f. $\text{Cl}_2\text{O}_7(g) + \text{Ca}(\text{OH})_2(aq) \rightarrow \text{Ca}(\text{ClO}_4)_2(aq) + \text{H}_2\text{O}(l)$
- g. $\text{PBr}_3(l) + 3\text{H}_2\text{O}(l) \rightarrow \text{H}_3\text{PO}_3(aq) + 3\text{HBr}(g)$
- h. $\text{Ba}(\text{ClO}_3)_2(s) \rightarrow \text{BaCl}_2(s) + 3\text{O}_2(s)$
42. a. $4\text{NaCl}(s) + 2\text{SO}_2(g) + 2\text{H}_2\text{O}(g) + \text{O}_2(g) \rightarrow 2\text{Na}_2\text{SO}_4(s) + 4\text{HCl}(g)$
- b. $3\text{Br}_2(l) + \text{I}_2(s) \rightarrow 2\text{IBr}_3(s)$
- c. $\text{Ca}(s) + 2\text{H}_2\text{O}(g) \rightarrow \text{Ca}(\text{OH})_2(aq) + \text{H}_2(g)$
- d. $2\text{BF}_3(g) + 3\text{H}_2\text{O}(g) \rightarrow \text{B}_2\text{O}_3(s) + 6\text{HF}(g)$
- e. $\text{SO}_2(g) + 2\text{Cl}_2(g) \rightarrow \text{SOCl}_2(l) + \text{Cl}_2\text{O}(g)$
- f. $\text{Li}_2\text{O}(s) + \text{H}_2\text{O}(l) \rightarrow 2\text{LiOH}(aq)$
- g. $\text{Mg}(s) + \text{CuO}(s) \rightarrow \text{MgO}(s) + \text{Cu}(l)$
- h. $\text{Fe}_3\text{O}_4(s) + 4\text{H}_2(g) \rightarrow 3\text{Fe}(l) + 4\text{H}_2\text{O}(g)$
43. a. $4\text{KO}_2(s) + 6\text{H}_2\text{O}(l) \rightarrow 4\text{KOH}(aq) + \text{O}_2(g) + 4\text{H}_2\text{O}_2(aq)$
- b. $\text{Fe}_2\text{O}_3(s) + 6\text{HNO}_3(aq) \rightarrow 2\text{Fe}(\text{NO}_3)_3(aq) + 3\text{H}_2\text{O}(l)$
- c. $4\text{NH}_3(g) + 5\text{O}_2(g) \rightarrow 4\text{NO}(g) + 6\text{H}_2\text{O}(g)$
- d. $\text{PCl}_5(l) + 4\text{H}_2\text{O}(l) \rightarrow \text{H}_3\text{PO}_4(aq) + 5\text{HCl}(g)$
- e. $\text{C}_2\text{H}_5\text{OH}(l) + 3\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(l)$
- f. $2\text{CaO}(s) + 5\text{C}(s) \rightarrow 2\text{CaC}_2(s) + \text{CO}_2(g)$
- g. $2\text{MoS}_2(s) + 7\text{O}_2(g) \rightarrow 2\text{MoO}_3(s) + 4\text{SO}_2(g)$
- h. $\text{FeCO}_3(s) + \text{H}_2\text{CO}_3(aq) \rightarrow \text{Fe}(\text{HCO}_3)_2(aq)$
44. a. $\text{Ba}(\text{NO}_3)_2(aq) + \text{Na}_2\text{CrO}_4(aq) \rightarrow \text{BaCrO}_4(s) + 2\text{NaNO}_3(aq)$
- b. $\text{PbCl}_2(aq) + \text{K}_2\text{SO}_4(aq) \rightarrow \text{PbSO}_4(s) + 2\text{KCl}(aq)$
- c. $\text{C}_2\text{H}_5\text{OH}(l) + 3\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(l)$
- d. $\text{CaC}_2(s) + 2\text{H}_2\text{O}(l) \rightarrow \text{Ca}(\text{OH})_2(s) + \text{C}_2\text{H}_2(g)$
- e. $\text{Sr}(s) + 2\text{HNO}_3(aq) \rightarrow \text{Sr}(\text{NO}_3)_2(aq) + \text{H}_2(g)$
- f. $\text{BaO}_2(s) + \text{H}_2\text{SO}_4(aq) \rightarrow \text{BaSO}_4(s) + \text{H}_2\text{O}_2(aq)$

- g. $2\text{AsI}_3(s) \rightarrow 2\text{As}(s) + 3\text{I}_2(s)$
- h. $2\text{CuSO}_4(aq) + 4\text{KI}(s) \rightarrow 2\text{CuI}(s) + \text{I}_2(s) + 2\text{K}_2\text{SO}_4(aq)$
45. $\text{C}_2\text{H}_2(g) + \text{O}_2(g) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}(g)$
46. $\text{Na}(s) + \text{O}_2(g) \rightarrow \text{Na}_2\text{O}_2(s)$
 $\text{Na}_2\text{O}_2(s) + \text{H}_2\text{O}(l) \rightarrow \text{NaOH}(aq) + \text{O}_2(g)$
47. $\text{KNO}_3(s) + \text{C}(s) \rightarrow \text{K}_2\text{CO}_3(s) + \text{CO}(g) + \text{N}_2(g)$
48. $\text{C}_{12}\text{H}_{22}\text{O}_{11}(aq) + \text{H}_2\text{O}(l) \rightarrow 4\text{C}_2\text{H}_5\text{OH}(aq) + 4\text{CO}_2(g)$
49. $2\text{H}_2(g) + \text{CO}(g) \rightarrow \text{CH}_3\text{OH}(l)$
50. $2\text{Al}_2\text{O}_3(s) + 3\text{C}(s) \rightarrow 4\text{Al}(s) + 3\text{CO}_2(g)$
51. $\text{Fe}_3\text{O}_4(s) + 4\text{H}_2(g) \rightarrow 3\text{Fe}(s) + 4\text{H}_2\text{O}(g)$
 $\text{Fe}_3\text{O}_4(s) + 4\text{CO}(g) \rightarrow 3\text{Fe}(s) + 4\text{CO}_2(g)$
52. $2\text{Li}(s) + \text{S}(s) \rightarrow \text{Li}_2\text{S}(s)$
 $2\text{Na}(s) + \text{S}(s) \rightarrow \text{Na}_2\text{S}(s)$
 $2\text{K}(s) + \text{S}(s) \rightarrow \text{K}_2\text{S}(s)$
 $2\text{Rb}(s) + \text{S}(s) \rightarrow \text{Rb}_2\text{S}(s)$
 $2\text{Cs}(s) + \text{S}(s) \rightarrow \text{Cs}_2\text{S}(s)$
 $2\text{Fr}(s) + \text{S}(s) \rightarrow \text{Fr}_2\text{S}(s)$
53. $\text{Fe}(s) + \text{O}_2(g) \rightarrow \text{FeO}(s)$
 $\text{Fe}(s) + \text{O}_2(g) \rightarrow \text{Fe}_2\text{O}_3(s)$
54. $\text{BaO}_2(s) + \text{H}_2\text{O}(l) \rightarrow \text{BaO}(s) + \text{H}_2\text{O}_2(aq)$
55. $4\text{B}(s) + 3\text{O}_2(g) \rightarrow 2\text{B}_2\text{O}_3(s)$
 $\text{B}_2\text{O}_3(s) + 3\text{H}_2\text{O}(l) \rightarrow 2\text{B}(\text{OH})_3(s)$
56. $2\text{KClO}_3(s) \rightarrow 2\text{KCl}(s) + 3\text{O}_2(g)$
57. $2\text{H}_2\text{O}_2(aq) \rightarrow 2\text{H}_2\text{O}(g) + \text{O}_2(g)$
58. $\text{NH}_3(g) + \text{HCl}(g) \rightarrow \text{NH}_4\text{Cl}(s)$
59. $\text{CaSiO}_3(s) + 6\text{HF}(g) \rightarrow \text{CaF}_2(aq) + \text{SiF}_4(g) + 3\text{H}_2\text{O}(l)$
60. The senses we call “odor” and “taste” are really chemical reactions of the receptors in our body with molecules in the food we are eating. The fact that the receptors no longer detect the “fishy” odor or taste suggest that adding the lemon juice or vinegar has changed the nature of the amines in the fish.

Chapter 6: Chemical Reactions: An Introduction

61. Many over-the-counter antacids contain either carbonate ion (CO_3^{2-}) or hydrogen carbonate ion (HCO_3^-). When either of these encounter stomach acid (primarily HCl), carbon dioxide gas is released.
62. $\text{Fe}(s) + \text{S}(s) \rightarrow \text{FeS}(s)$
63. $\text{Na}(s) + \text{Cl}_2(g) \rightarrow \text{NaCl}(s)$
64. $\text{K}_2\text{CrO}_4(aq) + \text{BaCl}_2(aq) \rightarrow \text{BaCrO}_4(s) + 2\text{KCl}(aq)$
65. $\text{H}_2\text{S}(g) + \text{Pb}(\text{NO}_3)_2(aq) \rightarrow \text{PbS}(s) + \text{HNO}_3(aq)$
66. $2\text{NaCl}(aq) + 2\text{H}_2\text{O}(l) \rightarrow 2\text{NaOH}(aq) + \text{H}_2(g) + \text{Cl}_2(g)$
 $2\text{NaBr}(aq) + 2\text{H}_2\text{O}(l) \rightarrow 2\text{NaOH}(aq) + \text{H}_2(g) + \text{Br}_2(g)$
 $2\text{NaI}(aq) + 2\text{H}_2\text{O}(l) \rightarrow 2\text{NaOH}(aq) + \text{H}_2(g) + \text{I}_2(g)$
67. $\text{Mg}(s) + \text{O}_2(g) \rightarrow \text{MgO}(s)$
68. $\text{CaC}_2(s) + 2\text{H}_2\text{O}(l) \rightarrow \text{Ca}(\text{OH})_2(s) + \text{C}_2\text{H}_2(g)$
69. $\text{P}_4(s) + \text{O}_2(g) \rightarrow \text{P}_4\text{O}_{10}(g)$
70. $\text{CuO}(s) + \text{H}_2\text{SO}_4(aq) \rightarrow \text{CuSO}_4(aq) + \text{H}_2\text{O}(l)$
71. $\text{PbS}(s) + \text{O}_2(g) \rightarrow \text{PbO}(s) + \text{SO}_2(g)$
72. $\text{Na}_2\text{SO}_3(aq) + \text{S}(s) \rightarrow \text{Na}_2\text{S}_2\text{O}_3(aq)$
73. a. $\text{Cl}_2(g) + 2\text{KBr}(aq) \rightarrow \text{Br}_2(l) + 2\text{KCl}(aq)$
b. $4\text{Cr}(s) + 3\text{O}_2(g) \rightarrow 2\text{Cr}_2\text{O}_3(s)$
c. $\text{P}_4(s) + 6\text{H}_2(g) \rightarrow 4\text{PH}_3(g)$
d. $2\text{Al}(s) + 3\text{H}_2\text{SO}_4(aq) \rightarrow \text{Al}_2(\text{SO}_4)_3(aq) + 3\text{H}_2(g)$
e. $\text{PCl}_3(l) + 3\text{H}_2\text{O}(l) \rightarrow \text{H}_3\text{PO}_3(aq) + 3\text{HCl}(aq)$
f. $2\text{SO}_2(g) + \text{O}_2(g) \rightarrow 2\text{SO}_3(g)$
g. $\text{C}_7\text{H}_{16}(l) + 11\text{O}_2(g) \rightarrow 7\text{CO}_2(g) + 8\text{H}_2\text{O}(g)$
h. $2\text{C}_2\text{H}_6(g) + 7\text{O}_2(g) \rightarrow 4\text{CO}_2(g) + 6\text{H}_2\text{O}(g)$
74. a. $\text{Cl}_2(g) + 2\text{KI}(aq) \rightarrow 2\text{KCl}(aq) + \text{I}_2(s)$
b. $\text{CaC}_2(s) + 2\text{H}_2\text{O}(l) \rightarrow \text{Ca}(\text{OH})_2(s) + \text{C}_2\text{H}_2(g)$
c. $2\text{NaCl}(s) + \text{H}_2\text{SO}_4(l) \rightarrow \text{Na}_2\text{SO}_4(s) + 2\text{HCl}(g)$
d. $\text{CaF}_2(s) + \text{H}_2\text{SO}_4(l) \rightarrow \text{CaSO}_4(s) + 2\text{HF}(g)$
e. $\text{K}_2\text{CO}_3(s) \rightarrow \text{K}_2\text{O}(s) + \text{CO}_2(g)$
f. $3\text{BaO}(s) + 2\text{Al}(s) \rightarrow \text{Al}_2\text{O}_3(s) + 3\text{Ba}(s)$

- g. $2\text{Al}(s) + 3\text{F}_2(g) \rightarrow 2\text{AlF}_3(s)$
- h. $\text{CS}_2(g) + 3\text{Cl}_2(g) \rightarrow \text{CCl}_4(l) + \text{S}_2\text{Cl}_2(g)$
75. a. $\text{SiCl}_4(l) + 2\text{Mg}(s) \rightarrow \text{Si}(s) + 2\text{MgCl}_2(s)$
- b. $2\text{NO}(g) + \text{Cl}_2(g) \rightarrow 2\text{NOCl}(g)$
- c. $3\text{MnO}_2(s) + 4\text{Al}(s) \rightarrow 3\text{Mn}(s) + 2\text{Al}_2\text{O}_3(s)$
- d. $16\text{Cr}(s) + 3\text{S}_8(s) \rightarrow 8\text{Cr}_2\text{S}_3(s)$
- e. $4\text{NH}_3(g) + 3\text{F}_2(g) \rightarrow 3\text{NH}_4\text{F}(s) + \text{NF}_3(g)$
- f. $\text{Ag}_2\text{S}(s) + \text{H}_2(g) \rightarrow 2\text{Ag}(s) + \text{H}_2\text{S}(g)$
- g. $3\text{O}_2(g) \rightarrow 2\text{O}_3(g)$
- h. $8\text{Na}_2\text{SO}_3(aq) + \text{S}_8(s) \rightarrow 8\text{Na}_2\text{S}_2\text{O}_3(aq)$
76. a. $\text{Pb}(\text{NO}_3)_2(aq) + \text{K}_2\text{CrO}_4(aq) \rightarrow \text{PbCrO}_4(s) + 2\text{KNO}_3(aq)$
- b. $\text{BaCl}_2(aq) + \text{Na}_2\text{SO}_4(aq) \rightarrow \text{BaSO}_4(s) + 2\text{NaCl}(aq)$
- c. $2\text{CH}_3\text{OH}(l) + 3\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 4\text{H}_2\text{O}(g)$
- d. $\text{Na}_2\text{CO}_3(aq) + \text{S}(s) + \text{SO}_2(g) \rightarrow \text{CO}_2(g) + \text{Na}_2\text{S}_2\text{O}_3(aq)$
- e. $\text{Cu}(s) + 2\text{H}_2\text{SO}_4(aq) \rightarrow \text{CuSO}_4(aq) + \text{SO}_2(g) + 2\text{H}_2\text{O}(l)$
- f. $\text{MnO}_2(s) + 4\text{HCl}(aq) \rightarrow \text{MnCl}_2(aq) + \text{Cl}_2(g) + 2\text{H}_2\text{O}(l)$
- g. $\text{As}_2\text{O}_3(s) + 6\text{KI}(aq) + 6\text{HCl}(aq) \rightarrow 2\text{AsI}_3(s) + 6\text{KCl}(aq) + 3\text{H}_2\text{O}(l)$
- h. $2\text{Na}_2\text{S}_2\text{O}_3(aq) + \text{I}_2(aq) \rightarrow \text{Na}_2\text{S}_4\text{O}_6(aq) + 2\text{NaI}(aq)$