Chapter 4: The Effects of Chemical Reactions

Mini Investigation: Back and Forth, page 151
A. The formation of a precipitate is evidence that a chemical change occurred.
B. The addition of sodium hydroxide to the test tube formed the precipitate, as predicted.
C. The sodium hydroxide first neutralized the excess acid present, allowing hydroxide ions to form a precipitate with iron(III) ions.

Section 4.1: Introduction to Chemical Reactions

Mini Investigation: Elephant Toothpaste, page 153
A. The production of a gas was evidence of a chemical reaction.
B. The same volumes of hydrogen peroxide and detergent were used. These were the controlled variables. The variable that was changed was the concentration of the hydrogen peroxide used.
C. The 6% hydrogen peroxide solution was more reactive than the 3% solution.
D. More concentrated hydrogen peroxide solutions produce the desired results faster. The technicians in salons should wear gloves when handling these concentrated solutions. They also must carefully control the amount of time the solution is on the customer’s hair.

Tutorial 1 Practice, page 155
1. (a) Step 1. Count the number of atoms of each type on either side of the arrow.
   \[ P + O_2 \rightarrow P_2O_5 \]
   \[
   \begin{array}{c}
   P & 1 P & 2 P \\
   O & 2 O & 5 O \\
   \end{array}
   \]
   Step 2. Multiply the formula by an appropriate coefficient until all the atoms are balanced. \( P_2O_5 \) on the right must be multiplied by 2 and \( O_2 \) on the left must be multiplied by 5 to balance the oxygen atoms.
   \[
   2 P + 5 O_2 \rightarrow 2 P_2O_5 \\
   \begin{array}{c}
   P & 4 P & 4 P \\
   O & 10 O & 10 O \\
   \end{array}
   \]
   Step 3. Write the final chemical equation.
The balanced chemical equation is:
   \[ 4 P + 5 O_2 \rightarrow 2 P_2O_5 \]
(b) Step 1. Count the number of atoms of each type on either side of the arrow.
   \[ K_2O + H_2O \rightarrow KoH \]
   \[
   \begin{array}{c}
   K & 2 K & 1 K \\
   O & 2 O & 1 O \\
   H & 2 H & 1 H \\
   \end{array}
   \]
   Step 2. Multiply the formula by an appropriate coefficient until all the atoms are balanced. \( KoH \) on the right must be multiplied by 2 to balance each type of atoms.
   \[ K_2O + H_2O \rightarrow 2 KoH \]
   \[
   \begin{array}{c}
   K & 2 K & 2 K \\
   O & 2 O & 2 O \\
   H & 2 H & 2 H \\
   \end{array}
   \]
Step 3. Write the final chemical equation.
The balanced chemical equation is:
$$K_2O + H_2O \rightarrow 2 KOH$$

(c) Step 1. Count the number of ions of each type on either side of the arrow.

$$AlBr_3 + K_2SO_4 \rightarrow KBr + Al_2(SO_4)_3$$

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<tbody>
<tr>
<td>$Al^{3+}$</td>
<td>$K^+$</td>
<td>$SO_4^{2-}$</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Step 2. Multiply the formula by an appropriate coefficient until all the ions are balanced. $AlBr_3$ on the left must be multiplied by 2 to balance the $Al^{3+}$ ions, and $K_2SO_4$ must be multiplied by 3 to balance the $SO_4^{2-}$ ions.

$$2 AlBr_3 + 3 K_2SO_4 \rightarrow 6 KBr + Al_2(SO_4)_3$$

Step 3. Write the final chemical equation.
The balanced chemical equation is:
$$2 AlBr_3 + 3 K_2SO_4 \rightarrow 6 KBr + Al_2(SO_4)_3$$

(d) Step 1. Count the number of ions of each type on either side of the arrow.

$$FeCl_3 + NaOH \rightarrow Fe(OH)_3 + NaCl$$

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<tr>
<td>$Fe^{3+}$</td>
<td>$Cl^-$</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
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</table>

Step 2. Multiply the formula by an appropriate coefficient until all the ions are balanced. $NaOH$ on the left must be multiplied by 3 to balance the $OH^-$ ions, and $NaCl$ on the right must be multiplied by 3 to balance the $Cl^-$ ions.

$$FeCl_3 + 3 NaOH \rightarrow Fe(OH)_3 + 3 NaCl$$

Step 3. Write the final chemical equation.
The balanced chemical equation is:
$$FeCl_3 + 3 NaOH \rightarrow Fe(OH)_3 + 3 NaCl$$

(e) Step 1. Count the number of ions of each type on either side of the arrow.

$$AgNO_3 + H_2S \rightarrow Ag_2S + HNO_3$$

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<tbody>
<tr>
<td>$Ag^+$</td>
<td>$NO_3^-$</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
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Step 2. Multiply the formula by an appropriate coefficient until all the ions are balanced. AgNO$_3$ on the left must be multiplied by 2 to balance the Ag$^+$ ions, and HNO$_3$ on the right must be multiplied by 2 to balance the H$^+$ ions.

\[
2 \text{AgNO}_3 + \text{H}_2\text{S} \rightarrow \text{Ag}_2\text{S} + 2 \text{HNO}_3
\]

\[
2 \text{Ag}^+ \\
2 \text{NO}_3^- \\
2 \text{H}^+ \\
1 \text{S}^{2-}
\]

Step 3. Write the final chemical equation.
The balanced chemical equation is:

\[
2 \text{AgNO}_3 + \text{H}_2\text{S} \rightarrow \text{Ag}_2\text{S} + 2 \text{HNO}_3
\]

(f) Step 1. Count the number of atoms of each type on either side of the arrow.

\[
(\text{NH}_4)_2\text{CO}_3 \rightarrow \text{NH}_3 + \text{H}_2\text{O} + \text{CO}_2
\]

2 N \hspace{1cm} 1 N
8 H \hspace{1cm} 5 H
1 C \hspace{1cm} 1 C
3 O \hspace{1cm} 3 O

Step 2. Multiply the formula by an appropriate coefficient until all the atoms are balanced. NH$_3$ on the right must be multiplied by 2 to balance the N atoms.

\[
(\text{NH}_4)_2\text{CO}_3 \rightarrow 2 \text{NH}_3 + \text{H}_2\text{O} + \text{CO}_2
\]

2 N \hspace{1cm} 2 N
8 H \hspace{1cm} 8 H
1 C \hspace{1cm} 1 C
3 O \hspace{1cm} 3 O

Step 3. Write the final chemical equation.
The balanced chemical equation is:

\[
(\text{NH}_4)_2\text{CO}_3 \rightarrow 2 \text{NH}_3 + \text{H}_2\text{O} + \text{CO}_2
\]

Section 4.1 Questions, page 155

1. (a) The formation of a precipitate coating the surface of the copper wire and the change in colour of the solution suggest that a chemical reaction has occurred.
   (b) The billowing action of the smoke particles suggests that they are being pushed by an invisible gas, which would be one of the reaction products of the flaring of the match.

2. The fact that atoms are neither created nor destroyed, only rearranged in a chemical reaction, means that all the atoms present initially must also be present when the reaction is complete. Therefore, the total mass of reactants and products must be equal.

3. (a) copper metal + nitric acid $\rightarrow$ nitrogen dioxide + water + copper(II) nitrate
   (b) Cu(s) + 4 HNO$_3$(aq) $\rightarrow$ 2 NO$_2$(g) + 2 H$_2$O(l) + Cu(NO$_3$)$_2$(aq)
   (c) The subscript for oxygen in nitric acid is 3.
   (d) The coefficient of nitric acid in the equation is 4.
   (e) There are 12 atoms of oxygen on the left side of the equation.
   (f) Solutions are designated the symbol (aq), which means aqueous or in water, while pure liquids like water are designated the symbol (l).

4. When balancing a chemical equation, the coefficients are sometimes changed in order to ensure that the total number of atoms or ions of each type in the reactants is the same as in the products.
5. (a) S₈ + 8 O₂ → 8 SO₂
   (b) N₂ + 3 H₂ → 2 NH₃
   (c) 2 Na + 2 H₂O → 2 NaOH + H₂
   (d) 3 Li + AlCl₃ → 3 LiCl + Al
   (e) 2 C₄H₁₀ + 13 O₂ → 8 CO₂ + 10 H₂O
   (f) 2 N₂ + 5 O₂ → 2 N₂O₅
   (g) 6 Li + B₂O₃ → 3 Li₂O + 2 B
   (h) Fe₂O₃ + 3 H₂SO₄ → Fe₂(SO₄)₃ + 3 H₂O
   (i) 2 H₃PO₄ + 3 Ca(OH)₂ → Ca₃(PO₄)₂ + 6 H₂O
   (j) 4 NH₃ + 3 O₂ → 2 N₂ + 6 H₂O
   (k) Ca₃(PO₄)₂ + SiO₂ + C → 3 CaSiO₃ + CO + 2 P
   (l) 2 C₆H₆ + 15 O₂ → 12 CO₂ + 6 H₂O