Chapter 7: Stoichiometry in Chemical Reactions

Mini Investigation: Precipitating Ratios, page 315

A. $ZnCl_2(aq) + Na_2CO_3(aq) \rightarrow ZnCO_3(s) + 2\ NaCl(aq)$
$3\ AgNO_3(aq) + Na_3PO_4(aq) \rightarrow Ag_3PO_4(s) + 3\ NaNO_3(aq)$
B. Test tube with the most precipitate:
Table 1: test tube #2
Table 2: test tube #6
C. These test tubes had the most precipitate because the proportion of the two chemicals used were the same as the proportion given in the chemical equation for each reaction.

Section 7.1: Mole Ratios in Chemical Equations

Mini Investigation: One Plus One Does Not Always Equal Two, page 318

A. Reaction 1: $H_2 + F_2 \rightarrow 2\ HF$
Reaction 2: $2\ H_2O \rightarrow 2\ H_2 + O_2$
Reaction 3: $C_2H_2 + 2\ F_2 \rightarrow C_2H_2F_4$
B. Reaction 1: There are 2 molecules on the left side of the arrow and 2 molecules on the right side.
Reaction 2: There are 2 molecules on the left side of the arrow and 3 molecules on the right side.
Reaction 3: There are 3 molecules on the left side of the arrow and 1 molecule on the right side.
C. These reactions illustrate the law of conservation of mass because the total number of atoms of each type in the reactants equals the total number of atoms of the same type in the products. Therefore, the total mass of reactants equals the total mass of products.

Tutorial 1 Practice, page 319

1. Given: $n_{P_2O_5} = 0.25\ \text{mol}$

Required: amount of oxygen, n_{O_2}

Solution:
Step 1. List the given value and the required value.
$P_4(s) + 5\ O_2(g) \rightarrow 2\ P_2O_5(g)$
n_{O_2} 0.25 mol

Step 2. Convert amount of diphosphorus pentoxide to amount of oxygen.

$$n_{O_2} = 0.25\ \cancel{\text{mol}_{P_2O_5}} \times \frac{5\ \text{mol}_{O_2}}{2\ \cancel{\text{mol}_{P_2O_5}}}$$

$$n_{O_2} = 0.63\ \text{mol}$$

Statement: 0.63 mol of oxygen is required to produce 0.25 mol of the product.

2. Given: $n_{\text{Fe}} = 1.4 \times 10^3$ mol
Required: amount of carbon monoxide, n_{CO}
Solution:
Step 1. List the given value and the required value.
$Fe_2O_3(s) + 3\ CO(g) \rightarrow 3\ CO_2(g) + 2\ Fe(s)$
n_{CO} $\quad$ 1.4×10^3 mol
Step 2. Convert amount of iron to amount of carbon monoxide.

$$n_{\text{CO}} = 1.4 \times 10^3\ \cancel{\text{mol}}_{\text{Fe}} \times \frac{3\ \text{mol}_{\text{CO}}}{2\ \cancel{\text{mol}}_{\text{Fe}}}$$

$$n_{\text{CO}} = 2.1 \times 10^3\ \text{mol}$$

Statement: To produce 1.4×10^3 mol of iron, 2.1×10^3 mol of carbon monoxide is required.
3. Given: $n_{\text{K}_2\text{O}} = 0.15$ mol
Required: amount of potassium, n_{K}
Solution:
Step 1. List the given value and the required value.
$2\ K_2O(s) \rightarrow 4\ K(s) + O_2(g)$
0.15 mol $\quad$ n_{K}
Step 2. Convert amount of potassium oxide to amount of potassium.

$$n_{\text{K}} = 0.15\ \cancel{\text{mol}}_{\text{K}_2\text{O}} \times \frac{4\ \text{mol}_{\text{K}}}{2\ \cancel{\text{mol}}_{\text{K}_2\text{O}}}$$

$$n_{\text{K}} = 0.30\ \text{mol}$$

Statement: When 0.15 mol of potassium oxide decomposes, 0.30 mol of potassium is produced.

Section 7.1 Questions, page 320

1. Balancing a chemical equation is necessary because the coefficients in the balanced equation give the ratio of the amount of reactant to the amount of product produced.
2. Mass is conserved in all chemical reactions. This occurs because the atoms present initially in the reactants are rearranged to form the products.
3. The mole ratio of potassium chlorate to oxygen in the chemical equation is 2:3.
4. Table 3 Amounts Involved in the Synthesis of Aluminum Chloride

Amount of Al(s) (mol)	Amount of Cl_2(g) (mol)	Amount of $AlCl_3$(s) (mol)
2	**3**	2
1	1.5	**1**
0.80	**1.20**	**0.80**
1.6	**2.40**	1.6
0.30	0.45	**0.30**

5. The coefficients of a balanced chemical equation give the mole ratio of one chemical to another. These values are relative amounts. The actual amounts of the reactants that react and products produced are in the same proportion as given by the coefficients.

6. (a) Given: $n_{NO} = 2.0$ mol
Required: amount of ammonia, n_{NH_3}; amount of oxygen, n_{O_2}
Solution:
Step 1. List the given value and the required values.
$4\ NH_3(g) + 5\ O_2(g) \rightarrow 4\ NO(g) + 6\ H_2O(g)$
n_{NH_3} n_{O_2} 2.0 mol
Step 2. Convert amount of nitric oxide to amount of ammonia and to amount of oxygen.

$$n_{NH_3} = 2.0\ \cancel{mol_{NO}} \times \frac{4\ mol_{NH_3}}{4\ \cancel{mol_{NO}}}$$

$$n_{NH_3} = 2.0\ mol$$

$$n_{O_2} = 2.0\ \cancel{mol_{NO}} \times \frac{5\ mol_{O_2}}{\cancel{4\ mol_{NO}}}$$

$$n_{O_2} = 2.5\ mol$$

Statement: To produce 2.0 mol nitric oxide, 2.0 mol of ammonia and 2.5 mol of oxygen are required.
(b) Given: $n_{H_2O} = 1.8\ mol$
Required: amount of ammonia, n_{NH_3}; amount of oxygen, n_{O_2}
Solution:
Step 1. List the given value and the required values.
$4\ NH_3(g) + 5\ O_2(g) \rightarrow 4\ NO(g) + 6\ H_2O(g)$
n_{NH_3} n_{O_2} 1.8 mol
Step 2. Convert amount of water to amount of ammonia and to amount of oxygen.

$$n_{NH_3} = 1.8\ \cancel{mol_{H_2O}} \times \frac{4\ mol_{NH_3}}{6\ \cancel{mol_{H_2O}}}$$

$$n_{NH_3} = 1.2\ mol$$

$$n_{O_2} = 1.8\ \cancel{mol_{H_2O}} \times \frac{5\ mol_{O_2}}{\cancel{6\ mol_{H_2O}}}$$

$$n_{O_2} = 1.5\ mol$$

Statement: To produce 1.8 mol of water, 1.2 mol of ammonia and 1.5 mol of oxygen are required.
(c) Given: $n_{NO} = 5.2 \times 10^{-3}$ mol
Required: amount of ammonia, n_{NH_3}; amount of oxygen, n_{O_2}
Solution:
Step 1. List the given value and the required values.
$4\ NH_3(g) + 5\ O_2(g) \rightarrow 4\ NO(g) + 6\ H_2O(g)$

n_{NH_3} n_{O_2} 5.2×10^{-3} mol

Step 2. Convert amount of nitric oxide to amount of ammonia and to amount of oxygen.

$$n_{NH_3} = 5.2 \times 10^{-3}\ \cancel{mol}_{NO} \times \frac{4\ mol_{NH_3}}{4\ \cancel{mol}_{NO}}$$

$$n_{NH_3} = 5.2 \times 10^{-3}\ mol$$

$$n_{O_2} = 5.2 \times 10^{-3}\ \cancel{mol}_{NO} \times \frac{5\ mol_{O_2}}{4\ \cancel{mol}_{NO}}$$

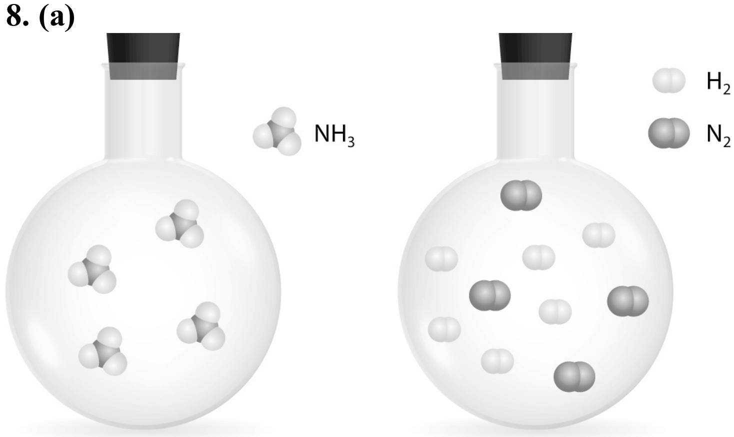
$$n_{O_2} = 6.5 \times 10^{-3}\ mol$$

Statement: 5.2×10^{-3} mol of ammonia and 6.5×10^{-3} mol of oxygen are required to produce 5.2×10^{-3} mol nitric oxide.

7. Table 4 Amount Involved in the Combustion of Methane

Amount of $CH_4(g)$ (mol)	Amount of $O_2(g)$ (mol)	Amount of $CO(g)$ (mol)	Amount of $H_2O(g)$ (mol)
3	**4.5**	**3**	**6**
6	9	**6**	**12**
0.2	**0.3**	0.2	**0.4**
0.5	**0.8**	**0.5**	1

8. (a)



(b) There are 6 molecules of hydrogen and 2 molecules of nitrogen after the reaction.
(c) According to the chemical equation, the reactant reacts to produce two products in the ratio 2:3:1.

9. (a) Given: $n_{NH_3} = 1.5$ mol

Required: amount of magnesium nitride, $n_{Mg_3N_2}$

Solution:

Step 1. List the given value and the required value.

$Mg_3N_2(s) + 6\ H_2O(l) \rightarrow 3\ Mg(OH)_2(s) + 2\ NH_3(g)$

$n_{Mg_3N_2}$ 1.5 mol

Step 2. Convert amount of ammonia to amount of magnesium nitride.

$$n_{Mg_3N_2} = 1.5\ \cancel{mol_{NH_3}} \times \frac{1\ mol_{Mg_3N_2}}{2\ \cancel{mol_{NH_3}}}$$

$$n_{Mg_3N_2} = 0.75\ mol$$

Statement: To produce 1.5 mol of ammonia, 0.75 mol of magnesium nitride is required.

(b) Given: $n_{NH_3} = 1.5\ mol$

Required: amount of water, n_{H_2O}

Solution:

Step 1. List the given value and the required value.

$Mg_3N_2(s) + 6\ H_2O(l) \rightarrow 3\ Mg(OH)_2(s) + 2\ NH_3(g)$

n_{H_2O} 1.5 mol

Step 2. Convert amount of ammonia to amount of water.

$$n_{H_2O} = 1.5\ \cancel{mol_{NH_3}} \times \frac{6\ mol_{H_2O}}{2\ \cancel{mol_{NH_3}}}$$

$$n_{H_2O} = 4.5\ mol$$

Statement: To produce 1.5 mol of ammonia, 4.5 mol of water is required.

(c) Given: $n_{H_2O} = 0.25\ mol$

Required: $n_{Mg_3N_2}$; $n_{Mg(OH)_2}$; n_{NH_3}

Solution:

Step 1. List the given value and the required value.

$Mg_3N_2(s) + 6\ H_2O(l) \rightarrow 3\ Mg(OH)_2(s) + 2\ NH_3(g)$

$n_{Mg_3N_2}$ 0.25 mol $n_{Mg(OH)_2}$ n_{NH_3}

Step 2. Convert amount of water to amount of magnesium nitride.

$$n_{Mg_3N_2} = 0.25\ \cancel{mol_{H_2O}} \times \frac{1\ mol_{Mg_3N_2}}{6\ \cancel{mol_{H_2O}}}$$

$$n_{Mg_3N_2} = 0.042\ mol$$

Step 3. Convert amount of water to amount of magnesium hydroxide.

$$n_{Mg(OH)_2} = 0.25\ \cancel{mol_{H_2O}} \times \frac{3\ mol_{Mg(OH)_2}}{6\ \cancel{mol_{H_2O}}}$$

$$n_{Mg(OH)_2} = 0.13\ mol$$

Step 4. Convert amount of water to amount of ammonia.

$$n_{NH_3} = 0.25\ \cancel{mol_{H_2O}} \times \frac{2\ mol_{NH_3}}{6\ \cancel{mol_{H_2O}}}$$

$$n_{NH_3} = 0.083\ mol$$

Statement: 0.42 mol of magnesium nitride is required to react with 0.25 mol of water. Then 0.13 mol of magnesium hydroxide and 0.083 mol of ammonia are expected.