We frequently need to know the relationship between the amounts of reactants and products in chemical reactions. When we synthesize a compound, we need to know how much of the reactants are needed to produce the desired amount of product.

Consider the reaction between ammonia and oxygen, one of the steps in the manufacture of nitric acid.

$$4\text{NH}_3(g) + 5\text{O}_2(g) \rightarrow 4\text{NO}(g) + 6\text{H}_2\text{O}(g).$$

One way of reading this balanced equation is to say four molecules of ammonia react with five molecules of oxygen to produce four molecules of nitric oxide and six molecules of water. Can we weigh such a small number of molecules? Of course not. On a larger scale, we can say four moles of ammonia react with five moles of oxygen to produce four moles of nitric oxide and six moles of water.

How many moles of $\text{O}_2$ will react with 12 moles of $\text{NH}_3$? We can use the unit conversion process to solve this problem. We want to convert moles of $\text{NH}_3$ into moles of $\text{O}_2$. The balanced equation provides the conversion factor because it says that 4 moles of $\text{NH}_3$ react with 5 moles of $\text{O}_2$.

Setting up the problem as a unit conversion, we find

$$\frac{5 \text{ mol } \text{O}_2}{? \text{ mol } \text{O}_2} = \frac{12 \text{ mol } \text{NH}_3}{4 \text{ mol } \text{NH}_3} \times \frac{15 \text{ mol } \text{O}_2}{1 \text{ mol } \text{NH}_3}.$$ 

How many moles of water would form along with 20 moles of $\text{NO}$? Again, this is a unit conversion. The balanced equation tells us that when 4 moles of $\text{NO}$ form, 6 moles of $\text{H}_2\text{O}$ will also form.

$$\frac{6 \text{ mol } \text{H}_2\text{O}}{? \text{ mol } \text{H}_2\text{O}} = \frac{20 \text{ mol } \text{NO}}{4 \text{ mol } \text{NO}} \times \frac{30 \text{ mol } \text{H}_2\text{O}}{1 \text{ mol } \text{NO}}.$$ 

**Example:** Find the number of moles of $\text{CO}$ that will react with 8.0 mole of $\text{Fe}_2\text{O}_3$. The reaction is $\text{Fe}_2\text{O}_3(s) + 3\text{CO}(g) \rightarrow 2\text{Fe}(l) + 3\text{CO}_2(g)$. The chemical equation tells us that three moles of $\text{CO}$ will react with one mole of $\text{Fe}_2\text{O}_3$. We can treat this problem as a unit conversion problem.

$$\frac{3 \text{ mol } \text{CO}}{? \text{ mol } \text{CO}} = \frac{8.0 \text{ mol } \text{Fe}_2\text{O}_3}{1 \text{ mol } \text{Fe}_2\text{O}_3} \times \frac{24 \text{ mol } \text{CO}}{1 \text{ mol } \text{Fe}_2\text{O}_3}.$$
PROBLEM 1 Given the reaction: \( 2Al(s) + Fe_2O_3(s) \rightarrow 2Fe(l) + Al_2O_3(s) \), how many moles of \( Fe_2O_3 \) are required to react 5.0 mol \( Al \) completely?

A) 1.0 mol  
B) 2.5 mol  
C) 5.0 mol  
D) 10.0 mol

PROBLEM 2 Phosphorous is obtained via the reaction:

\( 2Ca_3(PO_4)_2(s) + 6SiO_2(s) + 10C(s) \rightarrow 6CaSiO_3(s) + 10CO(g) + P_4(s) \).

How many moles of \( P_4 \) are formed when 42 mol of \( CaSiO_3 \) are formed?

A) 0.17 mol \( P_4 \)  
B) 1.0 mol \( P_4 \)  
C) 7.0 mol \( P_4 \)  
D) 252 mol \( P_4 \)

PROBLEM 3 Consider the reaction,

\( Ca_3P_2(s) + 6H_2O(l) \rightarrow 3Ca(OH)_2(s) + 2PH_3(g) \).

How many mol of \( PH_3 \) would be produced by the reaction of 0.24 mol \( H_2O? \)

A) 0.080 mol  
B) 0.48 mol  
C) 0.72 mol  
D) 1.4 mol

PROBLEM 4 The complete combustion of propane, \( C_3H_8 \), is

\( C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l) \).

How many grams of \( O_2 \) are required for the complete combustion of 35.7 g of propane?

A) 127 g \( O_2 \)  
B) 635 g \( O_2 \)  
C) 25.4 g \( O_2 \)  
D) 9.64 g \( O_2 \)

PROBLEM 5 One industrial method for making acetylene, \( C_2H_2 \), is

\( 2CH_4(g) \rightarrow C_2H_2(g) + 3H_2(g) \).

How many grams of \( CH_4 \) are required to make 750. g \( C_2H_2? \)

A) 1.85x10^3 g \( CH_4 \)  
B) 609 g \( CH_4 \)  
C) 304 g \( CH_4 \)  
D) 925 g \( CH_4 \)

PROBLEM 6 Breathalyzers use the following reaction to determine the amount of ethyl alcohol, \( C_2H_5OH \), in a person's breath (and blood).

\( 3C_2H_5OH + 2K_2Cr_2O_7 + 8H_2SO_4 \rightarrow 3KC_2H_3O_2 + 2Cr_2(SO_4)_3 + 2K_2SO_4 + 11H_2O \).

How many grams of ethyl alcohol react with 0.188 g \( K_2Cr_2O_7? \)

A) 0.0767 g  
B) 0.0227 g  
C) 0.0511 g  
D) 0.691 g

PROBLEM 7 How many grams of water are required for the oxidation of 5.47 g of \( Fe(OH)_2? \) The reaction is:

\( 4Fe(OH)_2(s) + O_2(g) + 2H_2O(l) \rightarrow 4Fe(OH)_3(s) \).
PROBLEM 8  What mass of NaCl is required to produce 1500. g of Cl₂ via the reaction, \( 2\text{NaCl(aq)} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH(aq)} + \text{H}_2(g) + \text{Cl}_2(g) \)?

A) 1820. g NaCl  
B) 2473 g NaCl  
C) 4946 g NaCl  
D) 909.9 g NaCl

A) 144 g N₂O₄  
B) 71.8 g N₂O₄  
C) 34.8 g N₂O₄  
D) 29.5 g N₂O₄

PROBLEM 10  Self-contained breathing apparatus replenish oxygen via the reaction: \( 4\text{KO}_2(s) + 4\text{CO}_2(g) + 2\text{H}_2\text{O}(l) \rightarrow 4\text{KHCO}_3(s) + 3\text{O}_2(g) \). How many grams of KO₂ are needed to supply 15.0 g of O₂?

A) 33.3 g KO₂  
B) 25.0 g KO₂  
C) 5.06 g KO₂  
D) 44.4 g KO₂