SAMPLE PROBLEM G

The black oxide of iron, Fe_3O_4, occurs in nature as the mineral magnetite. This substance can also be made in the laboratory by the reaction between red-hot iron and steam according to the following equation.

$$3Fe(s) + 4H_2O(g) \longrightarrow Fe_3O_4(s) + 4H_2(g)$$

a. When 36.0 g H_2O is mixed with 67.0 g Fe, which is the limiting reactant?
b. What mass in grams of black iron oxide is produced?
c. What mass in grams of excess reactant remains when the reaction is completed?

SOLUTION

1 ANALYZE

Given: mass of H_2O = 36.0 g
mass of Fe = 67.0 g
Unknown: limiting reactant
mass of Fe_3O_4, in grams
mass of excess reactant remaining

2 PLAN

a. First, convert both given masses in grams to amounts in moles. Then, calculate the number of moles of one of the products. Because the problem asks for the mass of Fe_3O_4 formed, we will calculate moles of Fe_3O_4. The reactant yielding the smaller number of moles of product is the limiting reactant.

$$\text{g Fe} \times \overbrace{\frac{\text{mol Fe}}{\text{g Fe}}}^{\text{molar mass factor}} \times \overbrace{\frac{\text{mol } Fe_3O_4}{\text{mol Fe}}}^{\text{mol ratio}} = \text{mol } Fe_3O_4$$

$$\text{g } H_2O \times \overbrace{\frac{\text{mol } H_2O}{\text{g } H_2O}}^{\text{molar mass factor}} \times \overbrace{\frac{\text{mol } Fe_3O_4}{\text{mol } H_2O}}^{\text{mol ratio}} = \text{mol } Fe_3O_4$$

b. To find the maximum mass of Fe_3O_4 that can be produced, we must use the amount of Fe_3O_4 in moles from the limiting reactant in a simple stoichiometric problem.

$$\text{mole } Fe_3O_4 \text{ from limiting reactant} \times \overbrace{\frac{\text{g } Fe_3O_4}{\text{mol } Fe_3O_4}}^{\text{molar mass factor}} = \text{g } Fe_3O_4 \text{ produced}$$

c. To find the amount of excess reactant remaining, we must first determine the amount of the excess reactant that is consumed. The calculated moles of the product (from the limiting reactant) is used to determine the amount of excess reactant that is consumed.

$$\text{mol product} \times \frac{\text{mol excess reactant}}{\text{mol product}} \times \frac{\text{g excess reactant}}{\text{mol excess reactant}} = \text{g excess reactant consumed}$$

The amount of excess reactant remaining can then be found by subtracting the amount consumed from the amount originally present.

original g excess reactant – g excess reactant consumed = g excess reactant remaining