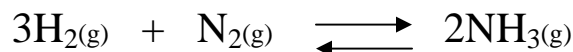


## 15 • Chemical Equilibrium

15.4 - 15.5 Calculating Equilibrium Concentrations and Constants

**The Reaction Quotient**

When we start with only reactants or only products, there is only one possible direction in which the reaction can go. In the case of the Haber process, if we start with  $\text{N}_2$  and  $\text{H}_2$  but no  $\text{NH}_3$ , the reaction can only proceed as



The reaction must proceed to the right in order to achieve equilibrium. Likewise, if we were to start with only  $\text{NH}_3$  and no  $\text{H}_2$  or  $\text{N}_2$ , the reaction must proceed to the left to achieve equilibrium. When we start with quantities of both reactants *and* products, we must *determine* which direction the reaction will go to achieve equilibrium. We do this by calculating the **reaction quotient**. The reaction quotient is calculated the same way as the equilibrium constant—by plugging concentrations of reactants and products into the equilibrium expression. The difference is that the concentrations we plug in to get the reaction quotient are not *equilibrium* concentrations.

If we start with a mixture that is 0.1 M  $\text{H}_2$ , 0.1 M  $\text{N}_2$ , and 0.1 M  $\text{NH}_3$ , the reaction quotient,  $Q$ , is

$$Q = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3} = \frac{(0.1)^2}{(0.1)(0.1)^3} = 100$$

Having calculated  $Q$ , we compare its value to that of  $K$ . If  $Q$  is *less* than  $K$ , the reaction will proceed to the right. If  $Q$  is *greater* than  $K$ , the reaction will proceed to the *left*.  $Q$  is *equal* to  $K$  at equilibrium.

At 472°C,  $K_c$  for this reaction is 0.105. Since  $Q$  is greater than  $K$ , this reaction will proceed to the left, meaning that  $\text{NH}_3$  concentration will decrease and the concentrations of  $\text{N}_2$  and  $\text{H}_2$  will increase to achieve equilibrium.

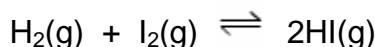
 $Q > K$  $Q = K$  $Q < K$ 

Reaction proceeds to the left  
to achieve equilibrium.

System is at equilibrium.

Reaction proceeds to the  
right to achieve equilibrium.

**Practice problem:** At 448°C the equilibrium constant,  $K_c$ , for the reaction is 51.



Predict how the reaction will proceed to reach equilibrium at 448°C if we start with  $2.0 \times 10^{-2}$  mol of HI,  $1.0 \times 10^{-2}$  mol of  $\text{H}_2$ , and  $3.0 \times 10^{-2}$  mol of  $\text{I}_2$  in a 2.0 L container.

