Chemistry Lecture #87: Chemical Equilibrium and the Equilibrium Constant

Hydrogen and iodine gas will react to form hydrogen iodide.

$H_2 + I_2 \rightarrow 2HI$

After being made, the hydrogen iodide will react to form hydrogen and iodine gas.

$2HI \rightarrow H_2 + I_2$ This reaction is just the reverse of the first reaction.

The above are examples of reversible reactions. These are reactions where after products are made, the products can react and produce the original reactants.

To indicate that a reaction is reversible, you draw two arrows pointing in opposite directions instead of a single arrow.

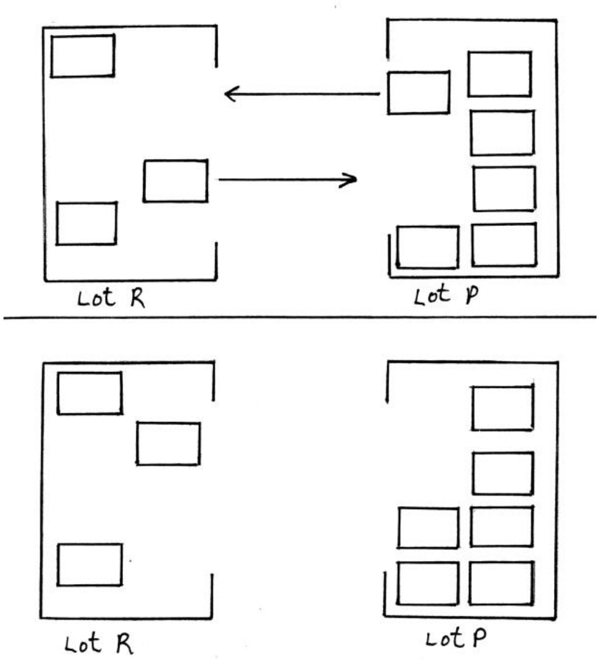
$H_2 + I_2 \rightleftarrows 2HI$

The reaction from left to right, $H_2 + I_2 \longrightarrow 2HI$, is the forward reaction.

The reaction from right to left, $H_2 + I_2 \longleftarrow 2HI$, is the reverse reaction.

If the rate of the forward reaction is equal to the rate of the reverse reaction, the system is in equilibrium. At equilibrium, the amount of product and reactant stays the same, or stays constant.

A chemical system in equilibrium is similar to cars moving back and forth between two parking lots. Let's say that there are two lots: lot R and lot P. Lot R has 3 cars in it and lot P has 6 cars in it. Every time a car from lot R leaves and moves into lot P, a car from lot P leaves and moves into lot R.



Under these conditions, the total number of cars in lot R will stay constant at 3, and the number of cars in lot P will stay constant at 6.

If the number of cars in each lot stays constant, then the ratio of cars in each lot will also be constant. If the number of cars in lot R is expressed as R, and the number of cars in lot P is expressed as P, then the ratio of P to R will equal a constant, K.

$$K = \frac{P}{R}$$

In this particular case, the value of K will always be 2 since P/R = 6/3 = 2.

For any reversible reaction at equilibrium, the ratio of products to reactants at a certain temperature will always equal a constant, K. In general,

$$K = \frac{\text{concentration of products}}{\text{concentration of reactants}}$$

Specifically, for any reversible reaction at equilibrium

$$aA + bB \rightleftarrows cC + dD$$

the equilibrium constant, Keq, is

$$Keq = \frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$$

$H_2 + I_2 \rightleftarrows 2HI$

The above reaction occurs in a container which has the following concentrations of reactants and products at equilibrium:

$[H_2] = 0.114$ M
$[I_2] = 0.114$ M
$[HI] = 0.772$ M

Find the value of Keq.

Answer

$$Keq = \frac{\text{concentration of products}}{\text{concentration of reactants}}$$

$$Keq = \frac{[HI]^2}{[H_2]\,[I_2]}$$

$$Keq = \frac{[0.772]^2}{[0.114][0.114]}$$

$$Keq = 45.9$$

At equilibrium, the value of Keq for this reaction will always be 45.9. If we know the value of Keq, we can solve for the concentration of product or reactant.

$3H_2 + N_2 \rightleftarrows 2NH_3$

The above reaction is at equilibrium and has a Keq = 6.00×10^{-2}. The concentration of H_2 is 0.250 M and that of NH_3 is 0.0500 M. Find the concentration of N_2.

Answer

$$Keq = \frac{[NH_3]^2}{[H_2]^3\,[N_2]}$$

$$6.00 \times 10^{-2} = \frac{[0.0500]^2}{[0.250]^3\,[N_2]}$$

$$[N_2] = \frac{[0.0500]^2}{[0.250]^3\,[6.00 \times 10^{-2}]}$$

$[N_2]$ = 2.67 M

$$Keq = \frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$$

If Keq > 1, then there is more product than reactant. This is because the numerator (products) in the above fraction is larger than the denominator (reactants).

If Keq < 1, then there is more reactant than product. This is because the denominator (reactants) is larger than the numerator (products).