Chemical Equilibrium

Chemical Equilibrium- the point in a reaction at which the rate of the forward reaction equals the rate of the reverse reaction (products are being formed at the same rate that they are decomposing to reactants)

Chemical Equilibrium is an actual, measurable quantity, and in order for equilibrium to be reached, the reaction must be reversible.

Calculating the Equilibrium Constant

The equilibrium constant is denoted as Keq, and is determined by comparing the concentrations of reactants and products when a reaction is at equilibrium.

$$K_{eq} = \frac{[\text{products}]}{[\text{reactants}]} = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

$$aA + bB \rightarrow cC + dD$$

As seen above, the mole amount of product/reactant is the concentration, and the coefficient of that product/reactant in the balanced chemical equation becomes the concentration's exponent.

*When calculating Keq, pure solids and liquids (denoted by a subscript of s or l) are not taken into account.

Example Chemical Equilibrium Problem

Find the Keq of the following equation:

$$2\ SO_{2(aq)} + O_{2(g)} \rightarrow 2\ SO_{3(aq)}$$

$$K_{eq} = \frac{[products]}{[reactants]} = \frac{[SO_2]^2\,[O_2]}{[SO_3]^2}$$

When no concentrations are given, as in the problem above, it suffices to write [chemical]. Once the concentrations are found or given at a later point, they can be simply plugged into the equation.

Homogeneous Equilibrium- This occurs when a reaction is at equilibrium with everything at the same phase

Heterogeneous Equilibrium- This occurs in an equilibrium system involving more than 1 phase.

Reaction Quotients

A reaction quotient is a way of comparing the progress of a reaction to its equilibrium state.

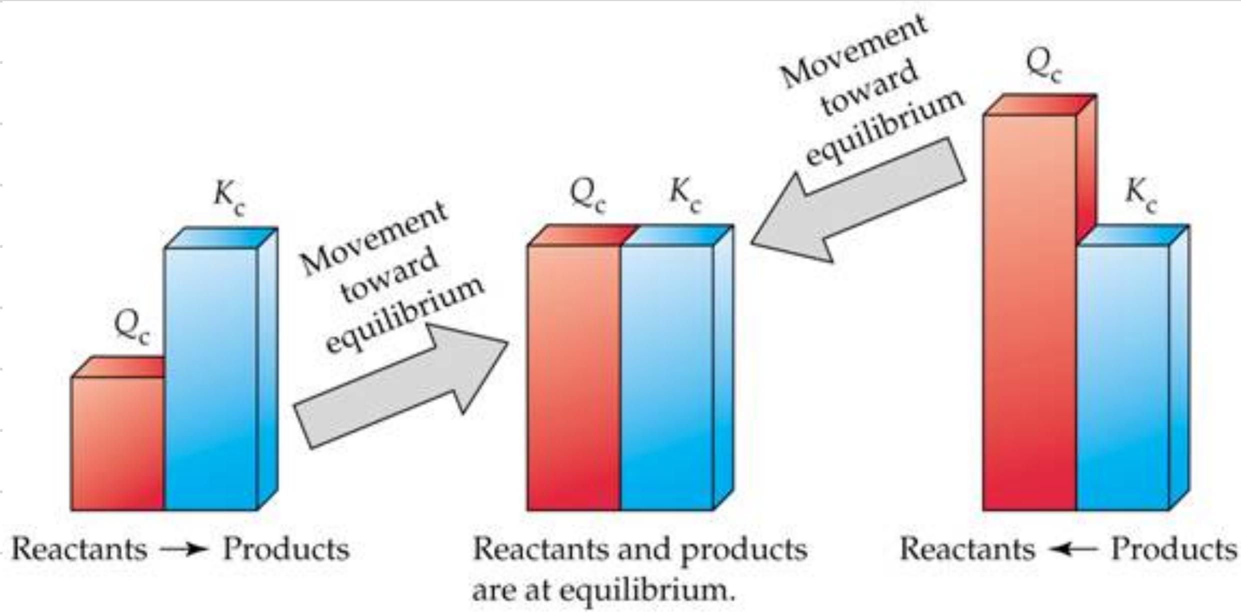
Reaction quotients (denoted by Q) are calculated the same way as a Keq: [products]/[reactants]. The reaction quotient is then compared to the Keq to determine how the reaction will proceed.

When...

Q = Keq --> the reaction is at equilibrium

Q < Keq --> the amount of products are too small compared to the amount of reactants at the time, as compared to the Keq. This means that the reaction must proceed to the right (forward reaction will continue) in order to create more products for the reaction to reach equilibrium

Q > Keq --> the amount of reactants are too small compared to the amount of products at the time, as compared to the Keq. This means that the reaction must proceed to the left (reverse reaction will occur faster) in order to create more reactants for the reaction to reach equilibrium.

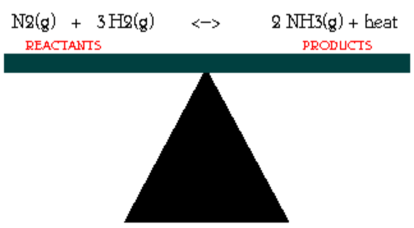


Shifting Equilibrium

Equilibrium is the state of no change. At this point, the rate of the forward reaction equals the rate of the reverse reaction. This point, however, can be changed (thus shifting the equilibrium) by adding certain stresses to a system.

Le Chatelier's Principal

Le Chatelier's Principle
"Restoring Balance"

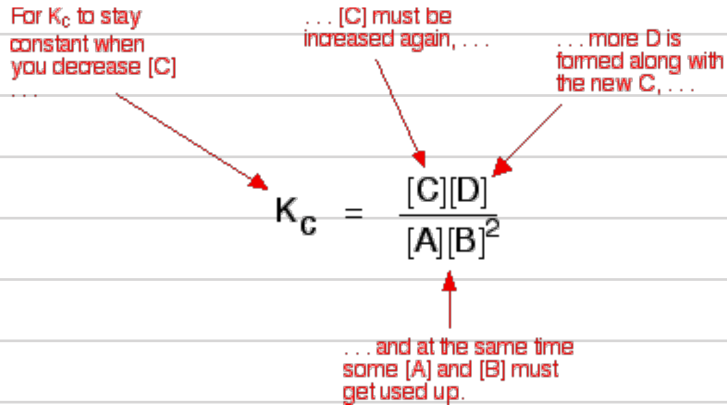


If you add more to the left side (*Reactants*), the lever will tip to the left. In order to restore balance, the system responds by making more of what is on the right (*Products*) and vice versa.

This principal basically states that a reaction will always move away from a stress in the system in order to re-establish equilbrium

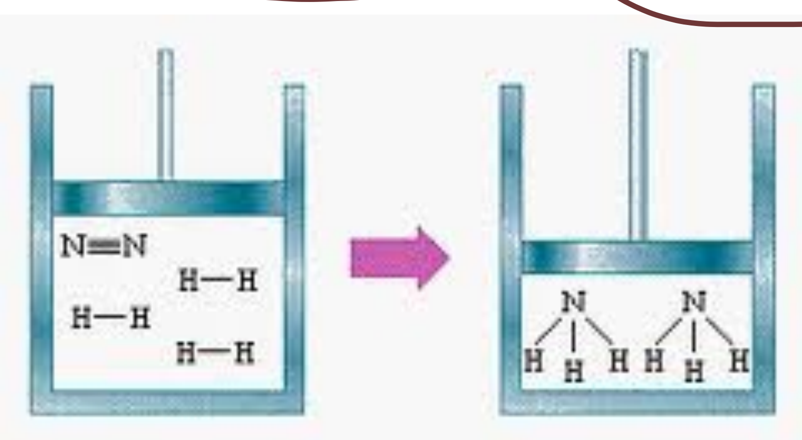
Three Factors Affecting Equilibrium

1. Concentration (add/take away)
-reactions will always shift away from the side that chemicals are added to.
-conversely, reactions will always shift toward the side that chemicals are removed from.



2. Pressure (only deals with gasses in a closed container)
-The more collisions you have, the more pressure/force is in the system. Therefore, the side with fewer molecules has less pressure (less free-floating molecules).
-Systems always move toward a decrease in pressure and away from an increase in pressure.

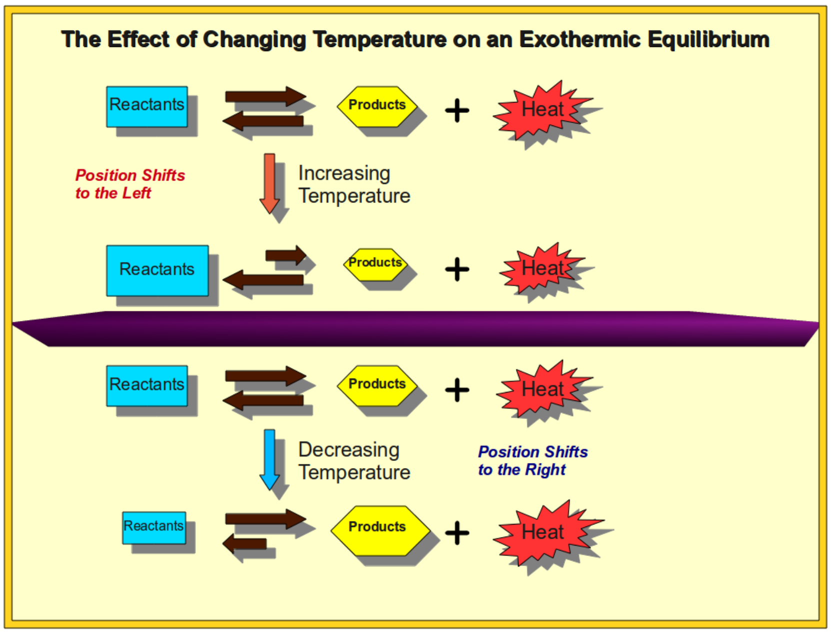
4 molecules; more pressure $N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)}$ 2 molecules; less pressure



Three Factors Affecting Equilibrium Cont.

3. Temperature (endothermic vs. exothermic)
endothermic reactions take in heat (endo = in)
exothermic reactions release heat (exo = out)
-This can also be viewed in terms of reactants as products. Endothermic reactions have heat as a reactant (it is needed to form products), whereas exothermic reactions have heat as a product (it is produced as the reactions proceeds).

Endothermic reactions proceed when heat is added.
Exothermic reactions proceed when heat is taken away.



Common Ion Effect

When you add something to an ongoing reaction that has an ion in common with the reactants or products, it increases that ion's concentration, thus inducing a stress to the reaction

Precipitation and Ksp

Precipitation reactions are the result of a double replacement reaction.
There are three indicators of a reaction reaction:
1. water (H20) is made
2. gas is released
3. a visible precipitate forms

To determine if something is a precipitate, a solubility table can be used. Alternatively, the solubility rules can be utilized.

The Solubility Rules

1. All common salts of the Group 1A elements and ammonium are soluble.
2. All common acetates and nitrates are soluble.
3. All binary compounds of Group VIIA elements (other than F) with metals are soluble except those of silver, mercury (I), and lead.
4. All sulfates are soluble except those of barium, strontium, lead, calcium, silver, and mercury(I).
5. Except for those in Rule 1, carbonates, hydroxides, oxides, and phosphates are insoluble.

Solubility Product Constant

The solubility product constant is a measure of how soluble a compound is.
It is abbreviated Ksp

$$AgCl_{(s)} \rightleftarrows Ag^{+} + Cl^{-}$$

$$K_{sp} = [Ag^{+}][Cl^{-}]$$

Since the Ksp is a measure of how soluble a compound is, when the value found is low, it means the compound is not very soluble, and when the value found is high, it means the compound is very soluble.

Since Silver Chloride is not very soluble, the Ksp for the above reaction would be low.