Chemical Reaction Equilibrium

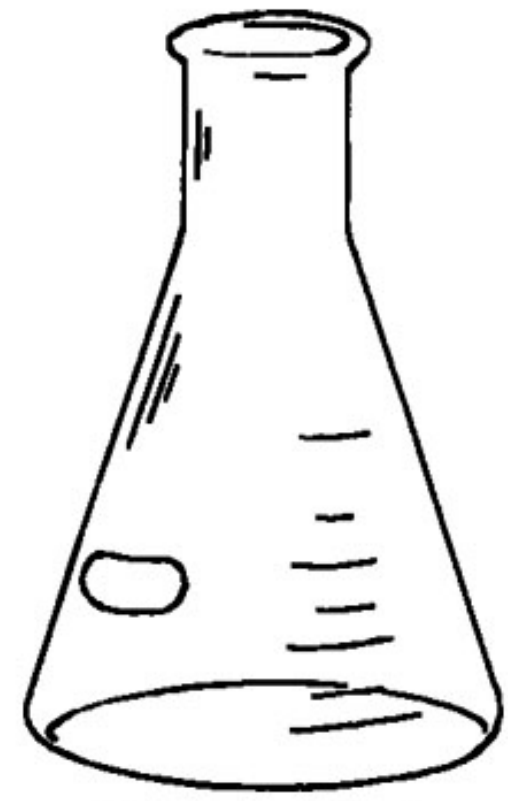
A Combination of Theories

- Chemical reaction equilibrium combines ideas from atomic theory, kinetic molecular theory, collision reaction theory and the concept of reversibility and dynamic equilibrium

Hydrogen-Iodine Reaction System

$$H_2(g) + I_2(g) \Leftrightarrow 2HI(g)$$

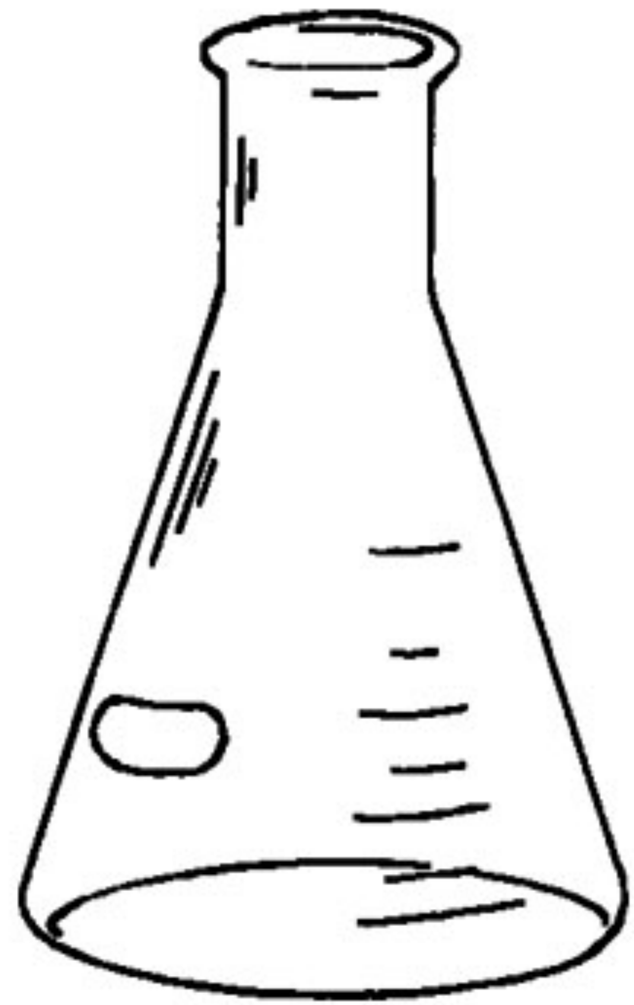
- Initially, hydrogen and iodine are placed in a flask and the iodine purple is the only visible color



Erlenmeyer Flask

$H_2(g) + I_2(g) \Leftrightarrow 2HI(g)$

- Early on, H_2 and I_2 combine to form HI faster than HI forms H_2 and I_2.
- Overall the amount of I_2 decreases so the color lightens


Erlenmeyer Flask

$H_2(g) + I_2(g) \Leftrightarrow 2HI(g)$

- At equilibrium the flask contains all 3 substances.
- The purple shows that some iodine remains
- The constancy of the color shows equilibrium is occurring
- Forward and reverse reactions are occurring at equal rates

Equilibrium

- The state in which both reactants and products are present at concentrations which have no further tendency to change with time. Usually this state results when the forward reaction proceeds at the same rate as the reverse reaction

Dynamic Equilbrium

- A dynamic equilibrium exists once a reversible reaction ceases to change its ratio of reactants and products, but substances move between the chemicals at an equal rate, meaning there is no net change

Static Equilibrium

- A system of particles is in static equilbrium when all the particles of the system are at rest and the total force on each particle is permanently zero

Equilibrium Expressions

- Use the general reaction:

$$aA + bB \Leftrightarrow cC + dD$$

A and B are reactants
C and D are products
Lower case letters are coefficients

$$K_c = \frac{[\text{products}]}{[\text{reactants}]}$$

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

Kc = equilibrium constant

- each Kc is for 1 specific temp
- all substances are assumed to be present or their concentration will be 0
- Kc may be large or small but never equal to zero

- The value of Kc depends on the temp and on large changes in the equilibrium concentration of reactants or products

- The value of Kc can be used to estimate whether reactants or products are favored at equilibrium

Quantitative Reaction

- Kc is very large (Kc > 10)
- Percent reaction is >99%
- product concentrations are greater than reactants

Favors Products

- Kc is large (Kc > 1.0)
- Percent reaction is >50%
- product concentrations are larger than reactants

Favors Reactants

- Kc is small (Kc < 1.0)
- percent reaction <50%
- reactant concentrations are larger than products

No Favor

- $K_c = 1.0$
- equilibrium contains 50% products
- percent reaction = 50%

General Rules of Kc

- Solids are omitted because concentrations don't change
- Liquids are omitted (if there is one as an aqueous solution)
- Water is not included because concentration does not change

- If there is more than one liquid, include them all in the expression
- Include all other states
- A complete description of equilibrium states includes the temp, composition and concentration of all entities

Example 1

- Write the equilibrium equation for the combustion of ethanol:

Example 2

- For the reaction of carbon and oxygen to produce carbon dioxide, the following equilibrium concentrations were measured:

[C(g)] = 0.50M **[O2(g)] = 0.80M** **[CO2(g)] = 0.30M**