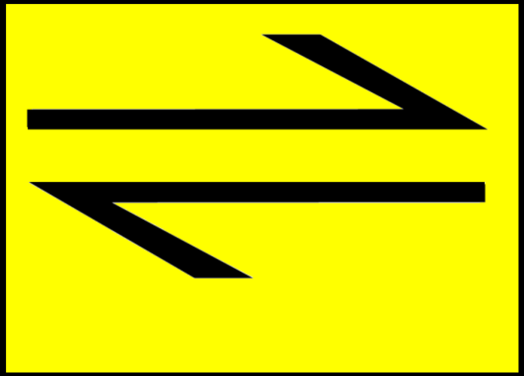
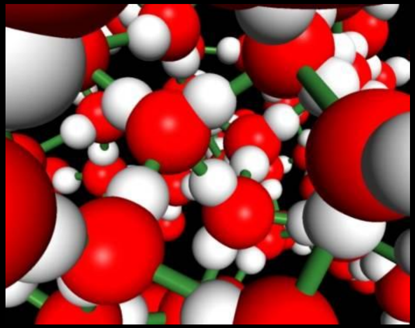
$$K = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

Equilibrium



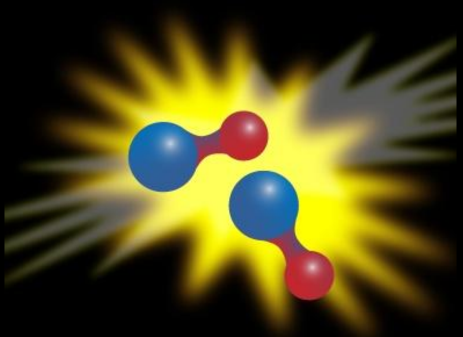


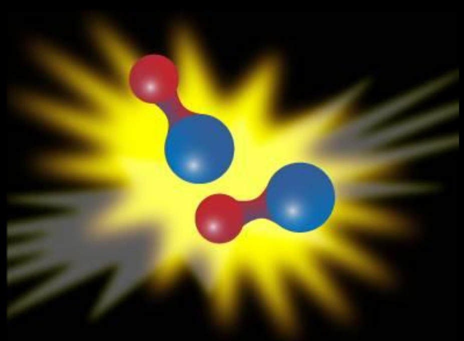
Chemical Reactions

Collision Theory:

Molecules react by colliding with each other

Collisions may rearrange electron density



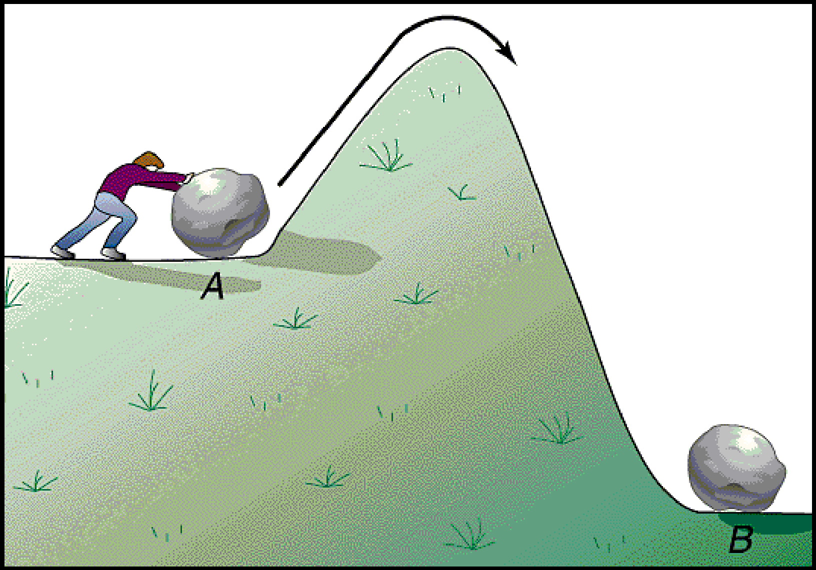


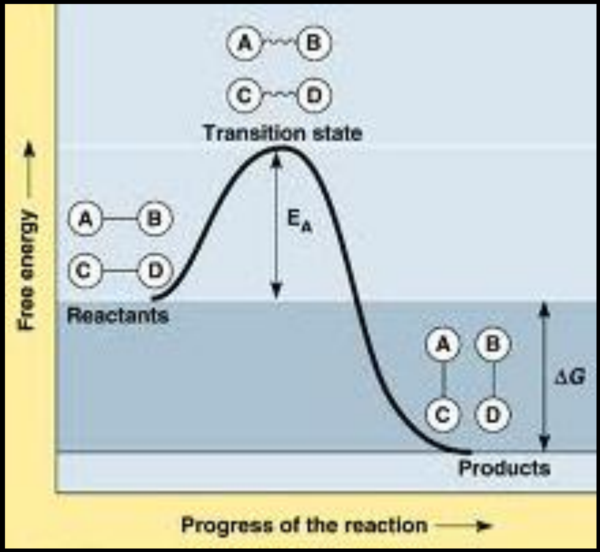
Chemical Reactions

A + B ➔ C + D Requires Activation energy (E_A)

Energy to bring molecules together

Energy to orient molecules to product geometry



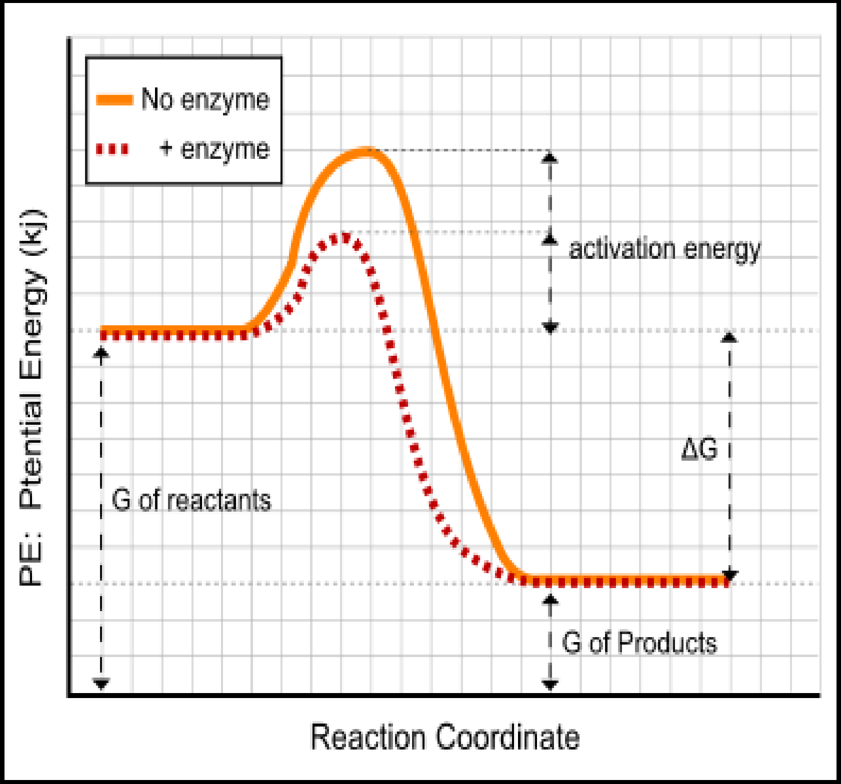


Chemical Reactions

Catalyst: speeds up a chemical reaction without being consumed

Changes rate only; equilibrium position unchanged

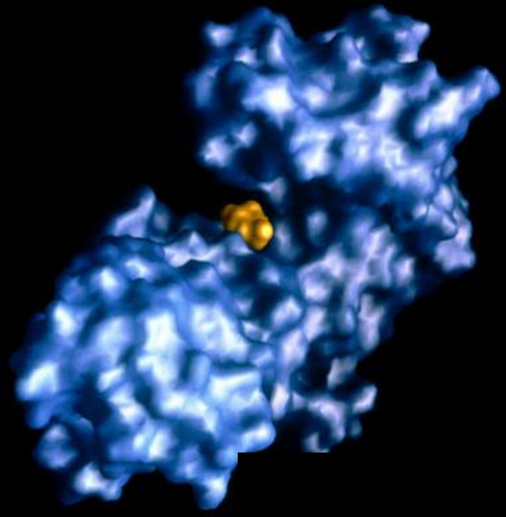
Enzymes are specialized protein catalysts



Substrate Binding Geometry

Approximates Transition State

Lowers E_A



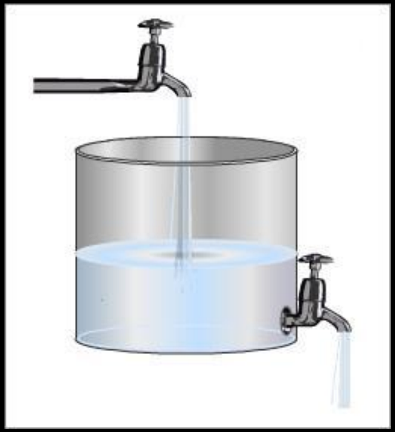
Equilibrium

Most chemical reactions are "reversible"

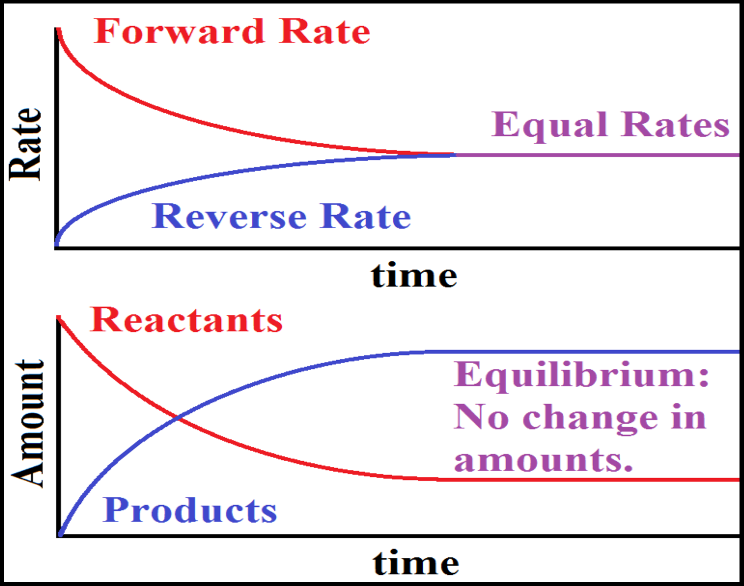
$$a\,A + b\,B \longrightarrow c\,C + d\,D$$

When forward rate = reverse rate
Overall concentrations remain constant

Equilibrium: Concentrations of all components stable



Steady State



LPT

Law of Equilibrium

For chemical reaction

$$a\,A + b\,B \longrightarrow c\,C + d\,D$$

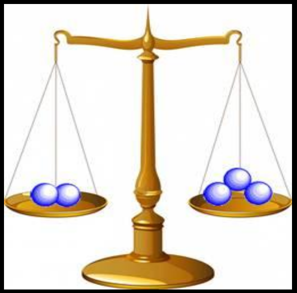
K = equilibrium constant:

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

$$K = \frac{\text{Products}}{\text{Reactants}}$$

LPT

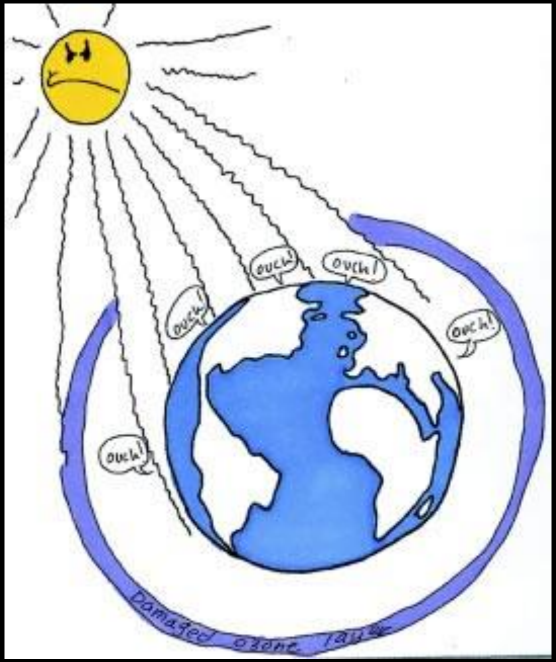
Equilibrium

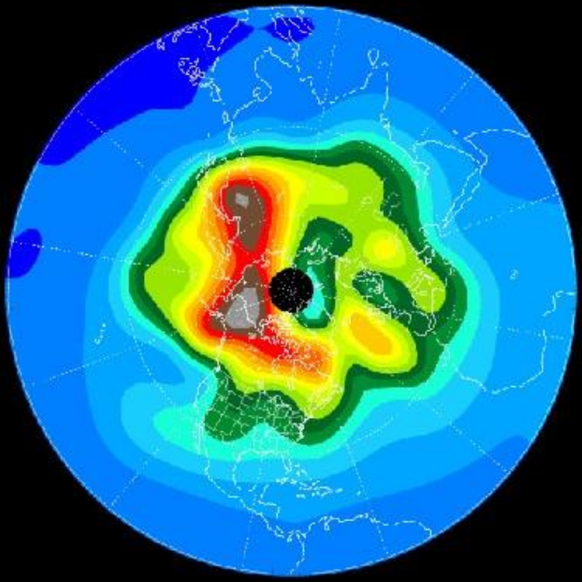


For the conversion of oxygen to ozone:

$$3\ O_{2(g)} \longrightarrow 2\ O_{3(g)}$$

$$K = \frac{[O_3]^2}{[O_2]^3}$$





LPT

Equilibrium

Ammonia gas reacts with oxygen gas in a closed container to produce nitrogen monoxide gas and water vapor. Write the balanced equation and the equilibrium expression:

Write the equation:

$$NH_{3(g)} + O_{2(g)} \longrightarrow NO_{(g)} + H_2O_{(g)}$$

Balance :

$$4\ NH_{3(g)} + 5\ O_{2(g)} \longrightarrow 4\ NO_{(g)} + 6\ H_2O_{(g)}$$

Write equilibrium expression:

$$K = \frac{[NO]^4[H_2O]^6}{[NH_3]^4[O_2]^5}$$

LPT

Equilibrium

Nitrogen gas in a closed container reacts with hydrogen gas to produce ammonia gas. Write the balanced equation and the equilibrium expression:

Write the equation:

$$N_{2\,(g)} + H_{2\,(g)} \longrightarrow NH_{3\,(g)}$$

Balance :

$$N_{2\,(g)} + 3\,H_{2\,(g)} \longrightarrow 2\,NH_{3\,(g)}$$

Write equilibrium expression:

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

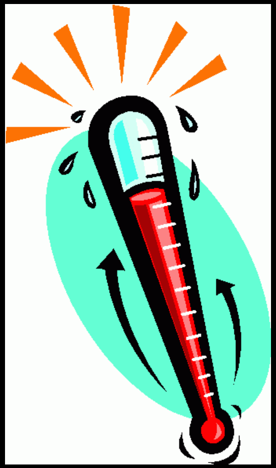
LPT

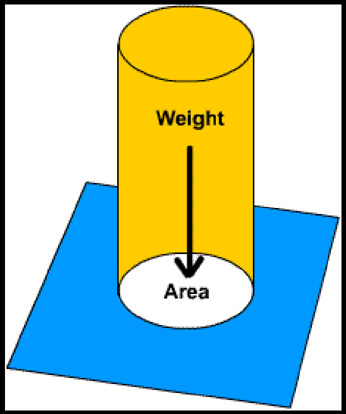
Equilibrium

Equilibrium Position: A single set of concentration values

Used to calculate K (equilibrium constant)

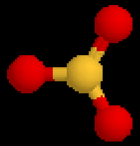
K value may change with alterations of temperature & pressure





LPT

Equilibrium



For: $2\ SO_{2\ (g)} + O_{2\ (g)} \longrightarrow 2\ SO_{3\ (g)}$

Equilibrium Position Observed at 600 °C:

$[SO_2] = 0.590\ M$

$[O_2] = 0.045\ M$

$[SO_3] = 0.260\ M$

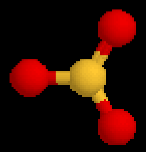
$$K = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

$$K = \frac{(0.260\ M)^2}{(0.590\ M)^2(0.045\ M)}$$

$$K = 4.32\ M^{-1}$$

LPT

Equilibrium



For: $2\ SO_{2\,(g)} + O_{2\,(g)} \longrightarrow 2\ SO_{3\,(g)}$

Given K, 4.32 M^{-1}

Equilibrium Positions at same T & P can be calculated:

For $[SO_2]$ = 1.50 M & $[O_2]$ = 1.25 M, Calculate $[SO_3]$

$$K = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

$$4.32\ M^{-1} = \frac{(x)^2}{(1.50\ M)^2(1.25\ M)}$$

$$(4.32\ M^{-1})\ (1.50\ M)^2(1.25\ M) = x^2$$

$$12.15\ M^2 = x^2$$

$$x = [SO_3] = 3.49\ M$$

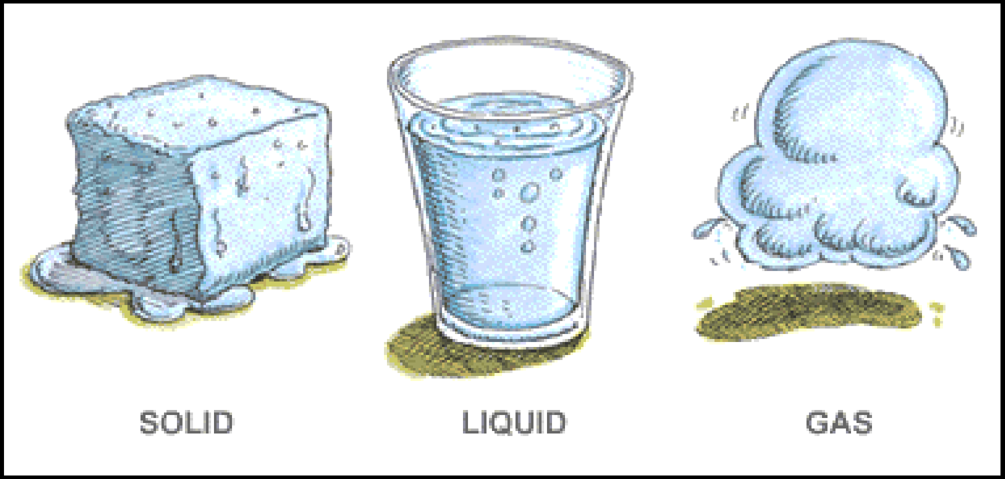
Solve with √ Calculator Function

Equilibrium

Homogeneous: All components in same phase

Heterogeneous: Components in different phases

Solids and Liquids have no influence on K
(Not involved in equilibrium equation)



LPT

Heterogeneous Equilibrium

For: $CaCO_{3\,(s)} \longrightarrow CaO_{\,(s)} + CO_{2\,(g)}$

$$K = \frac{[CO_2][CaO]}{[CaCO_3]}$$

But, $CaCO_3$ & CaO are solids (Constant Concentration):

$$K = \frac{[CO_2][Constant]}{[Constant]}$$

All constants combined:

$$K = [CO_2]$$

Heterogeneous Equilibrium

Equilibrium Expressions (K)

Depend only on the [species in solutions] and [gas phase]

Pure Solids or Pure Liquids Not Considered

LPT

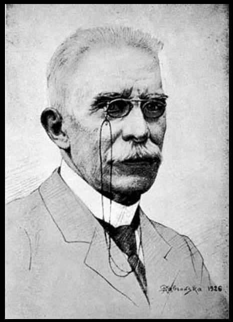
Heterogeneous Equilibrium

For: $NH_4NO_{3\,(s)} \longrightarrow N_2O_{\,(g)} + 2\,H_2O_{\,(g)}$

$$K = [N_2O][H_2O]^2$$

For: $CO_{2\,(g)} + MgO_{\,(s)} \longrightarrow MgCO_{3\,(s)}$

$$K = \frac{1}{[CO_2]}$$



Le Châtelier's Principle

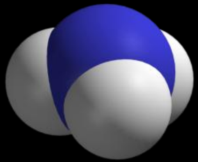
If a change is imposed on a system at equilibrium, the position of the equilibrium shifts to reduce the effect

Example - Changing Concentration:

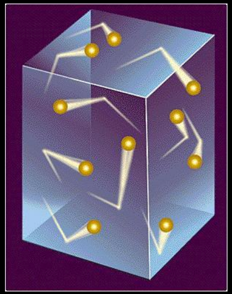
For: $3\ H_{2\,(g)} + N_{2\,(g)} \rightleftharpoons 2\ NH_{3\,(g)}$

Increasing $[N_2]$

$$3\ H_{2\,(g)} + N_{2\,(g)} \rightleftharpoons 2\ NH_{3\,(g)}$$



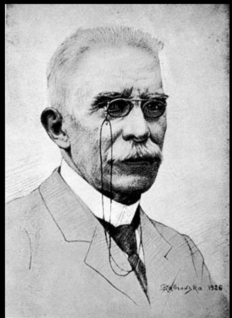
Reaction *shifts* to right



Increasing $[NH_3]$

$$3\ H_{2\,(g)} + N_{2\,(g)} \rightleftharpoons 2\ NH_{3\,(g)}$$

Reaction *shifts* to left



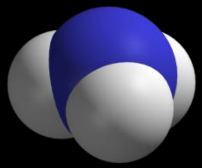
Le Châtelier's Principle

A change imposed on a system at equilibrium will shift equilibrium position to reduce the effect

Example - Changing Volume (Pressure):

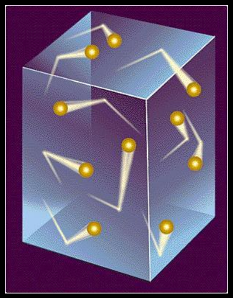
For: $3\ H_{2\,(g)} + N_{2\,(g)} \rightleftharpoons 2\ NH_{3\,(g)}$

Increasing Pressure (Lowers Volume)



$$3\ H_{2\,(g)} + N_{2\,(g)} \rightleftharpoons 2\ NH_{3\,(g)}$$

Reaction *shifts* to right (less molecules)

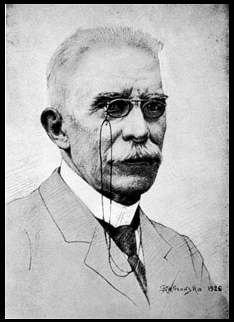


Increasing Volume (Lowers Pressure)

$$3\ H_{2\,(g)} + N_{2\,(g)} \rightleftharpoons 2\ NH_{3\,(g)}$$

Reaction *shifts* to left (more molecules)

LPT



Le Châtelier's Principle

If a change imposed on a system at equilibrium, the position of the equilibrium shifts to reduce the effect

Example - Changing Volume (Pressure)

For: $CaCO_{3\,(s)} \rightleftarrows CaO_{(s)} + CO_{2\,(g)}$

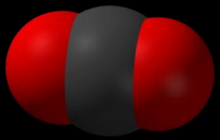
Increasing Volume (Decreasing Pressure)

$$CaCO_{3\,(s)} \rightleftarrows CaO_{(s)} + CO_{2\,(g)}$$

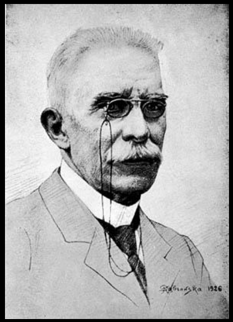
Reaction *shifts* to right (more space)

Decreasing Volume (Increasing Pressure)

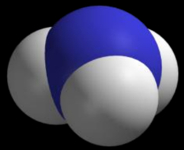
$$CaCO_{3\,(s)} \rightleftarrows CaO_{(s)} + CO_{2\,(g)}$$



Reaction *shifts* to left (less space)



Le Châtelier’s Principle



If a change imposed on a system at equilibrium, the position of the equilibrium shifts to reduce the effect

Example - Changing Temperature:

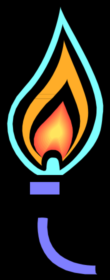
For: $3\ H_{2\,(g)} + N_{2\,(g)} \rightleftharpoons 2\ NH_{3\,(g)} + 92\ kJ$

Decreasing Temperature

$$3\ H_{2\,(g)} + N_{2\,(g)} \rightleftharpoons 2\ NH_{3\,(g)} + 92\ kJ$$

Reaction *shifts* to right (produce more product)

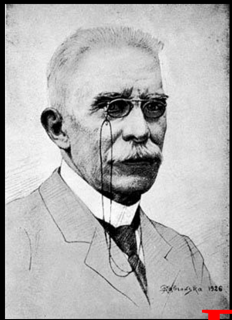
Increasing Temperature



$$3\ H_{2\,(g)} + N_{2\,(g)} \rightleftharpoons 2\ NH_{3\,(g)} + 92\ kJ$$

Reaction *shifts* to left (consider heat a product)

LPT



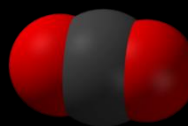
Le Châtelier's Principle

If a change imposed on a system at equilibrium, the position of the equilibrium shifts to reduce the effect

Example - Changing Temperature:

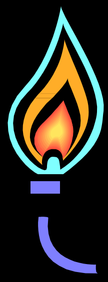
For: $CaCO_{3\,(s)} + 176.8\ kJ \rightleftharpoons CaO_{\,(s)} + CO_{2\,(g)}$

Increasing Temperature



$$CaCO_{3\,(s)} + 176.8\ kJ \rightleftharpoons CaO_{\,(s)} + CO_{2\,(g)}$$

Reaction *shifts* to right (consider heat a reactant)



Decreasing Temperature

$$CaCO_{3\,(s)} + 176.8\ kJ \rightleftharpoons CaO_{\,(s)} + CO_{2\,(g)}$$

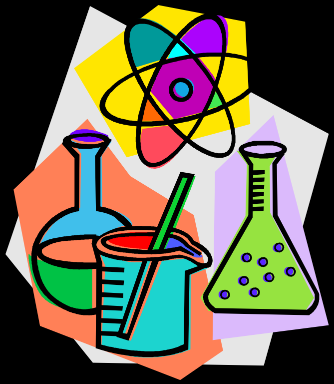
Reaction *shifts* to left (consider heat a reactant)

Equilibrium

Extent of reaction:

$K < 1.00$ Reactants Dominate

$K > 1.00$ Products Dominate


Chemical manufacturing and research strive to "drive reactions to the right"

Le Châtelier’s Principle

Driving Reaction to the Right

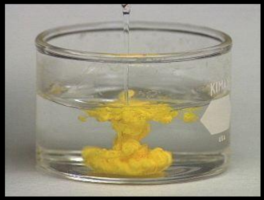
$\rightleftharpoons$

Industrial Tactic: Promote Product Formation

By Removing products as they form

LPT

Solubility Product (K_{sp})



For Dissociation of an ionic compound:

$$A_bB_{a\ (s)} \rightleftarrows b\,A^{+}_{(ag)} + a\,B^{-}_{(aq)}$$

The Equilibrium Expression:

$$K = \frac{[A^+]^b\,[B^-]^a}{[AB]}$$

For Saturated Solution [AB] (solid) ignored:

$$K_{sp} = [A^+]^b\ [B^-]^a$$

When K_{sp} exceeded, precipitation must occur

LPT

Solubility Product (K_{sp})

Copper (I) bromide has a solubility of 2.0×10^{-4} M at 25 °C. Calculate the K_{sp} for this compound.

$$CuBr \rightleftharpoons Cu^{+} + Br^{-}$$

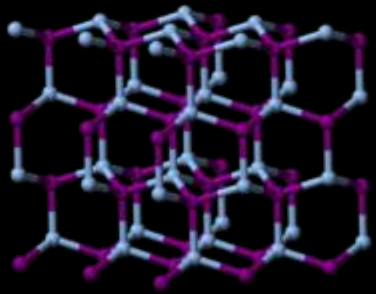
$$K_{sp} = [2.0 \times 10^{-4}]\,[2.0 \times 10^{-4}]$$

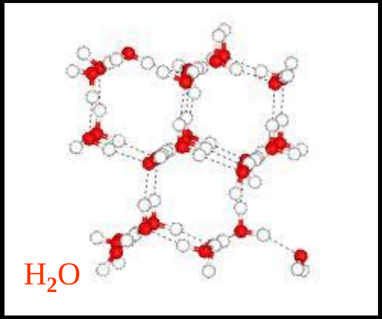
$$K_{sp} = 4.00 \times 10^{-8}$$

Solubility Product (K_{sp})

Calculate the solubility of AgI ($K_{sp} = 1.5 \times 10^{-16}$) at 25 °C

NaI





$$AgI \rightleftharpoons Ag^+ + I^-$$

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

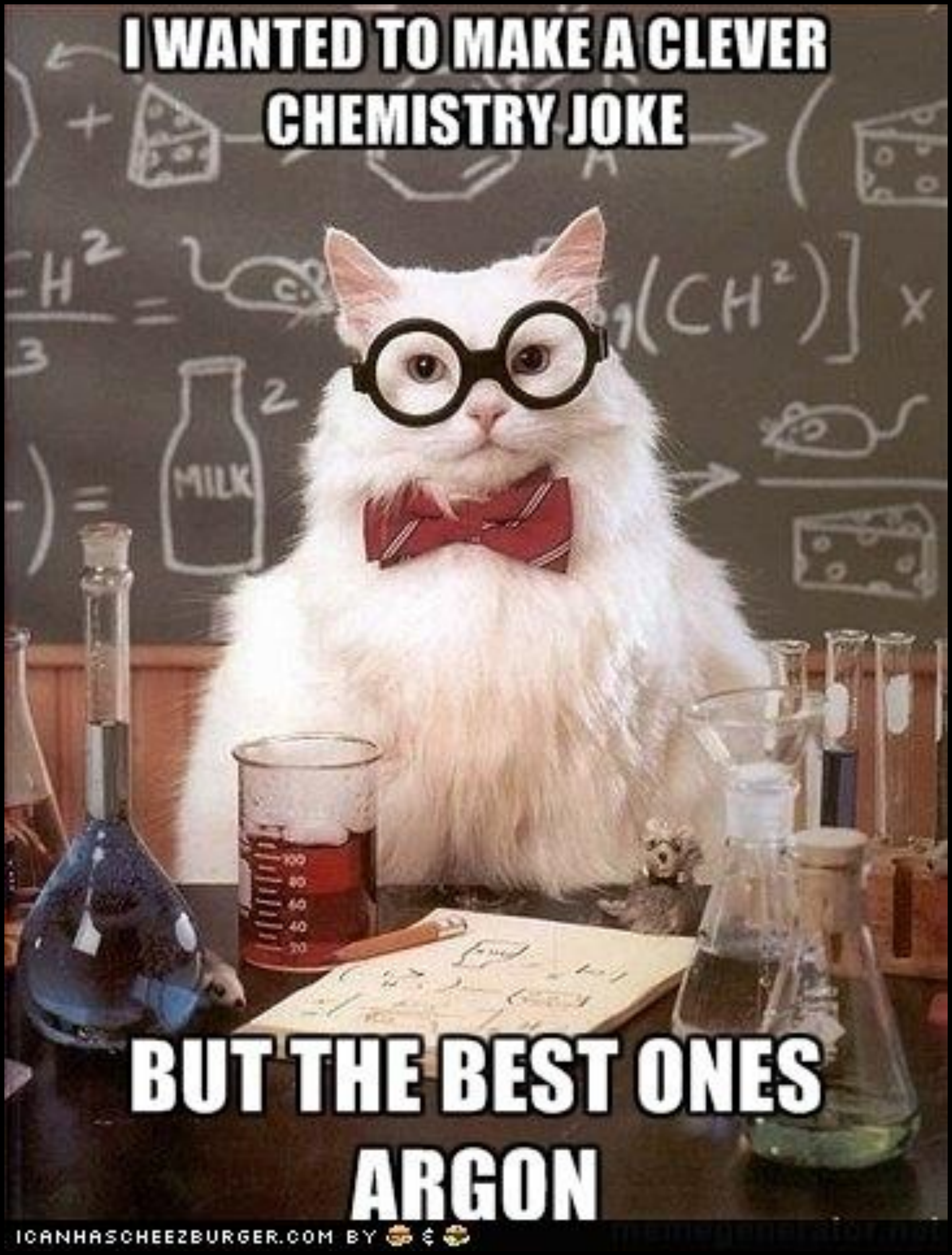
$$1.5 \times 10^{-16} = x^2$$

$$x = \sqrt{1.5 \times 10^{-16}\ M^2}$$

$$x = 1.2 \times 10^{-8}\ M$$

Solve with √ Calculator Function

AgI used to "Seed" Clouds to induce rain formation


I WANTED TO MAKE A CLEVER CHEMISTRY JOKE
BUT THE BEST ONES ARGON
MILK
ICANHASCHEEZBURGER.COM BY