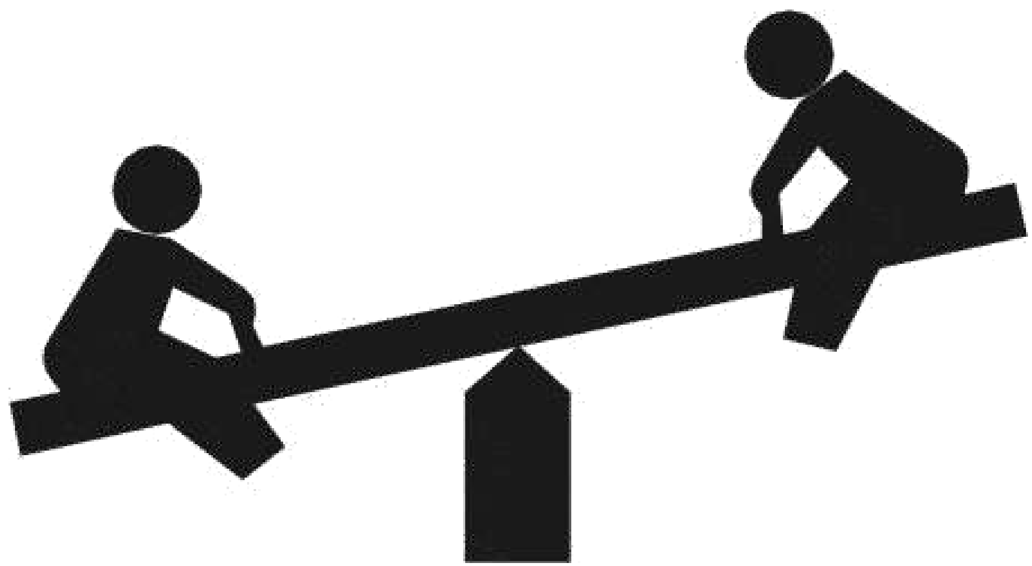
Unit 10
Equilibrium & Kinetics

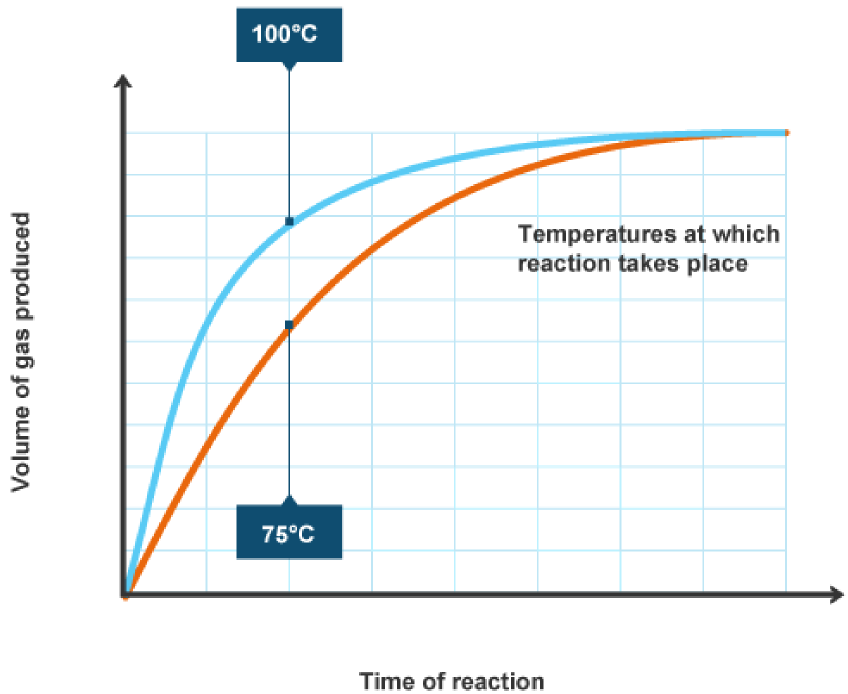


Reaction Kinetics

- Kinetics is the study of reaction rates.
- Several factors affect reaction rates including: temperature, concentration, surface area, and the presence of a catalyst.
- Reaction rates/kinetics are affected by activation energy, catalysis, and the degree of randomness (entropy).
- Catalysts decrease the amount of activation energy needed.

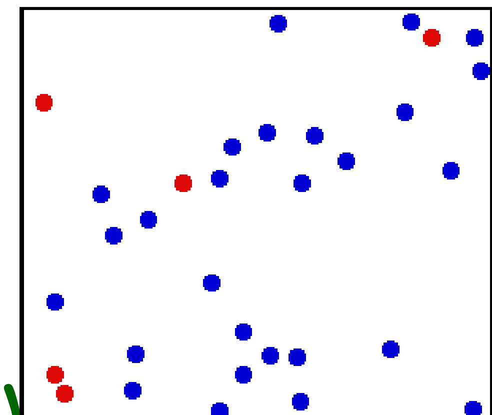
Temperature & Reaction Rates

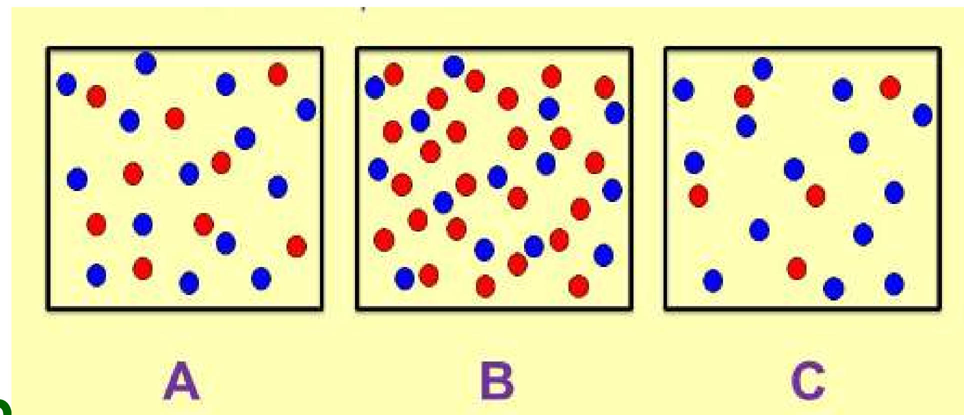
- Increasing the temperature increases the rate of a reaction because it produces more kinetic energy and increases rate of collisions.



Concentration & Reaction Rates

- Increasing the concentration of reactants will increase the rate of reaction because more molecules form more collisions.



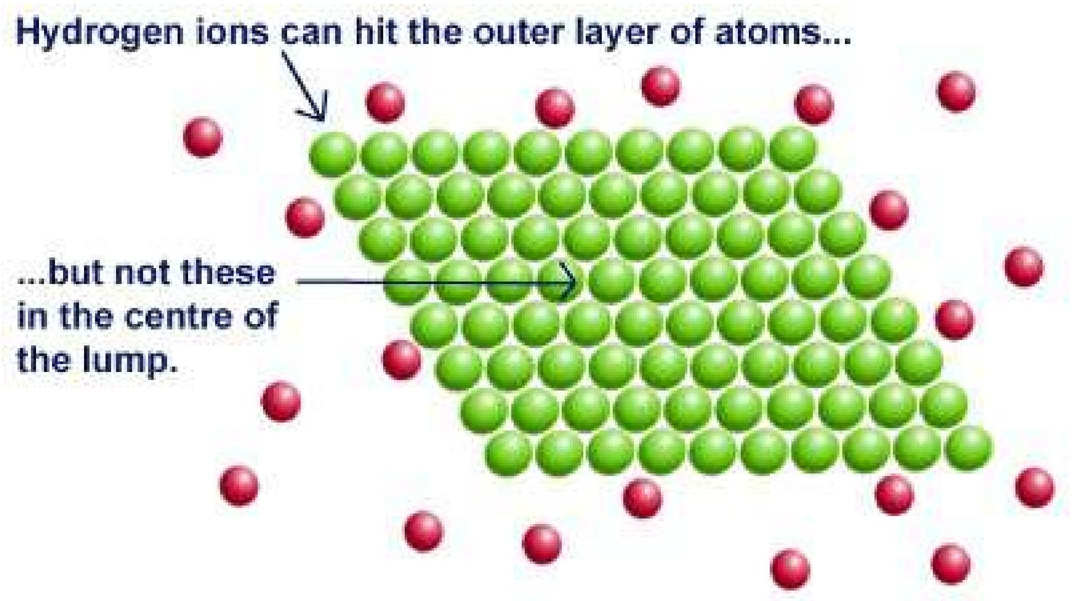


Which box will produce the most product? Why?

B Because it has the most particles.

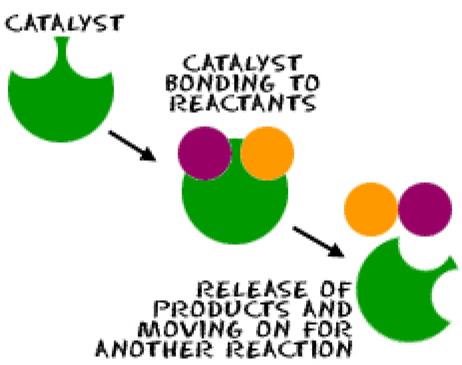
Surface Area & Reaction Rates

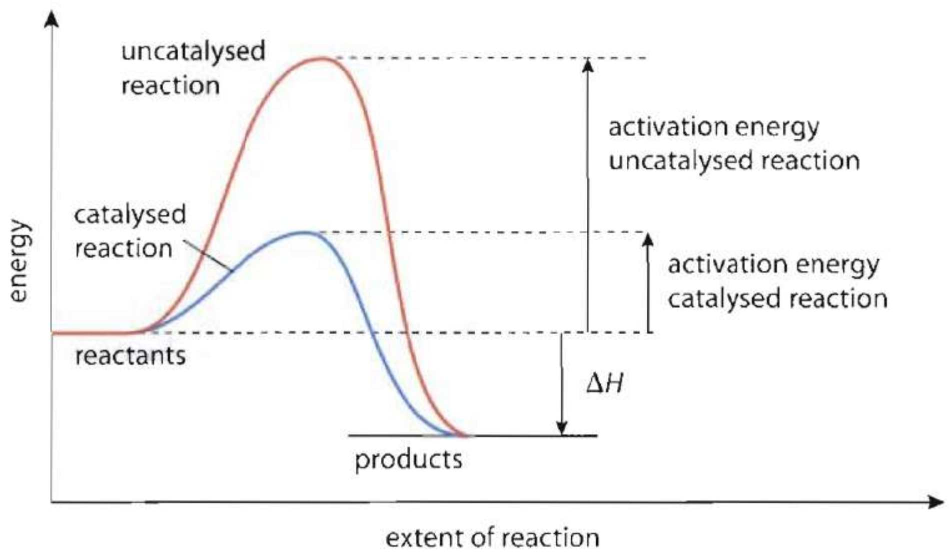
- Increasing the surface area of the reactants increases the rate of a reaction because there are more opportunities to create new bonds.



Catalysts & Reaction Rates

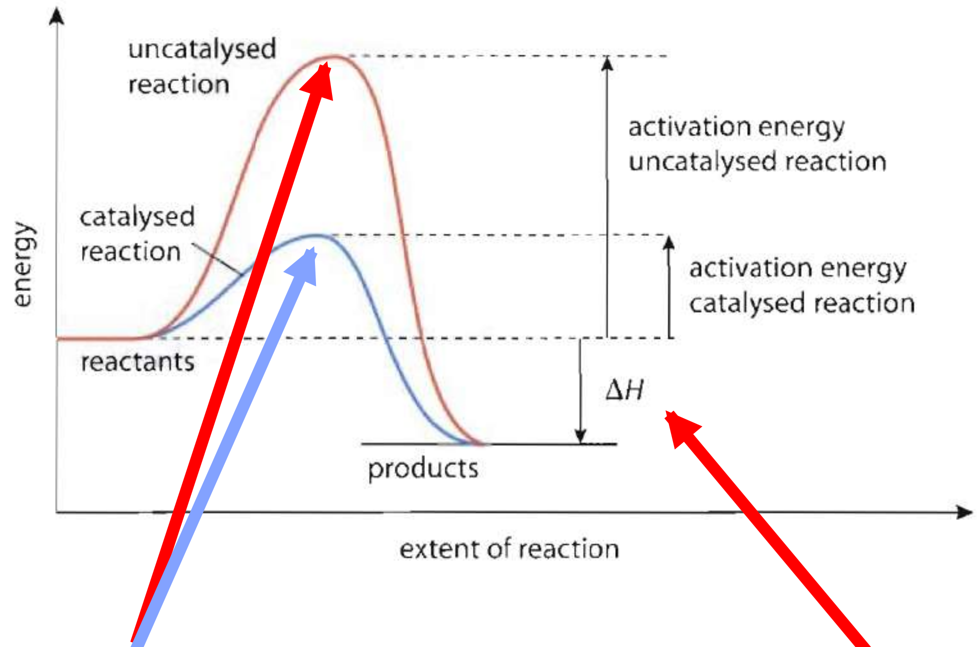
- *A* catalyst lowers the activation energy of a reaction by bringing the reactants together.
- *A* catalyst is **NOT** a reactant or product, because it is chemically unchanged at the end of the reaction.





Catalysts & Reaction Rates

Reactants
Starting ingredients



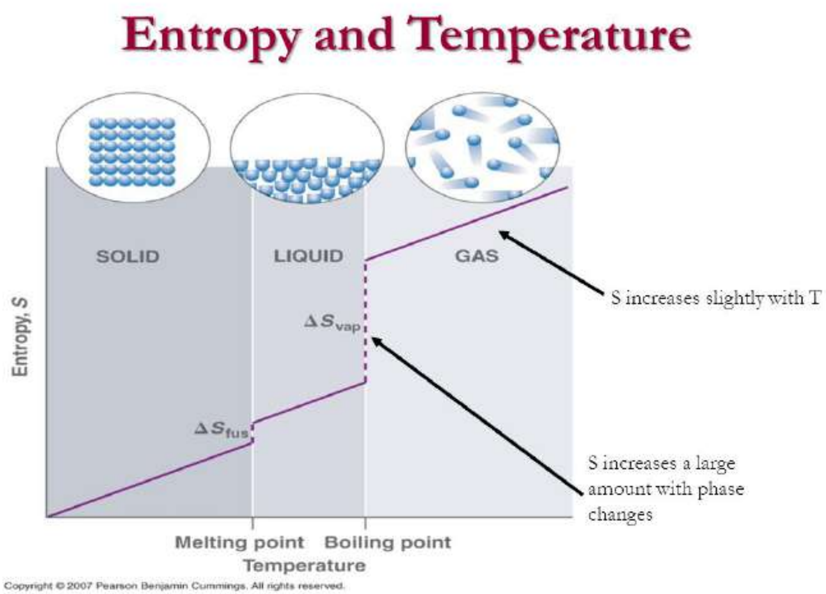
Products
Final ingredients

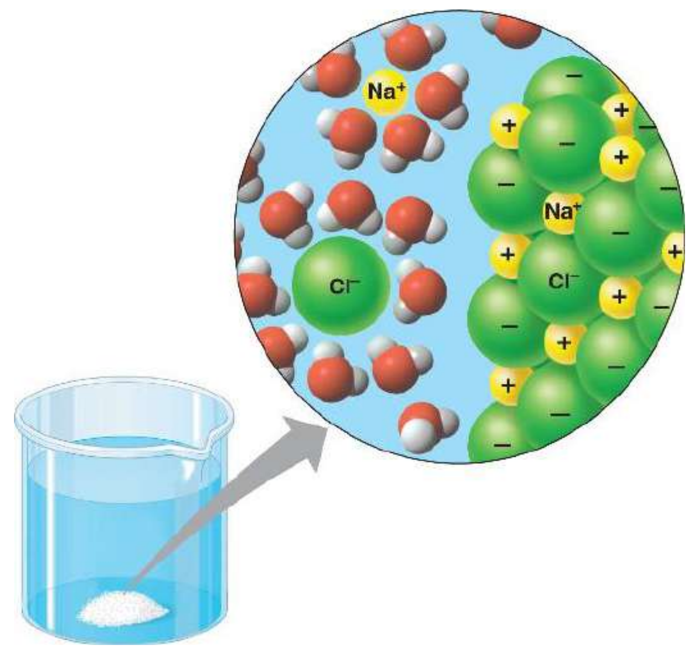
Activation Energy= the amount of energy required to break the bonds between atoms

ΔH = Heat of Reaction; called Enthalpy; equal to Product's PE minus Reactant's PE

Entropy & Reaction Rates

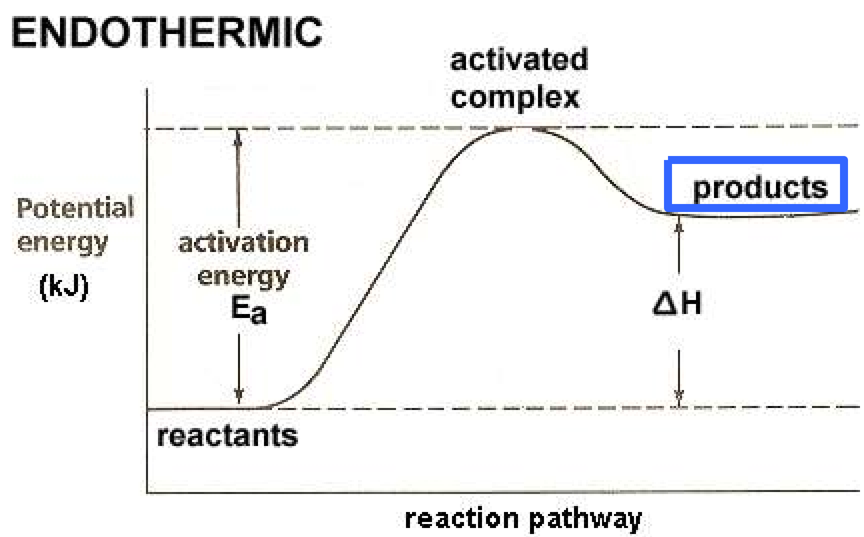
- **Entropy (ΔS) is a measure of the randomness or disorder of a substance.**
- **Gases and Aqueous ions have the most entropy.**





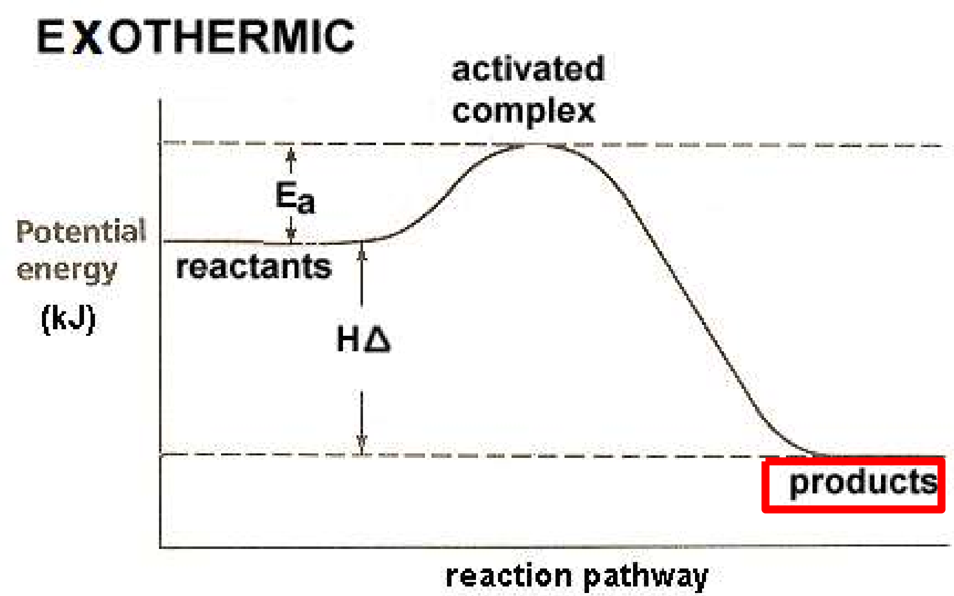
Endothermic Reactions

- Endothermic reactions absorb heat energy.
- Reactants + Energy (kJ) → Products
- Energy is considered a reactant.
- ΔH is positive
- ΔH = P - R
- Large Ea
- Feels cold
- ΔH = Enthalpy



Exothermic Reactions

- Exothermic reactions release heat energy.
- Reactants   Products + Energy (kJ)
- Energy is considered a product.
- ΔH is negative
- ΔH = P - R
- Small Ea
- Feels hot
- ΔH = Enthalpy



Chemical Equilibrium

Reversible Reactions:

A chemical reaction in which the products can react to re-form the reactants

Chemical Equilibrium:

When the rate of the forward reaction equals the rate of the reverse reaction and the concentration of products and reactants remains unchanged

$$2HgO(s) \leftrightarrows 2Hg(l) + O_2(g)$$

Arrows going both directions ($\leftrightarrows$) indicates equilibrium in a chemical equation

Equilibrium Constant

- The Equilibrium Constant (Keq) shows whether the reaction favors products or reactants.

$$aA + bB \rightleftharpoons cC + dD$$

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

Temperature, Pressure, and Concentration can effect Keq.

- If Keq > 1, then reaction favors products
- If Keq = 1, then reaction is at equilibrium
- If Keq < 1, then reaction favors reactants

Le Chatelier's Principle

When a system at equilibrium is placed under stress, the system will undergo a change in such a way as to relieve that stress.

When you take something away from a system at equilibrium, the system shifts in such a way as to replace what you've taken away.

Henry Le Chatelier

When you add something to a system at equilibrium, the system shifts in such a way as to use up what you've added.

Le Chatelier's Principle for an

Endothermic Reaction

Adding heat shifts towards products

Removing heat shifts towards reactants

$$\text{Heat} + Co(H_2O)_6^{2+}(aq) + 4\,Cl^-(aq) \rightleftharpoons CoCl_4^{2-}(aq) + 6\,H_2O(l)$$

Pink Blue

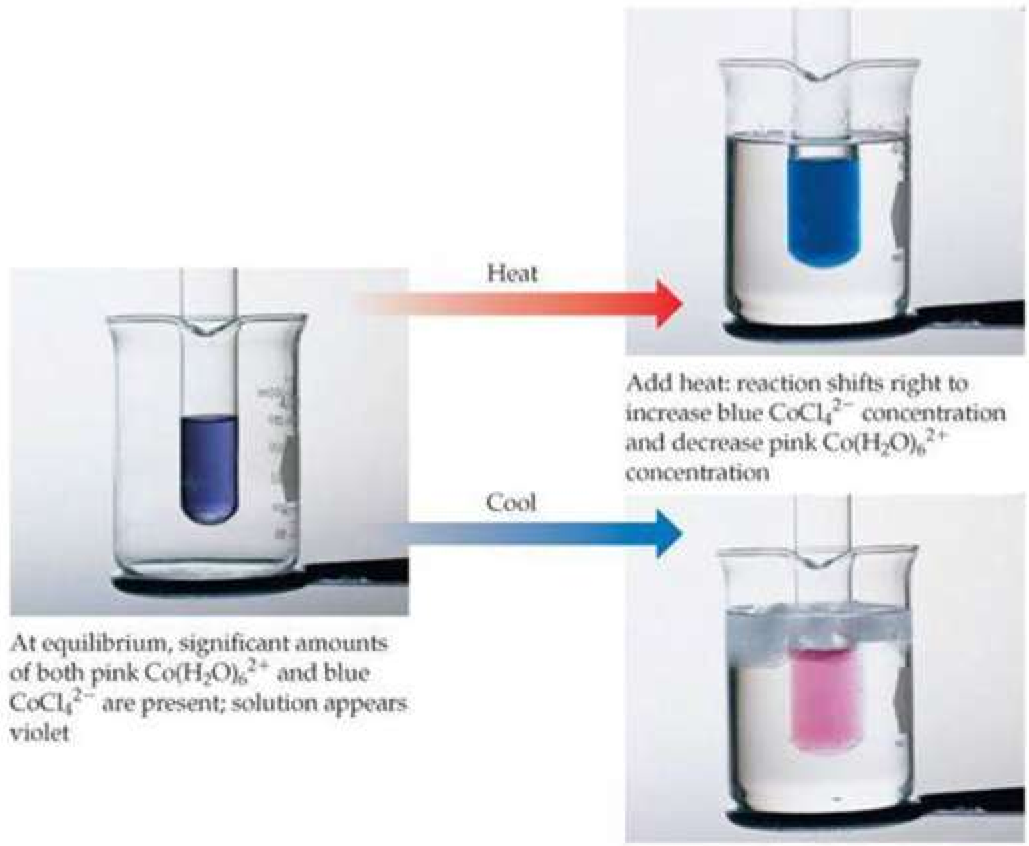


FIGURE 15.13 Temperature and Le Châtelier's principle.

Le Chatelier Example #1

A closed container of ice and water at equilibrium. The temperature is raised.

Ice + Energy ⇆ Water

The equilibrium of the system shifts to the __right__ to use up the added energy.

(Favors products and forward reaction)

Le Chatelier Example #2

A closed container of N_2O_4 and NO_2 at equilibrium. NO_2 is added to the container.

$$N_2O_4\,(g) + \text{Energy} \leftrightarrows 2\,NO_2\,(g)$$

The equilibrium of the system shifts to the __left__ to use up the added NO_2.

(Favors reactants and reverse reaction)

Le Chatelier Example #3

A closed container of water and its vapor at equilibrium. Vapor is removed from the system.

water + Energy ⇆ vapor

The equilibrium of the system shifts to the __right__ to replace the vapor.

(Favors products and forward reaction)

Le Chatelier Example #4

A closed container of N_2O_4 and NO_2 at equilibrium. The pressure is increased.

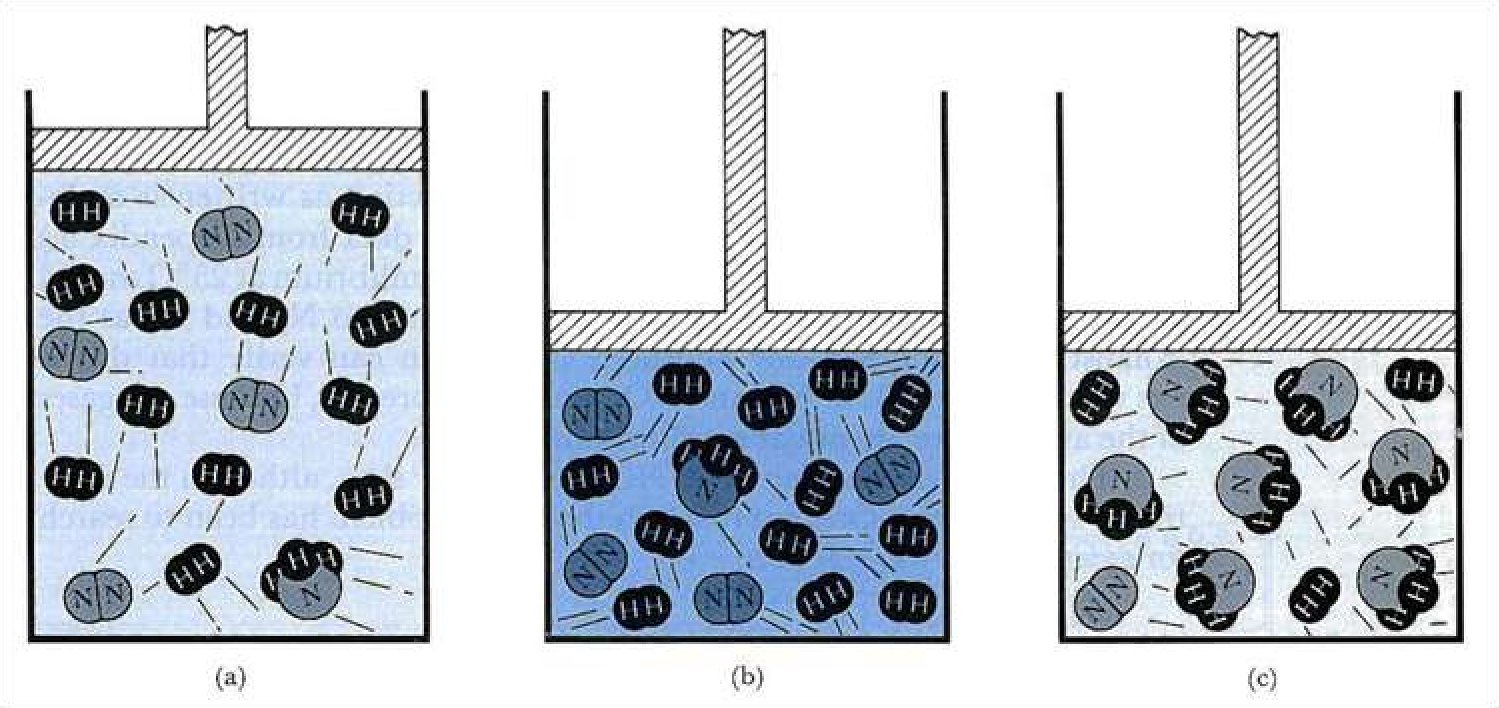
$$\longleftarrow$$

$$1\ N_2O_4\ (g)\ +\ \text{Energy}\ \leftrightarrows\ 2\ NO_2\ (g)$$

The equilibrium of the system shifts to the ___left___ to lower the pressure, because there are fewer moles of gas on that side of the equation.

(Favors reactants and reverse reaction)

High pressure favors fewer moles



$1\ N_2\ (g) + 3\ H_2\ (g) \quad 2\ NH_3\ (g)$

Pure Liquids and Solids don't effect equilibrium

Heterogeneous Equilibria

- The position of a heterogeneous equilibrium does not depend on the amounts of pure solids or liquids present

Write the equilibrium expression for the reaction:

$$PCl_5(s) \leftrightarrows PCl_3(l) + Cl_2(g)$$

Pure solid (PCl_5)

Pure liquid (PCl_3)

$$\therefore K = [Cl_2]$$

$$\therefore K_p = P_{Cl_2}$$