Reaction Rates and Equilibrium

Rates of Reaction

Essential Question:

How is the rate of a chemical change expressed, and what four factors influence the rate of a chemical reaction?

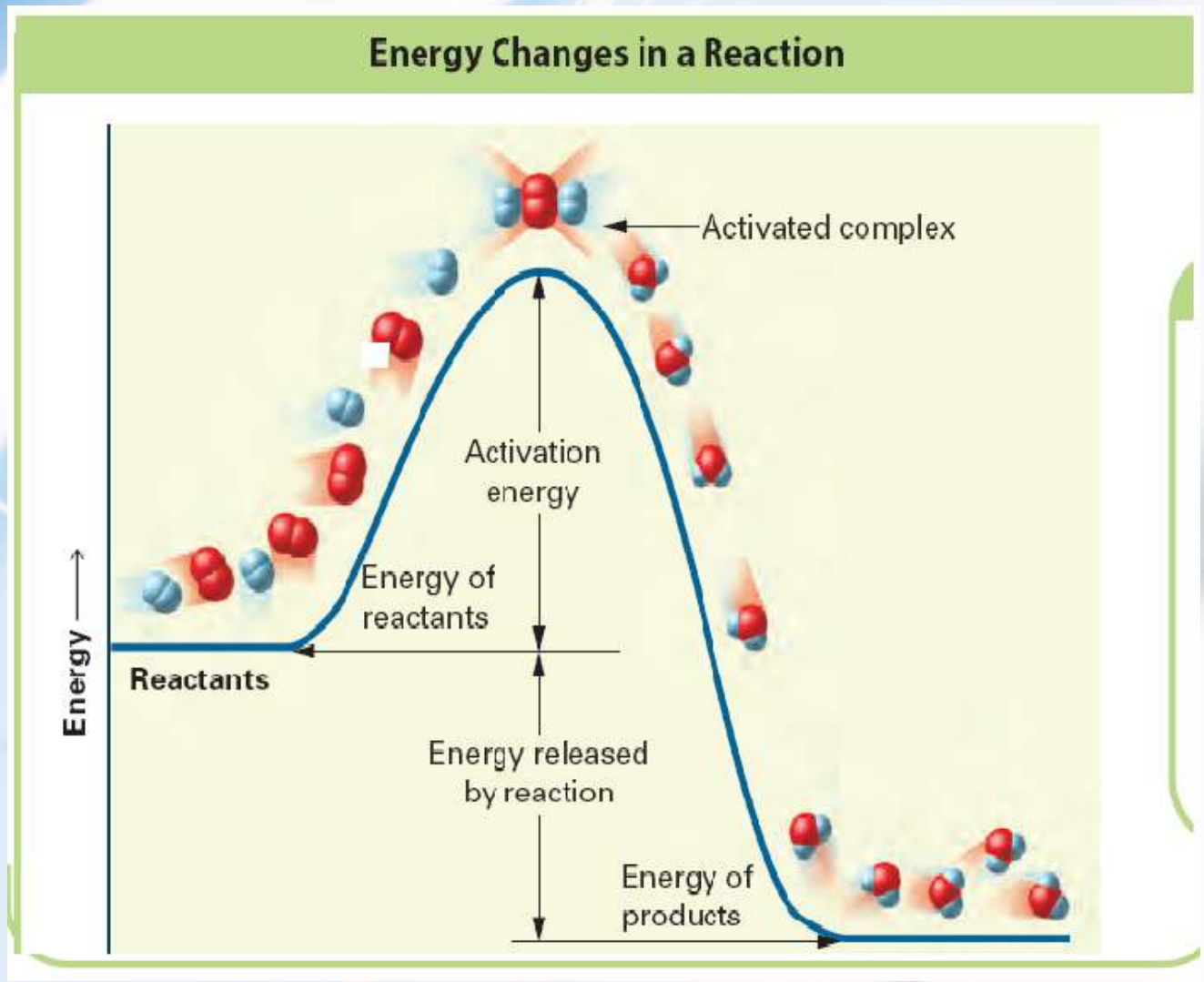
Reaction Rates

- The speed of chemical reactions can vary from instantaneous to extremely slow.
- A rate is a measure of the speed of any change per interval time.
- Reaction rate = amount of reactant changing per unit time.

Collision Theory

- Particles react when they collide with one another.
- The collision must have sufficient kinetic energy to break existing bonds.
- This minimum energy is called activation energy.

Energy Diagrams



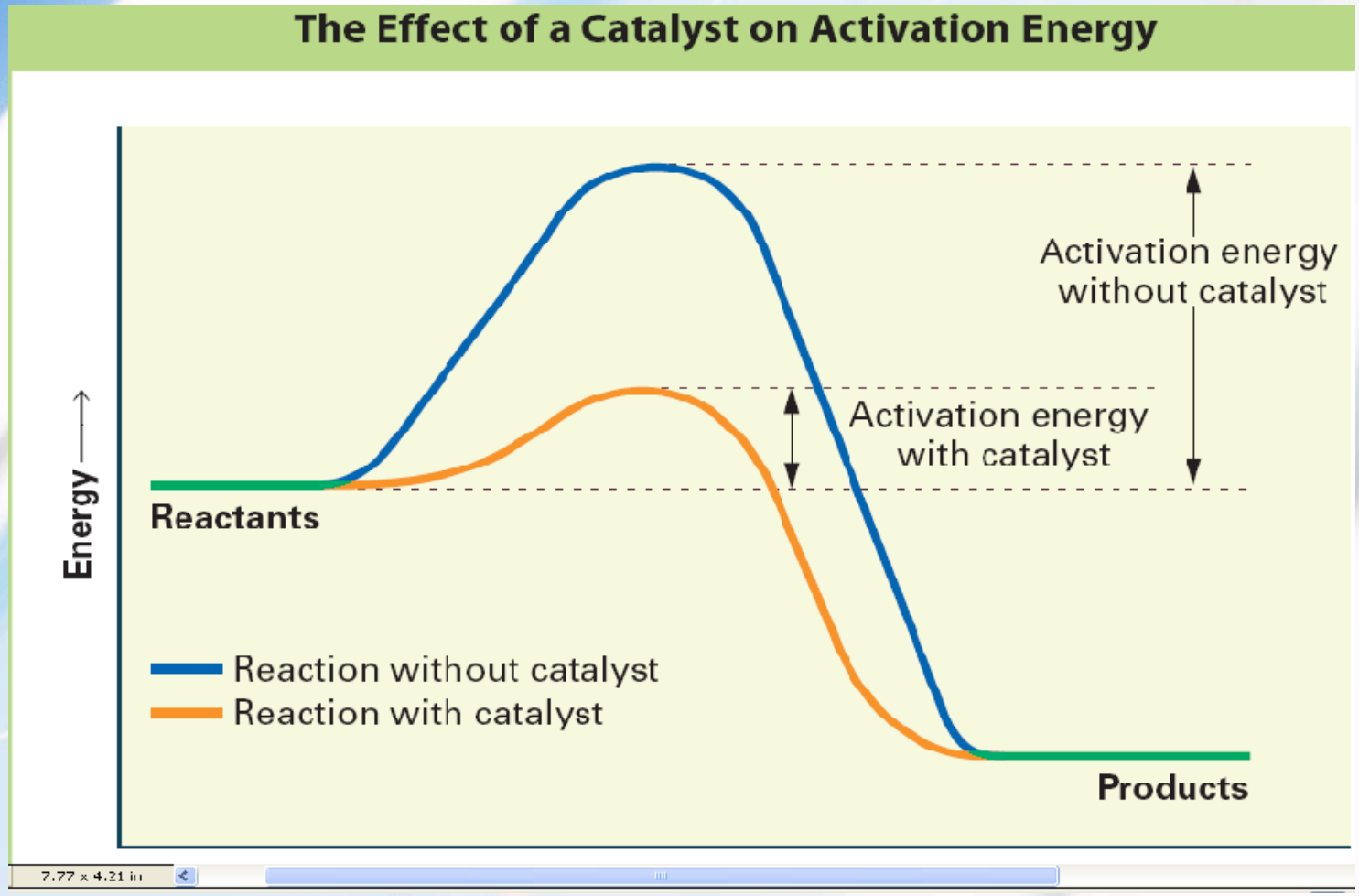
Energy Diagrams

- Activation Energy – minimum energy that colliding particles must have in order to react.
- Activated Complex – unstable arrangement of atoms that forms momentarily
- Transition State – synonym for the activated complex

Factors Affecting Reaction Rates

- Temperature
- Concentration
- Particle Size
- Presence of a catalyst (or inhibitor)

Effect of a Catalyst



Reversible Reactions and Equilibrium

Essential Question

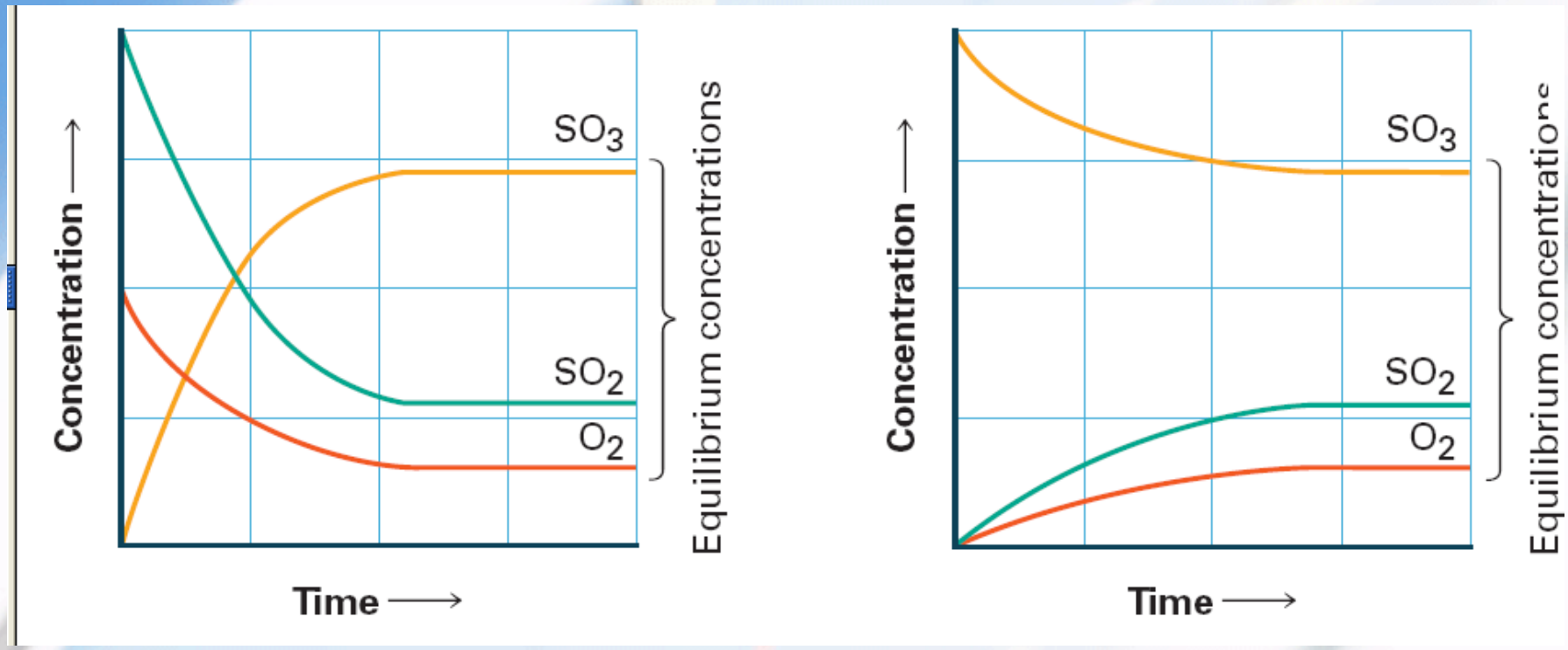
- How do the amounts of reactants and products change at equilibrium, and what three stresses can cause a change in the equilibrium position?

At Chemical Equilibrium

- Products are being formed…
- …reactants are being formed…
- …but no net change occurs in the actual amounts of either the reactants or products.

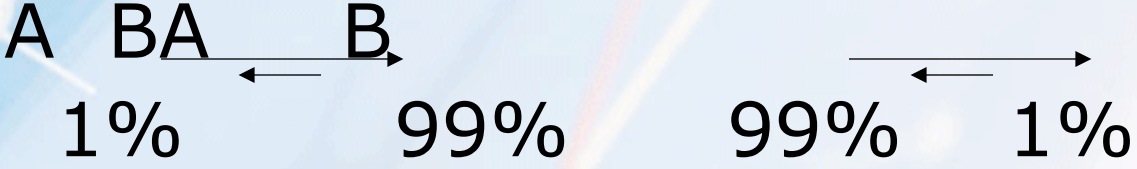
Reversible Reactions

Changes in Concentrations



Equilibrium Position

- Expresses the relative concentrations of reactants and products at equilibrium.



Certain factors can affect this position

Le Châtelier's Principle

- "If a stress is applied to a system in dynamic equilibrium, the system changes in a way that relieves the stress."

Equilibrium Constants

- The ratio of product concentrations to reactant concentrations at equilibrium
- Each concentration is raised to a power equal to their coefficient in a balance chemical equation.

Equilibrium Constants

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

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

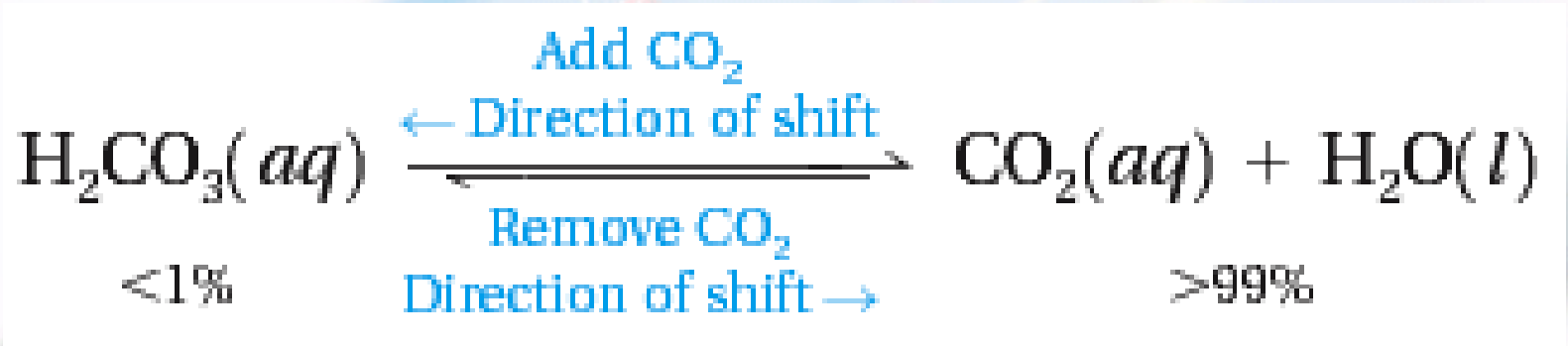
What K_{eq} Tells Us

- K_{eq} greater than 1 means that products are favored
- K_{eq} less than 1 means that reactants are favored
- K_{eq} equal to 1 means that products and reactants are equally favored

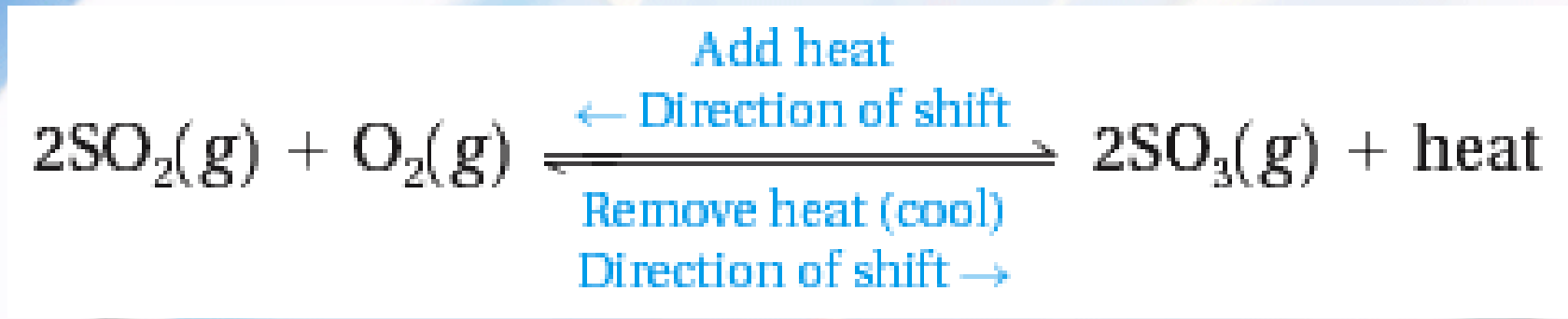
Factors Affecting Equilibrium

- Changes in concentration of reactants or products
- Changes in temperature
- Changes in pressure (of gases)

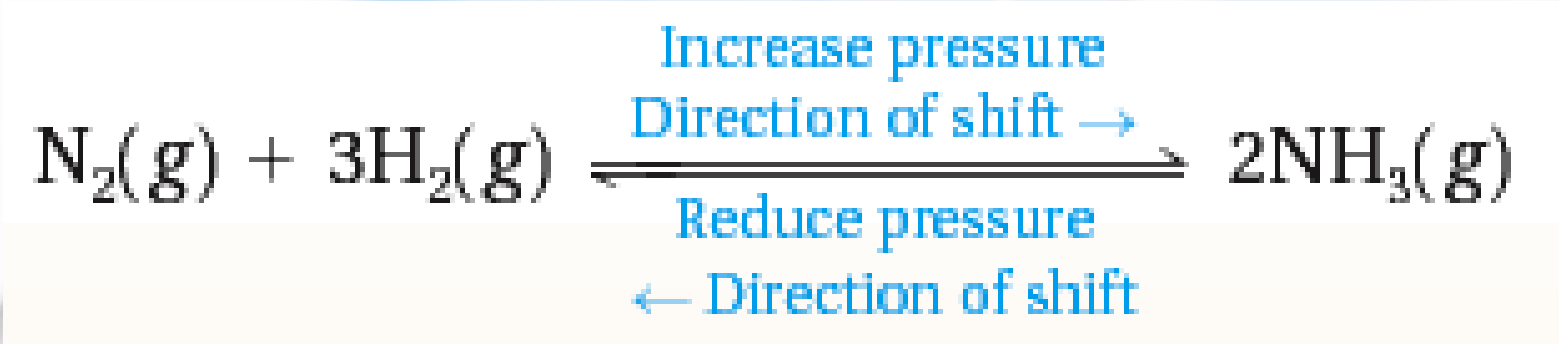
Changes in Concentration



Changes in Temperature



Changes in Pressure



Effect of Pressure on Equilibrium

Solubility Equilibrium

Essential Question

- What does the solubility product constant tell you about the solubility of a compound, and how can you predict whether a precipitate will form when salt solutions are mixed?

Solubility Product Constant

- Takes the same form as equilibrium constants

- $AgCl(s) \rightarrow Ag^{+}(aq) + Cl^{-}(aq)$

$$K_{eq} = \frac{[Ag^{+}] \times [Cl^{-}]}{[AgCl]}$$

Common Ion Effect

- Lowering the solubility of an ionic compound as a result of the addition of a common ion

- If the product of the concentrations of two ions in the mixture is greater than K_{sp} of the compound formed from the ions, a precipitate will form.

Entropy and Free Energy

Essential Question

- What two factors determine the spontaneity of a reaction, and what are the characteristics of spontaneous reactions?

Spontaneous Reactions

- Occur naturally and favor the formation of products
- Produce substantial amounts of products at equilibrium

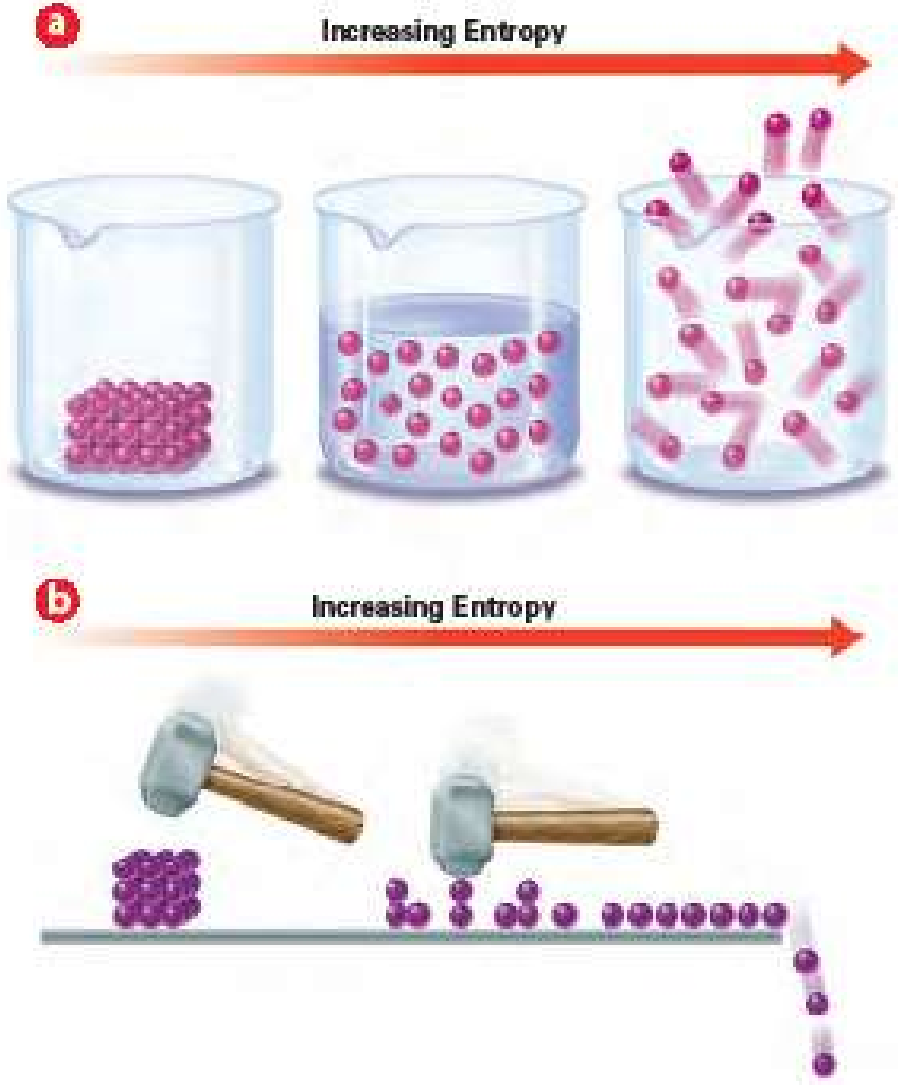
Nonspontaneous Reactions

- Does not favor the formation of products
- Do not produce substantial amounts of products at equilibrium
- Note: Speed is NOT a factor

Entropy Changes

- A measure of the disorder of a system
- Law of Disorder: the natural tendency is for systems to move in the direction of maximum disorder or randomness
- An increase in entropy favors spontaneous chemical reactions

Figure 18.24 Entropy is a measure of the disorder of a system.



a For a given substance, the entropy of the gas is greater than the entropy of the liquid or the solid. Similarly, the entropy of the liquid is greater than that of the solid. Thus entropy increases in reactions in which solid reactants form liquid or gaseous products. Entropy also increases when liquid reactants form gaseous products.

b Entropy increases when a substance is divided into parts. For instance, entropy increases when a crystalline ionic compound, such as sodium chloride, dissolves in water. This is because the solute particles—sodium ions and chloride ions—are more separated in solution than they are in the crystal form.

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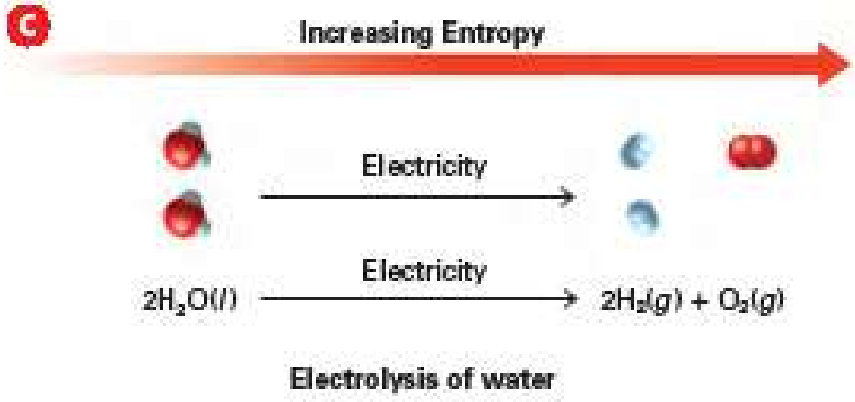
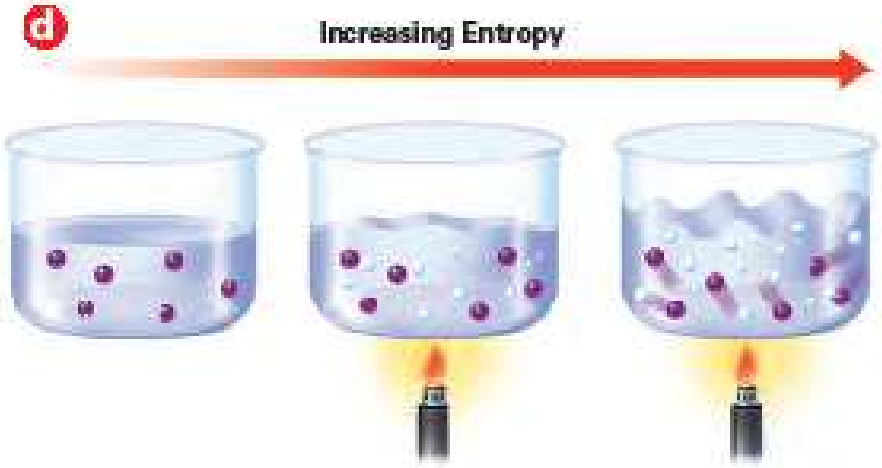


Electrolysis of water

c Entropy tends to increase in chemical reactions in which the total number of product molecules is greater than the total number of reactant molecules.



d Entropy tends to increase when temperature increases. As the temperature increases, the molecules move faster and faster, which increases the disorder.

Enthalpy Changes

- The decrease in enthalpy (exothermic reactions) indicates a spontaneous reaction.
- An increase in enthalpy (endothermic reactions) indicates a non-spontaneous reaction.

The Progress of Reactions

Essential Question

- What does the specific rate constant, k, communicate and how does one interpret a reaction progress curve?

Specific Rate Constant

- The value of the specific rate constant, k, is large if the products form quickly
- The value is small if the products form slowly.