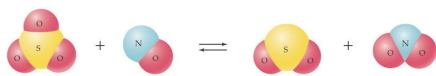


Why does a reaction occur?

Bonds are broken, and bonds are formed.

If the bonds that form are different than the bonds broken, then a chemical reaction occurred!

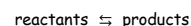


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Chemical Equilibrium

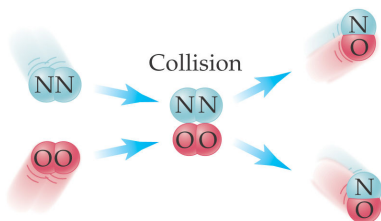
- Most chemical reactions do not continue until all of the reactants are used up.
- Most reactions are ongoing, reversible processes; proceeding in both the forward direction to give products and in the reverse direction to give the original reactants
- We indicate an equilibrium reaction with a double arrow:
reactants \rightleftharpoons products

- In an equilibrium reaction, initially the rate of the forward reaction is very fast.
- As more products are formed, the rate of the reverse reaction speed up.
- When the rates of the forward and reverse reactions are the same, the system is at equilibrium.



Collision Theory

- Molecules must collide in order to react.
- In a successful collision, existing bonds are broken as new bonds are formed and the reactants are transformed into products.
- This is the collision theory of reactions.



Factors That Effect Collisions

There are three factors that affect the rate of a chemical reaction.

1. **Collision Frequency:**
 - When we increase the frequency at which molecules collide, we increase the rate of reaction. The more collisions you have, the greater the odds that a collision will be successful.
2. **Collision Energy:**
 - For a reaction to occur, the molecules must collide with enough energy to form the new bonds.
3. **Collision Geometry:**
 - For a reaction to occur, the molecules must be oriented in the proper geometry for the reaction to occur.
 - In (a), the reactants have the correct geometry and products are formed after the collision. In (b), the reactants do not have the correct geometry and they do not react.

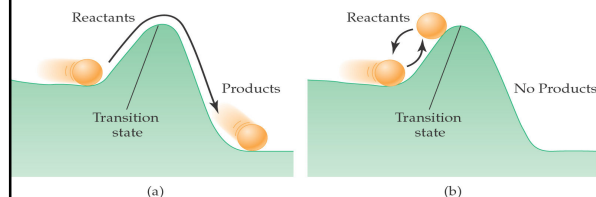
Factors That Effect Reaction Rate

There are three factors that effect the reaction rate:

1. **Reactant Concentration:**
 - As we increase the concentration of the reactant(s), the molecules are closer together and collide more frequently. The more collisions, the faster the reaction.
2. **Reaction Temperature:**
 - As we increase the temperature, we increase the energy of the reactants. As we increase the energy of the reactants, the rate of the reaction increases because of the increased collision frequency *and* the collision energy.
3. **Addition of a Catalyst:**
 - A catalyst increases the rate of a reaction. A catalyst increases the number of effective collisions by creating a more favorable collision geometry.
 - A catalyst is not consumed in a reaction.

Energy Barriers

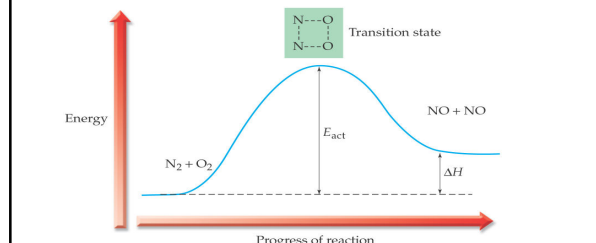
- For a chemical reaction to occur, the reactants must collide with sufficient energy to react.
- This energy is required to achieve the transition state required to form the products (a).
- Without sufficient energy, the reaction does not occur (b).



Endothermic Reactions

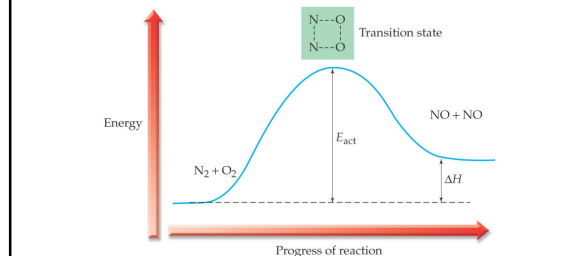
- An **endothermic** reaction absorbs heat as the reaction proceeds.

$$\text{N}_2(\text{g}) + \text{O}_2(\text{g}) + \text{heat} \rightleftharpoons 2 \text{NO}(\text{g})$$
- A **reaction profile** shows the energy of reactants and products during a reaction.
- The highest point on a reaction profile is the **transition state**.



Reaction Profile

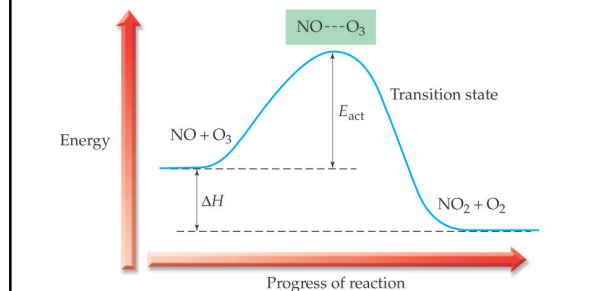
- The energy required for reactants to achieve the transition state is the **activation energy**, E_{act} .
- The energy difference between reactants and products is the **heat of reaction**, ΔH .
- The ΔH for an endothermic reaction is positive.



Exothermic Reactions

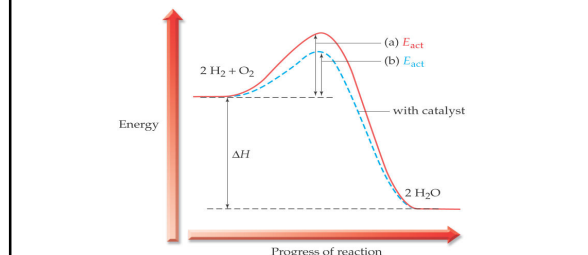
- An **exothermic** reaction releases heat as the reaction proceeds.

$$\text{NO}(\text{g}) + \text{O}_3(\text{g}) \rightleftharpoons 2 \text{NO}_2(\text{g}) + \text{O}_2(\text{g}) + \text{heat}$$
- The ΔH for an exothermic reaction is negative.

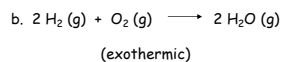
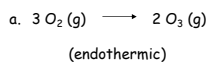


Addition of a Catalyst

- A catalyst is a substance that allows a reaction to proceed faster by lowering the activation energy.
- The reaction profile shows the effect of a catalyst on the reaction $2 \text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{H}_2\text{O} + \text{heat}$
- A catalyst does not change ΔH for a reaction.
- A catalyst speeds up both the forward and reverse reactions.



Example: Draw the reaction profiles for the following:



Example: Consider a general reaction, $A + B \longrightarrow C + D$, which is exothermic.

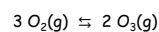
a. Draw a reaction energy profile for the reaction below:

b. Given that a catalyst lowers the activation energy for a reaction by providing an alternative mechanism for reaction, draw the new activation energy with a catalyst on the reaction energy profile above.

- c. In an exothermic reaction, the energy of the reactants is _____ than the energy of the products. (circle one)
- greater than less than equal
- d. The activation energy of the reaction with a catalyst is _____ compared to the reaction without a catalyst. (circle one)
- greater than less than equal
- e. The heat of reaction (ΔH) with a catalyst is _____ compared to the ΔH for the reaction without a catalyst. (circle one)
- greater than less than equal

Chemical Equilibrium Concept

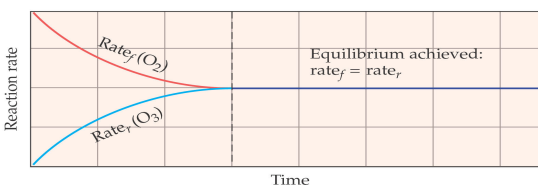
- A chemical change is a reversible process that can proceed simultaneously in both the forward and reverse directions.
- When the rate of the forward and reverse reactions are proceeding at the same rate, the reaction is in a state of **chemical equilibrium**.



- At equilibrium,
rate_f (O₂ reaction) = rate_r (O₃ reaction)

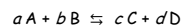
Rates & Equilibrium

- The **rate of reaction** is the rate at which the concentrations of reactants decrease per unit time.
 $3 \text{O}_2(\text{g}) \rightleftharpoons 2 \text{O}_3(\text{g})$
- Starting with only O₂, as O₂ is consumed, the rate of the forward reaction decreases.
- As O₃ is produced, the rate of the reverse reaction increases. When the rates are equal, equilibrium is achieved.



Law of Chemical Equilibrium

- Consider the following general reaction:



- The **law of chemical equilibrium** states that the molar concentrations of the products (raised to the powers c and d), divided by the molar concentrations of the reactants (raised to the powers a and b), equals a constant.

Equilibrium Constant, K_{eq}

- Mathematically, we express the law of chemical equilibrium as follows:

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

- The constant, K_{eq} , is the **general equilibrium constant**.
- The value of K_{eq} varies with temperature. So a given value of K_{eq} is valid only for a specific temperature.