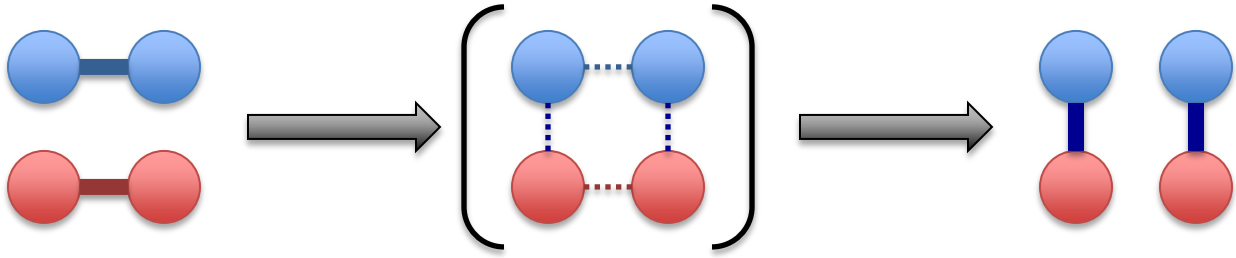
Chapter 11 – Equilibrium

11.1 Collision Theory

Collision Theory: Molecules must collide with each other in order to react!

⇒ If the collision is successful, reactant bonds are broken and new bonds are formed; thus, a chemical reaction has occurred.



Old bonds start to break and new bonds start to form. This is considered the ***transition state***.

Factors that affect the number of Successful Collisions

1) **Collision frequency**
   Increase the # of collisions ⇒ more chances for successful collisions to occur.
2) **Collision Energy**
   - For a reaction to occur, the molecules must collide with enough energy to break the existing reactant bonds and form new bonds.
   - $\mathbf{E_a}$, the activation energy, is the minimum amount of energy needed for a reaction to occur. In order to react, molecules have to surmount this activation energy barrier.
3) **Collision Geometry**
   - Molecules must be in the correct orientation for a reaction to occur

11.2 Rates of Reaction

Rate of Reaction is how fast the reactant molecules are turned into product molecules.

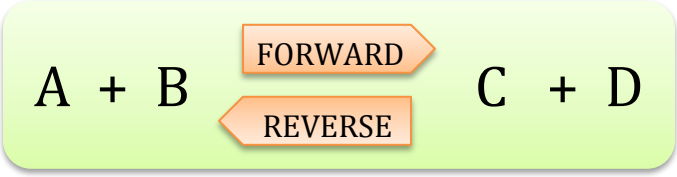
⇒ The speed at which the reaction occurs.

How can we increase the rate of reaction?

1) **Increase reactant concentration**
   Increase concentration of a reactant ⇒ more particles are present, which collide more frequently, so the reaction rate increases.
2) **Increase the temperature**
   Increase T causes molecules to move faster and collide more frequently.
   Increase T increases the energy of the reactants, so the molecules collide with more energy.
   ⇒ There are a higher number of successful collisions, so the reaction rate increases.
3) **Add a Catalyst -** a catalyst is a substance that speeds up a reaction without being consumed.
   ⇒ A catalyst increases the number of successful collisions by providing a more favorable collision geometry that creates an alternative path with lower activation energy.

11.3 Equilibrium

Equilibrium is defined as the point a reaction reaches when the ***rate*** of the forward reaction equals the ***rate*** of the reverse reaction.



⇒ **Forward Reaction**: Reactant molecules A + B becoming product molecules C + D.

⇒ **Reverse Reaction**: As product molecules C + D start to accumulate, they can react and move in the reverse direction, which allows them to be converted back to reactant molecules A + B.

11.4 Exothermic and Endothermic Reaction Profiles

A reaction profile shows the energy of reactants and products during a reaction.

TS transition state: arrangement of atoms at the top of the energy barrier, where reactant bonds are breaking and new product bonds are being formed. Very high energy and unstable species.

E_a, Activation Energy: energy required for reactant molecules to achieve the transition state.

ΔH, the heat of reaction: the difference in energy between the reactants and products.

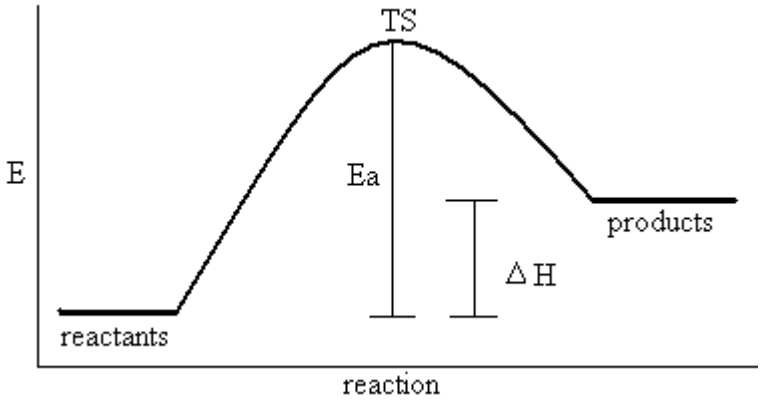
Endothermic reaction: **reactants absorb heat from the surroundings**, heat is a reactant.

Reactants + *heat* → Products

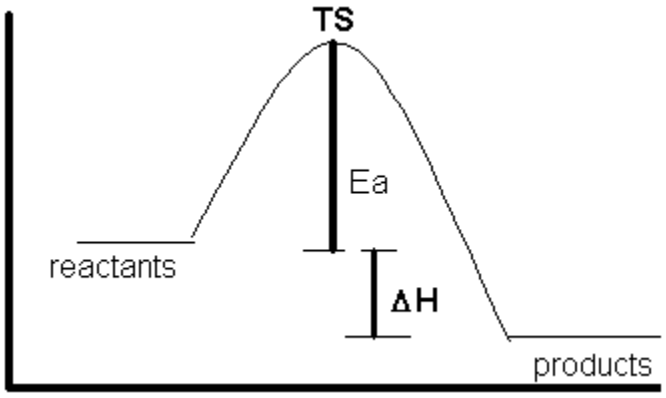
Exothermic reaction: **reactants release heat to the surroundings**, heat is a product.

Reactants → Products + *heat*

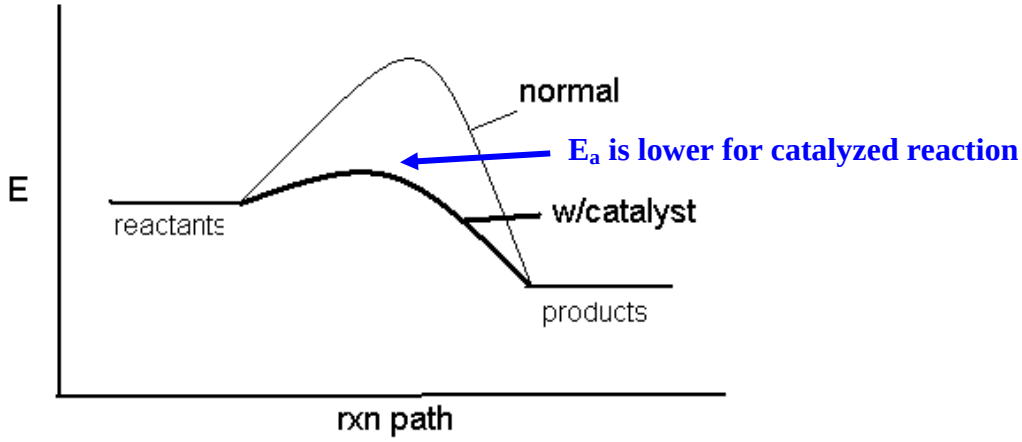
➢ **Reaction profile for endothermic reaction:**



- **Reaction profile for exothermic reaction:**



- **Reaction profile for a catalyzed reaction**:



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CHAPTER 11 PRACTICE PROBLEMS

1. State three things that can increase the rate of a chemical reaction:
   a. _____
   b. _____
   c. _____

2. Indicate if the following statements are true or false:
   T/F a. In an exothermic reaction, heat is a reactant.
   T/F b. In an endothermic reaction, the heat of the products is higher than the heat of reactants.
   T/F c. When a reaction reaches equilibrium, there is no ***net*** change in concentration of reactants and products.
   T/F d. The addition of a catalyst lowers the overall heat of reaction, ΔH.
   T/F e. The transition state occurs when the reaction is over and only products are left.

3. Draw an endothermic reaction profile. Label the x and y-axis, the transitions state, the reactants, products, Ea, and ΔH.

Answers to Practice Problems

1. State three things that can increase the rate of a chemical reaction:
   a. Increasing Concentration
   b. Increasing Temperature
   c. Addition of a Catalyst

2. Indicate if the following statements are true or false:
   False a. In an exothermic reaction, heat is a reactant. *Heat is released so heat is a product.*
   True b. In an endothermic reaction, the heat of the products is higher than the heat of reactants.
   True c. When a reaction reaches equilibrium, there is no ***net*** change in concentration of reactants and products. *The reaction does not stop, the product and reactant concentrations are constantly increasing and decreasing at the same rate so there is no NET change.*
   False d. The addition of a catalyst lowers the overall heat of reaction, ΔH. *The addition of a catalyst lowers the activation energy, E_a.*
   False e. The transition state occurs when the reaction is over and only products are left. *The transition state is at the top of the energy barrier. Old bonds are breaking and new bonds are forming simultaneously!*

3. Draw an endothermic reaction profile. Label the x and y-axis, the transitions state, the reactants, products, E_a, and ΔH.