Collision Theory and Rate of Reaction

Collision Theory

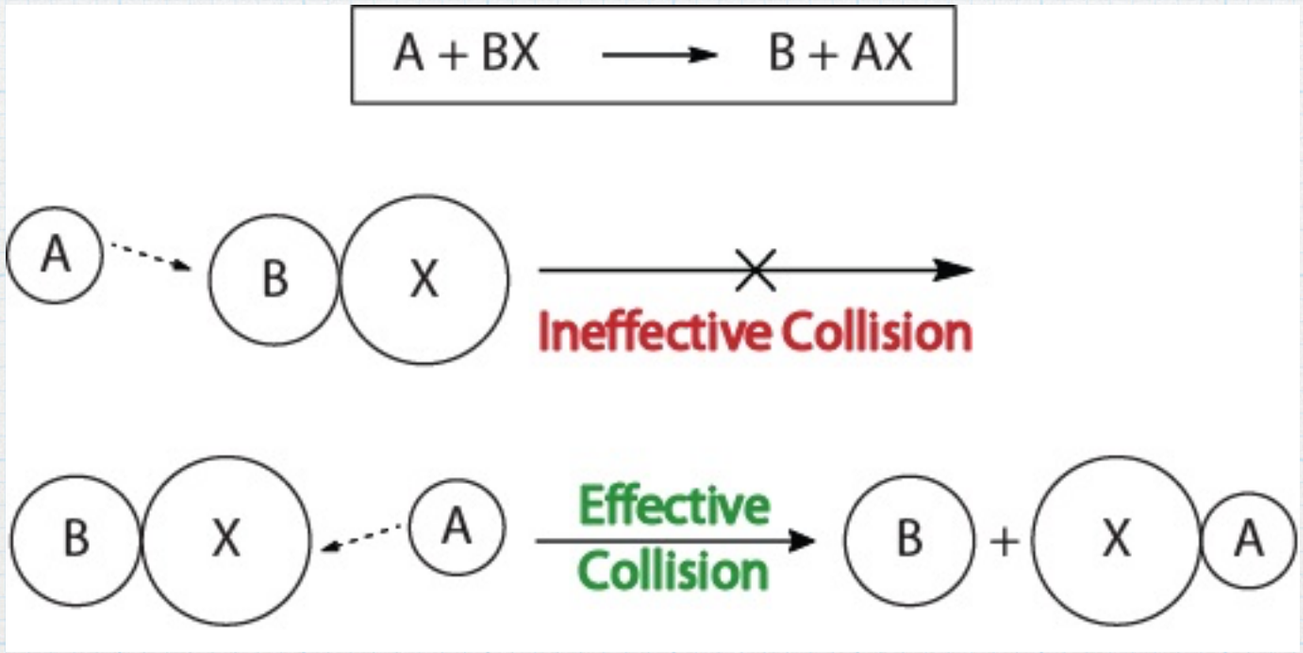
* A system consists of particles in motion at speed proportional to temperature.
* Chemical reaction involve collisions of particles with each other and with the walls of the containers

Collision Theory

* **effective collision :** has sufficient energy and correct orientation for bonds can be broken and new bonds form
* **ineffective collision :** particles rebound from collision, essentially unchanged

Correct Orientation

* Particles must collide with correct orientation for the collision to be effective

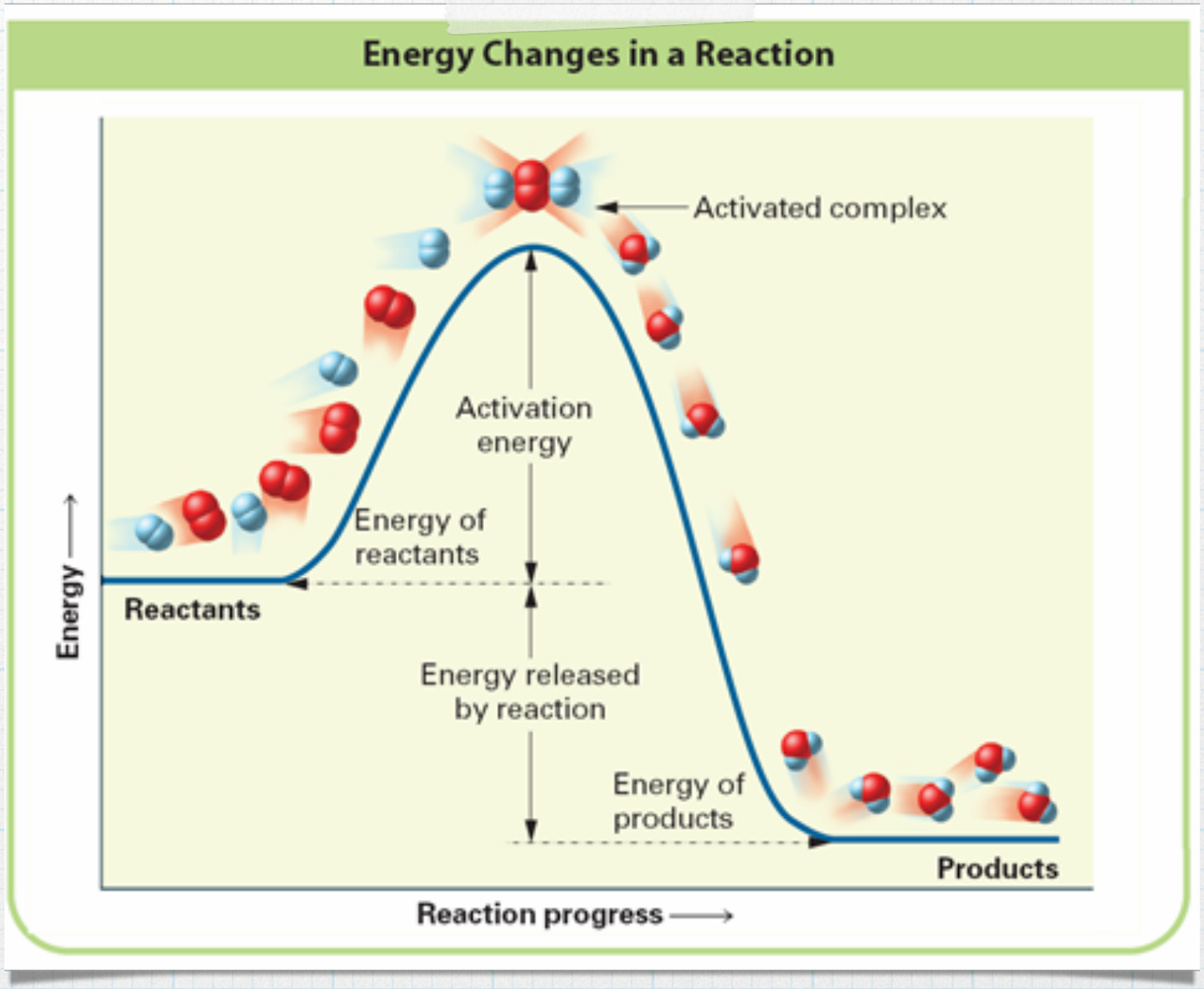


Collision Theory

* Rate of reaction depends on frequency of collisions number of collisions that are effective

Activation Energy

* **Activation Energy:** The minimum increase in potential energy of a system required for molecules to rearrange their structure and result in an effective collision

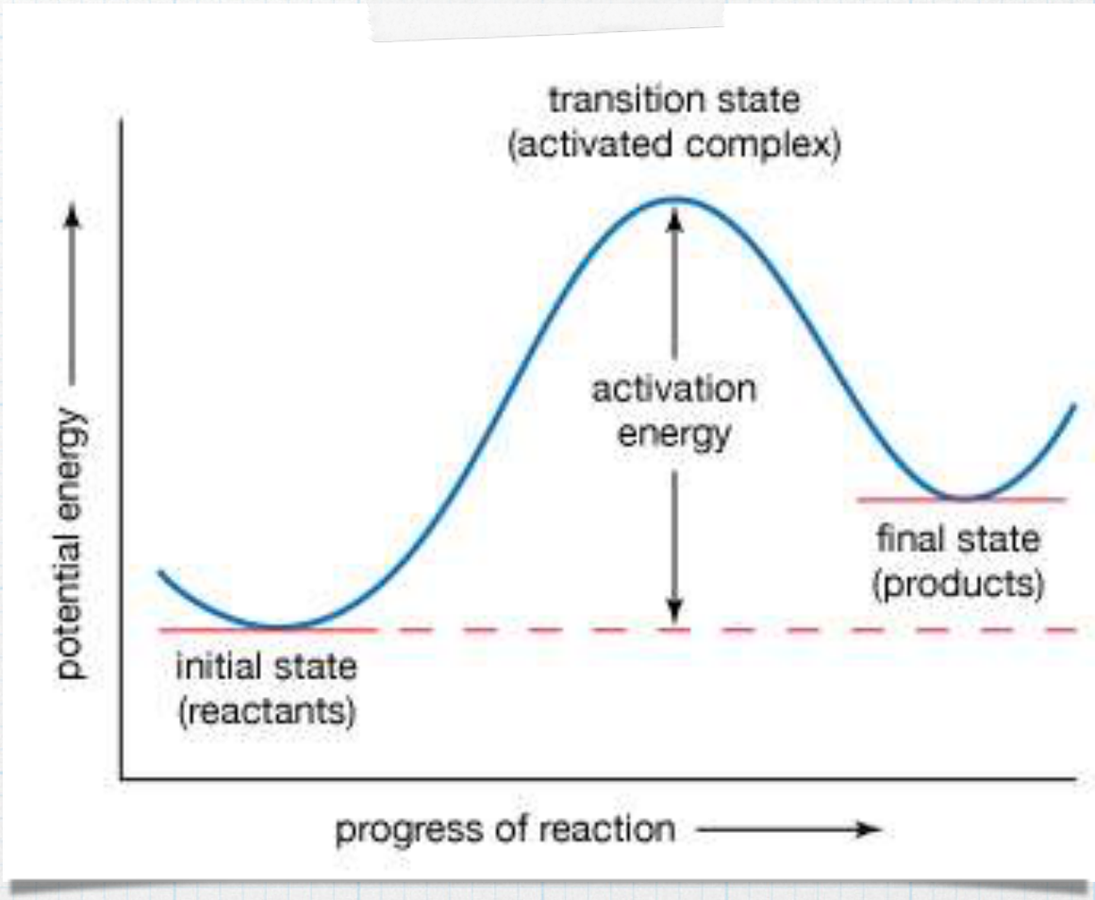


Transition State Theory

* **Activated Complex:** an unstable molecule containing partially broken and partially formed bonds representing the maximum potential energy point in the change

Transition State Theory

* Transition State: energy maximum where the activated complex is formed



Reaction Mechanisms

* Most chemical reactions actually occur in a sequence of elementary steps called the **reaction mechanism**

Example

* Consider the reaction
  * $NO_{2\,(g)} + CO_{(g)} \rightarrow NO_{(g)} + CO_{2\,(g)}$

* This reaction occurs in two steps:
  * 1) $NO_2 + NO_2 \rightarrow NO_3 + NO$ (slow)
  * 2) $NO_3 + CO \rightarrow NO_2 + CO_2$ (fast)

NO_3 is considered a <u>reaction intermediate</u>

Reaction Mechanisms

* The slow step in the mechanism is the **rate determining step** - it determines the rate of the overall reaction.

* To increase the rate of the overall process, the rate of the slow step must be increased.

Factors Affecting Reaction Rate

* There are five factors that affect the rate of reaction
    * chemical nature of reactants
    * concentration of reactants
    * temperature
    * presence of a catalyst
    * surface area

Chemical Nature of Reactants

* Similar elements (such as those in the same group of the periodic table) tend to react similarly, but at different rates

Example:
Sodium and other alkali metals react so quickly they are never found alone in nature

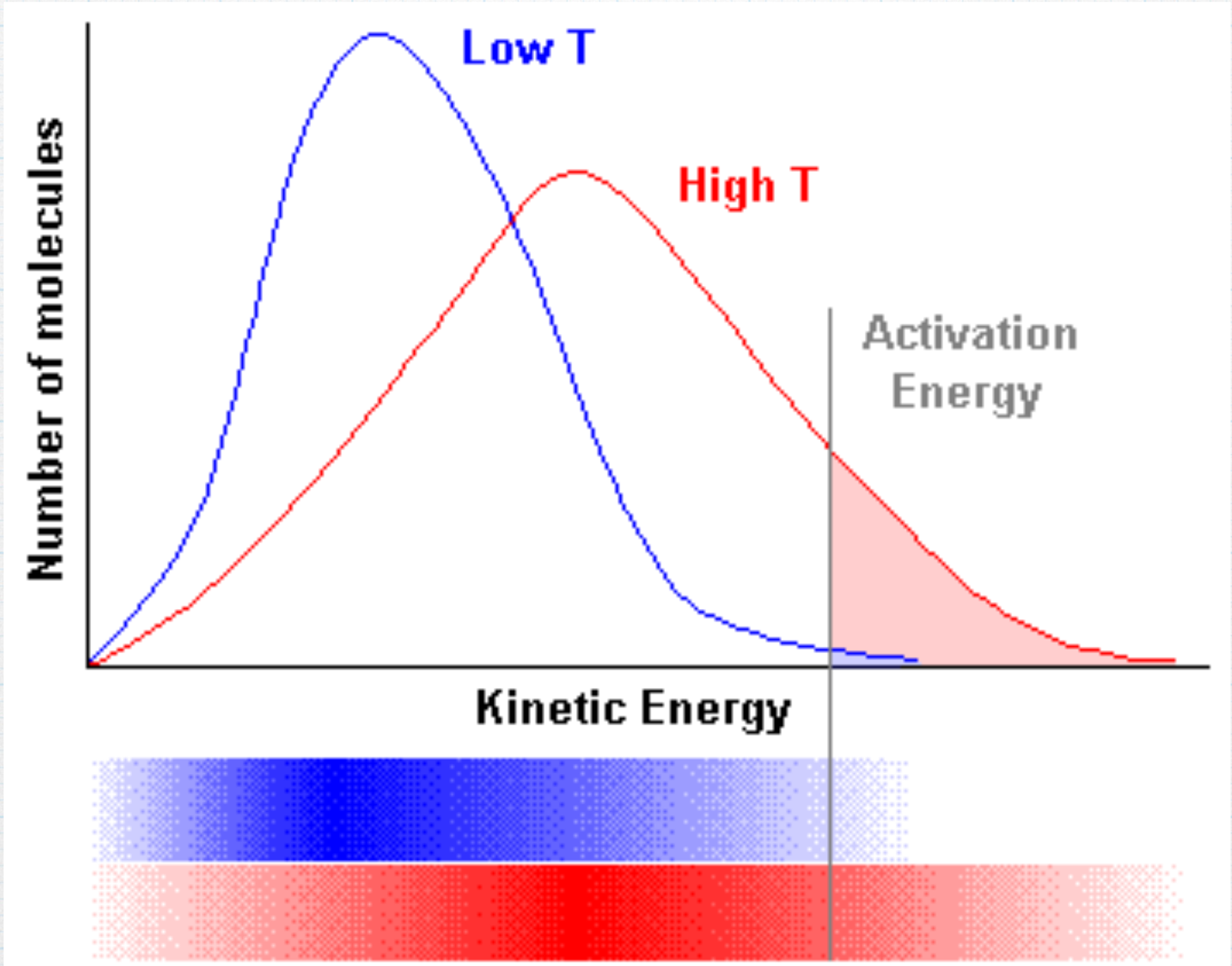
Example:
Gold and silver react so slowly that they are often used for jewelry

Concentration of Reactants

* If the initial concentration of the reactant is increased, the rate of the reaction is increased
* If twice the number of particles are present, there should be twice the number of effective collisions, increasing the rate of reaction.

Temperature

* If the temperature of the reaction is increased, the rate of the reaction is increased
* Increasing the temperature increases the kinetic energy of the particles causing them to collide more often and with more force.


Low T
High T
Activation Energy
Number of molecules
Kinetic Energy

Presence of a Catalyst

* **Catalyst:** a substance that alters the rate of a chemical reaction without being permanently changed itself
* A much larger fraction of collisions become effective.

Surface Area

* The amount of exposed surface area affects the reaction rate.

* The reaction rate increases with the increase in surface area.