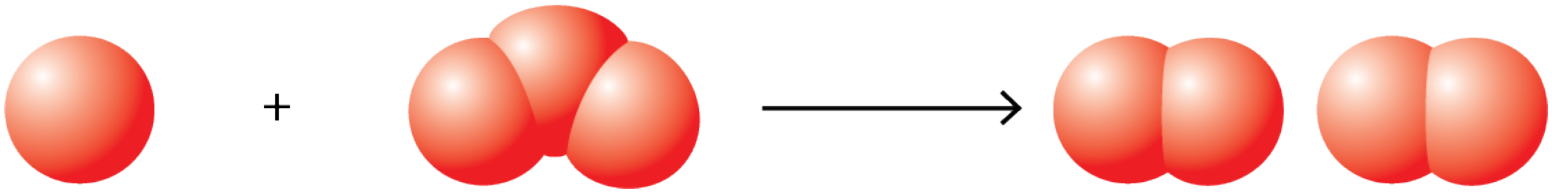
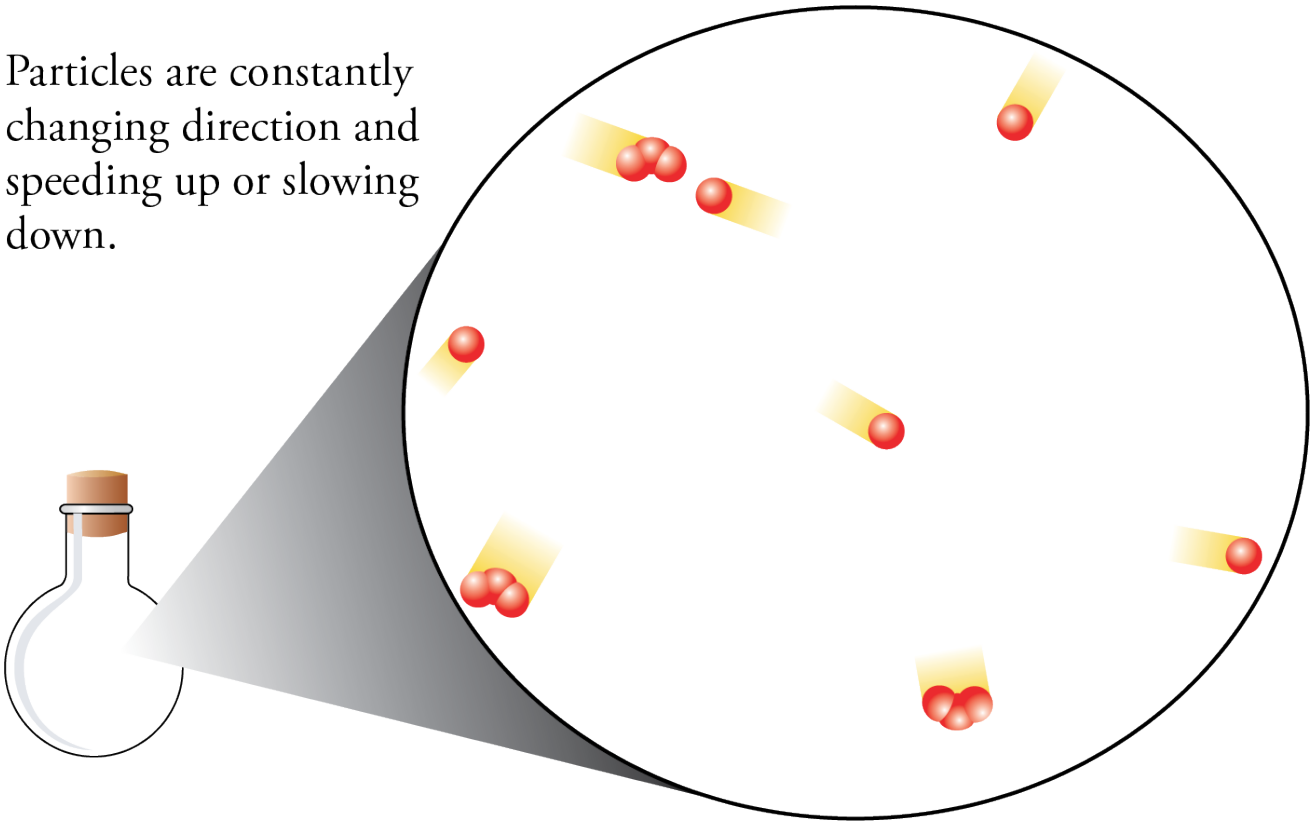
Example Reaction

$$O(g) + O_3(g) \longrightarrow 2O_2(g)$$

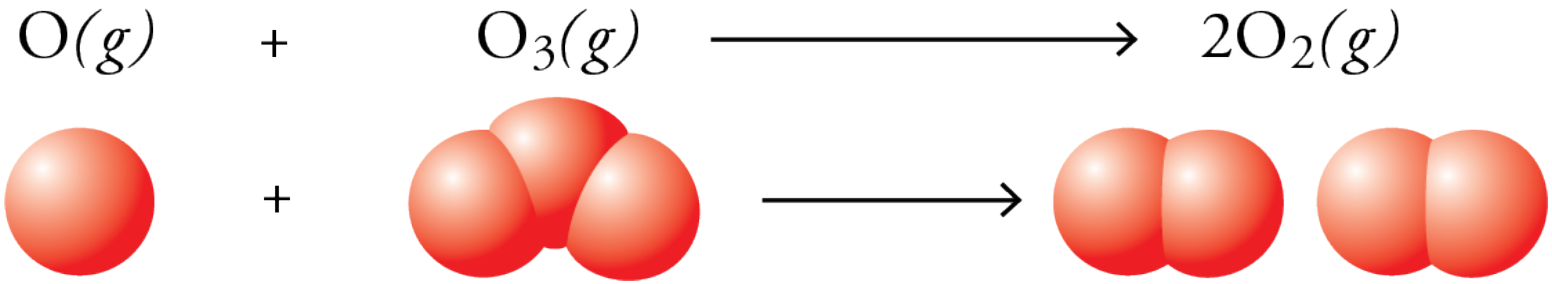


Particles are constantly changing direction and speeding up or slowing down.



Collision Theory

- Reactants must collide



  - collision brings contact between reactants
  - collision provides energy for reaction

Energy

- Energy = the capacity to do work.
- Work = what is done when something is moved against a resistance.
- Kinetic energy (KE) = energy of motion.
- Potential energy (PE) = stored, inactive energy due to position or state.

Kinetic Energy

- Kinetic energy (KE) = $\frac{1}{2}m\mu^2$
  - m = mass
  - μ = velocity
- The kinetic energy of a collision between an oxygen atom and an ozone molecule, provides the energy to move the oxygen atoms in the ozone molecule farther apart.

Exergonic Change

less stable system $\rightarrow$ more stable + energy

greater capacity to do work $\rightarrow$ lesser capacity to do work + energy

higher PE $\rightarrow$ lower PE + energy

Less stable so higher potential energy.

More stable so lower potential energy.

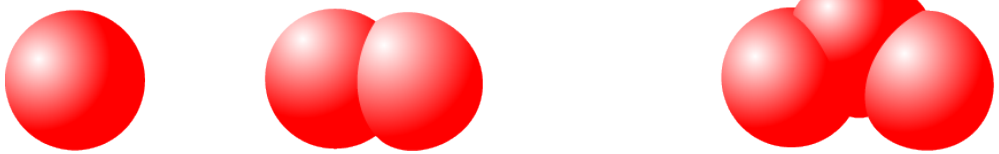
Bond Making and Potential Energy

separate atoms → atoms in bond + Energy

less stable → more stable + Energy

higher PE → lower PE + Energy

$O(g) + O_2(g) \rightarrow O_3(g) + \text{energy}$



Endergonic Change

more stable + energy → less stable system

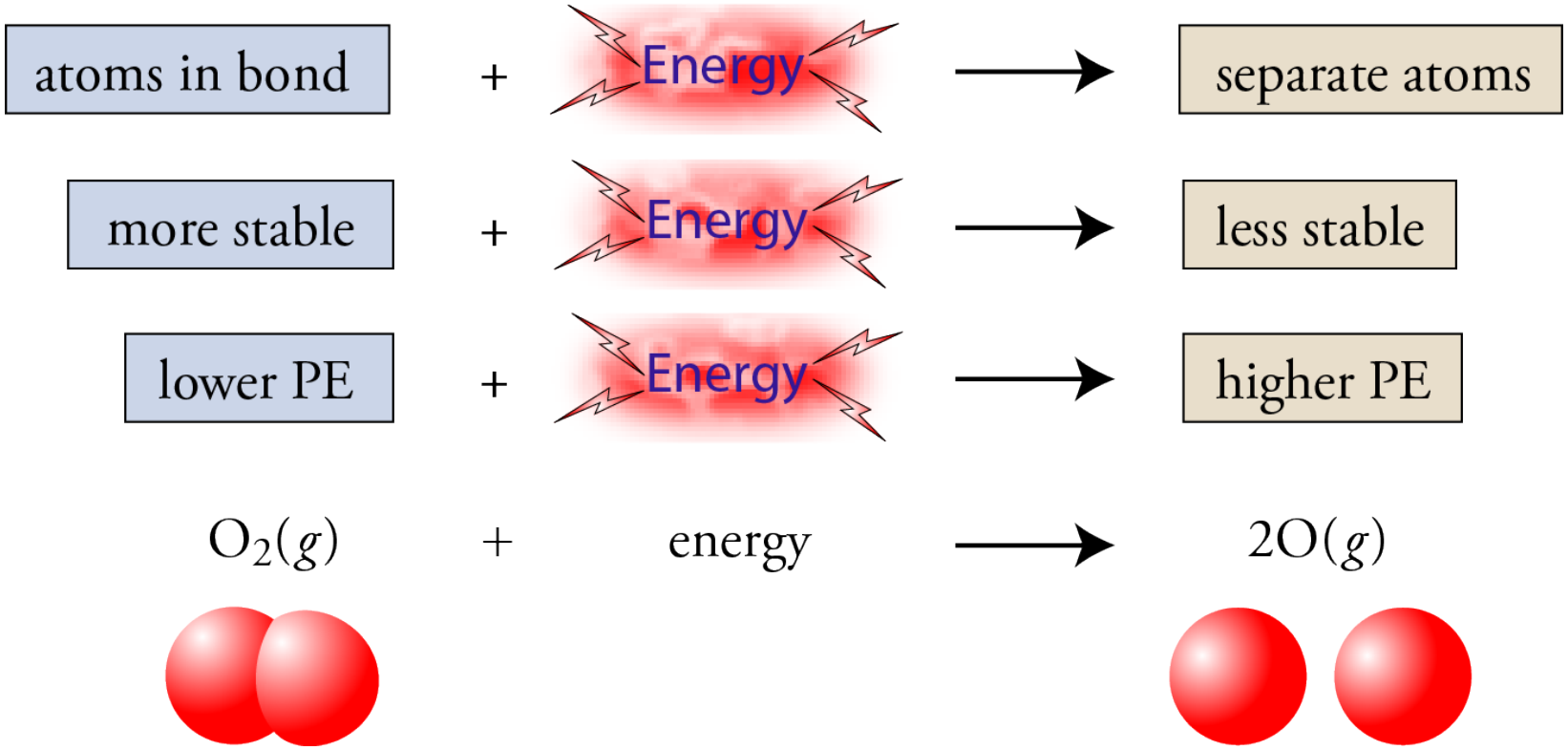
lesser capacity to do work + energy → greater capacity to do work

lower PE + energy → higher PE

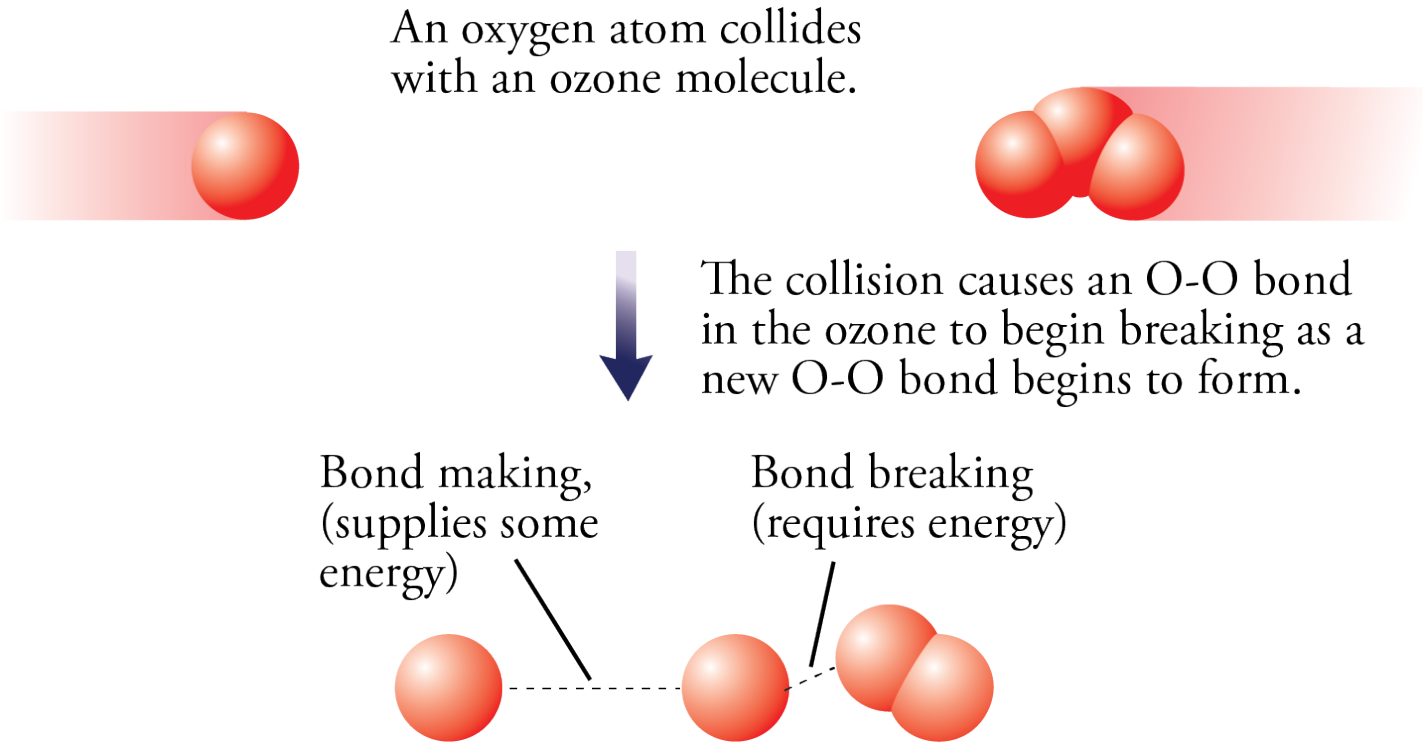
More stable so lower potential energy.

Less stable so higher potential energy.

Bond Breaking and Potential Energy

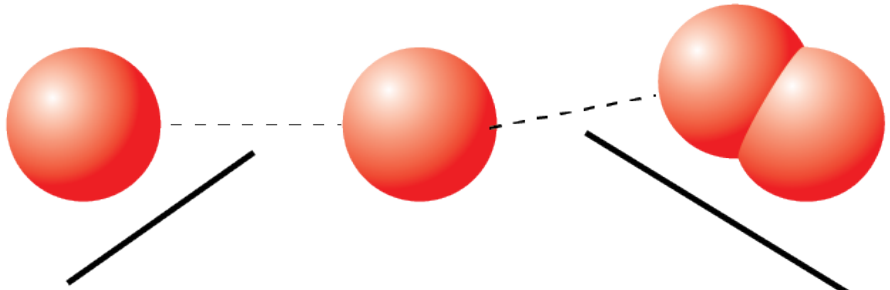


Bond Breaking and Making



Initially, the energy required for bond breaking is greater than the energy supplied from bond making. The extra energy necessary for the reaction comes from the kinetic energy of the colliding particles.

Formation of Activated Complex

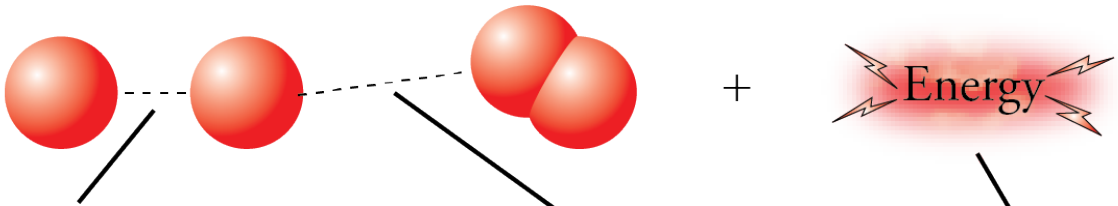


Bond making supplies energy
equal to the energy required for bond breaking.

- At some point, the energy released in bond making is equal to the energy necessary for bond breaking.
- The system at this point is call the activated complex or the transition state, which is defined as the highest energy intermediate in the lowest energy pathway between reactants and products.

Formation of Product

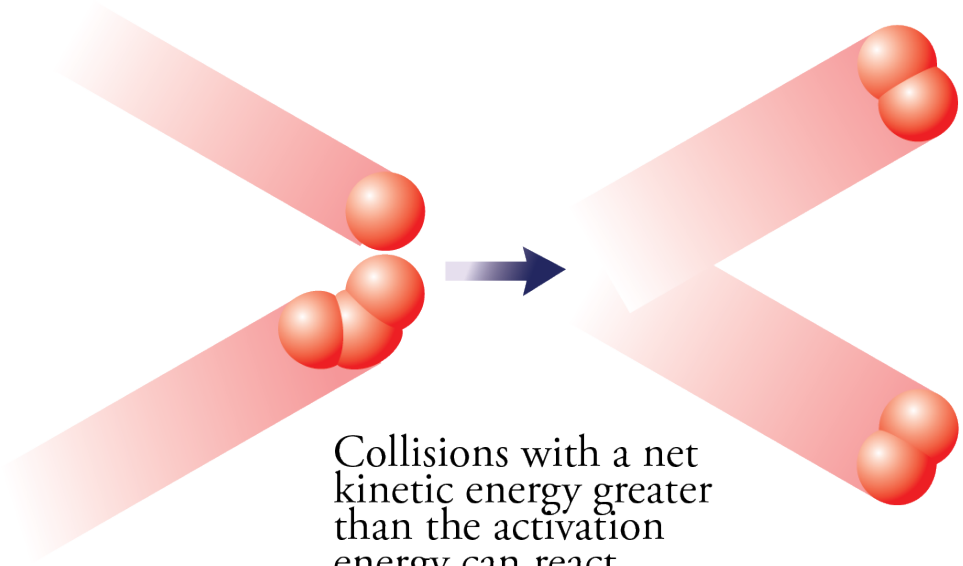
Beyond some point in the reaction, bond making predominates over bond breaking.



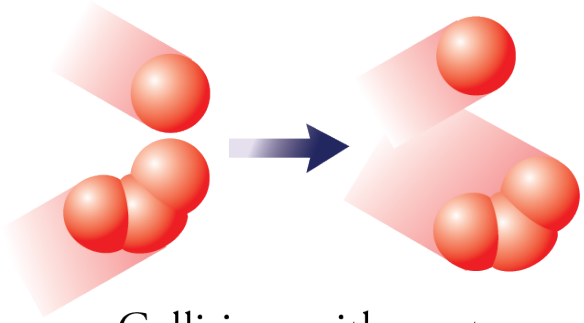
Bond making supplies more energy than is necessary for bond breaking...

so energy is released

Collision Energy and Activation Energy



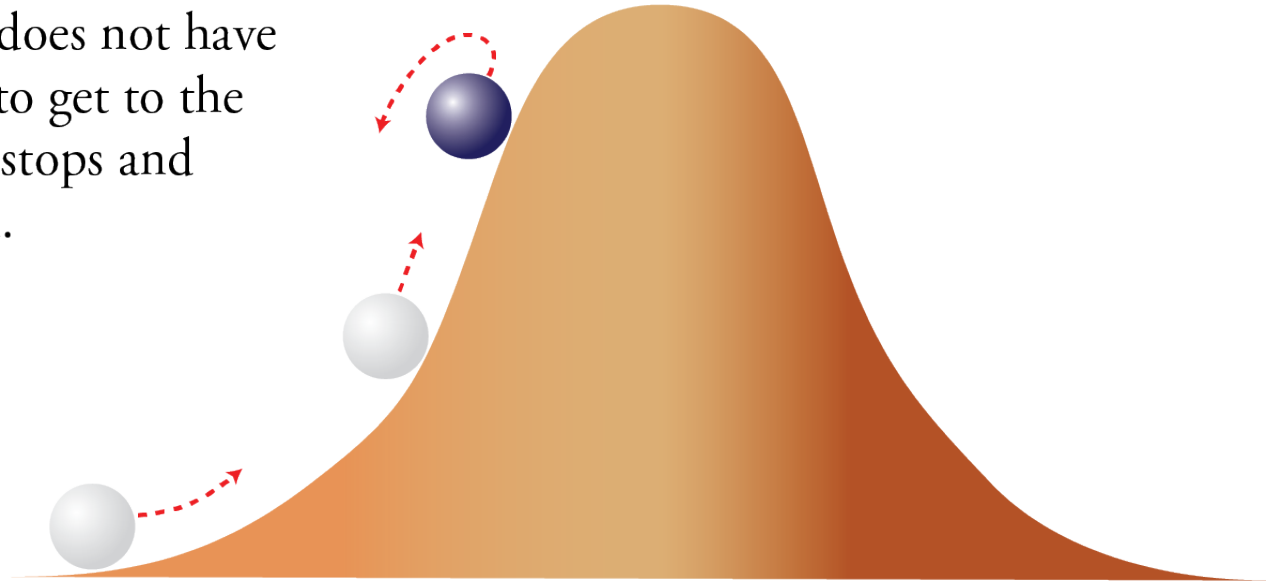
Collisions with a net kinetic energy greater than the activation energy can react.



Collisions with a net kinetic energy less than the activation energy cannot react.

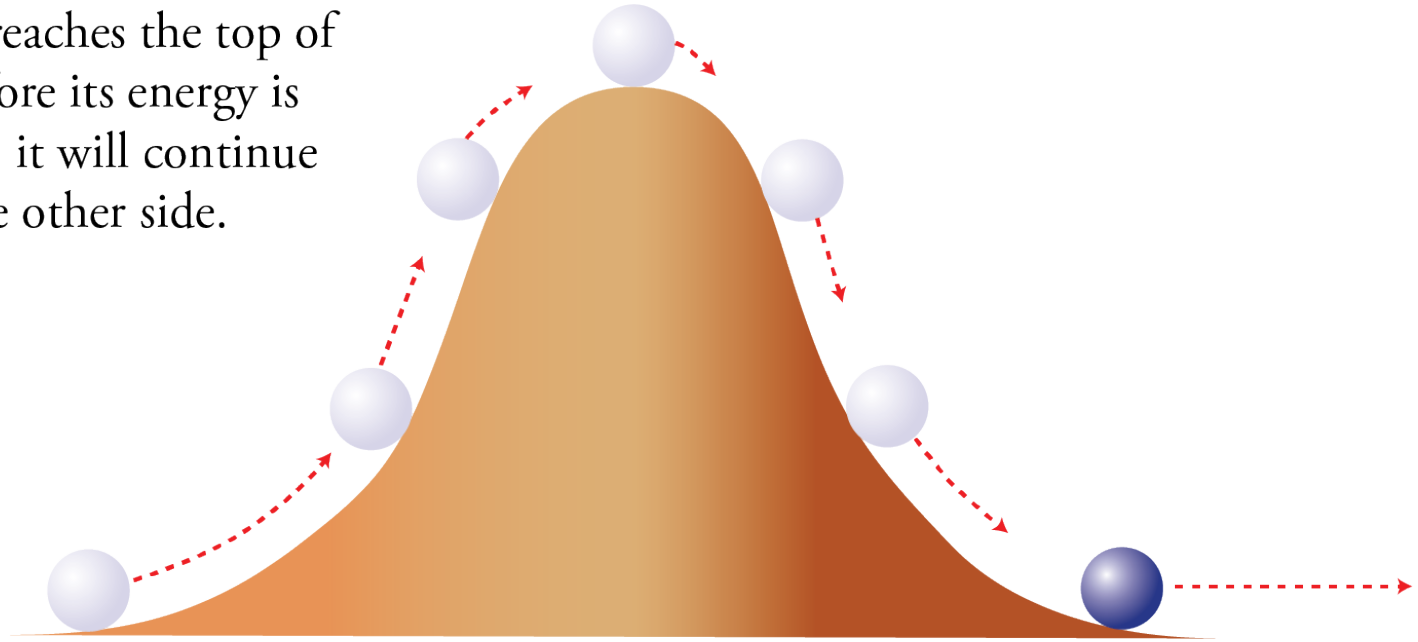
Reactions must have a minimum activation energy…if too little, no change

If a rolling ball does not have enough energy to get to the top of a hill, it stops and rolls back down.

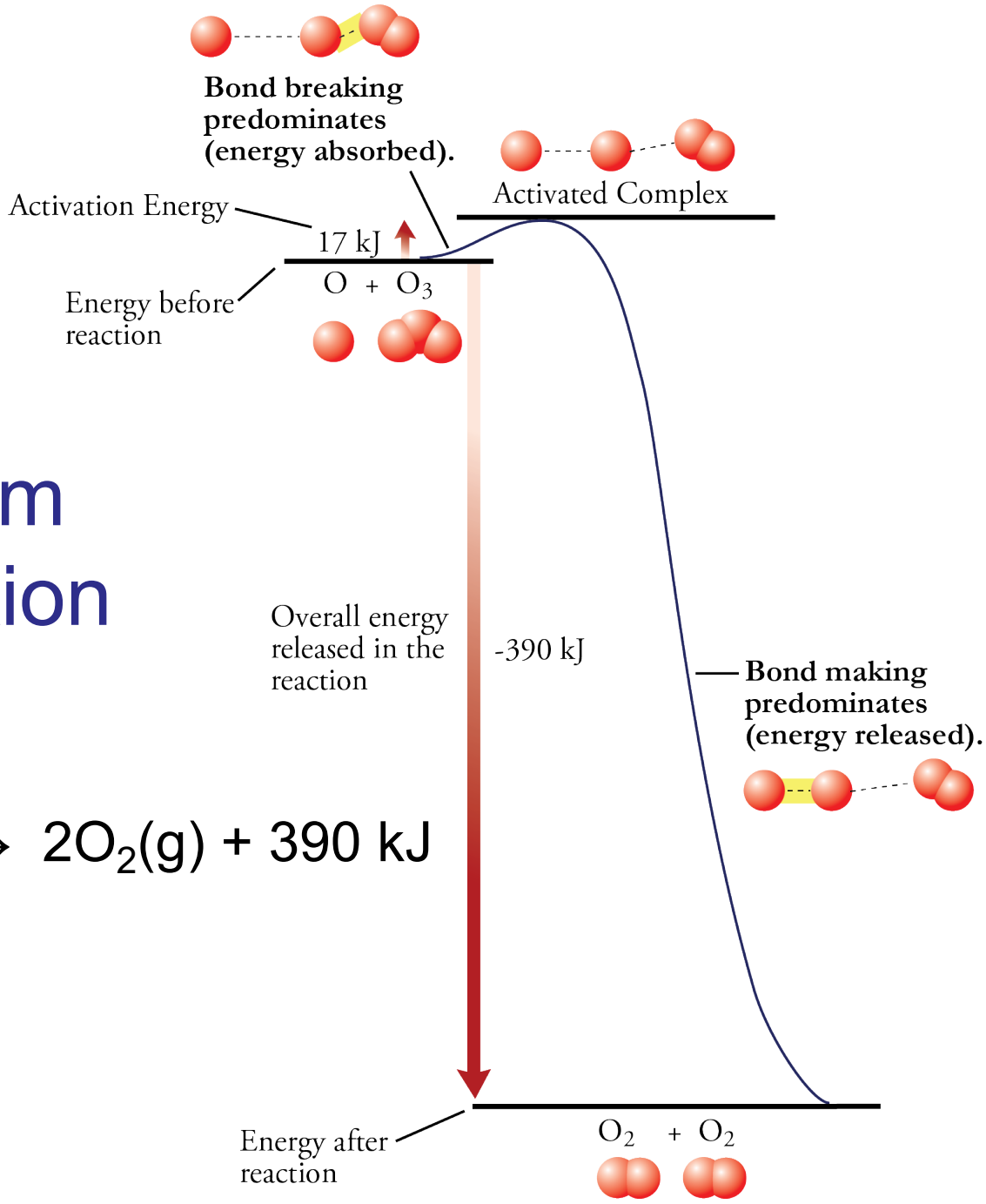


Reactions must have a minimum activation energy

If a ball reaches the top of a hill before its energy is depleted, it will continue down the other side.

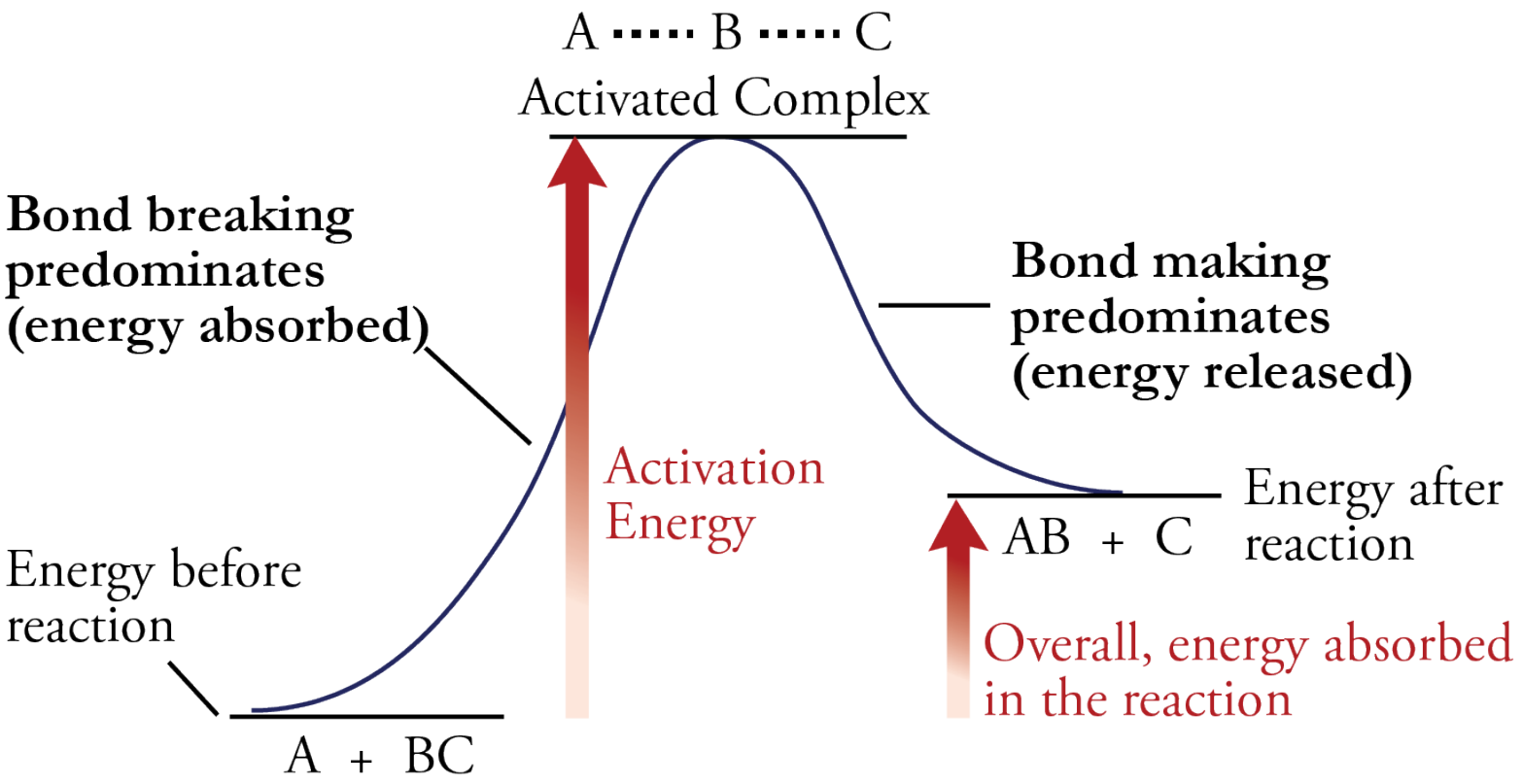


Energy Diagram for O/O_3 Reaction

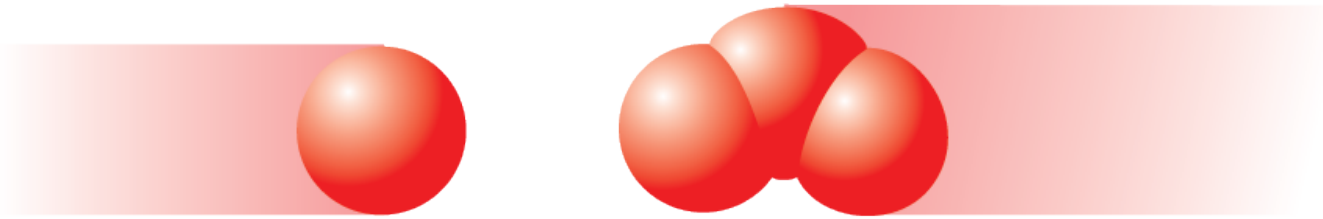


$$O(g) + O_3(g) \rightarrow 2O_2(g) + 390\ kJ$$

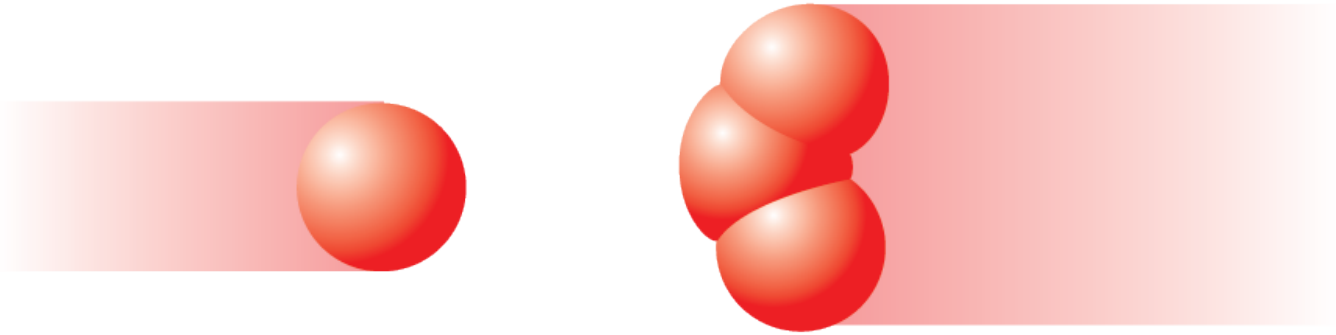
Endergonic Reactions



Orientation



One favorable orientation



One unfavorable orientation

Summary (part 1)

- **The reactant particles must collide.**
  - The collision brings the reactants together, and the kinetic energy of the particles provides the energy necessary for the reaction to proceed.

Summary (part 2)

- **The collision must provide at least the minimum energy necessary to produce the activated complex.**
  - It takes energy to initiate the reaction by converting the reactants into the activated complex. If the collision does not provide this energy, products cannot form.

Summary (part 3)

- **The orientation of the colliding particles must favor the formation of the activated complex, in which the new bond or bonds are able to form as the old bond or bonds break .**
  - Because the formation of the new bonds provides some of the energy necessary to break the old bonds, the making and breaking of bonds must occur more or less simultaneously. This is only possible when the particles collide in such a way that the bond-forming atoms are close to each other.