Chemistry Lecture #82: Reaction Rate & Collision Theory

Reaction rate is the rate at which a product is produced in a chemical reaction. It can also be the rate at which a reactant disappears in a chemical reaction.

Reaction rate is expressed in units of

$$\frac{\text{mol}}{\text{L s}}$$

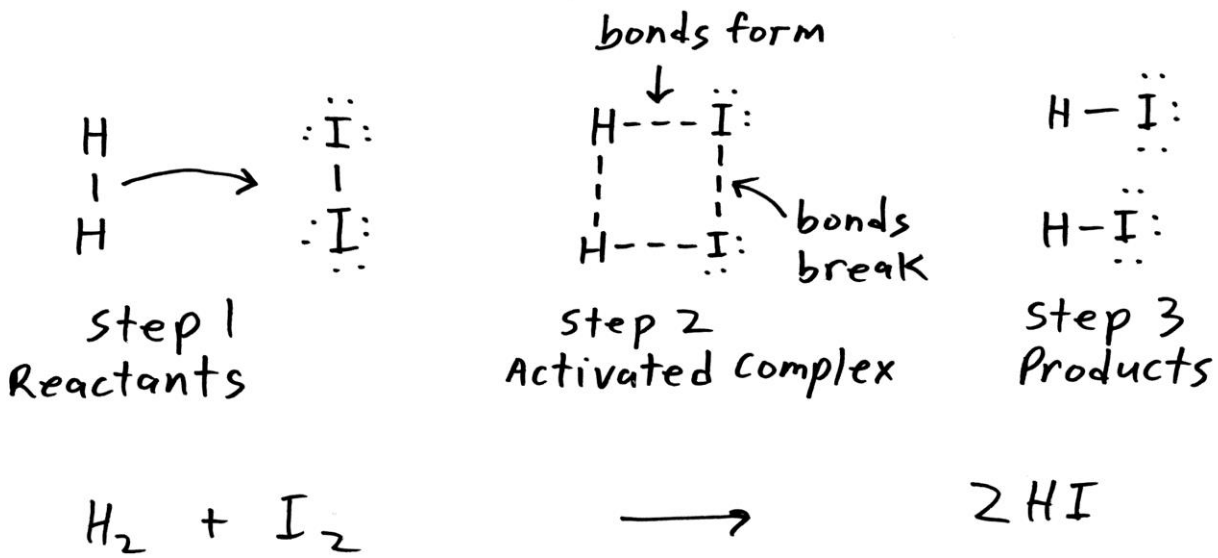
or (mol/L)/s. We pretend that the reaction is occurring in a 1 L container, and we're measuring the moles of product being made each second. Thus, if a product is made at a rate of 5 (mol/L)/s, it means that if the reaction were occurring in a 1 L container, 5 moles of product were being made each second.

Collision theory states that chemical reactions occur when molecules and atoms collide. The reaction rate depends on the collision rate. If collisions occur more frequently, the reaction rate will increase.

To show how molecules collide, let's look at a reaction between hydrogen and iodine gas.

$$H_2\,(g) + I_2\,(g) \rightarrow 2HI\,(g)$$

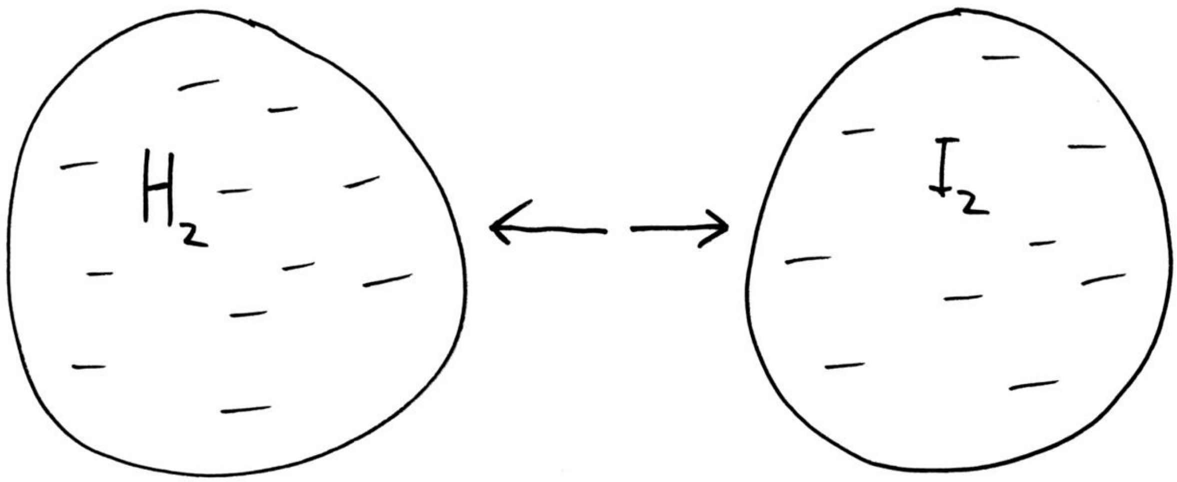
A hydrogen molecule collides with an iodine molecule. Below is a Lewis dot diagram of the molecules when they collide.



In step 1, the hydrogen molecule approaches the iodine molecule. In step 2, the molecules collide. The bond between the hydrogen atoms begin to break. The bond between the iodine atoms also begin to break. At the same time, bonds begin to form between the hydrogen atoms and the iodine atoms. This is called the activated complex.

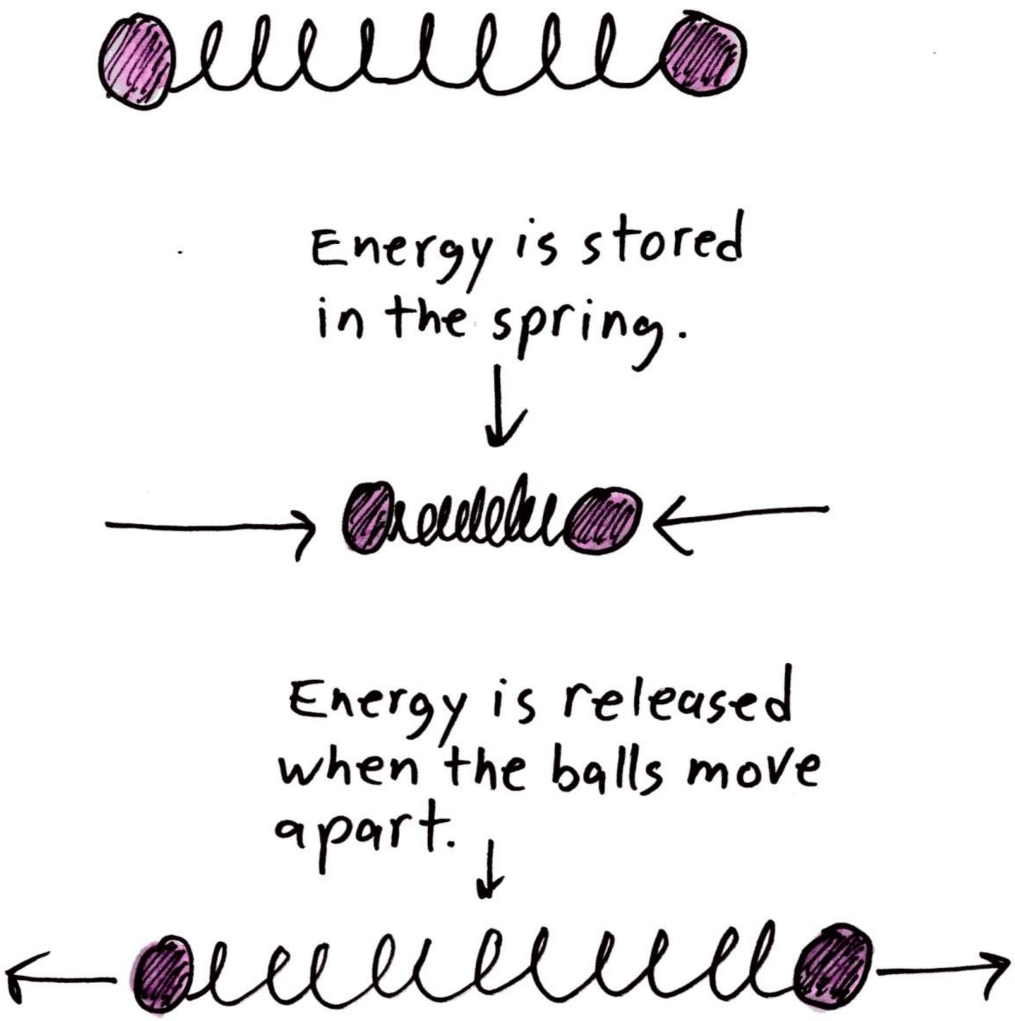
In step 3, the bond between the hydrogen atoms is completely broken. The bond between the iodine atoms is also completely broken. The bonds between the hydrogen and iodine atoms are fully formed, and the reaction is complete.

Not all collisions between molecules result in a chemical reaction. In fact, molecules tend to repel each other since they are surrounded by a sea of moving electrons. Electrons have negative charge, so if two molecules are surrounded by negative charges, the molecules will repel each other.



H_2 and I_2 repel each other since they are both surrounded by negatively charged electrons.

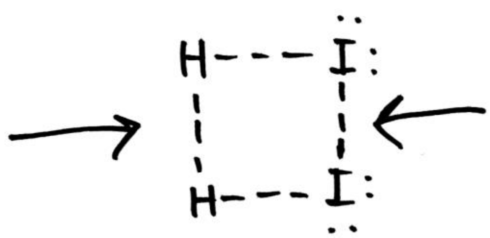
Pushing two objects together that are trying to repel each other is similar to placing a spring between two balls and pushing the balls together. It takes energy to push the balls and compress the spring. As the balls move closer together, more energy is stored in the spring. If you let go of the balls, the spring expands, releases energy, and the balls move apart.



In the same way, it takes energy to push H_2 and I_2 together. As they move closer together, potential energy is stored between them. When the molecules finally collide, the potential energy stored between them reaches its peak. Old bonds begin to break and new bonds form. Energy is released when new bonds form. Energy is also released when the new HI molecules move apart.

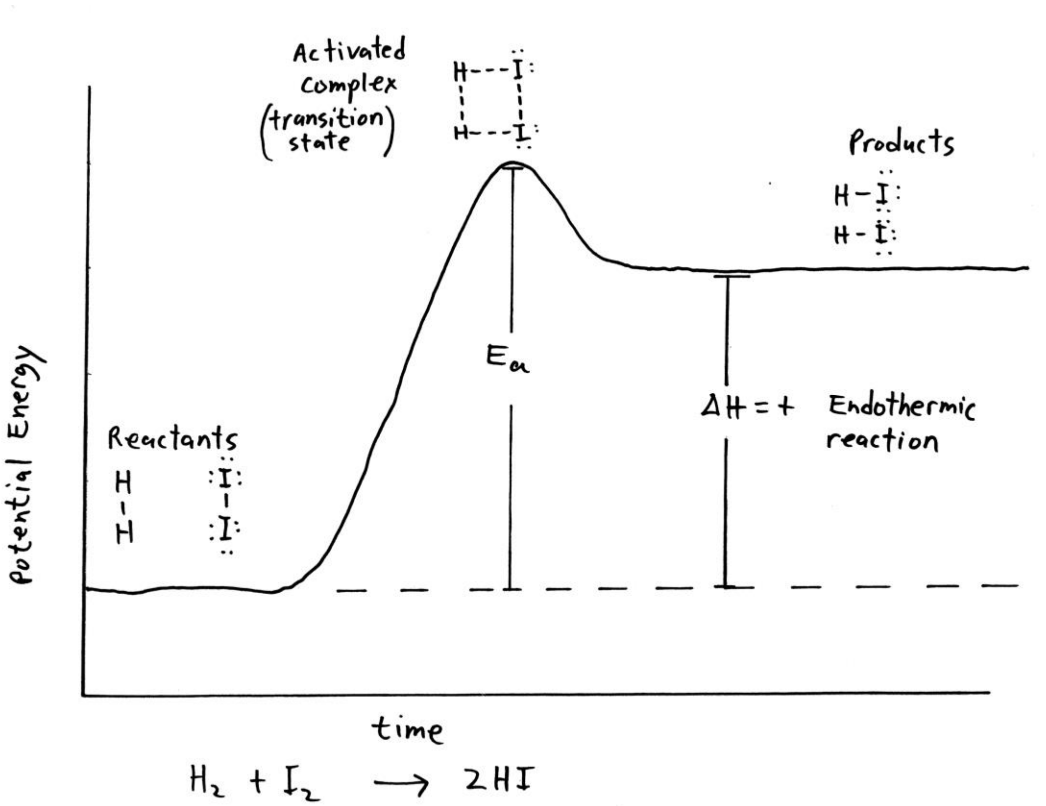
H_2 and I_2 approach each other.

When the molecules collide, the stored potential energy reaches a peak.



When the molecules move apart, energy is released.

We can plot a graph showing how the potential energy between the molecules increases and decreases as they approach and move away from each other.



At the peak of the energy curve is the activated complex. This is a transitional state between reactant and product where old bonds are partially broken and new bonds are partially formed.

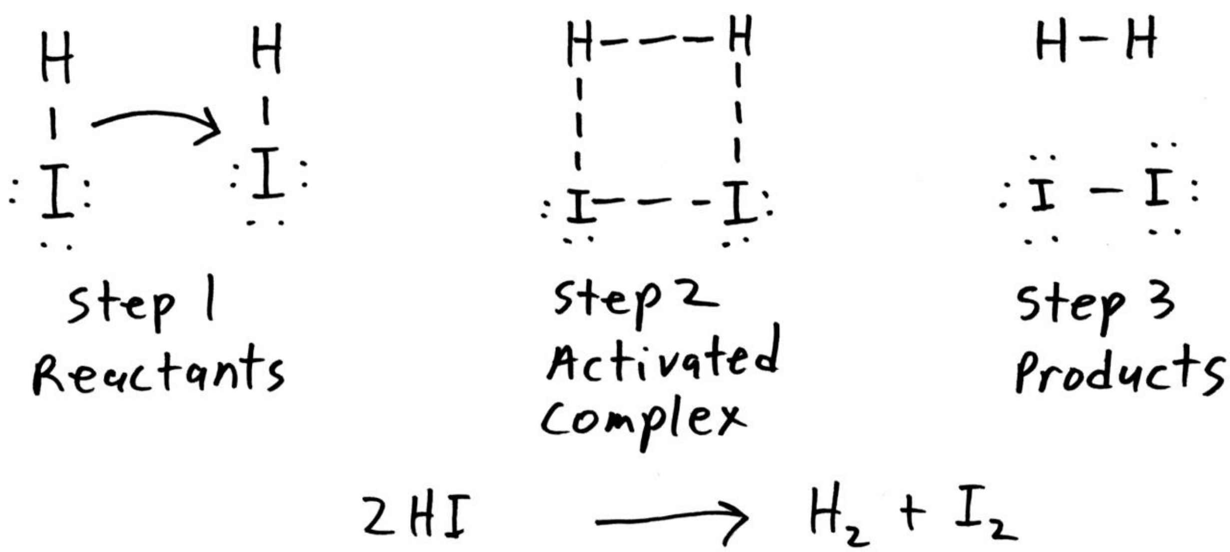
E_a is the activation energy. This is the energy required to push the reactants close enough together and with enough speed so that the activated complex can be formed.

ΔH is called the heat or enthalpy of the reaction. This is the energy that is absorbed or released in a chemical reaction. In the above graph, the energy absorbed is greater than the energy that is released, so this is an endothermic reaction, and ΔH = +. Since the reaction absorbs energy, the vessel that contains the reaction will become cold.

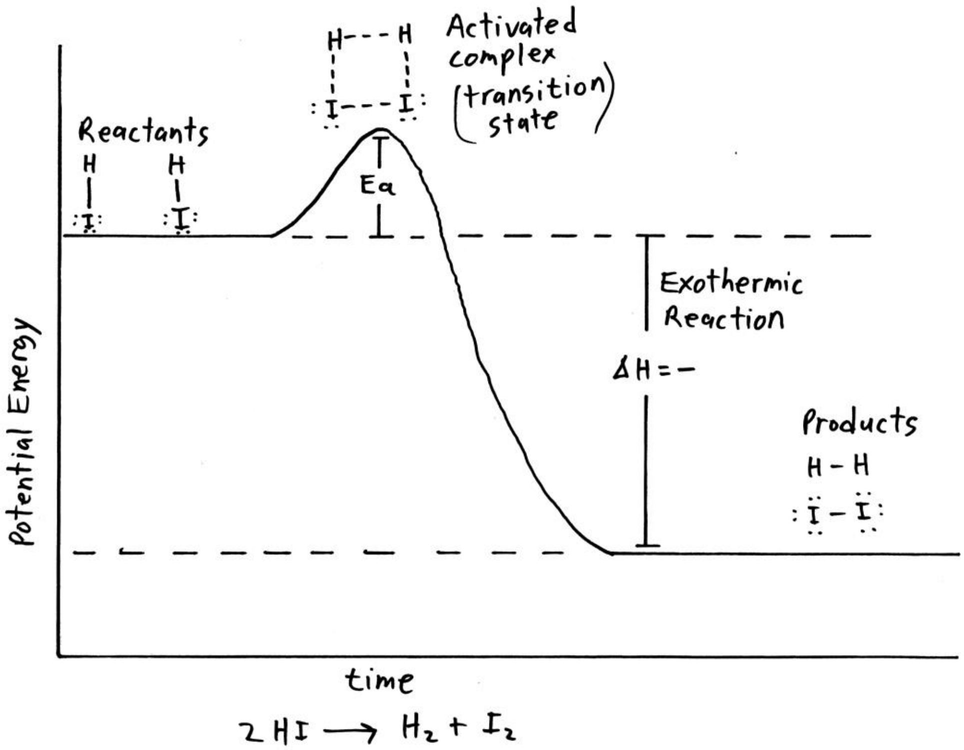
The reaction $H_2 + I_2 \rightarrow 2HI$ can go in reverse. The reverse reaction is

$$2HI\ (g) \rightarrow H_2\ (g) + I_2\ (g)$$

HI molecules also collide and form an activated complex, then separate and form H_2 and I_2.



We can also plot a graph showing how potential energy increases and decreases as the HI molecules approach each other, form an activated complex, and separate as H_2 and I_2.



Notice that the graph is just the reverse of the previous graph.

E_a or activation energy is smaller in the reverse reaction. It takes less energy to push the molecules together and break the bonds.

Notice also that the potential energy starts high but ends lower. This means that the energy released in the reaction is greater than the energy that was absorbed, so this is an exothermic reaction, and $\Delta H = -$. Since the reaction releases energy, the vessel that contains the reaction will become warm.