Part 5: Energy in Chemical Reactions:

Remember that atoms are made up of protons, neutrons and electrons. Protons and electrons have charge and can therefor apply forces to one another.

proton – proton: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_)

electron – electron: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_)

proton – electron: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_)

Because of this, chemical compounds have energy stored up within the bonds between atoms. Some reactions require energy to create bonds, other reactions release energy by the breaking of bonds. In general, larger molecules store more energy than smaller ones.

Chemical reactions always involve the breaking and/or forming of bonds and so energy is always involved. There are two basic types of chemical reaction, classified according to energy:

**Endothermic Reactions** are reactions in which the *chemical potential energy of the products is greater than the chemical potential energy of the reactants*. In other words, this reaction has absorbed energy from the surroundings. Remember, energy cannot be created, so the extra energy stored in the products had to come from somewhere. In most cases, this means the reaction will cause the surroundings to get colder. An instant cold pack is an example of an endothermic reaction.

**Exothermic Reactions** are reactions in which the *chemical potential energy of the reactants is greater than the chemical potential energy of the products*. In other words, this reaction has released energy to the surroundings. In most cases, this means the reaction will cause the surroundings to get warmer. In highly exothermic reactions there may also be a release of light and sound. An explosion is an example of a highly exothermic reaction.

**Activation Energy:** For a chemical reaction to occur, the molecules must collide. Furthermore, they must collide with enough *energy*; that is, they need to hit hard enough. How much energy the molecules need to hit with is called the activation energy. This is the extra energy, beyond what is stored in the molecules that must be present (think temperature) for the reaction to proceed.

**Activated Complex:** In chemical reactions there is usually an *intermediate* step between the reactants and the products, called the *activated complex*. The energy within this activated complex determines the activation energy of the reaction.

***Δ*H:** Virtually every chemical reaction involves some change in the amount of chemical energy within the reactants and the products. This change in energy is known as ΔH (pronounced “*delta* H”). Very simply it is the difference between the energy of the products and the energy of the reactants. Change is, by definition, the difference between the final value and the initial value of some quantity. Therefor:

***ΔH= final energy – initial energy***

***ΔH = energy of products – energy of reactants***

***ΔH = Hp - Hr***

For endothermic reactions ΔH will be positive.

For exothermic reactions ΔH will be negative.

**Notation:** Energy is an important part of a chemical reaction and, as such, it is often included in the chemical equation. There are 2 common ways to do this.

1. In *standard notation* the energy is written directly into the equation:

***A + B + 1000J → C+ D*** *(endothermic)*

***A + B → C + D + 1000J*** *(exothermic)*

2. In ΔH notation energy is shown to the side. It is positive for endothermic and negative for exothermic.

***A + B → C + D ΔH=1000J*** *(endothermic)*

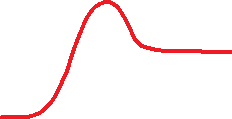
***A + B → C + D ΔH=-1000J*** *(exothermic)*

Potential Energy Diagrams:

Understanding energy in chemical reactions is incredibly important. It is essential to designing safe and efficient engines, furnaces, stoves and power plants. On smaller scales it is critical to understanding cellular processes in order to help diagnose disease, screen for and treat cancers. Understanding energy in chemical processes is essential to nutrition and diet in modern society where the majority of our food is purchased from a supermarket, rather than grown or raised or hunted.

To help understand energy in chemical reactions chemists make use of *potential energy diagrams*.

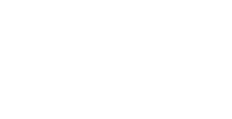
Energy



Reaction Progress



Energy



Reaction Progress

Collision Theory and Reaction Rates:

In order to understand collision theory, we must first recall *Kinetic Molecular Theory.*

**Kinetic Molecular Theory** is a theory with many applications. It can be used to explain the properties of the three basic states of matter (solid, liquid, gas), diffusion, conduction, convection, evaporation, diffusion as well as reaction rates.

**Kinetic Molecular Theory:**

1. All matter is composed of molecules.

2. The molecules are in continuous motion.

3. The spaces between the molecules are empty.

4. The speed of the molecules increases with temperature.

**Collision Theory:**

In order for a reaction to occur molecules must collide:

1. with a sufficient amount of energy.

2. with the correct orientation.

The majority of collisions between molecules will not result in a reaction.

What this means is that the molecules must hit each other hard enough, and they have to hit at the right angle and position.

Example: Consider the reaction shown. Imagine that in order to react the reactants must form a product, like shown:

+ →

* It should be clear that they can`t just bump into each other in any way, they must align properly and there must be sufficient energy for them to lock together.
* ***This is only an analogy***, molecules are not actually puzzle pieces.

In order to make a reaction occur more quickly it is necessary to do one (or more) of the following

* Increase the number of collisions.
* Increase the energy of the collisions.
* Improve the orientation of the collisions.

**Reaction Rate:** The reaction rate is measure of how much time is required for a reaction to proceed from reactants to products. In other words, it is a measure of how quickly a reaction proceeds. A higher reaction rate means a faster reaction, a lower reaction rate means a slower reaction.

**Factors Affecting Reaction Rate:**

1. Temperature: As temperature increases the speed of the molecules increases. If the molecules in a chemical reaction move more quickly, there will be *more collisions* AND the collisions will occur with *more energy*.

***Increased Temperature ⇒ Increased Reaction Rate***

2. Stirring/Physical Agitation: If the reactants are stirred together or shaken or agitated in some way, the speed of the molecule will increase and the chemicals can have more contact, especially for powdered solids. Again, there will be *more collisions* AND the collisions will occur with *more energy*.

***Increased Agitation ⇒ Increased Reaction Rate***

3. Surface Area: A reaction can only occur if the molecules of a reactant can collide. If a cube of solid zinc is placed into hydrochloric acid, only the zinc molecules on the surface of the cube can react; the molecules inside the cube cannot interact with the acid. If you were to cut the cube into smaller pieces more surface would be exposed, and so more zinc atoms would be able to be hit by acid molecules to react. This is also true for a reaction between a gas and a solid or a gas and a liquid. More surface area will result in *more collisions*.

***Increased Surface Area ⇒ Increased Reaction Rate***

4. Concentration: Concentration is a measure of how many molecules are in a certain amount of space. Higher concentration means more molecules in the same space. The higher the concentration of the reactants, the more likely it is they will collide. A simple analogy is to think of how crowded a room is. If you have a classroom with only 5 people walking around in it, it will be fairly easy to move around without bumping into anyone. If the same classroom is now packed with 40 people, all walking around, collisions will be very difficult to avoid. Increasing the concentration will result in *more collisions.*

***Increased Concentration ⇒ Increased Reaction Rate***

5. Catalysts: A catalyst is a chemical substance which participates in a chemical reaction, but is not used up in the reaction. In other words the catalyst is involved, and may even be altered, in the reaction, however it is present in equal amounts before and after the reaction. The roll of the catalyst is to make the reaction occur more efficiently by helping the reactants to align properly. The details of how catalysts work can be incredibly complex, however the overall effect is that *catalysts lower activation energy*. This means a *higher percentage of successful collisions.*

***Catalyst ⇒ Increased Reaction Rate***