

## **I. Energy and the Four Fundamental Forces-continued**

### A. Review Definitions:

**Energy-** The ability to do work. Measured in JOULES (J)  $\text{kg m/s}^2$  or calories

What is a calorie? The amount of energy required to raise 1 g H<sub>2</sub>O 1°C

There are 4.184 Joules/calorie

4,184 Joules/Calorie

**Kinetic Energy-** The energy of motion (also called released energy)

**Potential Energy-** The energy of position (also could be thought of a stored energy)

### **B. Review BIG IDEA: Potential energy is caused by the forces of nature.**

#### **1. Strong and Weak Forces are confined to the nucleus of atoms.**

#### **2. Gravitational Force $F = m/d^2$**

- a. Diana lifts a book → she is providing the energy to change the position of the book relative to the ground, giving the book potential energy. This stems from the fact that the fundamental force of gravity is causing an attraction between the book and the earth. Why is potential energy increasing? Because the book is moving AWAY from the direction of the force.
- b. Gravity is the weakest of the four fundamental forces ( $10^{-39}$  that of the Strong Force) Why is it so weak??? Well, think about atoms and molecules and look at the equation that defines the force exerted by gravity:  $F_{(g)} = m/d^2$  Because the mass of atoms/molecules is sooooo small, gravity becomes a negligible force.
- c. Electromagnetic Force creates the energy transitions we study in chemistry.

## **II. Electromagnetic Force**

Recall that this is an attractive/repulsive force based on + and - charges/ north and south magnetic poles.

Think about atoms: the positive nucleus attracts the negative electrons. The electrons repel each other; as a result, electrons are found in the most energetically favorable regions around the nucleus (remember 1s, 2s, 2p, etc) approximately 90% of the time!

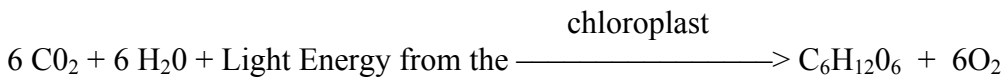
- A. Think about the Flame Test! How does it relate to electromagnetic force and energy conversions? What happens to the position of an electron that is excited by an outside energy source? It moves AWAY from the direction of the force, thus increasing Potential Energy. When it falls back to its original energy level, kinetic energy is released because it is moving IN THE DIRECTION of the force.

B. In your homework tonight you will stretch a rubberband → the potential energy stored in the rubberband is coming from the electromagnetic force which is causing the attraction between the molecules comprising the rubberband. As the band is stretched the potential energy stored in the band is increasing because the molecules are being pulled AWAY from the direction of the force.

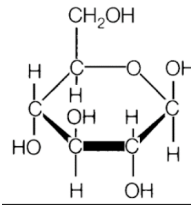
C. Chemical reactions happen when there are changes to the way electrons are interacting with their nuclei. Those interactions are governed by the electromagnetic force. Therefore in chemistry we will be most concerned with the electromagnetic force.

1. Gummi Bear Demo → P.E. → K.E. in a big way! Chemical potential energy stored in the chemical bonds of sugar molecules of the gummi bear was released in a chemical reaction with oxygen gas (combustion). That chemical potential energy is rooted in the electromagnetic force (the position of negative electrons and their positions relative to each other and the positive nuclei of the bonded atoms)

Let's look at this in more detail:



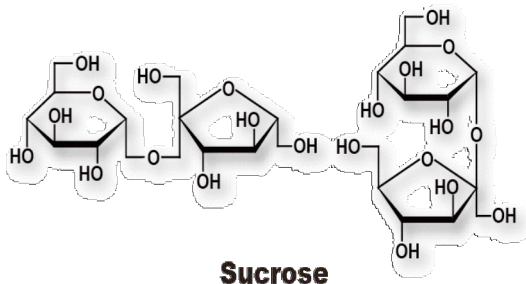
The sun's captured energy was used to rearrange the atoms from carbon dioxide and



water and build them into a large molecule, glucose: \_\_\_\_\_ and oxygen (O<sub>2</sub>)

The sun's energy was used to build chemical bonds that now hold that energy through the position of shared electrons that create these chemical bonds.

The gummi bear is made of an even bigger sugar! Sucrose is a sugar built by sugar cane and a single molecule looks like this:



Where is the energy that went into building this molecule held? How did it get there? When it is released chemical P.E. → Kinetic Energy (light and heat)

#### IV. Kinetic Energy

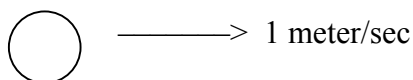
A. We have seen how we can increase potential energy in a system (by adding energy to move particles AWAY from the direction of the force)

How does Kinetic Energy increase? We know that K.E. is released when particles move IN the direction of a force.

Study this equation:

$$\text{K.E.} = 1/2 (\text{mass}) (\text{m/sec}^2)$$

Now think about this glob of clay moving at 1 meter/sec:



1. Generally, how can you increase the K.E.?
  - a. Increase the speed
  - b. Increase the mass
  
2. How can we increase K.E. on a microscopic (molecular) level?
  - a. Can you increase the internal energy/movement? Yes. How?
  - b. Can you increase the mass? No. Why?

B. Increasing the 'speed' of molecules

1. Basically, the faster the molecules in a sample are moving, the more kinetic energy those molecules have. This means both an increase in heat and temperature.

- a. What is heat?
  - 1) The measure of TOTAL kinetic energy in a sample (is affected by amount of sample)
  - 2) It is measured in Joules (or calories)
  - 3) It's symbol in equations is 'q'
  
- b. How is heat different from temperature?
  - 1) Temperature is the measure of the AVERAGE kinetic energy in a sample (is unaffected by the size of the sample)
  - 4) It is measured in °C (cesius), °F or K (Kelvin)

Huh? Well, consider this:

1 drop of boiling water (100° C)



Bathtub full of 100 °C water (yikes!)



Compare the temperature and the heat of each!  
 Did you come up with this? The AVERAGE kinetic energies (temperatures) are the same, but the TOTAL kinetic energy of System B is greater because there are many more molecules involved. Thus, it has more heat.

## V. Conservation of Energy-

**BIG IDEA: Energy can never be created or destroyed! It can however change forms. If we can't create it, it must come from somewhere...**

A. So, where did the energy come from that created the position of the book or the stretch of the rubber band from examples in the first section of these notes?

EXAMPLES:

- 1) Diana lifts a book → The potential energy stored in the book came from the chemical processes going on in her body. (Much like the gummi bear example- energy is released from ATP built through cellular respiration when the chemical bonds in food are broken.) By using her muscles, she is converting some of that energy of motion into gravitational potential energy.
- 2) For your homework you stretched a rubberband → Same as above. The energy of motion is possible because of the conversion chemical potential energy stored in bonds of the food you ate earlier.

B. When we look at energy transfers, we need to define the space we are discussing.

1. Definitions:

- System- Objects/reactions being studied
- Surroundings- Everything else in the universe, particularly anything that exchanges energy with the system.

2. We describe energy loss or gain to a particular system, keeping in mind the law of conservation of matter:  $\Delta = \text{"change in"}$

$$\Delta \text{ Energy of System} + \Delta \text{ Energy of Surroundings} = 0$$

Since the book dropped by Diana is falling towards the earth, it is losing potential energy because it is moving IN THE SAME DIRECTION as the force. If we define the book as the system than the following changes can take place:

SYSTEM- the book	SURROUNDINGS- floor, air, etc...
<b>Loss in PE (due to falling)</b>	→ Gain in PE
→ Gain in KE	→ Gain in KE

Hopefully from what we talked about in class and from this diagram you understand that there are 3 possible outlets for the energy to go:

- 1) The system (book) can gain KE
- 2) The surroundings can gain PE (increase in distance between air molecules)
- 3) The surroundings can gain KE (release of heat into surroundings, vibration, sound)

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- 4) The system (book) can gain KE
- 5) The surroundings can gain PE (increase in distance between air molecules)
- 6) The surroundings can gain KE (release of heat into surroundings, vibration, sound)

3. When heat energy is transferred there are 2 cases to understand:

- 1) EXOTHERMIC - heat energy is released from the system to the surroundings  
- feels warm

Example- loss of heat by a system during a chemical reaction

SYSTEM- reactants	SURROUNDINGS- beaker, air, table, etc...
<b>Loss in PE</b> → Gain in KE	→ Gain in PE → Gain in KE

- 2) ENDOTHERMIC - heat energy is absorbed by the system from the surroundings  
- feels cold

Warming of a beaker of cold water as it equilibrates to room temperature

SYSTEM	SURROUNDINGS
→ Gain in PE → Gain in KE	<b>Loss in KE</b> → Gain in PE

Potential Energy Diagrams-

For chemical reactions, we diagram these changes in a particular way.

The reaction: Reactants → Products can either be Exothermic or Endothermic. We will practice making these diagrams next class period!