Period 6b Activity Solutions: The Laws of Thermodynamics

6.3 Equilibrium and the Second Law of Thermodynamics

Your instructor will discuss equilibrium, which is a system or object that does not change over time.

1) Equilibrium Examples

a) List of examples of objects or systems in equilibrium.

Water at room temperature, floating magnets, uncharged capacitor

b) Which sets of photographs illustrate systems going toward equilibrium?

Sets of photos that show noticeable changes over time are going toward equilibrium.

2) Equilibrium and Entropy

Explain how equilibrium is related to entropy.

As systems come to equilibrium with their surroundings, the entropy of the systems increases. Objects that are at the same temperature or the same pressure as the room are in equilibrium. Objects that are not tipping over or falling are at equilibrium.

3) The Second Law of Thermodynamics

Your instructor will discuss several statements of the second law of thermodynamics. Give examples from the classroom to illustrate each statement.

a) The entropy of a physical system left to itself will increase or, if the system is already at its maximum entropy, the entropy will remain the same.

an ice cube melts and the water warms to room temperature

b) Any system, when left to itself, tends toward equilibrium with its surroundings.

an inflated balloon deflates

c) The entropy of a system that is in equilibrium with its surroundings remains constant.

There is no noticeable change to any object at equilibrium with its surroundings.

Your instructor will discuss the relationship between irreversible processes and perpetual motion machines. Another version of the second law is shown below. Give examples to illustrate it.

d) All physical processes are irreversible.

Examples showing work done as systems go to equilibrium: door closer, a capacitor or battery connected to a fan turns the fan blades, water a different temperatures in two beakers turns a fan

e) Group Discussion Question: What happens to entropy of the dorm room of a typical college student over the course of the academic year? What must be done to the room to decrease its entropy?

6.4 Reversible Processes and Perpetual Motion

4) Sand Mix together the two different colors of sand.

a) Will the mixed colors of sand naturally go back to its unmixed state? **_No_**

b) What must be done to separate the two colors of sand?

Work must be done on the system of the mixed sand to separate it.

c) Is the process of mixing the sand a reversible or irreversible process?

It is an irreversible process. It is possible to separate the colors of sand, but only if work is done on the system of the mixed sand.

5) The Dippy Duck revisited

Is the Dippy Duck a perpetual motion machine? If not, what is its source of energy?

It is not a perpetual motion machine. The dippy duck will stop when the water evaporates from the cup. The dippy duck draws water from a cup that requires someone to do work to fill the cup.

6) Perpetual Motion Machines?

Your instructor will show you examples of "perpetual motion" machines.

Can a machine run on its own forever without some kind of energy input? Why or why not?

No, perpetual motion machines do not work. Since some energy is wasted in every process, that energy must be replaced to keep the machine working. Perpetual motion would violate the second law of thermodynamics. A perpetual motion machine, from which you could take energy as it runs, violates the 1st law and the 2nd laws of thermodynamics.

6.5 Efficiency and Irreversible Processes

7) Engines Your instructor will discuss and demonstrate several types of engines, heat engines and motors.

a) What is the difference between a heat engine and an electric motor?

Both devices convert energy into mechanical energy of motion. Heat engines convert thermal energy, which is produced by combustion of some type of fuel, into mechanical energy. Electric motors convert electrical energy directly into mechanical energy with some energy wasted as heat.

b) How is work related to equilibrium?

Work or energy is required to change a system from an equilibrium state. That energy can be given off or work can be done by a system if it is moving back toward equilibrium. For example, the electric motor runs only if there is difference in voltage, and a steam engine runs only

if there is a difference is temperature. These devices will only run as long as a nonequilibrium situation exists.

c) Can a system ever return to a non-equilibrium state?

Yes, a system can return to a non-equilibrium state, but work must be done on that system or energy put into the system. Two examples are the compressed air tank and charging of the capacitor.

8) **Air Conditioners** Your instructor will demonstrate an air conditioner.

a) How does the palm glass filled with freon apply to an air conditioner (or a refrigerator)?

Freon has such a low boiling point that heating the glass bulb in your palm can cause some freon molecules to change phase from liquid to gas. This phase change increases the pressure in the palm glass.

b) What is the cooling mechanism in an air conditioner (or refrigerator)?

Cooling occurs in the air conditioner coils when the pressure on the freon (or other liquid) is quickly reduced as the freon is allowed to expand through a small opening. As the liquid freon expands, it becomes a gas. To change phase from a liquid to a gas, heat must have been added. That heat comes from the surroundings, and the surroundings are cooled.

9) **Calculations with Heat Engines, Heat Pumps, and Refrigerators**

a) What is the maximum efficiency of a heat engine that has 100 ^{o}C at the high temperature region and 20 ^{o}C in the low temperature region?

First, convert the temperatures from Celius to Kelvin by adding 273 K.

$$\mathbf{Eff} = \frac{T_H - T_L}{T_H} = \frac{\mathbf{373\ K - 293\ K}}{\mathbf{373\ K}} = \frac{\mathbf{80\ K}}{\mathbf{373\ K}} = \mathbf{0.21} = \mathbf{21\%}$$

b) You use a heat pump to warm your house. If the air temperature outside of the house is – 10 ^{o}C and the temperature inside is 23 ^{o}C, what is the maximum coefficient of performance for this heat pump?

First, convert the Celsius temperatures to Kelvin by adding 273 degrees. Then use equation 6.7.

$$\mathbf{COP} = \frac{Q_H}{W} = \frac{T_H}{T_H - T_C} = \frac{\mathbf{273 + 23}}{\mathbf{(273+23) - (273-10)}} = \frac{\mathbf{296}}{\mathbf{296 - 263}} = \mathbf{9.0}$$

c) Group Discussion Question: What is the difference between a heat pump and a refrigerator?