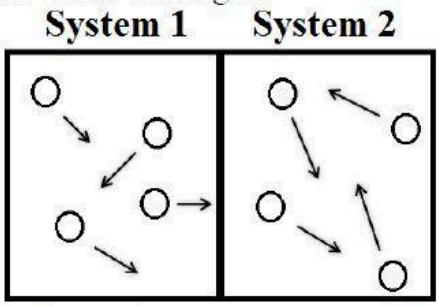
Thermodynamics
6.1 Endothermic and Exothermic Processes
6.2 Energy Diagrams
6.3 Heat Transfer and Thermal Equilibrium
Worksheet Key

1) Use the Boltzmann distribution curves from the slideshow to relate temperature to the motions of particles.

Temperature is a measure of the average kinetic energy of the particles in a system. The basic formula for kinetic energy is $KE = 1/2mv^2$. As the mass of atoms and molecules does not change, velocity increases as *KE* or temperature increases. The Boltzmann distribution curves show that the average velocity as well as the distribution of velocities (fast to slow) increase as temperature increases.

2) Arrows were used to represent the relative velocities of the particles in the following two pure samples of the same gas.



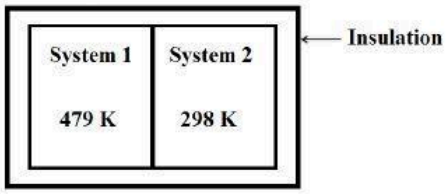
a. Is System #2 at a higher or lower temperature than System #1? Justify your answer.

System # 2 is at a higher temperature than System #1. Temperature is a measure of the average kinetic energy of the particles in a system. As both systems are pure samples of the same gas, all of the individual particles have the same mass. According the equation $KE = 1/2mv^2$, when all of the particles share the same mass, velocity is the only variable that affects kinetic energy. As the arrows in System #2 are longer, those particles are moving at higher velocities, and thus, possess a higher average kinetic energy.

b. Will kinetic energy be transferred from one of these systems to the other? Justify your answer in terms of molecular collisions.

Kinetic energy will be transferred from the higher temperature system (System #2) to the lower temperature system (System #1). Collisions between the gas particles and the molecules that make up the plane of thermal contact are similar to collisions between a series of billiard balls. One molecule collides with another and transfers some *KE* to it. This results in a decrease in *KE* in the higher temperature system and an increase in *KE* in the lower temperature system.

3) Consider the following two systems, which are housed in rigid containers that are in thermal contact with one another.



a. If the insulation of the outside of the two systems prevents any energy from flowing into the surroundings, will the energy lost by System #1 be greater than, less than or equal to the energy gained by System #2.

The energy lost by system #1 will be equal to the energy gained by System #2.

b. Identify the type of energy that is transferred from System #1 into System #2. Justify your answer.

Heat is transferred from System #1 to System #2. Initially, both systems are at different temperatures, so heat will flow from System #1 into System #2 until both systems reach the same temperature. Since the systems are housed in rigid containers, changes in volume are not possible so energy cannot be transferred between systems in the form of work.

4) Two solutions at 25°C were mixed in a beaker. A precipitate formed and temperature of the new solution dropped to 19°C.

a. Did the amount of energy contained by the system increase, decrease, or remain the same? Justify your answer.

The amount of energy contained by the system increased. Heat (energy) flowed from the water (part of the surroundings) into the system.

b. Was the chemical reaction that took place endothermic or exothermic?

Endothermic

c. Did the amount of energy contained by the surroundings increase, decrease, or remain the same? Justify your answer.

The amount of energy contained by the surroundings decreased. Heat (energy) flowed from the water (part of the surroundings) into the system.

5) A student puts a beaker with 150 mL of distilled water a hotplate. The temperature of the water increases from 22°C to 85°C.
   a. Did the amount of energy contained by the 150 mL of water increase, decrease, or remain the same? Justify your answer.

The amount of energy contained by the water increased. Energy flowed from the hotplate into the water. This caused the average kinetic energy of the water molecules to increase.

   b. Was this process endothermic or exothermic for the water? Explain.

The process was endothermic for the water. Energy flowed into the water from the surroundings.

6) A gas contracts from 4.26 L to 1.89 L in a cylinder under a constant external pressure of 1.10 atm. The temperature of the system remained the same during this process. Was this process endothermic or exothermic? Justify your answer.

The process was endothermic. The pressure caused by the gas particles colliding with the piston on the outside the cylinder was greater than the pressure caused by the gas particles colliding with the piston on the inside of the cylinder. This caused the piston to move in the direction that decreased the volume inside the cylinder. The gas outside the cylinder did work on the piston.

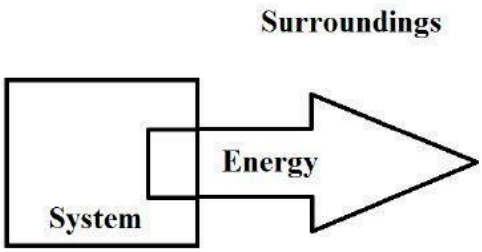
7) 1354 J of heat was absorbed by a balloon from the surroundings, which causes the gas inside the balloon to expand from 2.31 L to 3.98 L under a constant external pressure of 1.07 atm.
   a. Was the absorption of 1354 J of heat from the surrounding an exothermic or endothermic process? Justify your answer.

Absorption of heat from the surroundings is an endothermic process. Heat flows from the surroundings into the system and the internal energy of the system increases.

   b. Was the expansion of the balloon endothermic or exothermic? Justify your answer.

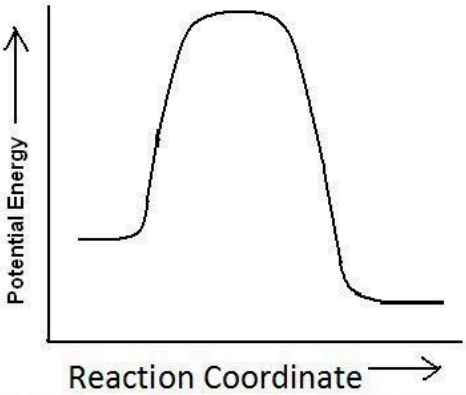
The expansion of the balloon was exothermic, as it expanded into the surroundings. This means that the gas inside the balloon did work on the surroundings.

8) Draw a symbolic representation that demonstrated the flow of energy between the system and the surroundings for an exothermic process.



9) The following questions pertain to the burning or methane gas, CH_4, in the presence of oxygen.

a. Sketch a reaction energy diagram for the reaction.



Products contain less *PE*. You need to be able to label the *x* and *y*-axis correctly. Potential energy is on the y-axis. Reaction Coordinate is on the *x*-axis.

b. Is this reaction endothermic or exothermic?

Exothermic

c. Did heat flow into or out of the system?

Heat flowed out of the system and into the surroundings.

10) Identify and describe the energy changes that take place when sample of sugar, $C_6H_{12}O_6$ dissolves in a pure sample of water.

Hydrogen bonds and London dispersion forces of attraction between the individual sugar molecules are broken, which are an endothermic processes. Some hydrogen bonds between water molecules are broken, which is an endothermic process. Hydrogen bonds between water molecules and sugar molecules are established, which is an exothermic process.