Introduction to the Laws of Thermodynamics

Name_____ ID_____ TA_____

Partners_____

Date_____ Section_____

Caution

Use extreme caution when you handle the hot water, otherwise it may result in serious personal injuries.

Equipment Needed: Two calorimeters (e. g. Styrofoam), Outer and inner aluminum cups, a heater to produce hot water, two thermometers, and a balance

Hints:
1. Heat radiates easily, so use the lids (aluminum foil, etc.) of cups always.
2. Please take a proper amount of waters. Otherwise, the water will overflow the cup when you mix them.

1. The first law of thermodynamics (Conservation of thermal energy)

Heat Energy: $\Delta Q = MC(\Delta T)$

Mass of the cup for "cold water": M_{cold} _____(kg)

Mass of the cup for "hot water": M_{hot} _____(kg)

Cold to hot or hot to cold ?	Total mass of cup and cold water	Total mass of cup and hot water	Net mass of cold water M1	Net mass of hot water M2	Cold water temperature T1	Hot water temperature T2	Final temperature T0	$M_1Cw(T0-T1)$ (J)	$M_2Cw(T2-T0)$ (J)
Cold→Hot									
Cold→Hot									
Hot→Cold									
Hot→Cold									

Questions:

☑ Is the thermal energy conserved?

☑ Why some case does not agree to the conservation of thermal energy? (Consider the heat capacitor of cups, heat dissipation, absorption, etc.)

2. The second law of thermodynamics (Entropy)

Mass of outside cup (larger one) of calorimeter _____ (kg) **(1)**

Mass of inside cup (smaller one) of calorimeter _____ (kg) **(2)**

☑ **Mass of water:**

M_1 = Mass of inside cup (smaller one) + cold water – **(2) =** _____(kg)

M_2 = Mass of outside cup (larger one) + hot water – **(1) =** _____(kg)

☑ **Calculation for the entropies:**
(*T_i and T_f are initial and final temperatures respectively*.)

Cold water

Heat change: $\Delta Q = M_1 C_W (T_f - T_i)$ = _____(J)

Average temperature: $T_{ave} = (T_f + T_i)/2 + 273.15$ =_____ (K)

Entropy: $\Delta S = \Delta Q / T_{ave}$ =_____ (J/K)

Hot water

Heat change: $\Delta Q = M_2 C_W (T_f - T_i)$ = _____(J)

Average temperature: $T_{ave} = (T_f + T_i)/2 + 273.15$ =_____ (K)

Entropy: $\Delta S^* = \Delta Q / T_{ave}$ =_____ (J/K)

*Note: In the hot water case, the entropy becomes negative. It seems that the law is violated. In fact the entropy increases in every natural process in an "isolated" system. In addition, only those processes are possible for which the entropy of the system increases or remains a constant. Therefore, the entropy of a non-isolated system may either increase, or decrease, depending on whether heat is added to or taken away from the system.

Questions:

☑ For this incompletely isolated system, which is the magnitude of entropy larger than the other?

☑ Discuss the answer for the previous question by reading the graph. (Think about the meaning of entropy.)

☑ Did you find out that the heat flows from a hot to a cold system by looking at the graph? Also explain it with the signs of entropy. (Read the above note.)

Lab Procedure for Introduction to the Laws of Thermodynamics

1. The 1st law of thermodynamics (Conservation of thermal energy)

- ☑ **Weigh the cup** (for cold water) **and the other one** (for hot water) **without water.**
  This is to obtain the net mass of water. You always have to subtract the weights from the total mass of cup and water.
- ☑ **Do not forget to make a lid for each cup.**
- ☑ **Take hot water with the small cup, and cold water with the large cup.**
  Take a small amount of waters, like 1/3 of the cup.
- ☑ **Weigh those for the total mass.**
  You should always use lids to minimize the radiation of heat.
- ☑ **Measure the both temperatures at the same time with the PASCO interface.**
  Those will be T1 and T2 after stabilized.
- ☑ **Pour the cold (hot) water into hot (cold) water, and measure the final temperature.**
  As specified, mix the waters, and stir it with thermometer appropriately. After stabilized, take the data for T0.
- ☑ **Calculate the energy transferred by following the data sheet.**
  The heat capacity of water will be 4186 J/kg·K.

2. The 2nd law of thermodynamics (Entropy)

- ☑ **Weigh the inside and outside cups of calorimeter.**
  Follow the data sheet.
- ☑ **Pour an appropriate amount of hot water into the inside cup, and pour cold water into the outside cup.**
- ☑ **Put both cups together so that they can contact each other.**
  This is the set-up to measure the heat transfer between two systems.
- ☑ **Turn on the interface, and plug two thermometers in the analog channels.**
- ☑ **Put the thermometers into both hot and cold systems; then, wait for 15 minutes to have the data.**
  Use a lid made of aluminum foil.
- ☑ **Weigh the total masses of inside cup and outside cup, and calculate the masses of hot and cold water.**
  Just follow the data sheet.
- ☑ **From the initial and final temperatures, calculate each entropy.**
  Follow the data sheet. For the hot water, you should read the note.
- ☑ **From the data obtained by Science workshop, plot a graph as shown below.**
  The appearance may be different.

	A	B	C
	Time(min.)	Temp. of hot water	Temp. of cold water
2	0	59	21
3	1	57.8	21.4
4	2	56.6	21.8
5	3	55.4	22.2
6	4	54.2	22.6
7	5	53	23
8	6	51.8	23.4
9	7	50.6	23.8
10	8	49.4	24.2
11	9	48.2	24.6
12	10	47	25
13	11	45.8	25.4
14	12	44.6	25.8
15	13	43.4	26.2
16	14	42.2	26.6
17	15	41	27