Temperature Measurement and the Heat of Fusion of Water

Purpose: To determine the boiling and freezing points of water in order to calibrate a thermometer and to determine the heat of fusion for water.

Equipment: Bunsen burner, thermometer, calorimeter, ice, water, glass beaker, ring stand, triple beam balance.

Introduction: The specific heat of a material is defined to be the amount of heat needed to raise the temperature of 1 gram of the material by one degree Celsius. The unit for heat is the same as that for energy, except that today, instead of using the SI unit of joules we will use calories. You may know that there are 1000 of these calories (with a small c) in 1 diet Calorie (with a capital C). The unit for temperature is the Celsius degree. The Celsius degree is defined by saying that there are 100 Celsius degrees between the freezing point (0˚C) and the boiling point of water (100˚C). The specific heat of water is 1 cal/(g˚C) which means it takes 1 cal of heat energy to raise the temperature of 1 gram of water by 1˚C.

Suppose we wanted to increase the temperature of 50 g of water by 10˚C. How much heat would we have to add? The answer is ΔQ = 1 cal/(g˚C) x 50 g x 10˚C = 500 cal. In general if the temperature of a material of mass, m, and specific heat, C, is changed from an initial temperature of T_i to a final temperature T_f, the heat added (to warm) or subtracted (to cool) is given by:

$$\Delta Q = m\, C\, (T_f - T_i)$$

The heat of fusion, L_f, of a material is the amount of heat needed to change 1 gram of the material from a solid to a liquid. There is no change in temperature during this process since all of the absorbed heat energy is being used to break the bonds between water molecules in the ice. For instance, in changing 5 g of ice into water, the number of calories of heat needed is 5 x L_f. Similarly, if 5 g of water are frozen into ice we must remove 5 g x L_f calories of heat from the water. In this experiment you will determine L_f—that is the number of calories needed to change 1 gm of ice into 1 g of water.

Procedure:

1) **Thermometer Calibration** (Treat the thermometer with care. It is made of glass!)

We will first check the accuracy of your thermometer. Record the room temperature. Place approximately 100 cc of water in a beaker and begin adding crushed ice to the water. Observe the temperature of the water as the temperature is lowered. Keep adding ice and stir in the mixture until the temperature can be lowered no more. Record this lowest temperature. This temperature should be 0˚C on your thermometer. Pour out the ice and water mixture and add 200 cm^3 of new water to the beaker and raise the temperature of the water using a Bunsen burner. Observe the temperature of the water until the temperature will rise no more. Record this maximum temperature. This is the boiling point of water and should be very close to 100˚C. If your thermometer is off somewhat, make a note of any corrections you should make to your later measurements. The steam table on the last sheet of the lab gives boiling points as a function of atmospheric pressure.

2) **Measurement of the heat of fusion of water.**

a. Record the room temperature, barometric pressure, material and mass of the calorimeter cup.
b. Fill the calorimeter cup approximately one-half full of water, at a temperature 10 to 12˚C above room temperature. Weigh the calorimeter cup and contents and determine the mass of the water.
c. Assemble the calorimeter, and stir the water gently for several minutes. With a paper towel, dry a piece of ice, or several small pieces of ice, weighing about one-sixth the weight of the water of the calorimeter cup. Place the dried ice in the water immediately after reading the initial temperature of the water. Stir gently until the ice is melted, and record the lowest temperature.

d. To determine the weight of ice added to the calorimeter cup, weigh the calorimeter cup after the ice has melted, and determine the amount of ice added.

The heat of fusion can now be calculated using the following reasoning: The amount of heat needed to change the ice into water plus the amount of heat needed to raise the temperature of this water (that used to be ice) to the final temperature T_f must be equal to the heat given up by the original water plus the heat given up by the calorimeter cup. If m_i is the mass of the ice, m_w the mass of the water, m_c the mass of the calorimeter cup, and T_i the original temperature of the warm water, then we can write an equation which says the same thing:

Heat gained = Heat lost

$$m_iL_f + m_iC_w (T_f - 0^\circ) = (m_wC_w + m_cC_c) (T_i - T_f)$$

where L is the heat of fusion for water, C_w is the specific heat of water, and C_c is the specific heat of the calorimeter cup.

Solve this equation for L_f and determine L_f from your experimental data. Compare your value with the accepted value for L_f. If time permits, repeat the experiment.

Water-Vapor Pressure and Water-Vapor Density in Saturated Air

This table may be used to find the vapor pressure, P, of water vapor in saturated air at the temperature, t, the dew point, or to find the boiling point, t, of water under the barometric pressure, P, Pressure, **P**, is in cm of mercury. Water-vapor density, **D**, is in gms per cubic meter. Temperature, **t**, is in degrees Centigrade.

t	P	D	t	P	D
-10	.21	2.2	55	11.80	104.6
-9	.23	2.3	60	14.93	130.7
-8	.25	2.5	65	18.76	162.1
-7	.27	2.8	70	23.37	199.5
-6	.29	3.0	75	28.91	243.7
-5	.32	3.2	80	35.51	295.9
-4	.34	3.5	81	36.97	
-3	.37	3.8	82	38.49	
-2	.40	4.1	83	40.06	
-1	.43	4.5	84	41.68	
0	.46	4.8	85	43.36	357.1
1	.49	5.2	86	45.09	
2	.53	5.5	87	46.87	
3	.57	5.9	88	48.71	
4	.61	6.3	89	50.61	
5	.65	6.8	90	52.58	428.4
6	.70	7.2	91	54.60	
7	.75	7.7	92	56.70	
8	.80	8.2	93	58.86	
9	.86	8.8	94	61.09	
10	.92	9.3	95	63.39	511.1
11	.98	9.9	96	65.76	
12	1.05	10.6	97	68.21	
13	1.12	11.2	98	70.73	
14	1.20	12.0	98.2	71.23	
15	1.28	12.7	98.4	71.74	
16	1.36	13.5	98.6	72.26	
17	1.45	14.3	98.8	72.79	
18	1.55	15.2	99	73.32	
19	1.65	16.1	99.2	73.85	
20	1.75	17.1	99.4	74.38	
21	1.86	18.1	99.6	74.92	
22	1.98	19.2	99.8	75.47	
23	2.11	20.4	100	76.00	606.2
24	2.24	21.5	100.2	76.55	
25	2.38	22.8	100.4	77.10	
26	2.52	24.1	100.6	77.65	
27	2.67	25.5	100.8	78.21	
28	2.83	26.9	101	78.76	
29	3.00	28.4	102	81.59	
30	3.18	30.0	103	84.51	
35	4.22	39.2	104	87.51	
40	5.53	50.9	105	90.61	715.4
45	7.19	65.3	107	97.06	
50	9.25	83.0	110	107.46	840.1