Determination of Specific Heat of Metal

Purpose

Use the method of mixing the cold and the hot to reach thermal equilibrium and the concept of energy conservation to accurately measure the specific heat of metal.

Theory

The specific heat is defined as the heat that one unit of mass absorbs or releases when the system temperature increases or reduces 1℃. When we heat up a metal block (mass m_1) to temperature t_1 and put the block into the cold water of calorimeter (mass m_2 and temperature t_2). When the temperature of the metal block drops and the temperature of the calorimeter and its water increase to reach thermal equilibrium, the system temperature is t_3. If the insulation function of calorimeter is well-designed, the lost heat of the metal block will equal to the acquired heat of cold water and the calorimeter.

Thus, the released heat of metal block = the absorbed heat of calorimeter + the absorbed heat of water. The equation can be expressed as

$$m_1S_1(t_1 - t_3) = m_2S_2(t_3 - t_2) + C(t_3 - t_2) \quad (1)$$

S_1 and S_2 are the specific heat of metal and water. C is the heat capacity of calorimeter. The specific heat of metal is

$$S_1 = \frac{(m_2S_2 + C)(t_3 - t_2)}{m_1(t_1 - t_3)} \quad (2)$$

Instruments

No	Accessory	Qty
1	Heater	1
2	Steam pot	1
3	Double layer heater	1
4	Heater base	1
5	Calorimeter	1
6	Lid of calorimeter	1
7	Metal	1
8	Digital thermometer	1
9	Stainless cup	1
10	Rubber stopper (large)	1
11	Rubber stopper (small)	1
12	Silicon tube	2

Procedure

1. Measurement of heat capacity of calorimeter

a. Dry the calorimeter (including the thermometer) (as shown in **Figure 1**). Use the balance to measure its weight m_i .

Figure 1

Figure 2

b. Take out the inner cup of calorimeter. Fill cold water to 1/3 of the cup. Put the cup back to the calorimeter. Measure the mass m_c of calorimeter and water (including the thermometer). The mass of water is $(m_c - m_i)$.

c. Insert the thermometer into the inner cup. Measure the temperature of cold water t_c .

d. Pour water to the cup and put the cup on the heater (as shown in **Figure 2**). Record the boiling temperature t_h .

e. Pour the boiling water to 2/3 of the calorimeter cup and fasten the lid (Note: do not splash the water). Pay attention to the thermometer and record the balanced temperature t .

f. Use the balance to measure the total weight of calorimeter. The mass of the boiling water is $(m_h - m_c)$.

g. Calculate the head capacity of the calorimeter $C = \frac{(m_h - m_c)(t_h - t)}{t - t_c} - (m_c - m_i)$.

2. Measurement of metal's specific heat

Figure 3

a. Record the heat capacity C of the calorimeter and its mass m_i.

b. Measure the mass of the metal m_1. The experiment includes 5 different types of metal, as shown in **Figure 4**.

c. Pour cold water to the calorimeter until the water covers the metal. Measure the total mass m_c of calorimeter (including the lid and the thermometer) and the cold water. The mass m_2 of cold water is m_2 ($m_2 = m_c - m_i$).

d. Measure the temperature t_2 of the cold water inside the calorimeter.

e. Hang the metal in the calorimeter by tying it on the rubber stopper. Put one thermometer on the metal, as shown in **Figure 5** and **Figure 6**. The temperature of the heated metal is t_1. (When heating the metal, the metal piece below the heater should cover the mouth of the calorimeter to prevent air convection. Put the metal close to the thermometer.)

Figure 4

Figure 5

Figure 6

f. When the temperature is 90-92 degrees, move away the metal piece on the calorimeter so the metal can drop into the calorimeter (note: do not splash the water). Record the final balanced temperature t.

g. Calculate the specific heat S of metal.

h. Repeat procedures b-f several times on each metal. Calculate the average value and compared the value with standard values.

3. Notice:

① Heat capacity measurement of calorimeter

A. Before measuring the mass of the calorimeter (include the lid and the thermometer), keep the calorimeter dry and clean.

B. When pouring hot water, do not splash the cold water to prevent experiment errors.

② easurement of metal's specific heat

A. The heat capacity calculated from the first experiment will be used in this experiment so users have to use the same calorimeter.

B. When putting the metal into the calorimeter, put it quickly and do not splash the cold water.

C. Heat up the metal to 90 degrees. Higher temperature will prolong the experiment.

③ When mixing cold and hot water, if the balanced temperature is close to room temperature, the lost temperature by the calorimeter will be small so we can minimize the errors.

Recording sheet

Chart 1. Heat capacity measurement of calorimeter

Calorimeter (include thermometer) mass m_i (gram)	
Total mass m_c (grams) of calorimeter (include thermometer) and the cold water	
Temperature of cold water (inside the calorimeter) t_c (℃)	
Temperature of boiling water t_h (℃)	
Balance temperature after mixing t (℃)	
Total mass m_h (grams) of calorimeter (including thermometer) and boiling water	
Heat capacity C (cal/℃) of calorimeter	

$$C = \frac{(m_h - m_c)(t_h - t)}{t - t_c} - (m_c - m_i)$$

Chart 2. Measurement of metal's specific heat

Heat capacity of calorimeter $C=$______Cal／℃。

Mass of the calorimeter $m_i=$______g

	Aluminum	Brass	Lead,	Zinc	Copper
Mass of metal m_1 （grams）					
Total mass m_c （grams） of calorimeter and coldwater m_c （grams）					
Mass of cold water $m_2=m_c-m_i$ （grams）					
Calorimeter and the initial temperature of cold water t_2 （℃）					
Temperature of metal t_1 （℃）					
Final temperature t （℃）					
Specific heat of metal S （cal/grams-℃）					
Standard specific heat of metal S_0 （cal/grams-℃）					
Errors（%）					

$$S=\frac{(m_2+C)(t-t_2)}{m_1(t_1-t)}$$

$$\text{Errors（\%）}=\frac{S-S_0}{S_0}\times 100\%$$

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