CENCO Physics

Selective Experiments In Physics

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HEAT OF FUSION

(Simple Calorimeter)

OBJECT: To measure the heat of fusion of ice, using the method of mixtures.

METHOD: The heat absorbed by the melting of a measured mass of ice is determined by allowing it to melt in warm water in a calorimeter. From the observed, temperature change of the water and calorimeter and their known thermal capacities, a working equation is set up in which all the factors are known or measurable except the heat of fusion, which can thereby be obtained.

THEORY: When a substance changes from the solid to the liquid state it must absorb a large quantity of heat to produce the change. However, for crystalline substances, the temperature remains constant during the change of state. For example, if a block of ice is brought from outside where the temperature is much below the freezing point of water and heat is supplied to the ice at a uniform rate, the temperature of the ice will rise uniformly (just as for any other solid being heated) until the ice reaches its melting point. Thereafter the ice remains at 0°C until it is all melted, in spite of the fact that it continues to absorb heat at a uniform rate. After the ice has all melted, the ice water will begin to rise in temperature at a fairly constant rate, although this rate will be less than that for the ice, since the specific heat of water is about twice that of ice. These phenomena are illustrated in the curve of Fig. 1.

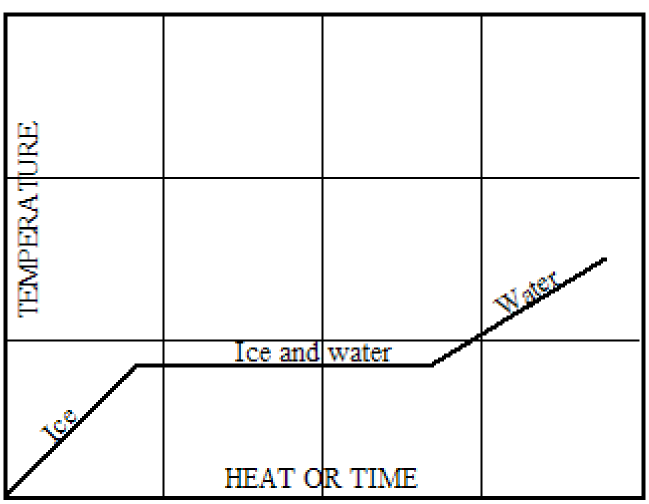

Fig. 1. Idealized diagram showing the heat required to raise the temperature of ice to the melting point, the heat of fusion and the heating of the ice water

The heat absorbed by a substance in changing from the solid to the liquid phase was formerly called the latent (hidden) heat of fusion. Since the nature of heat is now better known and it is recognized that considerable heat energy must be expended in producing the drastic changes in atomic configurations which differentiate the solid and liquid states, it is reasonable to omit the term "latent" and to refer to this energy in general terms as the *heat of fusion*. More *technically heat of fusion is defined as numerically the quantity of heat necessary to change a unit mass of the substance from the solid to the liquid state* (without a change of temperature). In symbols

$$L_f = H/M \quad \text{or} \quad H = L_f M \tag{1}$$

where L_f is the heat of fusion and H the heat required to change a substance of mass M from the solid to the liquid state.

The usual metric unit for L_f is the calorie per gram and the British unit is the British thermal unit (Btu) per pound. From the definitions of the calorie and the British thermal unit it follows that the number of British thermal units per pound is 9/5 times the number of calories per gram. For ice the heat of fusion is 79.67 calories per gram or 144 British thermal units per pound.

The Method of Mixtures: The method used in this experiment for the measurement of heat of fusion is known as the "method of mixtures". The technique is based upon the assumption that no heat is gained or lost from or to the surroundings so that the heat gained by the melting ice and the ice water is equal to that given up by the warm water and the calorimeter.

Derivation of Working Equation: In setting up equations for the heat transfers in experiments utilizing the method of mixtures it is vital to include every item which. gains or gives off heat. In this experiment the word statement of the heat transfers is

Heat absorbed by ice when melting + heat gained by ice water = heat given up by warm water + heat given up by the calorimeter

The following notation will be used: L_f = heat of fusion of ice, M_1 = mass of ice (also the mass of ice water), M_w = mass of warm water, M_c = mass of inner calorimeter vessel, t_1 = temperature of water and calorimeter after ice has melted, t_2

= temperature of warm water and calorimeter, C_w = specific heat of water, C_c = specific heat of calorimeter. Using Eq. (1) and the equation $H = Mc\,(t_2 - t_1)$, the symbolic equation for the heat transfers becomes

$$L_f M_i + M_i c_w (t_1 - 0) = M_w c_w (t_2 - t_1) + M_c c_c (t_2 - t_1) \qquad (2)$$

All of the factors in this equation are known or measurable except L_f and it may therefore be calculated from the observed data.

Minimizing Errors Due to Heat Losses: The working equation is derived upon the assumption that there are no heat losses or gains to or from the surroundings. This condition is approximated by the use of a properly constructed calorimeter and by properly adjusting the initial and final temperatures of the water in the calorimeter. The calorimeter (Fig. 2) consists of an inner vessel G, the calorimeter proper, made of aluminum (or sometimes copper) of high thermal conductivity, so that the vessel and its contents will quickly reach an equilibrium temperature. The inner vessel is kept from touching the outer jacket F by means of a non-conducting fiber ring H. Thus *conduction* of heat is reduced. Convection is minimized by the presence of the "dead" air space between the inner and outer vessels. To prevent radiation of heat, the vessels are made of polished metal. A wooden cover K reduces convection currents above the calorimeter cup. A stirrer L of the same material as the calorimeter is used to hold the ice under the water. Its weight should be added to that of the calorimeter.

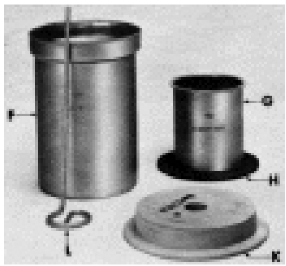
Fig. 2. Simple form Calorimeter

To further minimize heat losses the experimenter must arrange to have the original temperature of the water in the calorimeter as much higher than room temperature as the final equilibrium temperature will be below the temperature of the room. In this way the heat lost to the room while the temperature is above room temperature will be counter-balanced by the heat gained from the surroundings while the temperature is below room temperature.


Fig. 3. Water Heater

APPARATUS: Calorimeter (Fig. 2) , water heater (Fig. 3) , ice in lumps about the size of a walnut, 50°C thermometer, Bunsen burner, trip scales with weights, vessels for ice and water, and paper toweling.

PROCEDURE: Weigh the calorimeter cup (without the ring). Add about 200gm of water from the boiler to the calorimeter, adjusting its temperature until it is about 15°C above room temperature. Stir the water thoroughly and observe its temperature just before adding the ice.

Dry several lumps of ice with paper toweling. Quickly immerse the ice in the water and keep it submerged with the stirrer. Add other ice if necessary until the equilibrium temperature of the water in the calorimeter is about 5°C, after all the ice has melted. Note carefully this temperature. It is not advisable to remove any ice, as some water is necessarily removed with it. Keep the cover on the calorimeter and stir the water cautiously so as not to spill any.

Weigh the calorimeter and final contents. By subtraction the mass of the added ice is obtained. (Why is this technique better than trying to weigh the ice before adding it to the calorimeter?)

From the observed data determine the heat of fusion of ice, using the working equation. Take as many other observations as time permits, varying the values suggested above in accordance with the experience gained. Note the percentage difference between the average of the observed values and the standard value for the heat of fusion of ice.

The data may be tabulated as follows:

M_c = *mass of calorimeter*…………………….............			
M_1 = *mass of calorimeter and warm water*…………			
M_w = *mass of warm water*……………………………..			
M_2 = *mass of calorimeter, water and ice*..................			
M_t = *mass of ice (also the mass of ice water*…….....			
C_w = *specific heat of water*……………………………			
C_c = *specific heat of calorimeter*…………................			
t_1 = *equilibrium temperature (after ice has melted)*…			
t_2 = *initial temperature of warm water*……..............			
L_f = *heat of fusion of ice*……………………………….			
Percentage variation from standard value………			

QUESTIONS: 1. In the experiment above where you have determined the heat of fusion of water, determine the percentage error which would result from the various factors listed.

a. The introduction of 1gm of water on the ice added to the calorimeter.

b. An error of +0.5° in the temperature change of the warm water. Assume t_1 to be measured correctly.

c. An error of 0.2gm in the mass of warm water.

d. A neglect of taking into account a 1gm water equivalent of the thermometer.

2. Derive the relationship between the heat of fusion of ice in calories per gram and in British thermal units per pound.

3. How much ice, at -5°C, would be needed to cool a refrigerator and contents from 20°C to 5°C, the water from the melted ice running out at a temperature of 5°C? The refrigerator and contents have a water equivalent of 100kg.

4. An iron ball weighing 16gm is dropped at a temperature of 112°C into a cavity in a large block of ice. If 2.5gm of ice are melted, what must have been the specific heat of the iron?