

HEAT OF VAPORIZATION

OBJECT: To measure the heat of vaporization of water, using the method of mixtures.

METHOD: The heat liberated by the condensation of steam is measured by allowing it to condense in cold 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 quantities involved are known or measurable except the heat of vaporization, which is thereby determined.

THEORY: The evaporation of a liquid is a process in which the material changes state from the liquid to the vapor phase. A large quantity of heat is required to produce this change, this energy going into the potential energy of the molecular state and hot into kinetic energy. When a liquid is boiling, bubbles of its vapor are being formed throughout the volume of the liquid. These bubbles have a pressure within them which is equal to the maximum vapor pressure of the liquid at that temperature. When this pressure of saturated vapor is equal to the outside pressure, the liquid is said to be at its boiling temperature. For water this temperature is 100°C at a pressure of 76cm of mercury.

If a vessel of water has heat supplied to it at a constant rate, its temperature will steadily rise until the water begins to boil. While the water is boiling its temperature remains constant, even though heat is continually being supplied to it. This heat is being used to produce a change of state. The heat necessary to convert one gram of water from the liquid to the vapor phase (without a change of temperature) is about 540 calories. The heat of *condensation* of the vapor into the liquid state is identical with this heat of *vaporization*.

Heat of Vaporization: Technically, *the heat of vaporization of a substance is defined as numerically the heat required to change unit mass of the substance from the liquid to the vapor phase (without a change of temperature).* The defining equation is

$$L_v = H/M \quad \text{or} \quad H = L_v M \quad (1)$$

where L_v is the heat of vaporization and H is the heat necessary to change a substance of mass M from the liquid to the vapor state at constant temperature.

In the usual metric units L_v is expressed in calories per gram. In the British system the usual unit is the British thermal unit (Btu) per pound. Because of the manner of defining 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 example, for water

$$L_v = 540 \times 9/5 = 972 \text{ Btu per pound.}$$

Measurement of L_v by the Method of Mixtures: The technique of the method of mixtures used in this experiment for the measurement of the heat of vaporization of water is based upon the assumption that no heat is gained from or lost to the surroundings, so that the heat transfers are confined to the materials in the calorimeter. The procedure is simply to allow a measurable mass of steam to condense in some cold water in a calorimeter and to observe the resulting increase in temperature of the water and the calorimeter.

Derivation of Working Equation: In deriving working equations for experiments utilizing the method of mixtures it is vital to be sure that every heat transfer is included. In the present case the word statement of the heat exchanges is

Heat given off by steam in condensing + heat given off by water formed by condensed steam = heat gained by cold water + heat gained by calorimeter

A symbolic equation for these terms is

$$L_v M_s + M_s C_w (t_3 - t_2) = M_w c_w (t_2 - t_1) + M_c c_c (t_2 - t_1) \quad (2)$$

where M_s = the mass of steam, M_w = mass of cold water, M_c = mass of calorimeter, C_w = specific heat of water, C_c = specific heat of calorimeter, t_1 = initial temperature of calorimeter and cold water, t_2 = final equilibrium temperature of water and calorimeter, t_3 = temperature of the hot water condensed from steam.

Since all of the factors in Eq. (2) except L_v are known or measurable, L_v may be calculated from the known and observed data.

Minimizing Errors Due to Heat Losses:

The working equation is based 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 adjusting the initial and final temperatures of the water in the calorimeter. The calorimeter (Fig. 1) consists of an inner vessel K , the calorimeter proper, made of aluminum (or sometimes copper) of high thermal conductivity, so that the



Fig. 1. Simple form of Calorimeter

