Experiment 7

DETERMINATION OF THE SPECIFIC LATENT HEAT OF VAPORIZATION OF WATER

The specific latent heat of vaporization of water is measured by the method of mixtures.

INTRODUCTION

The quantity of heat, Q, required to increase the temperature of a mass, m, from t_1 to t_2 is proportional to the change of the temperature $\Delta t = t_2 - t_1$ and to the mass m

$$Q = m\,c\,\Delta t \tag{7.1}$$

c is the specific heat capacity (specific heat) for the material and is different for different materials. Q can be either positive or negative depending on whether the heat transfer increases or decreases the temperature of the body. The heat transfer takes place when there is a temperature difference between two bodies.

The quantity of heat required to evaporate a mass m of liquid is

$$Q = m\,L \tag{7.2}$$

L is the specific latent heat of vaporization and is the heat required to convert a unit mass of liquid into vapour at the same temperature as the boiling point. L and the boiling temperature, both depend on the pressure.

Heat transfer occurs between bodies that are in contact with each other. When two bodies are thermally isolated from any other bodies, the amount of heat Q_l lost by the first body is equal to the amount of heat Q_r received by the second body

$$Q_l = Q_r \tag{7.3}$$

This principle is a direct result of the conservation of energy.

The heat transfer is usually studied using calorimeters (figure 7.1) which are designed to reduce heat losses to the surroundings. In the measurement the temperature of the calorimeter changes together with the temperature of the fluid

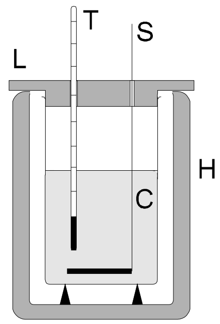

Fig. 7.1. Schematic diagram of a calorimeter. H is a heat shield, C is the calorimeter itself, L is a calorimeter lid, T is a thermometer and S is a spoon to mix the liquids

studied and the calorimeter itself is taking part in a transfer of heat equal to

$$Q = K\,\Delta t \tag{7.4}$$

where K is the heat capacity of the calorimeter.

APPARATUS AND METHOD

The specific latent heat of vaporization of water, L, is found by a method of mixtures using a set up shown in figure 7.2. Water is boiled in flask F and the steam is introduced into the calorimeter via a vessel V which traps any water

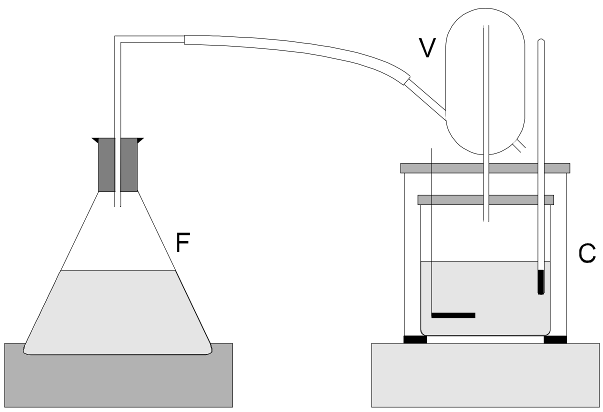

Fig. 7.2. Schematic diagram of the apparatus used in the measurements of specific latent heat of vaporization of water. F is a flask containing water, V is a glass vessel and C is a calorimeter

carried by the steam. The calorimeter is initially filled with water of mass m_w. The mass, m_s, of the steam condensed in the calorimeter is found by weighting the calorimeter before and after the condensation. If the initial temperature of the water in the calorimeter is t_i and the final temperature is t_f, from the conservation of energy (see (7.3))

$$m_s L + m_s c_w (t_s - t_f) = (m_w c_w + K)(t_f - t_i) \tag{7.5}$$

where c_w is the specific heat capacity of water, and t_s=100ºC is the temperature of the steam and is taken to be equal to the boiling point of water. The heat given up by the steam in the condensation and the heat lost by the amount of water obtained from the steam are equal to the amount of heat gained by the water in the calorimeter and the calorimeter itself. From (7.5) the heat of vaporization is given by

$$L = \frac{(m_w c_w + K)(t_f - t_i)}{m_s} - c_w (t_s - t_f) \tag{7.6}$$

The heat capacity K of the calorimeter is found in separate measurements. Here an amount of water m_2 at temperature t_2 is added into the calorimeter filled with water of mass m_1 and temperature t_1. If the final temperature in the calorimeter is t_3, again from the conservation of energy

$$m_2 c_w (t_2 - t_3) = (m_1 c_w + K)(t_3 - t_1) \tag{7.7}$$

and K is

$$K = c_w \left(m_2 \frac{t_2 - t_3}{t_3 - t_1} - m_1 \right) \tag{7.8}$$

MEASUREMENTS

1. Find the heat capacity of the calorimeter. Take about 100g of water for the initial mass m_1. Add about 100g of water of higher temperature t_2, in the range 40-50ºC. Repeat the measurements 3 times and calculate the mean value.
2. Find the specific latent heat of vaporization of water. Take about 150g of water for m_w. After a few minutes of condensation of the steam read out the

final temperature t_f and then find the mass m_s. Repeat the measurements 3 times and calculate the mean value. In the calculations take c_w=(4190±10) J/ kg K.

ANALYSIS OF ERRORS

The errors in the measurements of K and L are calculated from the following expressions obtained from (7.8) and (7.6) using the rules of propagation of errors

$$\Delta K = \left| m_2 \frac{t_2 - t_3}{t_3 - t_1} - m_1 \right| \Delta c_w + \left| c_w \frac{t_2 - t_3}{t_3 - t_1} \right| \Delta m_2 + c_w \Delta m_1 + \\ + \left| 2 c_w m_2 \frac{t_2 - t_1}{\left(t_3 - t_1 \right)^2} \right| \Delta t \tag{7.9}$$

where it has been assumed that

$$\Delta t_1 = \Delta t_2 = \Delta t_3 = \Delta t$$

and

$$\Delta L = \left| \frac{\left(t_f - t_i \right) m_w}{m_s} - \left(t_s - t_f \right) \right| \Delta c_w + \left| \frac{t_f - t_i}{m_s} \right| \Delta K + \left| \frac{c_w \left(t_f - t_i \right)}{m_s} \right| \Delta m_w + \\ + \left| \frac{\left(m_w c_w + K \right)\left(t_f - t_i \right)}{m_s^2} \right| \Delta m_s + c_w \Delta t_s + \left(\frac{2\left(m_w c_w + K \right)}{m_s} + c_w \right) \Delta \tag{7.10}$$

$$\left(\Delta t_i = \Delta t_f = \Delta t \right)$$

The error in the measurement of the temperatures is determined from the uncertainty in the reading of the thermometer scale. The error in the measurement of the masses is twice the uncertainty in the weighing of the calorimeter containing water. For the final mean results of K and L calculate the average value of ΔK and ΔL.