(HT1-10) Newton's Law of Cooling

Aim of experiment

Determination of specific heat of a liquid.

Apparatus

Two Thin Aluminum Calorimeters - Constant Temperature Enclosure - Two Thermometers - Stop watch, Known Liquid, Water.

Theory of experiment

Newton's law of cooling states that the rate of loss of heat of body is directly proportional to the excess of its temperature from its surrounding.

$$-(dT/dt)\ \alpha\ (T-T_r)$$

Where $-(dT/dt)$ is called the rate of cooling, T_r is the temperature of the medium.

$$-(dT/dt) = k\,(T-T_r)$$

where k is a numerical constant. By rearrangement and integration, and considering the condition at $t=0,\ T=T_o$, one gets

$$(T-T_r)=(T_o-T_r)\,e^{-kt}$$

$$T' = T_o'\,e^{-kt}$$

This equation shows an exponential decay of temperature as a function of time.

Determination of specific heat of a liquid

This method is only applied to liquids. The rate of loss of heat from a liquid by radiation depends on the following factors:

1. Temperature excess between liquid and its surrounding
2. Area of the liquid surface.
3. Nature of the radiated surface.

Consider two calorimeters, of the same metal and have the same dimensions and be polished carefully, which contain two different liquids one of them has known specific heat, e.g. water, while the other has unknown specific heat, *figure 1.*

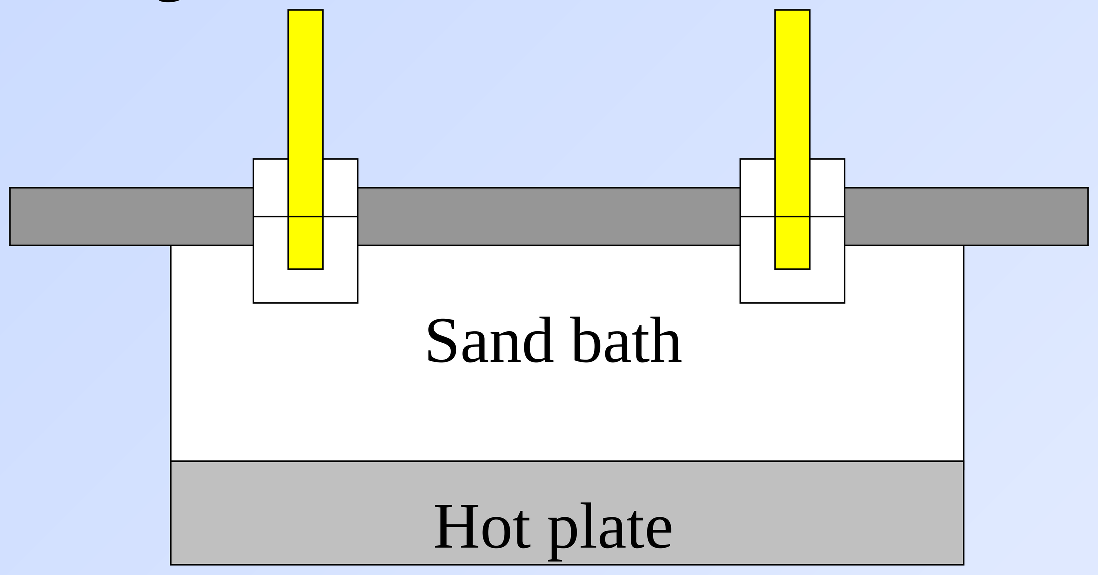

Figure 1. A sketch diagram of the apparatus

Heat the two liquids up to a temperature T_o and let them to cool. Take the temperature reading as a function of time and draw a graph between time and record temperature. If identical ranges of temperature are taken, for both liquids, the average rates of heat will be identical, though the average rates of fall of temperature will not. If the rates of fall of temperature are found from the curves of both liquids, then we can find expressions for the rates of loss of heat, and by equating these we can determine the specific heat of unknown liquid, hence

$$(dQ/dt)_w = (dQ/dt)_L$$

$$(m_w s_w + Ms)\,(T_o - T_f)/t_w = (m_L s_L + M's)\,(T_o - T_f)/t_L$$

$$(m_w s_w + Ms)/t_1 = (m_L s_L + M's)/t_2$$

m_w, = mass of water, m_L= mass of liquid, M= mass first calorimeter, M'= mass of the second calorimeter, T_f= the final temperature, t_w, t_L= cooling times for water and liquid, s_w, and s = specific heat capacity of water and calorimeter respectively. From this equation since m_w, t_w, m_L, t_L, s_w, M, M' and s are all known, s_L could be calculated.

Procedures

1. Weigh the two calorimeters; let their masses be M and M' (gm).
2. Put about two thirds of its volume of water and into the second the same volume of liquid. Weigh again to find the masses of water and liquid, let them be m_w and m_L (gm), respectively.
3. The calorimeters are supported from a board by means of corks, which protrude through the board and carry the thermometers as in *figure 1.* Then the calorimeters are immersed in a sand bath.
4. Raise the temperature of the sand path by heating until the temperature of liquid and water increases up to 90 ^oC.
5. Leave it to cool and record the temperature of water and liquid each 1 minute in a table until it reaches 30 ^oC.
6. Draw the relation between time on x-axis and the temperature of water and liquid on y-axis on the same sheet, *figure 2.*
7. Draw a line parallel to x-axis intersecting the two curves at t_w for water and at t_L for liquid.
8. Calculate the specific heat of the liquid, s_L from the above relation

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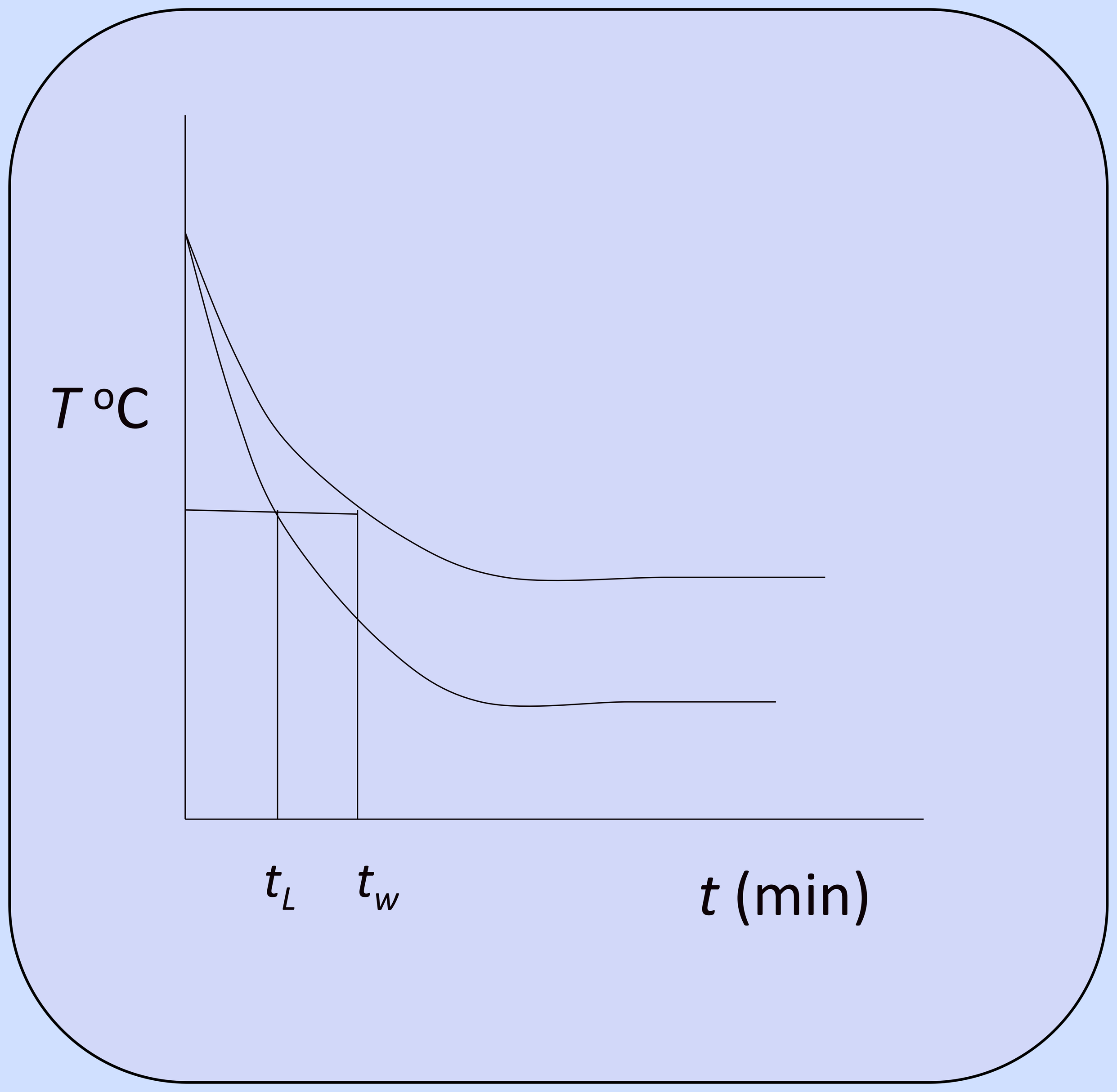

Figure 2. Cooling curves of water and a liquid

Mass of the first calorimeter $M =$ gm
Mass of the second calorimeter $M' =$ gm
Mass of water only $m_{w=}$ gm
Mass of liquid only $m_{L=}$ gm
The cooling time of water $t_{w=}$ sec
The cooling time of liquid $t_{L=}$ sec
The specific heat of water $s_w=1$ cal/gm ºC
The specific heat of liquid $s_{L=}$ cal/gm ºC

Results

t (min.)	T_w	T_L	*t (min.)*	T_w	T_L