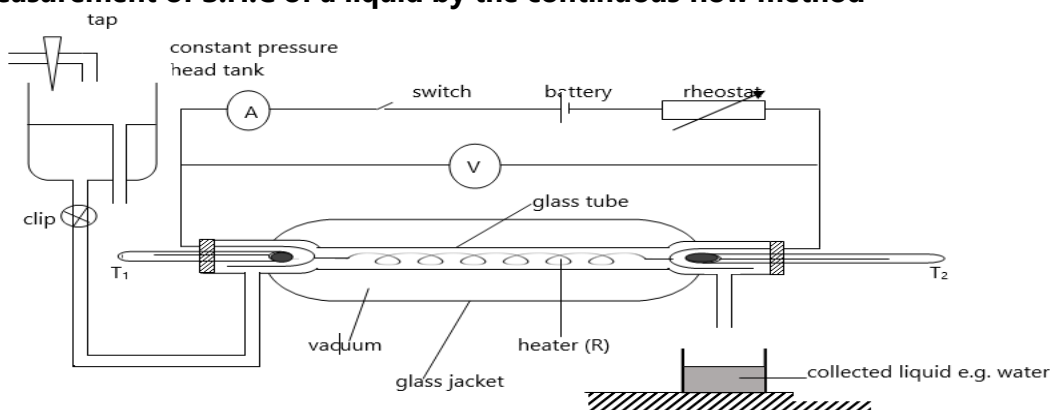


Measurement of S.H.C of a liquid by the continuous flow method



- Liquid from a constant pressure flows at a constant rate through an electric heater R.
- The inlet temperature θ_1 of the liquid is measured by the thermometer T_1
- As the liquid flows through the heater while the switch is closed, it is heated and its temperature θ_2 at the outlet is measured by T_2
- The setup is left to run until a steady state is attained (*i.e. when the temperatures θ_1 and θ_2 are constant*)
- The readings of the ammeter I_1 and voltmeter V_1 are recorded.
- The readings of the thermometer θ_1 and θ_2 are also recorded.
- The liquid of mass M_1 is collected in the beaker in a time t .
- The mass per second m_1 of the liquid is calculated from $m_1 = \frac{M_1}{t_1}$

Electric power from the heater = (heat absorbed by the liquid) + (rate of heat loss to the surrounding)

$$I_1 V_1 = m_1 c (\theta_2 - \theta_1) + h \dots \dots \dots \text{(i) where } h \text{ is the rate of heat loss to the surrounding}$$

- In order to eliminate the heat loss h from the above equation, the experiment is repeated by altering the rate of flow of the liquid at the clip.
- The rheostat is adjusted until a steady state is attained with the same values of θ_1 and θ_2 as before.
- Values of current I_2 and p.d V_2 are recorded.
- The mass M_2 of the liquid is collected in a time t_2
- The mass per second m_2 of the liquid is calculated from $m_2 = \frac{M_2}{t_2}$

Also: $I_2 V_2 = m_2 c (\theta_2 - \theta_1) + h \dots \dots \dots \text{(ii)}$

Combine (i) and (ii)
$$c = \frac{I_2 V_2 - I_1 V_1}{(m_2 - m_1)(\theta_2 - \theta_1)}$$

Advantages of the continuous flow method

- (i) The heat capacity of the liquid need not to be known (*this is because the temperatures are recorded at steady state*)
- (ii) More accurate thermometers can be used such as the resistance thermometer (*this is because the temperatures are recorded at steady state*)
- (iii) The presence of vacuum prevents heat loss by convection and conduction
- (iv) By repeating the experiment, cooling correction is eliminated.
- (v) The apparatus can be used to determine the specific heat capacity of the liquid at different temperatures.

Disadvantages of the continuous flow method

- (i) The set up requires large volume of liquid flowing
- (ii) It is not easy to maintain the outlet and the inlet temperatures constant (*the same*) throughout the experiment.
- (iii) It consumes a lot of time

Examples:

1. The following results were obtained in an experiment to find the S.H.C of water by the continuous flow method.

Experiment	A	B
Heater power	12.0W	5.0W
Inlet temperature	20.6°C	20.6°C
Outlet temperature	24.1°C	24.1°C
Room temperature	18.5°C	18.5°C
Mass of water collected	0.047kg	0.037kg
Period of experiment	60.0S	120.0S

- (a) Find the S.H.C of water
- (b) Calculate the rate of heat loss
- (c) What is the significance of the room temperature in the experiment?

Solution

$$\begin{aligned} P_1 &= \frac{m_1}{t_1} c (\theta_2 - \theta_1) + h \quad \dots\dots\dots (i) \\ P_2 &= \frac{m_2}{t_2} c (\theta_2 - \theta_1) + h \quad \dots\dots\dots (ii) \\ \text{Subtract (ii) - (i)} \\ P_2 - P_1 &= c \left(\frac{m_2}{t_2} - \frac{m_1}{t_1} \right) (\theta_2 - \theta_1) \end{aligned}$$
$$\begin{aligned} \Rightarrow c &= \frac{P_2 - P_1}{\left(\frac{m_2}{t_2} - \frac{m_1}{t_1} \right) (\theta_2 - \theta_1)} \\ c &= \frac{5.0 - 12.0}{\left(\frac{0.037}{120.0} - \frac{0.047}{60.0} \right) (24.1 - 20.6)} \\ &= 4,210.53 \text{ Jk}^{-1} \text{ gK}^{-1} \end{aligned}$$

(b) Rate of heat loss (*also referred to as power*) is obtained by substituting value of SHC calculated above in any of the equations above

$$\text{From eqn (i): } P_1 = \frac{m_1}{t_1} c (\theta_2 - \theta_1) + h \quad \dots\dots\dots(i)$$

$$12.0 = \frac{0.047}{60.0} \times 4210.53 \times (24.1 - 20.6) + h$$

$$\therefore h = 0.46 \text{ Js}^{-1}$$

2. Water flows at a steady rate of 6.0 gs^{-1} through a continuous flow calorimeter. When the p.d across the coil is 11V and current is 5.0A. The difference between the inflow and outflow temperatures is 2.0K. When the flow changes to 2.0 gs^{-1} , current is adjusted to 3.1A so as to produce the same temperature rise. Find

- (i) The p.d across the heating coil, and hence the new input power
- (ii) The specific heat capacity of the water.

Approach: *electrical resistance of the heating coil remains constant in the both experiments*

$$\text{From Ohms law; } R = \frac{V}{I}$$

$$\text{From the eqn; } c = \frac{I_2 V_2 - I_1 V_1}{(m_2 - m_1)(\theta_2 - \theta_1)}$$

$$(i) \Leftrightarrow \frac{V_1}{I_1} = \frac{V_2}{I_2} \Rightarrow V_2 = \frac{3.1 \times 11}{5.0} = 6.82 \text{ V}$$

$$(ii) \quad c = \frac{3.1 \times 6.82 - 5.0 \times 11}{(2.0 - 6.0)(2)}$$

Hence the new power input

$$c = 4238 \text{ Jk}^{-1} \text{ gK}^{-1}$$

$$\text{Power} = IV = 6.82 \times 3.1 = 21.142 \text{ W}$$

3. In continuous flow experiment it was found that when applied was 12.0V, current 1.5A, a rate of flow of liquid of 50.0g/minute cause the temperature of inflow liquid to differ by 10°C . When the p.d was increased to 16.0V with current of 1.6A, the rate of flow of 90.0g/minute was required to produce the same temperature difference as before. Find;

- (i) S.H.C of the liquid (Ans: $1140 \text{ Jk}^{-1} \text{ gK}^{-1}$)
- (ii) Rate of heat loss to the surrounding (Ans: 8.50 W)

4. Using water which enters at 18°C and leaves at 22°C , the rate of flow is 20 gmin^{-1} , current in the heating coil is 2.3A and the p.d across is 3.3V. Now using oil which flows in and out at the same temperature as water, the rate of flow is 70g/min and the current is 2.7A with p.d of 3.9V. If the S.H.C of water is $4200 \text{ Jkg}^{-1} \text{ K}^{-1}$, find;

- (i) The rate of heat loss from the apparatus (Ans: 1.99 W)
- (ii) The specific heat capacity of the oil. (Ans: $1830 \text{ Jk}^{-1} \text{ gK}^{-1}$)

5. In a continuous flow method for measuring specific heat capacity of a liquid of density 800 kgm^{-3} , $3.6 \times 10^{-3} \text{ m}^3$ of a liquid flows through the apparatus in 10 minutes, when the electrical energy is supplied to the heating coil at the rate of 44w a stead difference of 4k is obtained between the temperature of the out flowing and inflowing liquid. When the flow

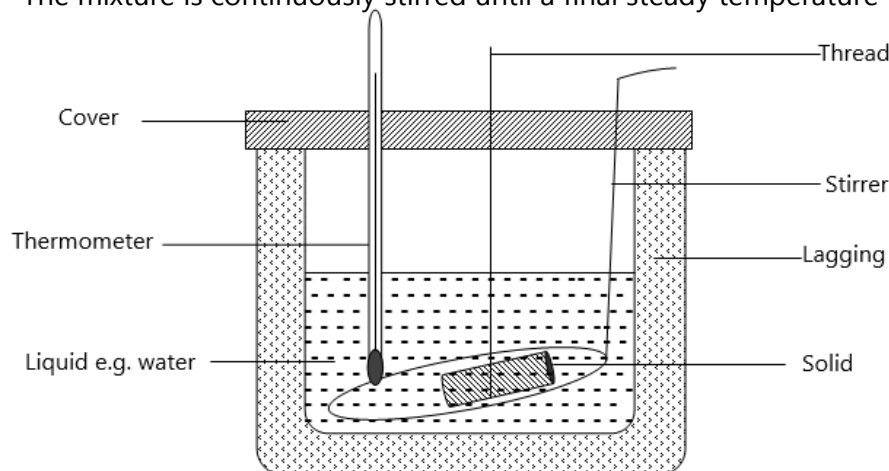
rate is increased to $4.8 \times 10^{-3} \text{ m}^3$ of the liquid in 10 minutes, the electrical power required to maintain the temperature difference is 58W. Find the;

- Specific heat capacity of the liquid.
- Rate of heat loss to the surrounding.

MEASUREMENT OF SPECIFIC HET CAPACITY BY THE METHOD OF MIXTURES

Principle (steps) of the method of mixtures

- A calorimeter of known S.H.C c_c is weighed when empty and its mass m_c recorded.
- The calorimeter is half filled with a liquid and weighed again to determine the mass m_L of the liquid
- The initial temperature θ_1 of the calorimeter and the liquid recorded from the thermometer
- A solid of known mass m_s is heated in a water bath to a known temperature θ_2
- The solid is quickly transferred into the liquid in the calorimeter.
- The mixture is continuously stirred until a final steady temperature θ_3 is attained



Assuming there is no heat loss to the surrounding;

Heat from the hot solid = (heat absorbed by the liquid) + (heat absorbed by the calorimeter)

$$m_s c_s (\theta_2 - \theta_3) = m_L c_L (\theta_3 - \theta_1) + m_c c_c (\theta_3 - \theta_1)$$

For solid: $c_s = \frac{m_L c_L (\theta_3 - \theta_1) + m_c c_c (\theta_3 - \theta_1)}{m_s (\theta_2 - \theta_3)}$; where c_L is the known S.H.C of liquid and c_s is the required S.H.C of the solid.

For liquid: $c_L = \frac{m_s (\theta_2 - \theta_3) - m_c c_c (\theta_3 - \theta_1)}{m_L (\theta_3 - \theta_1)}$; where c_s is the known S.H.C of solid and c_L is the required S.H.C of the liquid.

Precautions for accurate results in the method of mixtures

- (i) The solid should be transferred as quickly as possible
- (ii) The calorimeter must be well lagged (*insulated*) to prevent heat loss by conduction
- (iii) The calorimeter must be highly polished in the inner walls to prevent heat loss by radiation
- (iv) The mixture must be continuously stirred to ensure uniform distribution of heat
- (v) The calorimeter should be covered at the top to prevent heat loss by evaporation

Assignment: *outline the possible sources of error/disadvantages of the method of mixtures*

Examples

1. A copper block of mass 600g is heated to a temperature of 80°C and then quickly transferred to a copper calorimeter of mass 10g containing 100g of water at 25°C. Find the equilibrium temperature of the mixture; stating any assumptions (SHC of copper and water are 400 Jk⁻¹gK⁻¹ and 4200 Jk⁻¹gK⁻¹ respectively) (Ans: 44.88°C)

2. A container of negligible heat capacity contains 2.0kg of water at 21°C. A tap that issues hot water at 70°C at a rate of 90g/min is opened into the cold water. How long will it take for the temperature of the mixture to rise to 30°C.?

Approach:

First obtain the mass of the hot water that will have been added to the cold water to attain 70°C

$$\begin{aligned} \left(\begin{array}{l} \text{Heat given off by} \\ \text{hot water at } 70^{\circ}\text{C} \end{array} \right) &= \left(\begin{array}{l} \text{heat absorbed by the} \\ \text{cold water at } 21^{\circ}\text{C} \end{array} \right) & \Rightarrow \text{Now from, flow rate of 90g/min} \\ m_h c_w (70 - 30) &= m_c c_w (30 - 21) & 90\text{g will take 1minute} \\ \therefore m_h &= 450\text{g} & 450\text{g will take } \frac{1}{90} \times 450 = 5.0\text{minutes} \end{aligned}$$

3. When a block of metal of mass 0.11kg and S.H.C 400 Jkg⁻¹K⁻¹ is heated to 100°C and quickly transferred to a calorimeter containing 0.2kg of a liquid at 10°C the resulting temperature is 13°C. On repeating the experiment with 0.4kg of the liquid in the same container at same temperature of 10°C the resulting temperature is 14.5°C. Calculate;

(i) S.H.C of the liquid (Ans: 1925 Jk⁻¹gK⁻¹)

(ii) Heat capacity of the calorimeter (Ans: 66 JgK⁻¹)

Hint: Heat from the hot solid = (heat absorbed by the liquid) + (heat absorbed by the calorimeter); Form two equations and solve.

4. A copper block of mass 250g with S.H.C of 410 Jkg⁻¹K⁻¹ is heated to 145°C and then dropped into a copper calorimeter of mass 300g which contains 250cm³ of pure water at 20°C.

(a) Calculate the new equilibrium temperature of the liquid (Ans: 30.0°C)

(b) Sketch on the same axes, a graph to show variation of temperature with time for copper block and water;

COOLING OF BODIES

Cooling is the continuous fall in the temperature of a body placed in a draught until when it attains an equilibrium temperature.

Cooling as a result of evaporation using the kinetic theory

- The K.E of the molecules of a liquid is directly proportional to their mean temperature
- When fast moving molecules reach the surface of the liquid with sufficient energy, they break free from the molecular forces and escape with their mean K.E.
- This leaves behind slow moving molecules with less energy hence causing the body to cool.

Factors affecting the rate of cooling of a body

- Temperature of the body:** a body at higher temperature cools faster than an identical body at low temperature placed in the same environment.
- Temperature of the surrounding:** a body cools faster when placed in an environment of relatively low temperature compared to when placed in an environment of relatively high temperature *i.e. rate of cooling is directly proportional to the temperature difference*
- The nature of the cooling body:** A good conductor of heat will lose heat faster than a poor conductor of heat.
- Size of the cooling body:** Small bodies cool faster than large ones, because of the larger volume to surface area ratio of the small body
- Humidity:** rate of cooling increase as humidity increases i.e. more water vapour aids cooling of a body