SENIOR FIVE TERM 2

TOPIC 4/7: HEAT QUANTITIES

Competency: The learner explores the behaviour of substances when heat is applied to them in order to sustainably apply them in heat systems.

Heat capacity

This is the quantity of heat required to raise the temperature of the body by 1^0C or 1K.

It follows that if the temperature of a body whose heat capacity C rises by $\Delta\theta$ when the amount of heat ΔQ is added to it

$\Delta Q = C\Delta\theta$ ……………………… (i)

Specific heat capacity (s.h.c), c

This is the amount of heat required to raise the temperature of 1kg mass of a substance through 1^0C or 1K.

It follows that if the temperature of a body of mass m and s.h.c, c rises by $\Delta\theta$ when an amount of heat ΔQ is added it, then

$\Delta Q = mc\Delta\theta$ ………………….. (ii)

From (i) and (ii)

$C = cm$

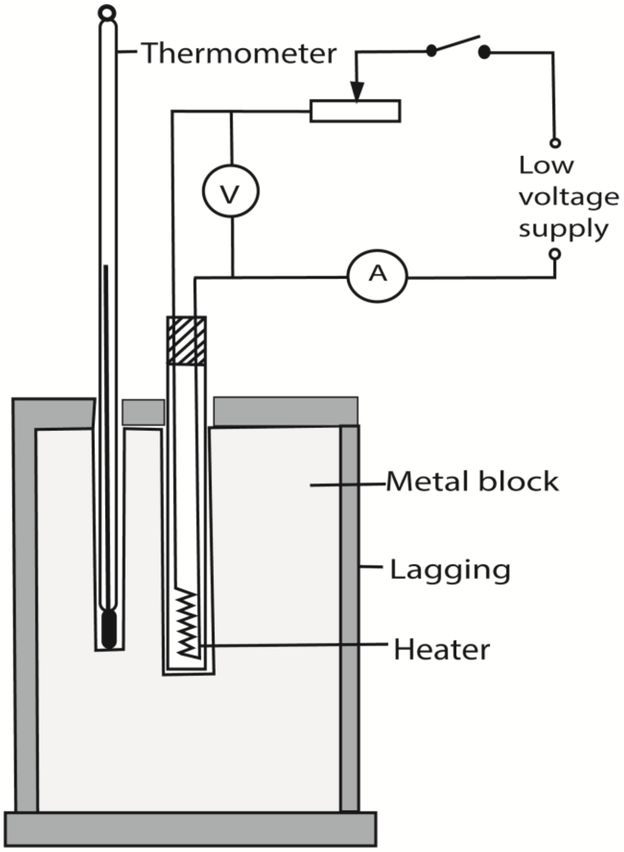
Molar heat capacity

This is the heat required to raise the temperature of 1 mole of a substance by 1Kor 1^0C.

Units: $Jmol^{-}1K^{-1}$

Measurement of specific heat capacity

(a) Measurement of specific heat capacity of solid/metal (copper, and aluminium) that are good conductors using electrical method



Simple solid block calorimeter

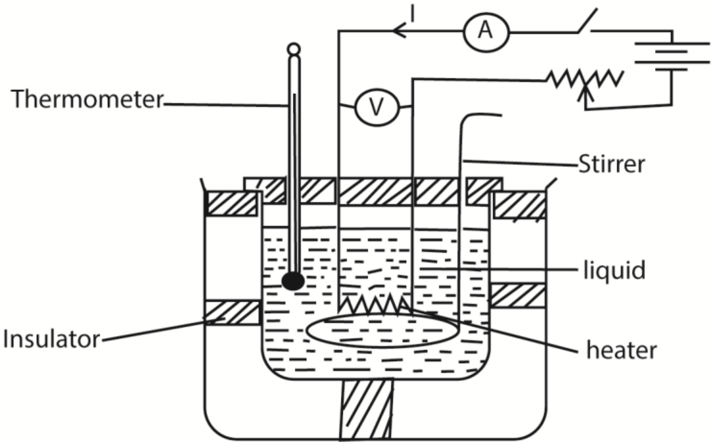
- Two holes are drilled into the specimen solid of mass m.
- A thermometer is inserted in one of the holes and an electric heater into the other hole. The holes are then filled with a good conducting fluid, e.g. oil to ensure thermal contact.
- The apparatus is insulated and initial temperature θ_0 is recorded.
- The heater is switched on at the same time a stop clock is started.
- The steady values of ammeter reading, I and voltmeter reading, V are recorded.
- After considerable temperature rise, the heater is switched off and stop clock stopped.
- The highest temperature θ_1 recorded and time t taken noted.
- Assuming negligible heat loss, the specific heat capacity, c, of the conducting solid is calculated from

  $$c = \frac{IVt}{m(\theta_1 - \theta_0)}$$

Precautions

- The block of metal should be highly polished and heavily lagged.
- The two holes should be filled with either mercury or light oil to improve thermal contact with the heater and thermometer.

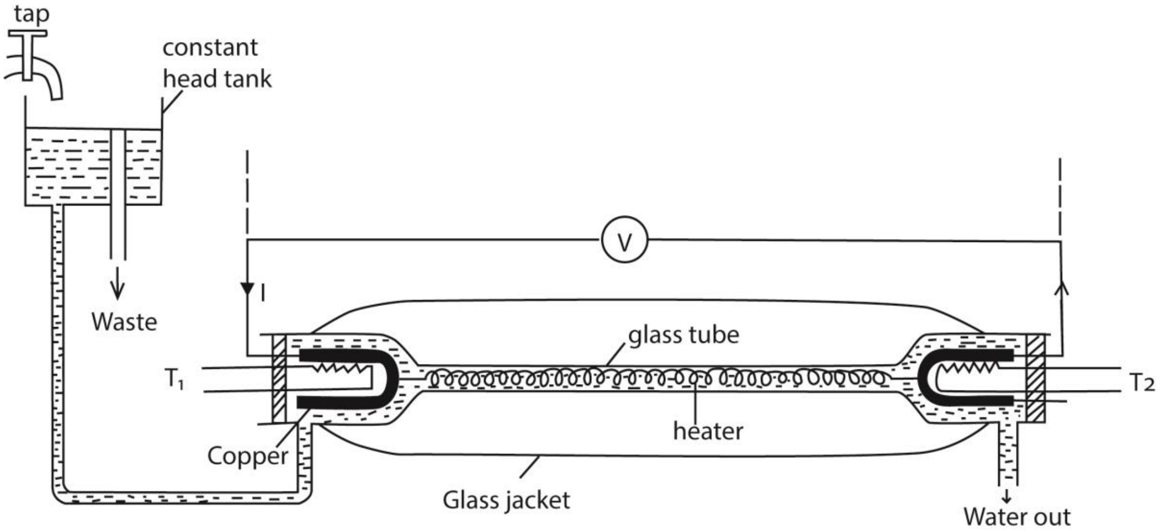
(b) Measurement of specific heat capacity of a liquid by electrical method



- A liquid of known mass, m is poured in a double walled calorimeter of a known heat capacity, C
- The setup is as shown above
- The initial temperature θ_1 of the liquid and calorimeter is recorded.
- Switch K is closed and simultaneously a top clock is started.
- The ammeter and voltmeter readings I and V are respectively recorded.
- The liquid is stirred as it is heated, and after sometime, t of heating, the current is switched off and final temperature θ_2 noted.
- Assuming no heat loss; heat supplied by the heater = heat received by water and calorimeter

  i.e. $IVt = (mc + C)(\theta_2 - \theta_1)$, where c is the specific heat capacity of a liquid.

(c) Measurement of specific heat capacity of a liquid by continuous flow method



- A liquid is allowed to flow at constant rate
- Power is switched on and the liquid is heated until temperatures registered by T_1 and T_2 are steady and the values θ_1 and θ_2 respectively are recorded.

- The p.d V and current I are recorded from the voltmeter and ammeter respectively
- The mass, m of a liquid collected in time t is recorded
- At steady state; $VIt = mc(\theta_2 - \theta_1) + h$ …………. (i)
  where h is heat lost to the surrounding
- The rate of flow is changed and the voltage and current are adjusted until the steady readings of T_1 and T_2 are θ_1 and θ_2 respectively
- If m_1, V_1 and I_1 are the values mass of liquid collected in time t, voltmeter and ammeter readings respectively, then
  $V_1I_1t = m_1c(\theta_2 - \theta_1) + h$ ……………………….. (ii)
  Subtracting (ii) from (i)
  $c = \frac{(VI - V_1I_1)t}{(m - m_1)(\theta - \theta_1)}$

Example 1

In a continuous flow experiment, a steady difference of temperature of 1.5^0C is maintained when the rate of liquid flow is $4.5gs^{-1}$ and the rate of electrical heating is 60.5W. On reducing the liquid flow rate to $1.5gs^{-1}$, 36.5W is required to maintain the same temperature difference.

Calculate the

(i) Specific heat capacity of the liquid. (04marks)

$P = \frac{m}{t}c\theta + h$

$60.5 = 4.5 \times 10^{-3} \times c \times 1.5 + h$ ……….. (i)

$36.5 = 1.5 \times 10^{-3} \times c \times 1.5 + h$ ……….. (ii)

Subtracting (ii) from (i)

$24 = 3 \times \times 10^{-3} \times c \times 1.5$

c = 5,333Jkg

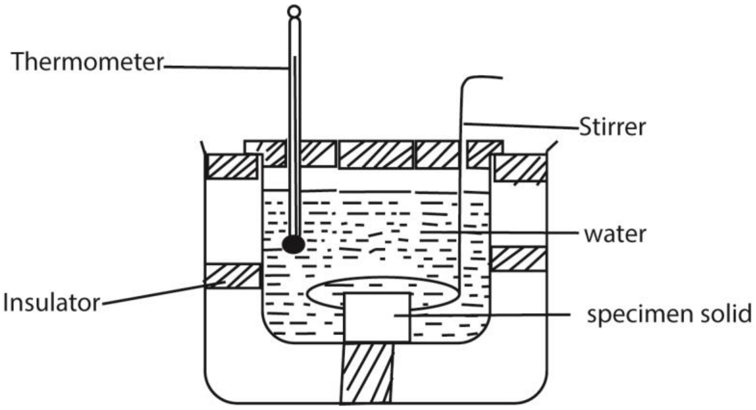
(ii) Rate of heat loss to the surroundings (03marks)

Substituting c in (i)

$60.5 = 4.5 \times 10^{-3} \times 5333 \times 1.5 + h$

h = 24.5W

(d) Measurement of specific heat capacity of a solid by the method of mixtures

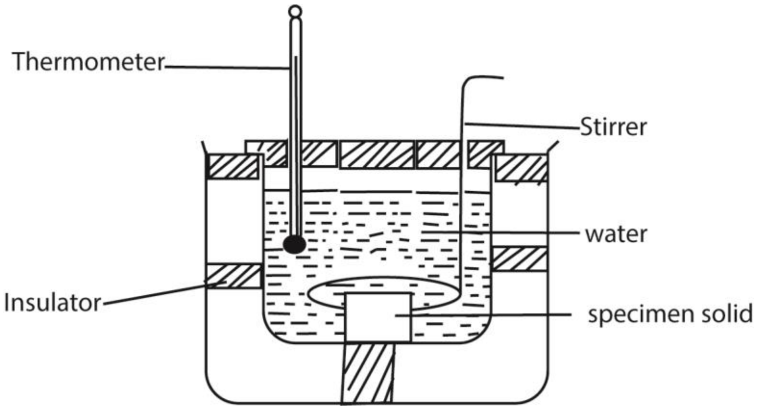


- A solid on mass m_s kg and specific heat capacity, c_s, is heated in boiling water at temperature at temperature $\theta_1{}^0$C and quickly transferred to a calorimeter of heat capacity, C, containing water of mass, m_1 and , at the temperature θ_2.
- The final constant temperature θ_3 of the mixture is determined.
  Assuming there is no heat loss
  Heat lost by the solid = heat gained by calorimeter + heat gained by water
  $m_s \text{ x } c_s \text{ x } (\theta_1 - \theta_3) = (C + c_w m_1)(\theta_3 - \theta_2)$

  $c_s = \frac{(C + c_w m_1)(\theta_3 - \theta_2)}{m_s c_s}$ where c_w is specific heat capacity of water

  Precautions
  - The calorimeter must be heavily lagged.

(e) Measurement of specific heat capacity of a liquid by the method of mixtures



- A solid on mass m_s kg and specific heat capacity, c_s, is heated in boiling water at temperature at temperature $\theta_1{}^0$C and quickly transferred to a calorimeter of heat capacity, C, containing a liquid of mass, m_1 and , at the temperature θ_2.
- The final constant temperature θ_3 of the mixture is determined.
  Assuming there is no heat loss
  Heat lost by the solid = heat gained by calorimeter + heat gained by water

  $m_s \text{ x } c_s \text{ x } (\theta_1 - \theta_3) = C(\theta_3 - \theta_2) + c_l m_l(\theta_3 - \theta_2)$

  $c_l = \frac{(m_s \; x \; c_s \; x \; (\theta_1 - \theta_3)) - (C(\theta_3 - \theta_2)}{m_l(\theta_3 - \theta_2)}$ C_l = specific heat capacity of the liquid.

  Precautions
  - The calorimeter must be heavily lagged.

Example 2

Apiece of copper of mass 100g is heated to 100^0C and then transferred to a well-lagged copper can of mass 50g containing 200g of water at 10^0C. Neglecting heat loss, calculate the final steady temperature of the mixture.

[Specific heat capacity of copper and water are $400Jkg^{-1}K^{-1}$ and $4200Jkg^{-1}K^{-1}$)

Solution

Let the final temperature be θ.

Heat lost by the copper mass = heat gained by the copper can + heat gained by water

$0.1 \times 400 \times (100 - \theta) = 0.05 \times 400 \times (\theta - 10) + 0.2 \times 4200 \times (\theta - 10)$

$\theta = 14.0^0C$

Example 3

(i) State two advantages of the continuous flow method over the method of mixtures. (01mark)

- No cooling correction is required
- Heat capacity of the apparatus is not requires
- Temperature measured at leisure when steady
- Resistance of the heater not required

(ii) State two disadvantages of the method in (c)(i) (01mark)

- larger volumes of liquid required
- not suitable for volatile liquids.

Newton's law of cooling

Newton's law of cooling states that under forced convection, the rate of loss of heat of a body is directly proportional to its excess temperature over that of the surrounding.

i.e.$\frac{dQ}{dt} \propto (\theta - \theta_R)$

where $\frac{dQ}{dt}$ is the rate of heat loss, θ = body's temperature, θ_R = temperature of the surroundings.

The rate of heat loss also depends on

- Surface area of the body and,
- Nature of the surface, i.e. whether dull or shiny

Hence for a body of a uniform temperature, θ and surface area A

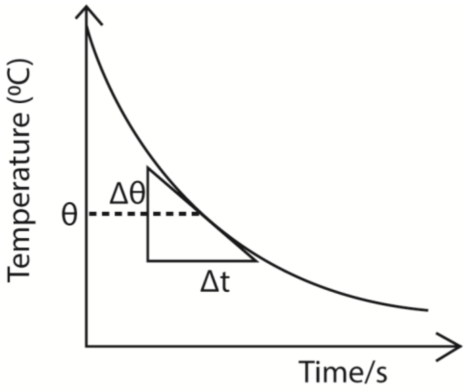
Rate of heat loss, $\frac{dQ}{dt} = kA(\theta - \theta_R)$ where k is a constant.

NB. A small body cools faster than a big body because a small body has a larger surface area to volume ration.

An experiment to verify Newton's law of cooling

- Hot water is placed in a calorimeter that is standing on an insulating surface and is put in a draught.
- The temperature, θ, of the water is recorded at suitable intervals.

- The room temperature θ_R is recorded.
- Plot a graph of temperature against time to get a graph similar to the one below.



- Draw tangent at various temperatures, θ and obtain their slopes. These slopes give the rate of temperature fall.
- Plot these slopes with corresponding excess temperatures $(\theta - \theta_R)$
- A straight line graph is obtained implying that the rate of heat loss is proportional to excess temperature.

Example 4

Describe an experiment to verify Newton's law of cooling. (05marks)

Cooling correction

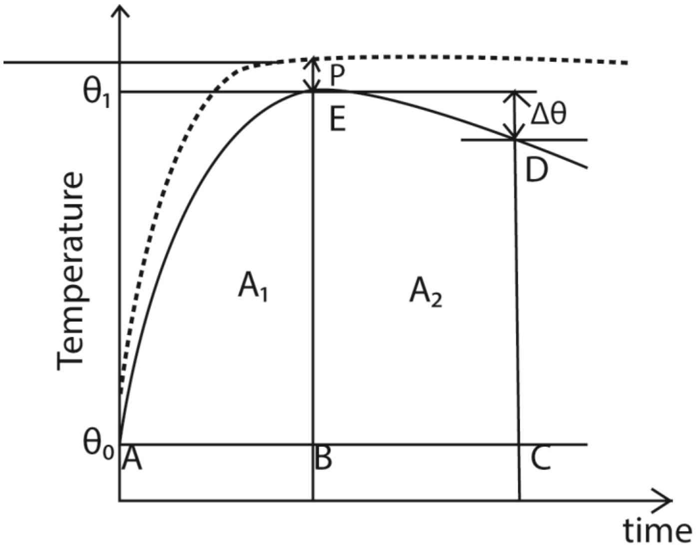
Despite all precautions to prevent heat losses in experiments of the mixtures, still there will be some significant heat loss that will prevent the mixture to attain maximum temperature rise. An estimate has to be made of the temperature that would have been attained if these heat losses were not there. The small temperature added to the observed maximum temperature to make up for the heat lost to the surrounding during the experiment is called cooling correction.

Definition of cooling correction

This is the extra temperature difference to be added to the observed maximum temperature of the mixture to make up for the heat lost to the surrounding during the experiment.

Experiment to determined cooling correction

- Pour a liquid in a calorimeter and place it on a table
- Place a thermometer into the liquid and after sometime, record the temperature of the surroundings, θ_0.
- Gently place a hot solid into the liquid and stir.
- Record the temperature of the mixture at suitable interval until the temperature of the mixture has fallen by about 1^0C below the observed maximum temperature, θ_1.
- Plot a graph of temperature against time



- The broken line shows how we would expect the temperature to rise if no heat were lost and the difference, P, between the plateau of this imaginary curve, and the crest of the experimental curve, E. is known as the 'cooling correction'
- Draw a line AC through θ0 parallel to the time axis.
- Draw a line BE through θ1 parallel to the temperature axis.
- Draw a line CD beyond BE parallel to the temperature axis and note Δθ
- Estimate the area A1 and A2 under the graph by counting the square on the graph paper
- Cooling correction, P s given by the graph
- Cooling correction, P = $\frac{A_1}{A_2}\ x\ \Delta\theta^0$C

Example 5

i) What is meant by cooling correction? (01marks)

This is the extra temperature difference to be added to the observed maximum temperature of the mixture to make up for the heat lost to the surrounding during the experiment.

(ii) Explain how the cooling correction may be estimated in the determination of the heat capacity of poor by the method of mixtures (05marks)

Latent heat

Definition

This is the quantity of heat absorbed or released when a substance changes physical state at constant temperature. E.g. during melting, evaporation, sublimation, condensing, solidification

Example 6

Explain why there is no change in temperature when a substance is melting (04marks)

Supply of heat to a melting solid reduces the forces of attraction between the molecules and increases the separation between them. This increases the potential energy (P.E) between the molecules while keeping kinetic energy (K.E) of the molecules the same. Further increase in separation between the molecules causes the regular pattern to collapse as the solid changes to liquid. Until this process is complete, the temperature does not change.

Example 7

Explain the changes that take place in the molecular structure of substances during fusion and evaporation (04marks)

Heat supplied during fusion breaks down the forces that keep ordered pattern of molecules is solid crystalline structure to form a liquid. The potential energy of the molecules increase but the average kinetic energy and temperature of the molecules remain unchanged.

Heat supplied during evaporation breaks molecular bonds in liquids and allows gas molecules to expand against atmospheric pressure which allows then to move independently.

Example 8

Explain why the specific latent heat of evaporation is always greater than specific latent heat of fusion of a substance at the same pressure are different. (04marks)

Change from solid to liquid, intermolecular bonds are weakened and there is a small increase in volume. This implies there negligible change in volume and thus little work done against atmospheric pressure.

During vaporization, a lot of heat is required to break molecular bonds in a liquid and to enable expansion to larger volume of a gas against atmospheric pressure.

Specific latent heat of fusion

Specific latent het of fusion is the amount of heat required to change 1kg mass of a substance from solid to liquid without change of temperature. Units are Jkg^{-1}

Experiment to determine the specific latent heat of fusion by the method of mixtures

- A known mass m_1 kg of water at temperature θ_1 (a few degrees above room temperature) is placed in a calorimeter of mass m_c kg and heat capacity. C.
- A small piece of dry ice (dried by blotting paper) is added to the water and stirred to a constant temperature θ_2.
- The total mass, m, of the calorimeter and water and ice is determined.

  Calculation

  Mass of ice = $(m - (m_1 + m_c) = m_3$kg

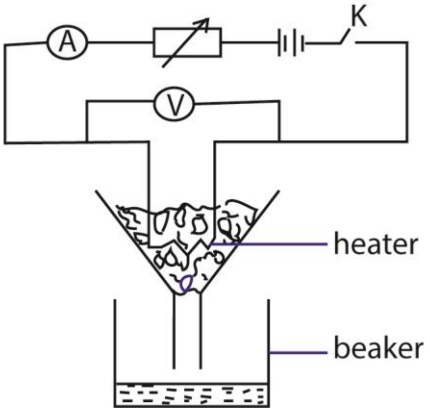
  Heat lost by water and calorimeter = heat gained by ice to melt and again temperature to θ_2.

  Suppose c and l_f are the specific heat capacity and latent heat of fusion of water, then

  $(m_1c +)(\theta_1 - \theta_2) = m_3l_f + m_3c(\theta_2 - 0)$

$$l_f = \frac{\left(((m_1c+C)(\theta_1 - \theta_2)) - (m_3c(\theta_2 - 0))\right)}{m_3}$$

Experiment to determine the specific latent heat of fusion by electrical method



- Place pure ice in a funnel such that it submerge the heater
- With R set, close K and simultaneously start a stop clock.
- Collect a known mass m of water in a specified time, t.
- Record the readings I and V of the ammeter and voltmeter spectively.

Assuming no heat gain from the surrounding

Heat supplied by the heater = heat gained by ice.

IVt -= ml_fb where l_f is the specific latent heat of fusion

NB: if heat lost gained from the surrounding is h

Then IVt + h = mlf …………………. (i)

The experiment is repeated for different values of V', I' and m' in the same time

I'V't + h = m'lf …………………. (ii)

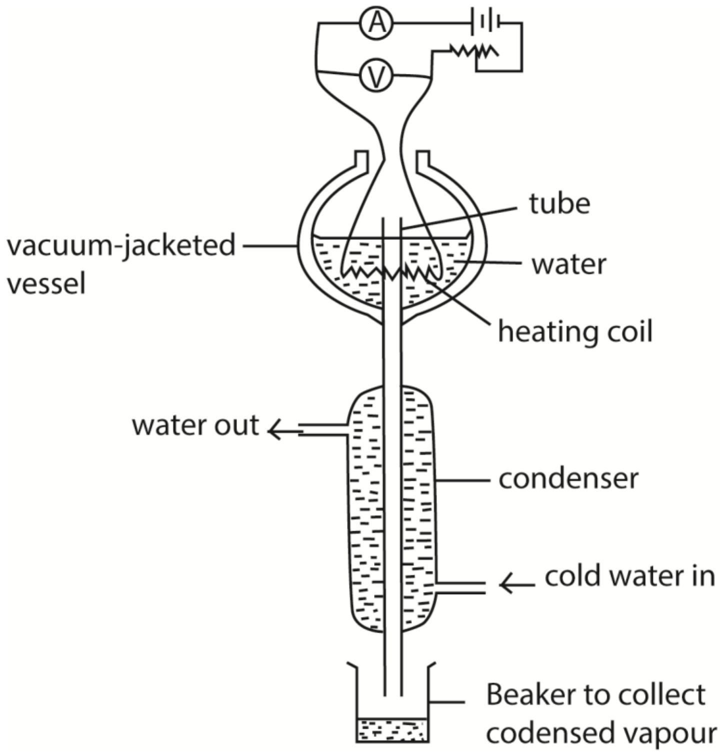
Combining (i) and (ii)

$$l_f = \frac{(IV - I'V')t}{(m - m')}$$

Specific latent heat of vaporization

Specific latent het of vaporization is the amount of heat required to change 1kg mass of a substance from liquid to vapor without change of temperature. Units are Jkg^{-1}.

Experiment to determine the specific latent heat of vaporization of water by electrical method



- Put the liquid whose specific latent heat of vaporization is required in a vacuum jacketed vessel as shown above.
- The liquid is heated to boiling point.
- The current, I, and voltage, V are recorded.
- The mass of condensed water, m, condensed in time, t, is determined.
- Then IV = $\frac{m}{t}L + h$,

  where h is the rate of heat loss to the surroundings
- To eliminate, h, the experiment is repeated for different values of I' and V' and the mass of the condensed water, m' condensed in tie t is determined.
- Again I'V' = $\frac{m'}{t}L + h$
- Latent heat of vaporization, L =$\frac{(I'V'-IV)t}{(m'-m)}$

Example 9

An appliance rated 240V, 200W evaporates 20g of water in 5 minutes. Find the heat loss if specific latent heat of vaporization is 2.26 x 10^6Jkg^{-1}. (03marks)

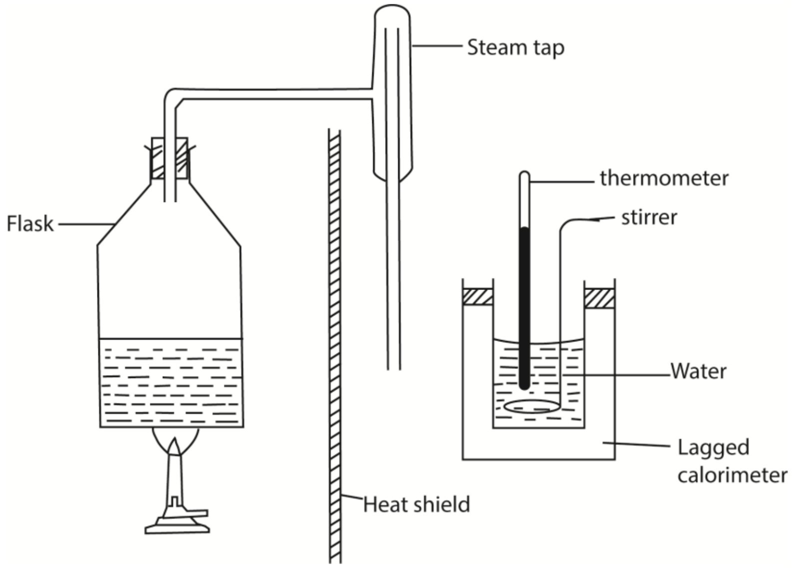
Electrical energy supplied = mlv + h

Power x time = mlv + h

200 x 5 x 60 = 20 x 10^{-3} x 2.26 x 10^6 + h

h = 14800J

An experiment to determine the specific latent heat of vaporization of water by the method of the mixtures



- The initial temperature θ_0 and mass, m of water in the calorimeter are measured
- Steam from boiling water is passed into water in a calorimeter and after a reasonable temperature rise, flow of steam is stopped and final temperature, θ_f is recorded.
- Mass m_2 of water in the calorimeter is then taken
- The mass of steam condensed, $m_s = (m_2 - m)$
  Given that the heat capacity of the calorimeter= C
  Heat gained by steam = heat gained by water and calorimeter
  $m_sc_v + m_sc(100 - \theta_f) = (m_2 - m)c(\theta_f - \theta_0) + C(\theta_f - \theta_0)$
  c_v = specific latent heat of vaporization
  c= specific heat capacity of water

Example 10

Explain why evaporation causes cooling? (03marks)

When a liquid evaporate molecules with high kinetic energy escape leaving molecules with low kinetic energy. Since temperature of the liquid depends on the average kinetic energy of its molecules, the temperature drops.

Example 11

Explain the effect of pressure on the boiling point of a liquid. (02marks)

- Since a liquid boils when its saturated vapour pressure is equal to external pressure.
- Increasing the external pressure increases the boiling point of a liquid because the liquid has to be heated to a higher temperature to make its saturated vapour pressure equal to external pressure

Revision exercise (Question as previous examinations of global examination bodies)

1. (a) Define the following:

(i) Specific heat capacity (01mark)

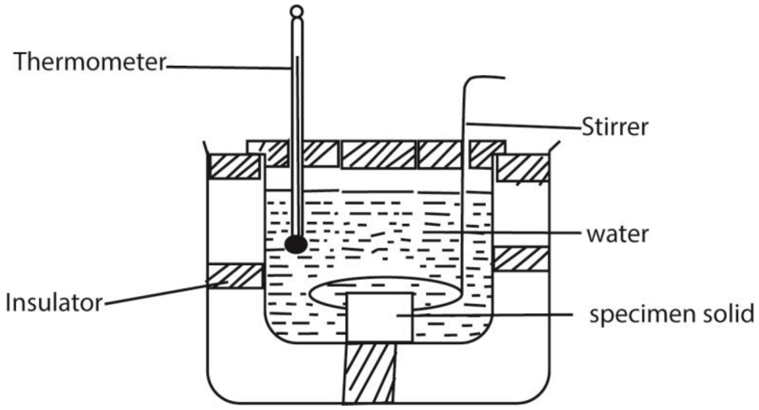
Specific heat capacity is the amount of heat required to rise the temperature of 1kg mass of a substance by 1K or 1^0C

(ii) Latent heat. (01marks)

Latent heat is energy absorbed or released by a substance during a change in its physical state (phase) without changing its temperature.

(b) (i) Describe an experiment to determine the specific heat capacity of a solid using the method of mixtures. (06marks)

Measurement of specific heat capacity of a solid by the method of mixtures



- A solid on mass m_s kg and specific heat capacity, c_s, is heated in boiling water at temperature at temperature $\theta_1{}^0$C and is quickly transferred to a calorimeter of heat capacity, C, containing water of mass, m_1 and , at the temperature θ_2.
- The final constant temperature θ_3 of the mixture is determined.

Assuming there is no heat loss

Heat lost by the solid = heat gained by calorimeter + heat gained by water

$m_s \times c_s \times (\theta_1 - \theta_3) = (C + c_w m_1)(\theta_3 - \theta_2)$

$c_s = \frac{(C + c_w m_1)(\theta_3 - \theta_2)}{m_s c_s}$ where c_w is specific heat capacity of water

(iii) State two precautions taken in (b)(i). (02marks)

- The calorimeter must be heavily lagged to minimize heat loss from the mixture.
- Transfer the solid is fast to minimize heat loss from it during the transfer.
- Stir the mixture gently to ensure uniform temperature distribution without causing splashing or heat loss.
- Carry out the experiment several times to minimize errors
- Make correction for heat loss.

(c) An electric heater of 2.2kW was used to heat 2kg of water, initially at 25^0C, in a kettle of heat capacity 400JK^{-1} until the water boiled at 100^0C. The heating was continued for 3 more minutes and it was found that the mass of water in the kettle was 1.802kg.

Calculate;

(i) how long it took the water to boil

Heat given out by the heater = heat gained by the kettle and water

$VIt = C\theta + mc\theta$

$2.2 \times 10^3 t = 400(100 - 25) + 2 \times 4200\ (100 - 25)$

$t = 300s = 5minutes$

(ii) the specific latent heat of vaporization (05mark)

Mass of water vaporized = 2 – 1.802 =0.198

Let specific latent heat be L

$VIt = mL$

$2.2 \times 10^3 \times 3 \times 60 = 0.198L$

$L = 2 \times 10^6 Jkg^{-1}$

(d) Explain why the specific latent heat of vaporization in much higher than the specific lantent heat of fusion for the same substance. (05marks)

Latent heat of fusion only supply energy to breaks down the forces that keep ordered pattern of molecules is solid crystalline structure to form a liquid. The potential energy of the molecules increase but the average kinetic energy and temperature of the molecules remain unchanged.

While,

Latent heat of vaporization is always greater that latent heat of fusion because energy is supplied to break down stronger molecular bonds in liquids and to provide energy to liquid molecules in order to expand into gas molecules against atmospheric pressure.

2. (a) Define the following:

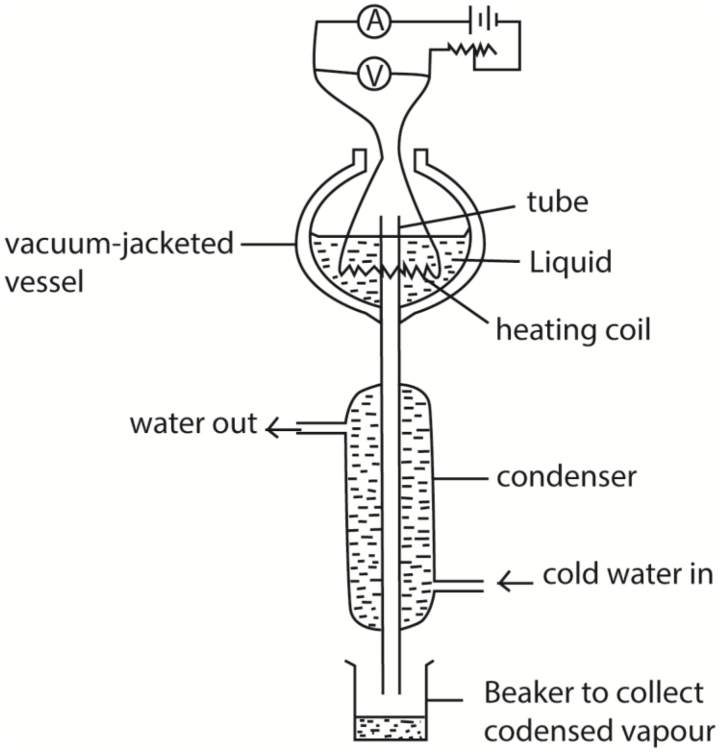
(i) specific heat capacity (01 mark)

Specific heat capacity is the amount of heat requires to raise the temperature of 1kg mass of a substance by 1K or 1^0C

(ii) specific latent heat of vaporization. (01mark)

Specific latent heat of vaporization is the amount of heat energy required to change 1kg of a liquid to vapour at constant temperature.

(b) With the aid of a labelled diagram, describe an experiment to determine the specific latent heat of vaporization of a liquid. (07 marks)



- Put the liquid whose specific latent heat of vaporization is required in a vacuum jacketed vessel as shown above.
- The liquid is heated to boiling point.
- The current, I, and voltage, V are recorded.
- The mass of liquid, m, condensed in time, t, is determined.
- Then IV = $\frac{m}{t}L + h$, where h is the rate of heat loss to the surroundings
- To eliminate, h, the experiment is repeated for different values of I' and V' and the mass of the liquid, m' condensed in tie t is determined.
- Again I'V' = $\frac{m'}{t}L + h$

  Latent heat of vaporization, L =$\frac{(I'V'-IV)t}{(m'-m)}$

3. (a) The inlet and outlet temperatures of water flowing in a continuous flow method are 15.2^{0}C and 17.4^{0}C respectively. A flow rate of 20 g min^{-1} is obtained when a current of 2.3A flows and a p.d of 3.3V is applied. When oil, which flows in and out at the same temperatures as water is used, the flow rate obtained is 70.0 g min^{-1}. Calculate the specific heat capacity of the oil, if a p.d 3.9V is applied and a current of 2.7A flows. (05 marks)

   VIt = mcθ+ h where h is the rate of heat loss

   1.3 x 2.3 = $\frac{20}{1000\,x60}x4200x(17.4-15.2)+h$ ……………….. (i)

   3.9 x 2.7 = $\frac{70}{1000\,x60}xcx(17.4-15.2)+h$……………………….(ii)

Subtracting (i) from (ii)

$2.94 = 2.5667 \times 10^{-3}c - 3.08$

$c = 2345 Jkg^{-1}K^{-1}$

hence specific heat capacity of the liquid = 2,345 $Jkg^{-1}K^{-1}$

(b) Explain the effect of pressure on:

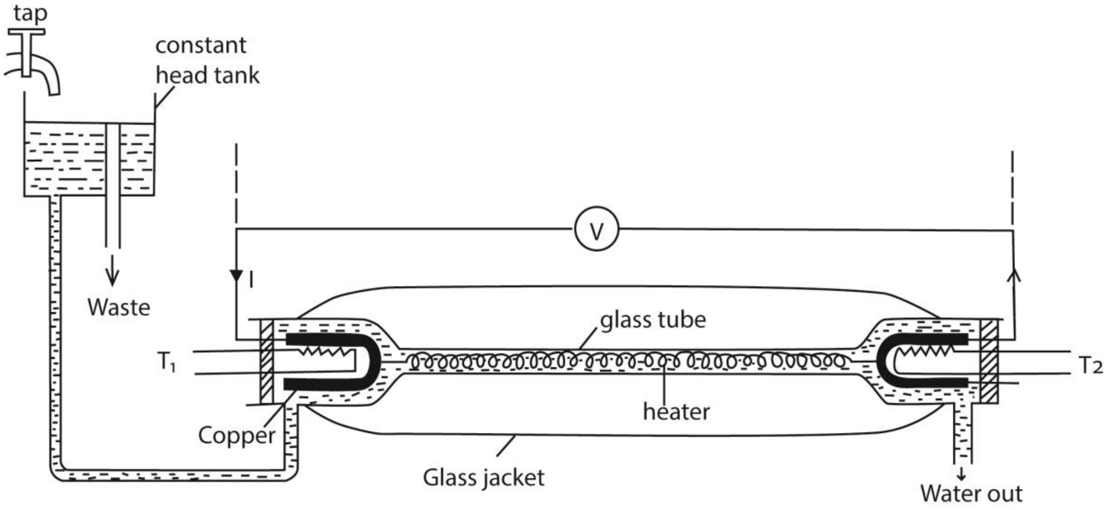
(i) boiling point of a liquid. (03marks)

When the liquid boils its saturated vapour pressure = external pressure and saturated vapour pressure increases with increasing temperature. When external pressure is raised, a liquid will boil at higher saturated pressure which occurs at high temperature.

(ii) Melting point of ice. (03 marks)

Increase in pressure lowers the melting point of ice because melting of ice is followed by a decrease in volume.

(c) (i) Describe with the aid of a diagram, an experiment to determine the specific heat capacity of a liquid using the continuous flow method. (07marks)



- A liquid is allowed to flow at constant rate
- Power is switched on and the liquid is heated until temperatures registered by T_1 and T_2 are steady and the values θ_1 and θ_2 respectively are recorded.
- The p.d V and current I are recorded from the voltmeter and ammeter respectively
- The mass, m of a liquid collected in time t is recorded
- At steady state; $VIt = mc(\theta_2 - \theta_1) + h$ …………. (i)
  where h is heat lost to the surrounding
- The rate of flow is changed and the voltage and current are adjusted until the steady readings of T_1 and T_2 are θ_1 and θ_2 respectively

- If m_1, V_1 and I_1 are the values mass of liquid collected in time t, voltmeter and ammeter readings respectively, then
  $V_1I_1t = m_1c(\theta_2 - \theta_1) + h$ …………. (ii)
  Subtracting (ii) from (i)
  $c = \frac{(VI - V_1I_1)t}{(m - m_1)(\theta - \theta_1)}$

(ii) State two advantages of the continuous flow method over the method of mixtures. (01mark)

- No cooling correction is required
- Heat capacity of the apparatus is not requires
- Temperature measured at leisure when steady
- Resistance of the heater not required

(i) State two disadvantages of the method in (c)(i) (01mark)
- larger volumes of liquid required
- not suitable for volatile liquids.

(c) The brake lining of the wheel of a car of mass 800kg have total mass of 4.8kg and are made of a material of specific heat capacity 1200$Jkg^{-1}K^{-1}$. If the car is at 15ms^{-1} and is brought to rest by applying the brakes, calculate the maximum possible temperature rise of the brake lining. (04marks)

Mechanical energy = heat absorbed by the lining

$\frac{1}{2}mv^2 = mc\theta$ where θ is temperature change

$\frac{1}{2}\ x\ 800\ x\ 15^2 = 4.81\ x\ 1200\ x\ \theta$

$\theta = 15.6\ ^0C$

4. (a) (i) Define specific latent het of fusion (01mark)

Specific latent het of fusion is the amount of heat required to change 1kg mass of a substance from solid to liquid without change of temperature.

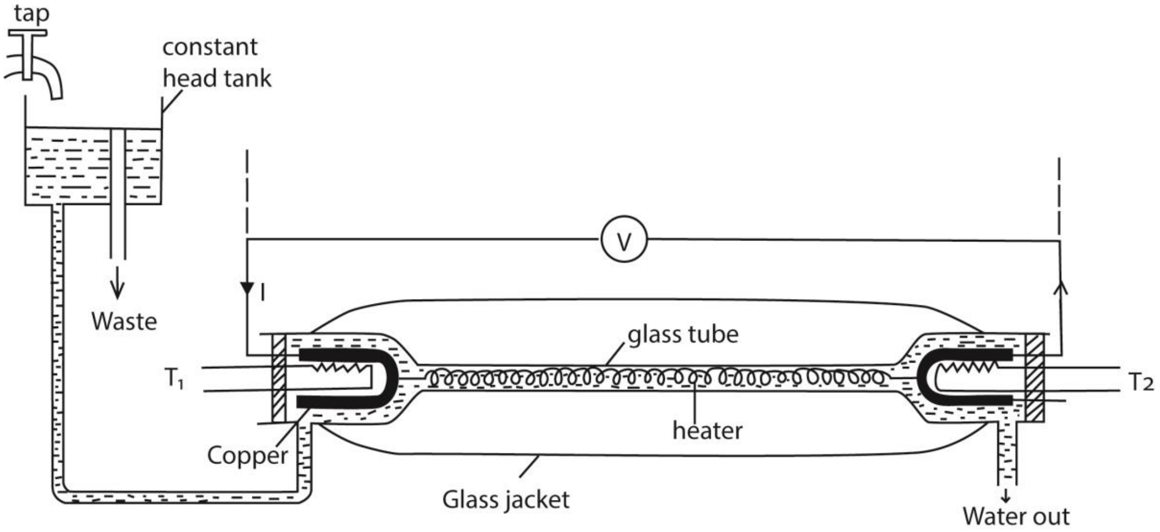
(ii) State effect of impurities on melting point (01mark)

Impurities lower the melting point.

(b) Explain why there is no change in temperature when a substance is melting (04marks)

Supply of heat to a melting solid reduces the forces of attraction between the molecules and increases the separation between them. This increases the potential energy (P.E) between the molecules while keeping kinetic energy (K.E) of the molecules the same. Further increase in separation between the molecules causes the regular pattern to collapse as the solid changes to liquid. Until this process is complete, the temperature does not change.

(c) With the aid of a labelled diagram, describe the continuous flow method of measuring the specific heat capacity of a liquid. (06marks)



- A liquid is allowed to flow at constant rate
- Power is switched on and the liquid is heated until temperatures registered by T_1 and T_2 are steady and the values θ_1 and θ_2 respectively are recorded.
- The p.d V and current I are recorded from the voltmeter and ammeter respectively
- The mass, m of a liquid collected in time t is recorded
- At steady state; $VIt = mc(\theta_2 - \theta_1) + h$ …………. (i)
  where h is heat lost to the surrounding
- The rate of flow is changed and the voltage and current are adjusted until the steady readings of T_1 and T_2 are θ_1 and θ_2 respectively
- If m_1, V_1 and I_1 are the values mass of liquid collected in time t, voltmeter and ammeter readings respectively, then
  $V_1I_1t = m_1c(\theta_2 - \theta_1) + h$ …………. (ii)
  Subtracting (ii) from (i)
  $c = \frac{(VI - V_1I_1)t}{(m - m_1)(\theta - \theta_1)}$

(d) In an experiment to determine the specific latent heat of fusion of ice, heating coil is placed in a filter funnel and surrounded by lumps of ice. The following sets of reading were obtained.

V(V)	4.0	6.0
I(A)	2.0	3.0
Mass of water m (g) collected in 500s	14.9	29.8

Calculate

(i) Specific latent heat of fusion of ice (04marks)

Specific latent heat $c_l = \frac{(VI - V_1I_1)}{(m - m_1)} = \frac{4\ x 2 - 6\ x\ 3}{\frac{14.9}{500\ x\ 10^3} - \frac{29.8}{500\ x\ 10^3}}$ = 3.36 x 10^5Jkg

(ii) Energy gained in the course of obtaining the first set of readings (03marks)

$I_1V_1 = m_1c_l + h$

$4 \times 2 = \frac{14.9}{500 \ x \ 10^3} \ x \ 3.36 \ x \ 10^5 + h$

h = -2W

Energy gained from surrounding = h x t = 2 x 500 = 1000J

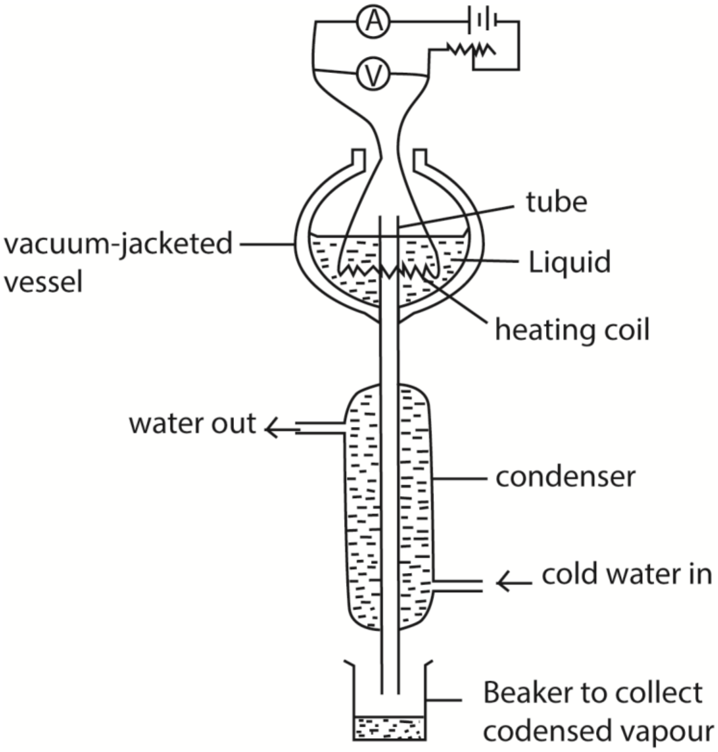
(e) Why are two sets of reading necessary n (d) above? (01mark)

To account for heat gained from surrounding

5. (a) Define specific latent heat of vaporization. (01mark)

Specific latent heat of vaporization is the amount of heat required to change 1kg mass of a liquid into vapour at constant temperature.

(b) With the aid of labelled diagram, describe an experiment to measure the specific latent heat of vaporization of a liquid using an electrical method. (07marks)



- Put the liquid whose specific latent heat of vaporization is required in a vacuum jacketed vessel as shown above.
- The liquid is heated to boiling point.
- The current, I, and voltage, V are recorded.
- The mass of liquid, m, condensed in time, t, is determined.
- Then IV = $\frac{m}{t}L + h$, where h is the rate of heat loss to the surroundings
- To eliminate, h, the experiment is repeated for different values of I' and V' and the mass of the liquid, m' condensed in tie t is determined.
- Again I'V' = $\frac{m'}{t}L + h$

  Latent heat of vaporization, L =$\frac{(I'V' - IV)t}{(m' - m)}$

(c) Explain the effect of pressure on the boiling point of a liquid. (02marks)

- Since a liquid boils when its saturated vapour pressure is equal to external pressure.
- Increasing the external pressure increases the boiling point of a liquid because the liquid has to be heated to a higher temperature to make its saturated vapour pressure equal to external pressure

(d) A liquid of specific heat capacity $2.8 \times 10^3 Jkg^{-1}K^{-1}$ and specific latent heat of vaporization $9.00 \times 10^5 Jkg$ is contained in a flask of heat capacity $800JK^{-1}$ at a temperature of 32^0C. An electric heater rated 1kW is immersed in 2.5kg of the liquid and switched on for 12 minutes, calculate the amount of liquid that boiled off, given that the boiling point of the liquid is 80^0C. (06marks)

Heat supplied by the heater = $mc\theta + C\theta + m_1L$

$1000 \times 12 \times 60 = 2.5 \times 2.8 \times 10^3(80-32) + 800 \times (80- 32) + 9.00 \times 10^5 m_1$

Mass of the liquid evaporates, $m_1 = 0.384kg$

(e) (i) Two thermometers are used to measure the temperature of a body. Explain why the temperatures may be different. (02marks)

Because thermometric properties vary differently with temperature and only agree at fixed points.

(ii) A platinum resistance thermometer has a resistance of 5.42Ω at the triple point of water. Calculate the resistance at a temperature of 50.0^0C. (02marks)

$T = \frac{R_T}{R_{tr}} x\ 273.16$

$(273 + 50) = \frac{R_{50}}{5.42} x\ 273.16$

$R_{50} = 6.41\Omega$

6. (a)(i) Define the terms specific heat capacity and specific latent heat of fusion (02marks)

Specific heat capacity is the amount of heat required to raise the temperature of 1kg mass of a substance by 1K of 1^0C.

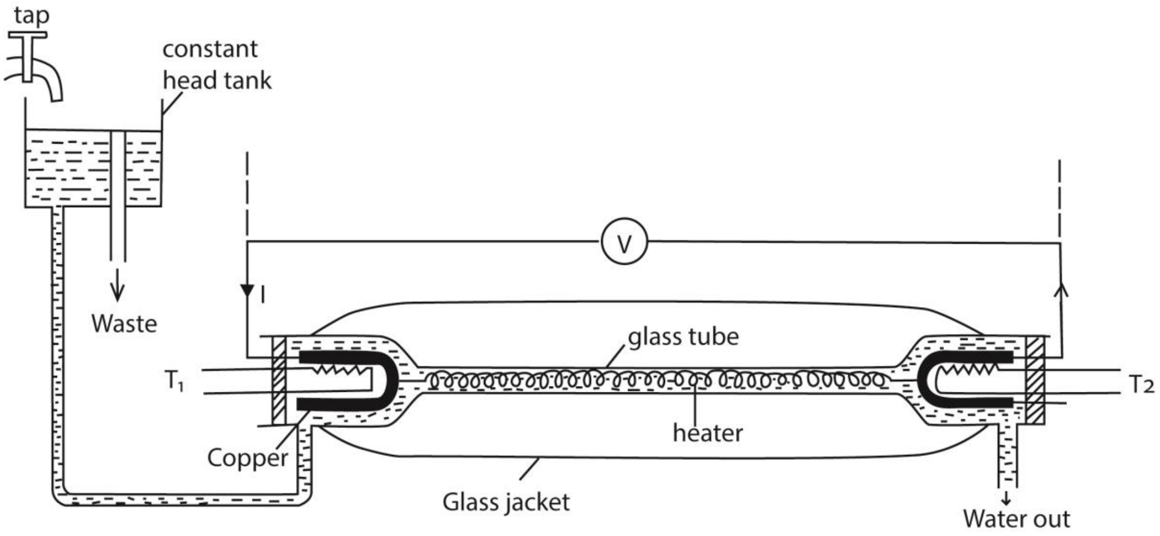
Specific latent heat of fusion is the amount of heat required to change 1kg of solid substance to a liquid at constant temperature.

(ii) Explain the changes that take place in the molecular structure of substances during fusion and evaporation (04marks)

Heat supplied during fusion breaks down the forces that keep ordered pattern of molecules is solid crystalline structure to form a liquid. The potential energy of the molecules increase but the average kinetic energy and temperature of the molecules remain unchanged.

Heat supplied during evaporation breaks molecular bonds in liquids and allows gas molecules to expand against atmospheric pressure which allows then to move independently.

(b) With the aid of a labelled diagram describe an experiment to determine the specific heat capacity of a liquid using the continuous flow method. (08marks)



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- Power is switched on and the liquid is heated until temperatures registered by T_1 and T_2 are steady and the values θ_1 and θ_2 respectively are recorded.
- The p.d V and current I are recorded from the voltmeter and ammeter respectively
- The mass, m of a liquid collected in time t is recorded
- At steady state; $VIt = mc(\theta_2 - \theta_1) + h$ ………….. (i)
  where h is heat lost to the surrounding
- The rate of flow is changed and the voltage and current are adjusted until the steady readings of T_1 and T_2 are θ_1 and θ_2 respectively
- If m_1, V_1 and I_1 are the values mass of liquid collected in time t, voltmeter and ammeter readings respectively, then
  $V_1I_1t = m_1c(\theta_2 - \theta_1) + h$ ………….. (ii)
  Subtracting (ii) from (i)
  $c = \frac{(VI - V_1I_1)t}{(m - m_1)(\theta - \theta_1)}$

7. (a) Steam at 100^0C is passed into a copper calorimeter of mass 150g containing 340g of water at 15^0C. This is done until the temperature of the calorimeter and its content is 71^0C. If the mass of the calorimeter and its content is found to be 525g, calculate the specific latent heat of vaporization of water. (06marks)

Mass of condensed steam = 525 - (340+ 150) = 35g

Heat lost by steam = heat gained water and calorimeter

$Ml_v + mc\Delta\theta = m_1c\Delta\theta + C\Delta\theta$

$0.035l = 0.340(100 - 71) + 0.150\ (100 - 71)$

Specific latent heat capacity, $l_v = 2.259 \times 10^6 Jkg^{-1}$.

(b) An appliance rated 240V, 200W evaporates 20g of water in 5 minutes. Find the heat loss if specific latent heat of vaporization is $2.26 \times 10^6 Jkg^{-1}$. (03marks)

Electrical energy supplied = mlv + h

Power x time = mlv + h

$200 \times 5 \times 60 = 20 \times 10^{-3} \times 2.26 \times 10^6 + h$

h = 14800J

8. (a) (i) Define latent heat (01mark)

Latent heat is the amount of heat required to change a unit mass of a substance from one state to another at constant temperature.

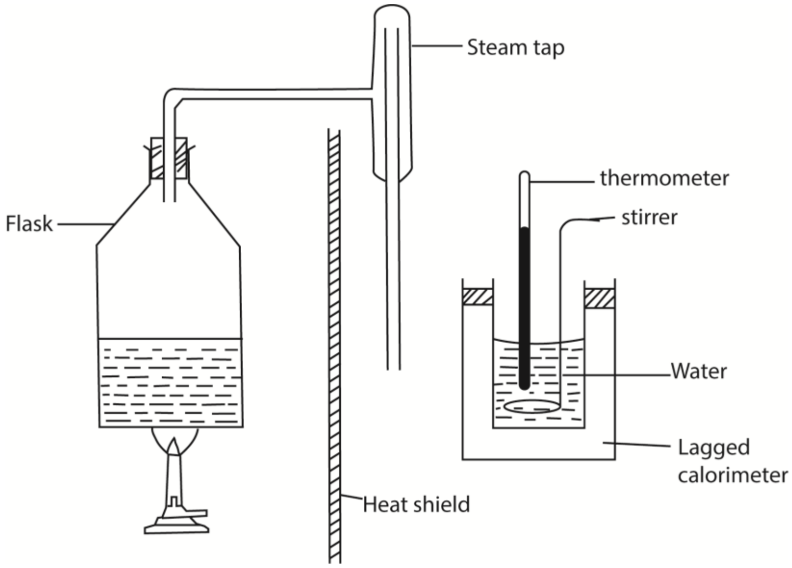
(ii) Explain the significance of latent heat in regulation of body temperature (03marks)

On a hot day, the body sweats. Evaporation occurs at the surface of the body leading to the cooling of the body since the evaporating water draws heat from the body.

(b) (i) using kinetic theory, explain boiling of a liquid (03mark)

Molecules of a liquid through moving randomly have attractive forces between them. When a liquid is heated, the molecules move faster and forces of attraction weakened until they are overcome at the boiling temperature. At this point, saturated vapour pressure (SVP) of liquids is equal to external pressure. Liquid molecules with enough energy escape from the bulk to the atmosphere.

(ii) Describe how you would determine the specific latent heat of vaporization of water by the method of the mixtures (05marks)



- The initial temperature θ_0 and mass, m of water in the calorimeter are measured
- Steam from boiling water is passed into water in a calorimeter and after a reasonable temperature rise, flow of steam is stopped and final temperature, θ_f is recorded.
- Mass m_2 of water in the calorimeter is then taken
- The mass of steam condensed, $m_s = (m_2 - m)$

Given that the heat capacity of the calorimeter= C

Heat gained by steam = heat gained by water and calorimeter

$m_s c_v + m_s c(100 - \theta_f) = (m_2 - m)c(\theta_f - \theta_0) + C(\theta_f - \theta_0)$

c_v = specific latent heat of vaporization

c= specific heat capacity of water

(iii) Explain why latent heat of vaporization is always greater than that of fusion. (02marks)

In evaporation energy is needed to break intermolecular forces of attraction ad to expand against atmospheric pressure while in fusion, energy is needed to weaken molecular attraction only.

(c) In an experiment to determine the specific latent heat of vaporization of a liquid using the continuous flow calorimeter, the following results were obtained.

Voltage, V/V	Current, I/A	Mass collected in 300s/g
7.4	2.6	5.8
10.0	3.6	11.3

Calculate the power of the heater required to evaporate 3.0g of water in 2 minutes (06marks)

$I_1V_1 = m_1l + h$ ……………………………….(i)

$I_2V_2 = m_2l + h$ ……………………………….(ii)

From (i) and (ii)

l = $\frac{I_2V_2 - I_1V_1}{m_2 - m_1}$ = $\frac{10\ x\ 3.6 - 7.4\ x\ 2.6}{(11.3\ x\ 10^{-3} - 5.8\ x\ 10^{-3})/300}$ = 9.14 x 10^5Jkg^{-1}

$$m_3 = \frac{3.0\ x\ 10^{-3}}{2\ x\ 60} = 2.5\ x\ 10^{-5} kgs^{-1}$$

l = $\frac{I_2V_2 - I_3V_3}{m_2 - m_3}$

9.14 x 10^5n = (10 x 3.6 –I_3V_3)÷ $\left(\frac{11.3\ x\ 10^{-3}}{300} - 2.5\ x\ 10^{-5}\right)$

11.59 = 36 – I_3V_3

Power = I_3V_3 = 36 – 11.59 = 24.41W

9. (a) (i) Define specific heat capacity of a substance. (01mark)

Specific heat capacity is the energy required to raise the temperature of 1kg mass of a substance by 1K.

(ii) State three advantages of the continuous flow method over the method of mixtures in determination of the specific heat capacity of a liquid. (03marks)

- The heat capacity of the apparatus is not required.
- Heat loss is eliminated in the calculation
- Resistance thermometer can be used.
- Temperatures are read at leisure

(b) In a continuous flow experiment, a steady difference of temperature of 1.5^{0}C is maintained when the rate of liquid flow is 4.5gs^{-1} and the rate of electrical heating is 60.5W. On reducing the liquid flow rate to 1.5gs^{-1}, 36.5W is required to maintain the same temperature difference.

Calculate the

(i) Specific heat capacity of the liquid. (04marks)

P = $\frac{m}{t}$cθ + h

60.5 = 4.5 x 10^{-3} x c x 1.5 + h ……….. (i)

36.5 = 1.5 x 10^{-3} x c x 1.5 + h ……….. (ii)

Subtracting (ii) from (i)

24 = 3 x x 10^{-3} x c x 1.5

c = 5,333Jkg

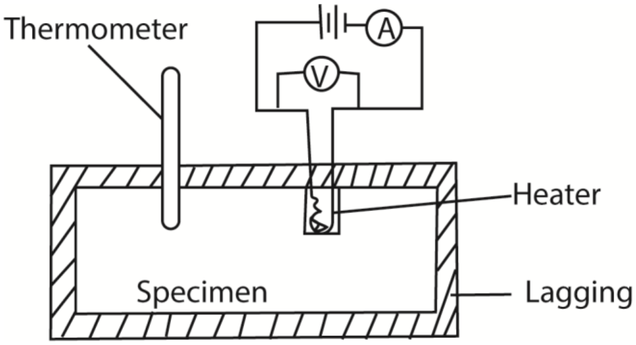
(ii) Rate of heat loss to the surroundings (03marks)

Substituting c in (i)

60.5 = 4.5 x 10^{-3} x 5333 x 1.5 + h

h = 24.5W

(c) (i) Describe an electrical method for determination of the specific heat capacity of a metal. (06marks)



- Two holes are drilled into the specimen solid of mass m.
- A thermometer is inserted in one of the holes and an electric heater into the other hole. The holes are then filled with a good conducting fluid, e.g. oil to ensure thermal contact.
- The apparatus is insulated and initial temperature θ_0 is recorded.
- The heater is switched on at the same time a stop clock is started.
- The steady values of ammeter reading, I and voltmeter reading, V are recorded.
- After considerable temperature rise, the heater is switched off and stop clock stopped.
- The highest temperature θ_1 recorded and time t taken noted.
- The specific heat capacity, c, of the conducting solid is calculated from

$$c = \frac{IVt}{m(\theta_1 - \theta_0)}$$

(ii) State the assumptions made in the above experiment. (02marks)

- All heat supplied by the heater is gained by the metal block
- The volume of the metal does not change.

(iii) Comment about the accuracy of the results of the experiment in (c)(i) above. (01marks)
The value of specific heat capacity is accurate as long as there is not heat loss to the surrounding.

10. (a) (i) Define specific heat capacity of a substance (01mark)
Specific heat capacity is the quantity of heat required to raise the temperature of 1kg mass of a substanceby1K without change of state

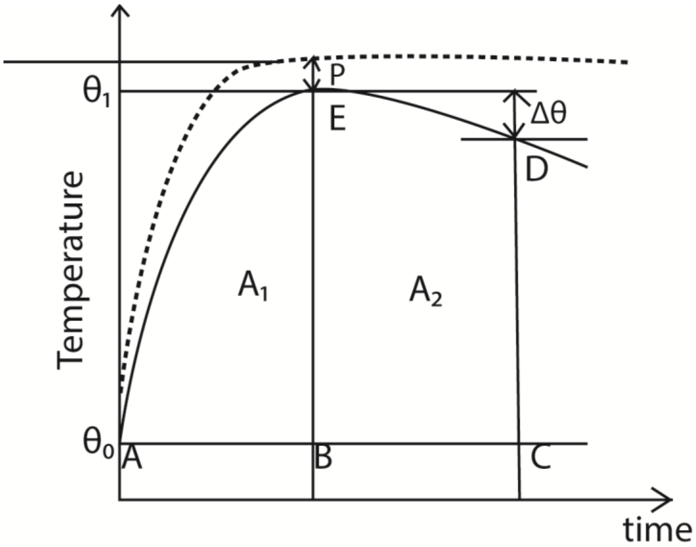
(ii) State how heat losses are minimized in calorimetry (02mark)

- Surrounding the calorimeter vacuum
- Using a highly polished surface
- By lagging the calorimeter using insulating material
- Surrounding the calorimeter with a layer of still air.

(b) (i) What is meant by cooling correction? (01marks)

This is the extra temperature difference to be added to the observed maximum temperature of the mixture to make up for the heat lost to the surrounding during the experiment.

(ii) Explain how the cooling correction may be estimated in the determination of the heat capacity of poor by the method of mixtures (05marks)



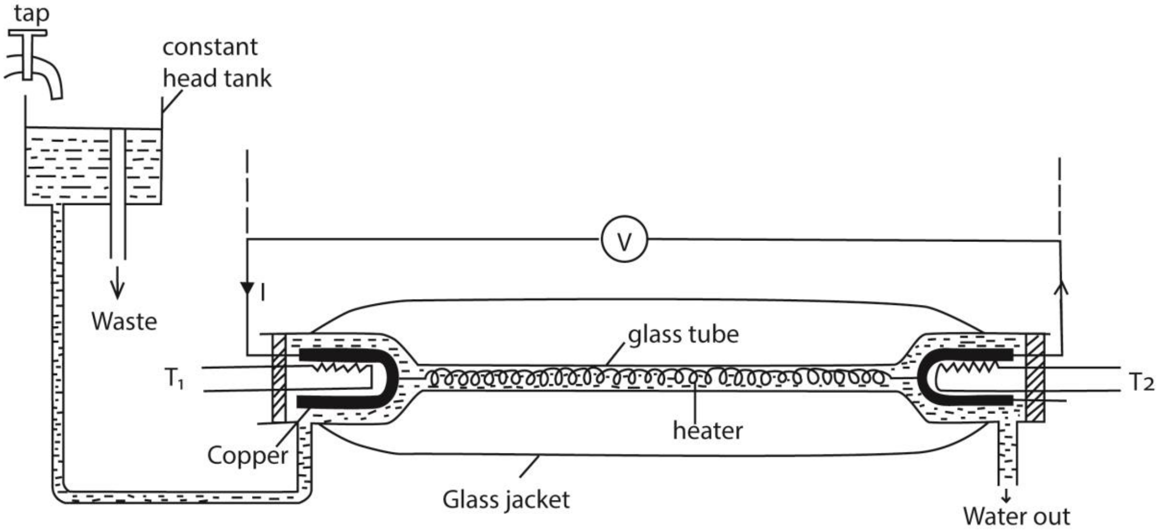
- The broken line shows how we would expect the temperature to rise if no heat were lost and the difference, P, between the plateau of this imaginary curve, and the crest of the experimental curve, E. is known as the 'cooling correction'
- Draw a line AC through θ_0 parallel to the time axis.
- Draw a line BE through θ_1 parallel to the temperature axis.
- Draw a line CD beyond BE parallel to the temperature axis and note Δθ
- Estimate the area A_1 and A_2 under the graph by counting the square on the graph paper
- Cooling correction, P s given by the graph

  Cooling correction, P = $\frac{A_1}{A_2}\ x\ \Delta\theta^0$C

(iii) Explain why a small body cools faster than a larger one of the same material. (04marks)

Small body has a large surface area to volume ratio and small quantity of heat compare to the big body. And the rate of heat is proportional to the surface area while the rate of temperature fall is inversely proportional to the quantity of heat held by the body

(c) Describe how you would determine the specific heat capacity of a liquid by the continuous flow method. (07marks)



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  Subtracting (ii) from (i)
  $c = \frac{(VI - V_1I_1)t}{(m - m_1)(\theta - \theta_1)}$

Thank you
Dr. Bbosa Science