HEAT CAPACITY

This is the heat required to rise the temperature of a substance by $1^0c$ or 1k

S.I units is $J^oc^{-1}$ or $JK^{-1}$

Heat capacity =

Specific heat capacity

This is the heat required to raise the temperature of the 1 kg mass of a substance by $1^0c$ or 1 K

S.I units is $Jkg^{-1}K^{-1}$

Specific capacity has a symbol C = ______ =

Heat = mass x c x temperature

Example

1. 6000J of heat is used to heat a liquid of mass 3kg $^0$C from 25$^o$C to 45$^0$C. Find the specific heat capacity of the liquid.

$H = M C\theta$

$6000 = 3 \times c \times 20$ $C = 100 Jkg^{-1}\, {}^oC^{-1}$

2. 10,000J of heat is used to heat the metal block of mass 400m 20$^0$c - 100$^0$c.find the (C) of the metal block.

$\theta = (100 - 20) = 80^0C$

$H = M C \theta$

$10,000 = 0.4 \times c \times 80$

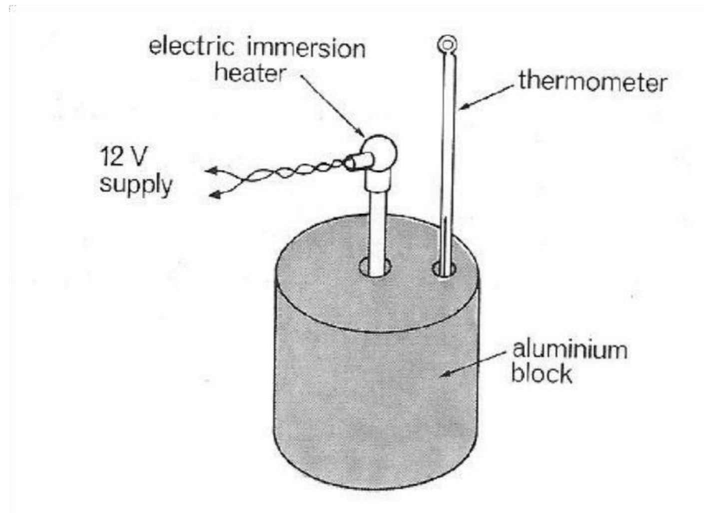
$C = 312.5 Jkg^{-1}\, {}^oC^{-1}$

3.Find the heat required to raise the temperature of a block of mass 200g from25$^0$C to 65$^0$C (specific heat capacity of the block is 130Jkg$^{-1}$$^o$C$^{-1}$)

H = M C θ

H = 0.2 X 130 X 40 =1040J

DETERMINATION OF SPECIFIC HEAT CAPACITY OF A METALIC BLOCK




The mass (m ) of the metallic block is first measured and recorded using a beam balance.
The heater of known power (P) and thermometer are placed in the block. The initial temperature of the block is recorded. The heater is switched on and left to heat for some time (t).

The purpose of cotton wool is to ensure that no heat is lost to the surrounding. Assume no heat is lost to the surrounding

Heat supplied = heat absorbed or gained by the metal

$Pt= m\ c_m \times \theta$

$C_m$ =

Where $c_m$ is the specific heat capacity of the metal

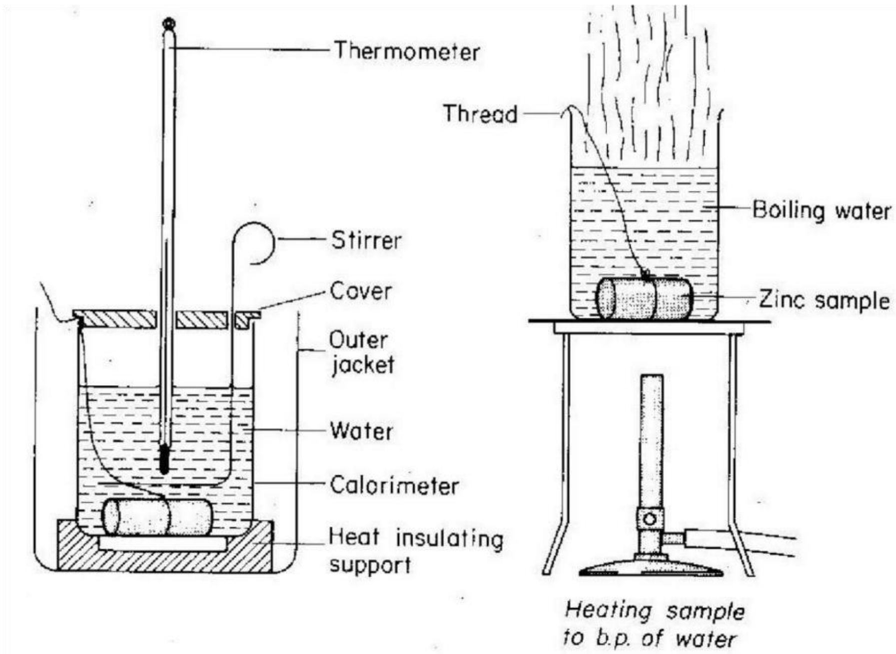
Θ- Is the temperature change i.e. ($\theta = \theta_2 - \theta_1$)

Question

A heater rated 2kw Find the heat in

i) 5 seconds ii) 10 minutes iii) 2 hour DETERMINATION OF

# SPECIFIC HEAT TEMEPRATURE OF A SOLID BY METHOD OF MIXTURES.




Procedure

- Put water of mass $m_1$ in a container of heat capacity $c_1$

- Put calorimeter and its contents in a calorimeter jacket and record their initial temperature $\theta_1$
- Mean while, put the solid of mass m in boiling water in a beaker as shown in figure(i) above for some minutes
- Record the boiling point $\theta_2$
- Quickly transfer the solid from boiling water to the calorimeter using a string.
- Begin to stirrer until the final steady temperature $\theta_3$ is obtained(the heat shield is to prevent the heating from boiling water to reach the calorimeter).
- Assume negligible heat to the surrounding.

Heat lost by solid = heat gain θ d by the calorimeter + heat gained by H20.

$MC_S\ (\theta_3 - \theta_2) = M_1C_1\ (\theta_3 - \theta_1) + M_2C_2\ (\theta_3 - \theta_1)$

$$C_s = \frac{(\qquad\qquad)\ (\theta\ \ -\theta\ \ )}{(\theta\quad \theta\ )}$$

Knowing values of $C_1$,$M_1$, $M_2$, $C_2$,M and temperature changes, specific heat capacity of a solid $C_s$ can be obtained from the above expression.

Examples:

1. 252,000J of heat are supplied to 4kg of H20 at $40^0$c.Find the final temperature of water (specific capacity of $H_2O$ is $4200JKg^{-1o}C^{-1}$)

$H = MC(\theta_2 - \theta_1)$

$252{,}000 = 4 \times 4200(\theta_2 - 40)$

Final temperature = $55^0C$

2. In an experiment to determine the specific heat capacity of a solid. It was put in boiling $H_20$ for 5min.It was then quickly transferred in 5kg liquid at $46^0C$ in plastic beaker. The final temperature of the mixture was found to be $50^0C$.Find the specific heat capacity of the solid (specific capacity of liquidis $2000JKg^{-10}C^{-1}$.

1. Heat lost by = Heat gained by liquid.

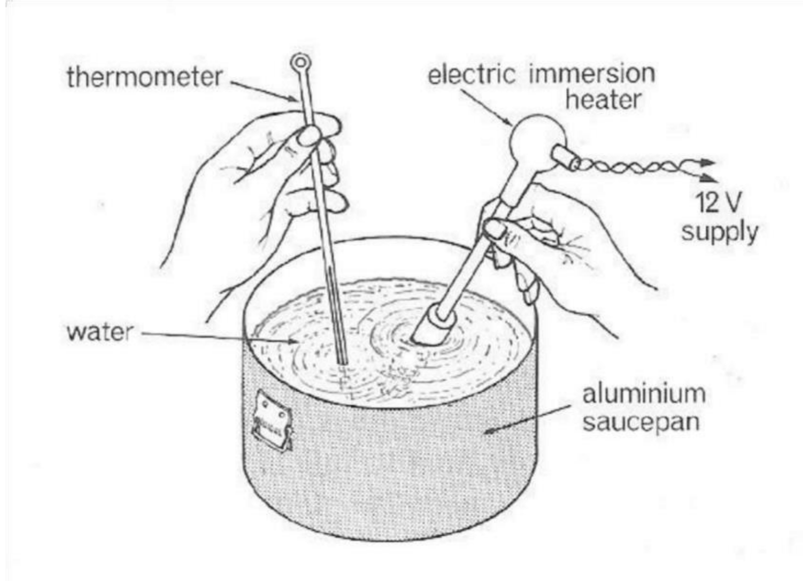
Solid

$MC(\theta_1-\theta_2) = M_1C_1(\theta_3-\theta_2)$

2. x C (100-50) = 5 x 2000 (50 – 46 C = $400JKg^{-}$

$_{1o}C_{-1}$

Determination of specific heat capacity of a liquid by electrical method




Procedure;

- Pour the liquid of known mass (m) in a plastic beaker or insulated aluminium pan
- Put the heater of known power (P) and the thermometer in the plastic beaker containing a liquid.
- Measure and record the initial temperature $\theta_1$ of the liquid. - Switch on the heater to warm the liquid for time (t).
- Read and record the final stable temperature $\theta_2$ of the liquid.

Calculate the specific capacity.

Heat gained by liquid = Heat supplied by the heater.

$$MC(\theta_2 - \theta_1) = Pt$$

Specific heat capacity of the liquid C = 

$\overline{\quad\quad\quad\quad}$

$( )$

Assumptions the;

- The amount of heat absorbed by the plastic beaker is negligible.
- No heat is absorbed by $H_20$ (liquid) from the surroundings.

Example;

1. An immersion heater of 60W was used to heat a liquid of 1Kg for a minute. Find the specific capacity of the liquid if the initial temperature was $27^0C$ and $87^0C$Heat absorbed by water = Heat supplied by the heater

$MC(\theta_2 - \theta_1) = Pt$

$1x\ C(87 - 27) = 60 \times 30$

$C = 30JKg^{-1o}C^{-1}$

2. Atifa was to have a warm bath. She mixes 5Kg of hot H20 at $85^0C$ with 15Kg of cold water at $25^0C$ taking C to be $4200JKg^OC^{-1}$. Find the final temperature of the mixture.

Heat lost by hot water = Heat gained by cold water

$M_hC(\theta 2 - \theta_3) = M_cC(\theta_3 - \theta_1)$ $5 \times 4200 (85 - \theta_3) = 15 \times 14200 (\theta_3 - 25)$ $\theta_3 = 40°C$

Importance of high specific capacity of $H_20$ $C = 4200JKg^{-1}°C^{-1}$

4400J of heat required to increase the temperature by $1^0C$ is extremely high, because of this high value of (C) of $H_20$, it is commonly used as a cooling agent in many cooling systems e.g. car radiators

LATENT HEAT

Latent heat is the heat lost or absorbed by the body during change of state at constant temperature.

There 2 types of latent heat

(i) latent heat of vaporization ($L_v$) (ii) Latent heat of fusion ($L_f$) Latent heat of vaporization;

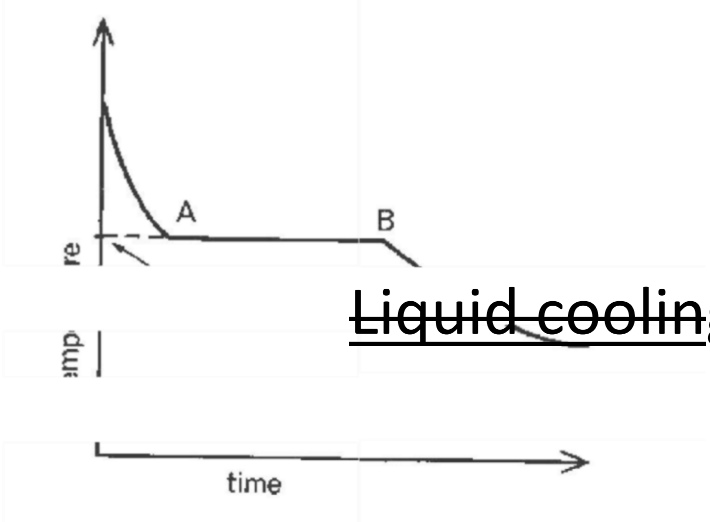
This is the amount of heat absorbed by a body to change its state 4rm liquid to vapour at constant temperature.

NB: The constant temperature is the boiling point of the liquid.

Latent heat of fusion;

This is the amount of heat absorbed by a body to change its state from solid to liquid at constant temperature. The constant temperature is the melting or freezing point.

Cooling curve of a substance




~~Liquid coolin~~g

~~Liquid~~ in equilibrium with solid

Solid cooling

Specific latent heat of vaporization $L_v$

This is the amount of heat required to change 1Kg M of a substance from liquid to vapour at constant temperature.

$H = ML_v$ where H is amount of heat supplied or lost by a body.

M = mass of the body. $L_v$ = Specific latent heat of vaporization of the body.

Examples

1. Find the amount of heat required to convert 5kg of water at boiling point to steam (Take $l_v$ of steam as $2.3 \times 10^6$ $Jkg^{-1}$)

Quantity of heat H = MLV

= 5 X 2.3 X 10J

$= 11.5 \times 10^6 J$

$= 1.15 \times 10^5 J$

2. How much heat is needed to change 4kg of water at $10^0c$ to steam at $100^0c$

H = mlv

$H = 4 \times 2.3 \times 10^6 J$

$H = 9.2 \times 10^6 J$

3. A three (kilowatt electrical kettle is left on for 2 minutes after the water starts boiling. What mass of water is boiled off in this time ?

Latent heat absorbed by $H_20$ = Heat supplied by heater

$M \times 2.3 \times 10^6 = 3 \times 1000 \times 2 \times 60$

M = 0.1565kg= 156.5g

4. Find the heat given out when 10g of steam at $100^0$Ccondenses and cool to water at $50^0$C Heat given = heat required to cool steam to water + heat required to cool water from $100^0$Cto $50^o$C.

$H = mlv + mc(\theta_2 - \theta_1)$

( )

= +

= 25100J

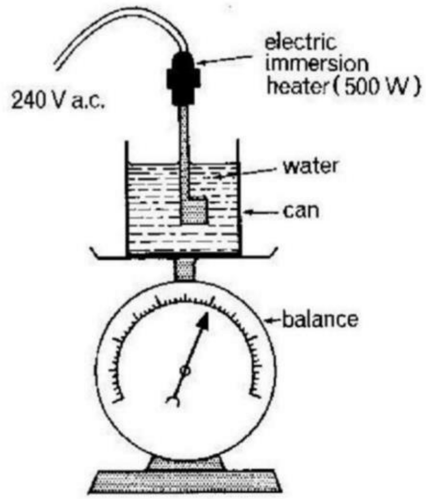
Since the amount of heat in steam is 5 times of heat in boiling water, therefore steam is more fatal than boiling water.

Importance of high value of specific latent heat of vapourization

1. Because of high value, steam is used as a heating agent e.g. In cookers (cooking) 2.
3. ++ .

2.Can be used for sterilizing medical tools e.g.blades, forceps.

Determination of specific latent heat of vaporization of steam.




Procedure

- Assume the apparatus as in the diagram above. - When the weight mass of in the beaker and record it as $m_1$. - Switch on the heater to heat water in the beaker.
- While water is boiling, read the position of the pointer of the stop clock.
- After time (t) weigh the mass of water ($m_2$)
- Calculate the mass of steam from

$M = m_1 - m_2$

Obtain specific latent heat of vapourizationfrom:

Latent heat absorbed by boiling water =

heat supplied by heater

$Mlv = pt$

Lv =

Where lv is the specific latent heat of vaporization.

## SPECIFIC LATENT HEAT OF FUSION ($L_F$)

Specific latent heat of fusion is a mount of heat required to change the state of 1 kg mass of a substance from solid to liquid at constant temperature S.I unit J/kg

Example

1(a) how much heat will change 10g of ice at 0°C to water 0°C (take specific latent heat of fusion of ice to be 340,000J/kg) H = mlv

,

H = = 3400J

2. What quantity of heat must be removed from 20g of water at 0°C to change it to ice at 0°C.

$H = ml_f$

,

= = 6800J.

3. How much heat is needed to change 5 g of ice at -5°C.

H = mcθ + mlf +mcwθ

( )

= +_____ +

= 2,802.5J Question

1. (a)What is meant by specific heat capacity?

b) 2 kg of ice initially at -10°C is heated until it changes to steam at 100°C.

i) Sketch a graph to show how the temperature changes with time.

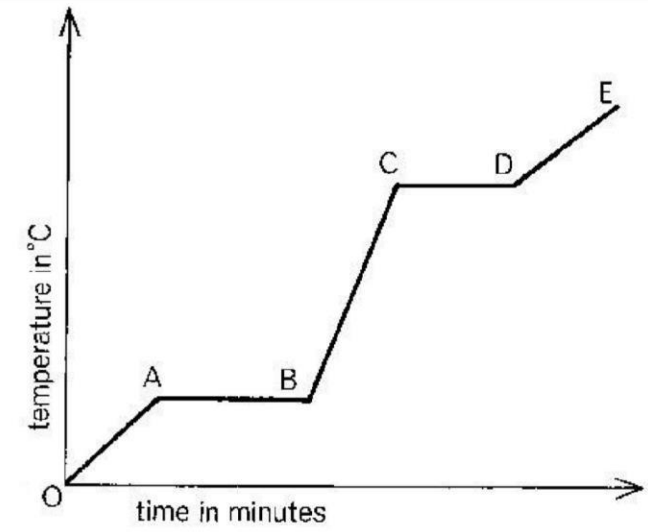
Ii) Calculate the thermo energy required at each section of the graph sketched in b(i) above .

Specific latent heat of fusion of ice is = 3.36 $x10^5Jkg^{-1}$

Specific latent heat of vapourization of water is = 2.26 x $10^6Jkg^{-1}$. Specific heat capacity of water = 42 $X10^3$ J/kgk

Specific heat capacity of ice is = 2.1 $x10^3$J/kgk.

GRAPH TO SHOW HOW TEMPERATURE CHANGES WITH TIME




(iii) Thermal energy

along AB, = $MC_{ice}$

θ

= 2 x 2.1 x $10^3$ (0 - $^-5$)= 4.2 x $10^4$J

Thermal energy

along BC H =

$ML_f$

= 2 x 3.36 x $10^5$= 6.72 x $10^5$J

Thermal energy along CD,

= MCwθ

= 2 x 4.2 x $10^3$ x (100-0) = 8.4 x $10^5$J

Thermal energy along DE,

$= Mlv$

$= 2 \times 2.26 \times 10^6 = 4.52 \times 10^6 J$

Exercise;

1. (i)State and define the 3 major methods of heat transfer.

2.(a) Distinguish between specific heat capacity and specific latent heat of a substance.

(b)Describe an experiment to determine the specific latent heat of fusion of ice.

3. The Graph showing a heating curve of a metal

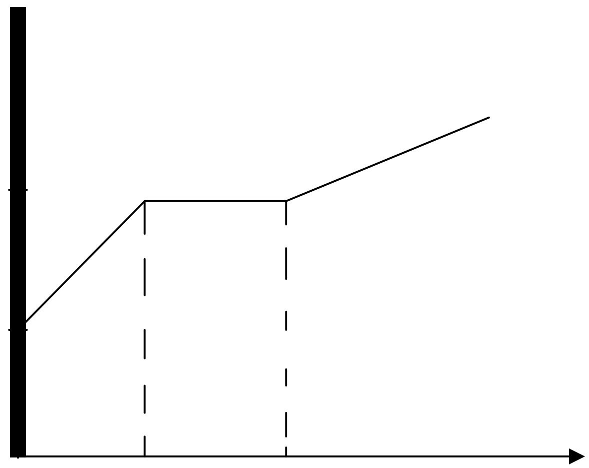
D

200 B

C

Temp/$^0$C

50 A



0 200 500 Time/s

(i) Explain what happens to the metal.

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(ii)If the metal absorbs heat at the rate of 3000J/S and specific heat capacity is 400JKg$^{-1o}$C$^{-1}$, calculate mass of the metal.

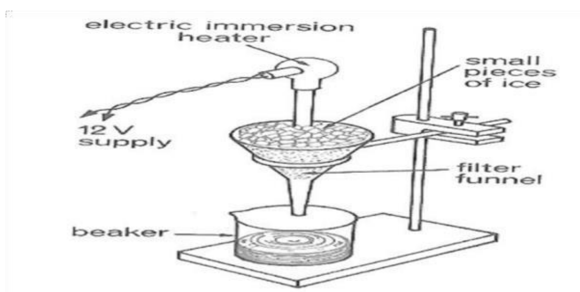
(ii) Find the specific latent heat of the metal,

3. (a) Find the ways you would modify a liquid in glass thermometer so that it can register temperature more quickly.

(b) Why is it usually not a good idea to have a thermometer with high heat capacity?

4. (a) Explain why the freezing compartment of a refrigerator is at the top.

(b) A glass of orange squash contains 0.2 kg of water at temperature of $24^0$C.What is the minimum amount of ice you would need to add in order that the temperature of the drink is $0^0$C? Experiment to determine the specific latent heat of fusion of ice Set up.



Procedure; Support the plastic funnel using the retort stand.

Arrange the apparatus as in the diagram without the beaker.

When the water in the funnel starts dripping at a uniform rate, switch on the immersion heater and place the beaker under the funnel at the same time.

After sometime (t) of warming ice using the heater (of known power (p),

Remove the beaker and the mass (m) of the water collected in the beaker is weighed.

Calculate the specific latent heat of fusion of ice from:

Heat absorbed by ice = Heat supplied by heater

MLf = Pt

Lf =

Assumption;

-No heat is absorbed from the surrounding.

- All heat supplied by the heater has been absorbed by the ice only.

Significance of high value of specific latent heat of fusion   Ice is often used as a cooling agent e.g. ice cubes are added to juice to keep it cold.

Example:

An aluminum tray of mass 400g containing 300g of water is placed in a refrigerator, after 80 minutes, of tray is removed and it is found that 60g of water remain un frozen at $0^0$C. If the initial temperature of tray and its content was 200c, determine the average amount of heat removed per minute by the refrigerator. Specific capacity of aluminum = $1J/g^0C^{-1}$

Specific capacity of water = $4Jg^{-1o}C^{-1}$

Specific latent heat of fusion of ice = 340J/g

Heat removed by the fridge = Heat loss by water from $20^0$C to $0^0$C + Heat loss bywater to ice+ heat loss by tray.

$= M_wC_w(\theta_2 - \theta_1) + M_{ice}L_f + M_tC_1(\theta_2 - \theta_1)$

$= 0.3 \times 4000 (20 - 0) + 0.24 \times 340{,}000 + 0.4 \times 1000 (20 - 0)$

= 113600J

Heat removed per minute = ___

= 1420J/min  question1:

In an experiment to determine specific latent heat of fusion of ice, the following results were obtained. Mass of water obtained in the beaker = 20g Power of the heater = 50W.
Time heater is switched on = 2min 6seconds
Determine specific latent heat of fusion of ice. Latent heat and kinetic theory (a)

Latent heat of fusion.

During change of state from solid to liquid (melting at constant temperature, the heat supplied weakens the intermolecular forces of attraction, the molecular spacing increase, changing from static molecules of solid to fast moving molecules in liquid state.

The average K.E of molecules remaining constant because melting takes place at constant temperature.

(b) Latent heat of vaporization;

During change of state from liquid to vapour, the molecules must overcome of intermolecular forces of attraction so that they gain freedom to move about independently. As a result, the supplied is used to overcome these forces resulting in gain molecular potential energy but not their kinetic energy and also the work to expand against atmospheric pressure.

Why specific latent heat of vaporization of a substance is always greater than specific latent heat of fusion for the same substance. Specific latent heat of vaporization is always great

er than Lf because for molecules of a liquid to escape. *h* *h hh* . *h* .

While for latent heat of fusion very low amount of heat is required to weaken the intermolecular forces of attraction.