Temperature

Temperature :-

Def: <u>Average Kinetic energy</u> of particals of matter is temperature.

Symbol: T or θ

Formula: Temperature = Average E_k = $<E_k>$

$$T = \frac{\text{Total Kinetic energy}}{\text{No. of particles}}$$

P.S   Scalar

Units   Kelvin (K) or Centigrade/celsius scale (°C)

Significance: It defines the path for the flow of heat.

Heat :-

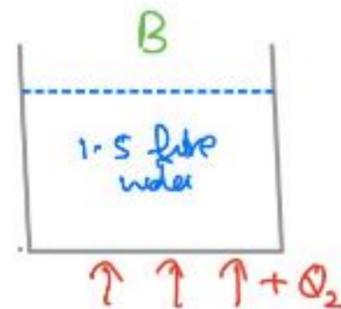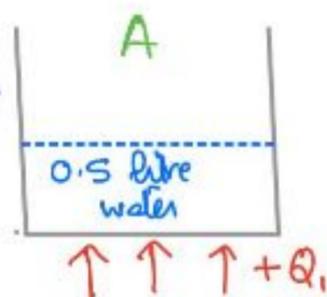Def It is the <u>total kinetic energy</u> of particles of matter

Symbol: Q

Formula: Average E_k = $\frac{\text{Total } E_k}{\text{no. of particles}}$

$$T = \frac{Q}{n}$$

Example :-

Identical Containers

A
0.5 litre water
↑ ↑ ↑ +Q₁

B
1.5 litre water
↑ ↑ ↑ +Q₂

$+Q_1 = +Q_2$

$$(\Delta T)_A > (\Delta T)_B \quad \text{because} \quad N_A < N_B$$

$$\text{as} \quad \Delta T \propto \frac{1}{N} \quad \text{as} \quad Q_1 = Q_2$$
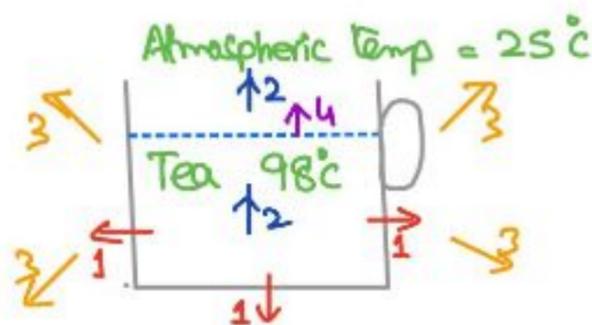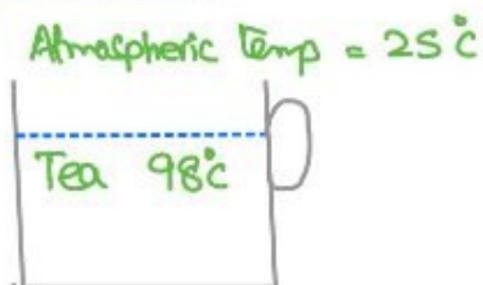
P.S   Scalar

Units   Joule (J)

Thermal equilibrium :-

<u>Meaning/Concept</u>: Two objects are said to be in thermal equilibrium if

(i) there is no net transfer of heat/energy in between them.

(ii) their temperature is also constant/same.

Explanation:

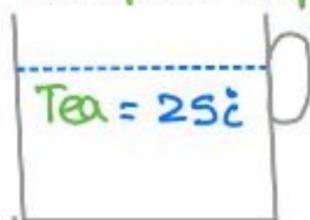Atmospheric Temp = 25°C   Tea 98°C

Atmospheric Temp = 25°C   Tea 98°C

1- Conduction
2- Convection
3- Radiation
4- Evaporation

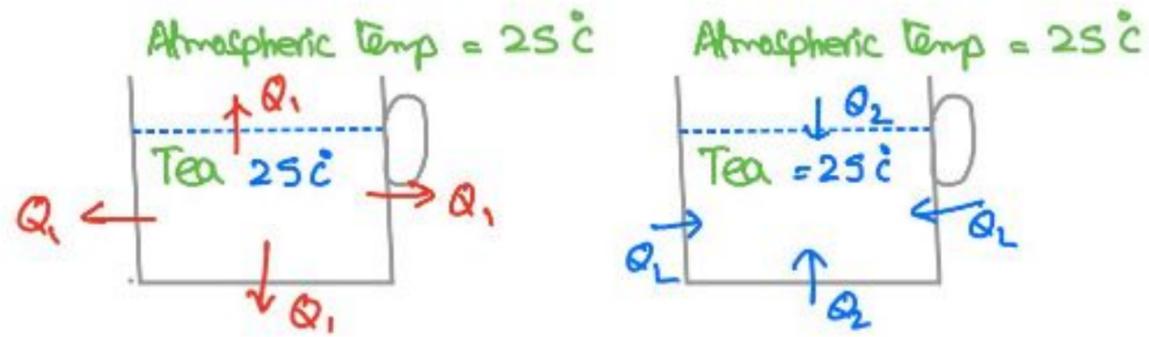Heat is released by tea particles to atmosphere due to temperature difference.

$$\Delta T \downarrow = \frac{E_k}{N \uparrow}$$

Atmospheric Temp = 25°C increases 25.1°C

Tea = 25°C

but rise in temperature of atmosphere is negligible due to greater no. of particles.

Atmospheric Temp = 25°C   Atmospheric Temp = 25°C

Tea 25°C   Tea = 25°C

with arrows Q_1 (left diagram) and Q_2 (right diagram)

Now $$Q_1 = Q_2$$

or $$\Delta Q = Q_1 - Q_2 = 0$$ ie no net transfer of Heat ie Heat lost = Heat gained

Also temperature of tea and atmosphere is same. So tea is in thermal equilibrium with Surrounding.

Zeroth law of thermodynamics:-

Concept: Atmosphere 25°C

Lid 25°C

Tea = 25°C

Cup 25°C
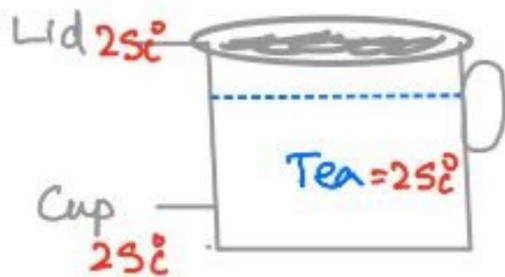
Since tea is in thermal equilibrium with (cup and lid).
Also
(cup and lid) are in thermal equilibrium with atmosphere.

So tea and surrounding are also in thermal equilibrium.

Statement: If an object A is in thermal equilibrium with object B and object B is in thermal equilibrium with another object C. So object A and C are also in thermal equilibrium.

If | A | B | and | B | C | So | A | C |

Thermal equilibrium ⎵   Thermal equilibrium ⎵   Thermal equilibrium ⎵

Linearity law of thermomery:-

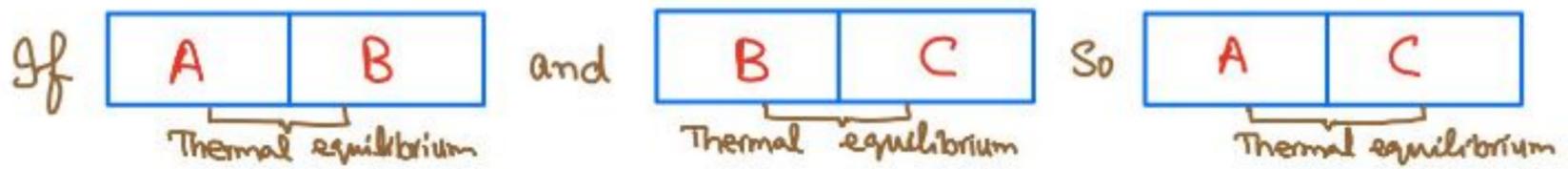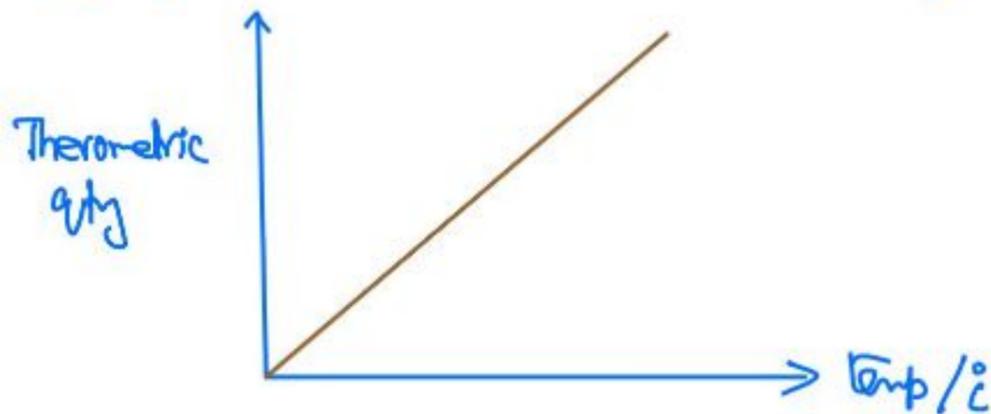Statement: Change in the thermometer quantity/property is directly proportional to the rise of Temperature.

Thermometric qty ↑ (vertical axis)

Temp/t → (horizontal axis)

Example:

S.No	Type of thermometer	Variation in thermometic quantity.
1.	Liquid in glass	$\Delta l \propto \Delta\theta$ $\Delta V \propto \Delta\theta$ $\Delta\rho \propto \dfrac{1}{\Delta\theta}$ density
2.	Gas thermometer	Δ Pressure $\propto \Delta\theta$ for constant volume
3.	Resistance thermometer	$R_{metal} \propto \Delta\theta$
4.	Thermocouple thermometer	$\Delta(e.m.f) \propto \Delta\theta$

Analysis:

l_0 $0\,t$

l_{100} $100\,t$

l_0 $\theta\,t = ?$
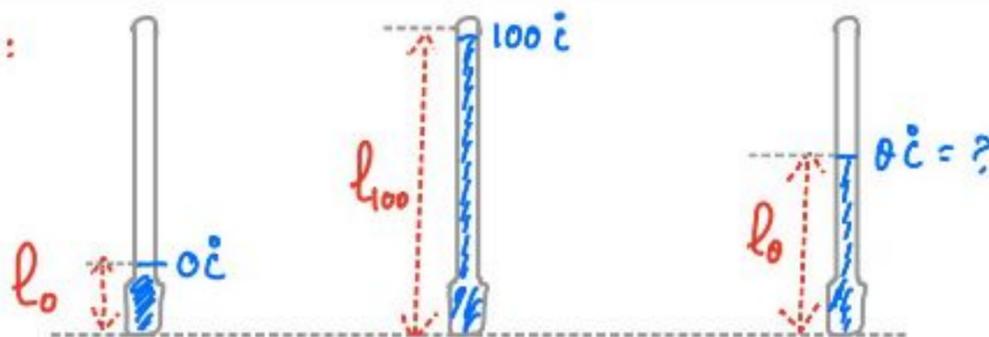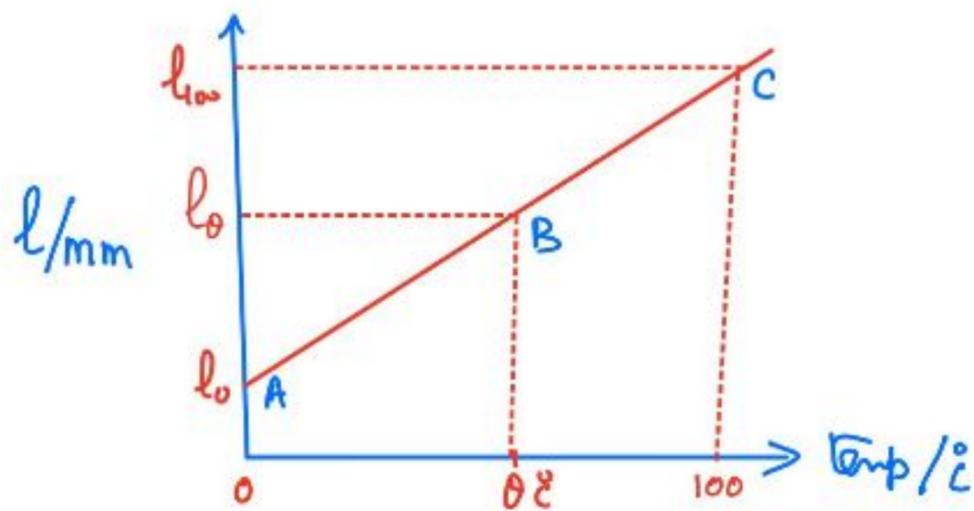
Since ABC is a straight line, so

Gradient of AB = Gradient of AC

$$\frac{l_\theta - l_0}{\theta - 0} = \frac{l_{100} - l_0}{100 - 0}$$

$$\frac{l_\theta - l_0}{\theta} = \frac{l_{100} - l_0}{100}$$

$$\boxed{\theta = \left(\frac{l_\theta - l_0}{l_{100} - l_0}\right) 100}$$

For any other thermometric quantity X,

$$\boxed{\theta/^\circ C = \left(\frac{X_\theta - X_0}{X_{100} - X_0}\right) 100}$$

Scales of temperature:-

- Empirical scale
  - → Centigrade scale ($^\circ C$)
- Theoretical scale
  - → Kelvin or Absolute scale

Fixed point :- Constant Temperature at which matter co-exist in its two states.

→ Lower fixed pt $\xrightarrow{0\,^\circ C}$ Melting point of ice (ice + water)

→ upper fixed pt $\xrightarrow{100\,^\circ C}$ Boiling point of water (water + steam)

<u>Fundamental interval</u>:- This is the gap between upper and lower fixed point.

Scale	Lower fixed pt.	upper fixed pt.	Fundamental interval
Centigrade or Celsius scale	$0°C$	$100°C$	$100 - 0$ $= 100$
Absolute or Kelvin scale.	$273.15\ K$	373.15	$373.15 - 273.15$ $= 100$

<u>Relationship</u>:

$$T/K = \theta/\overset{\circ}{C} + 273.15$$

<u>Tripple point of water</u>:-

     Constant temperature at which all three states of water co-exist simultaneously ie ice + water + steam. This Temperature is monitored by a special apparatus known as tripple point cell. For water, tripple point is <u>273.16 K</u>

<u>Thermodynamic scale of temperature</u>:-

     This is a theoretical scale which is independent of any empirical property/quantity which varies linearly with the rise of Temperature but depends upon the ideal gas equation

$$PV = nRT.$$

$$PV \propto T$$

As no. of moles (n) and molar gas constant (R) are constants.

Formula:

$$\frac{PV}{(PV)_{tr}} = \frac{T}{273.16}$$

$$T = \frac{PV}{(PV)_{tr}} \times 273.16$$

Here   PV – Product of pressure and volume at unknown Temperature T

$(PV)_{tr}$ – Product of pressure and volume at tripple point of water

Note:

(1) Lowest possible Temperature on Kelvin scale is zero Kelvin and is known as Absolute zero.

(2) $T \propto \langle E_k \rangle$

At Absolute zero ie OK, T=0 so $\langle E_k \rangle = 0$ i.e particles have no Kinetic energy and hence no motion is observed in any state of matter.

Akhtar Mahmood (0333-4281759)
LGS, BLL, ALJT, ALBT, TCS Ravi,
TCS ALCG, TMS, SALT Academy
teacher_786@hotmail.com

Q. 1

(a) Explain what is meant by the statement that two bodies are in *thermal equilibrium*.

There is no net transfer of heat in between them and both are at same temperature.

.... [1]

(b) Suggest suitable types of thermometer, one in each case, to measure

   (i) the temperature of the flame of a Bunsen burner,

   Thermocouple

.... [1]

   (ii) the change in temperature of a small crystal when it is exposed to a pulse of ultrasound energy.

   Thermocouple

.... [1]

(c) Some water is heated so that its temperature changes from 26.5 °C to a final temperature of 38.0 °C.

State, to an appropriate number of decimal places,

   (i) the change in temperature in kelvin,

   $38.0 - 26.5 = 11.5 \,°C = 11.5 \,K$

   or $(38.0 + 273.15) - (26.5 + 273.15) = 11.5 \,K$

   change = ... K [1]

   (ii) the final temperature in kelvin.

   $T/K = \theta/°C + 273.15$

   $= 38.0 + 273.15$

   Answer should either be in 3 sf or 4 sf

   final temperature = ... K [1]

[Total: 5]
{Q.3/ June 2016 /42 variant}

2.

(a) A resistance thermometer and a thermocouple thermometer are both used at the same time to measure the temperature of a water bath.

Explain why, although both thermometers have been calibrated correctly and are at equilibrium, they may record different temperatures.

Their thermometric quantity may not vary linearly as assumed by law.

.... [2]

(b) State

    (i) in what way the absolute scale of temperature differs from other temperature scales,

Absolute scale is independant of thermometric quantity which varies linealy with the rise of Temp [1]

    (ii) what is meant by the absolute zero of temperature.

0 Kelvin

$<E_K> = \frac{3}{2}KT \Rightarrow <E_K> = \frac{3}{2}k(0) = 0$

Particles have no K.E. at absolute zero. [1]

(c) The temperature of a water bath increases from 50.00 °C to 80.00 °C. Determine, in kelvin and to an appropriate number of significant figures,

    (i) the temperature 50.00 °C,

$$T/K = \theta/°C + 273.15$$
$$= 50.00 + 273.15$$

temperature = ... 323.15 .... K [1]

    (ii) the change in temperature of the water bath.

$$80.00 - 50.00 = 30.00 °C$$
$$= 30.00 K$$

temperature change = ... K [1]

{Q.2/ Nov. 2011 /43 variant}

3.

(a) The resistance of a thermistor at 0 °C is 3840 Ω. At 100 °C the resistance is 190 Ω. When the thermistor is placed in water at a particular constant temperature, its resistance is 2300 Ω.

    (i) Assuming that the resistance of the thermistor varies linearly with temperature, calculate the temperature of the water.

$$\theta/°C = \left(\frac{R_\theta - R_0}{R_{100} - R_0}\right)100$$
$$= \left(\frac{2300 - 3840}{190 - 3840}\right)100$$
$$= 42 °C$$

temperature = ... °C [2]
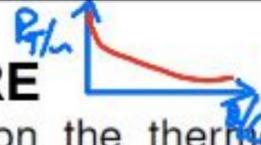
(ii) The temperature of the water, as measured on the thermodynamic scale of temperature, is 286 K.

By reference to what is meant by the thermodynamic scale of temperature, comment on your answer in **(i)**.

$T/K = \theta/^{\circ}C + 273.15 \Rightarrow T/K = 42 + 273.15 = 315.15 K$

Thermodynamic scale is independent of emperical property which varies with temp while change in resistance of thermistor with temp is a curved graph. [3]

(b) [4 marks question from Thermal properties of materials]

{Q.3/ June 2010 /42& 43 variant}

4. The e.m.f. generated in a thermocouple thermometer may be used for the measurement of temperature. Fig.4.1 shows the variation with temperature *T* of the e.m.f. *E*.
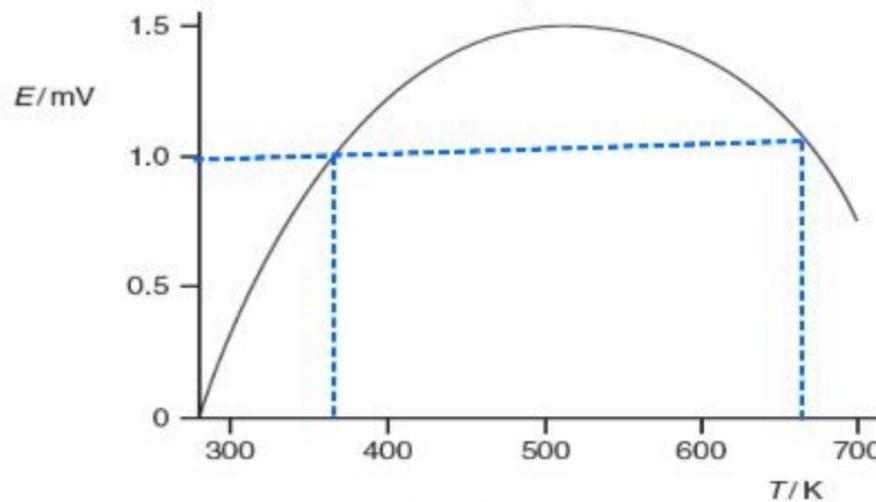
Fig. 4.1

(a) By reference to Fig. 4.1, state two disadvantages of using this thermocouple when the e.m.f. is about 1.0mV.

1. Two values of temperature are obtained at 1.0 mV.

2. Trend of graph is curved, so it does not follow linearity law.   [2]

(b) An alternative to the thermocouple thermometer is the resistance thermometer.
State two advantages that a thermocouple thermometer has over a resistance thermometer.

1. ....

....

2. ....

....   [2]

No more in syllabus

Note: Resistance Thermometer is excluded from June 2016. {Q.7/ Nov 2004 / 9702-4}

TEMPERATURE

Q. 5 The electrical resistance of a thermistor is to be used to measure temperatures in the range 12 °C to 24 °C. Fig. 5.1 shows the variation with temperature, measured in degrees Celsius, of the resistance of the thermistor.

$$\frac{1600-1400}{10} = 20$$

2040 ∓ 20

Fig. 5.1

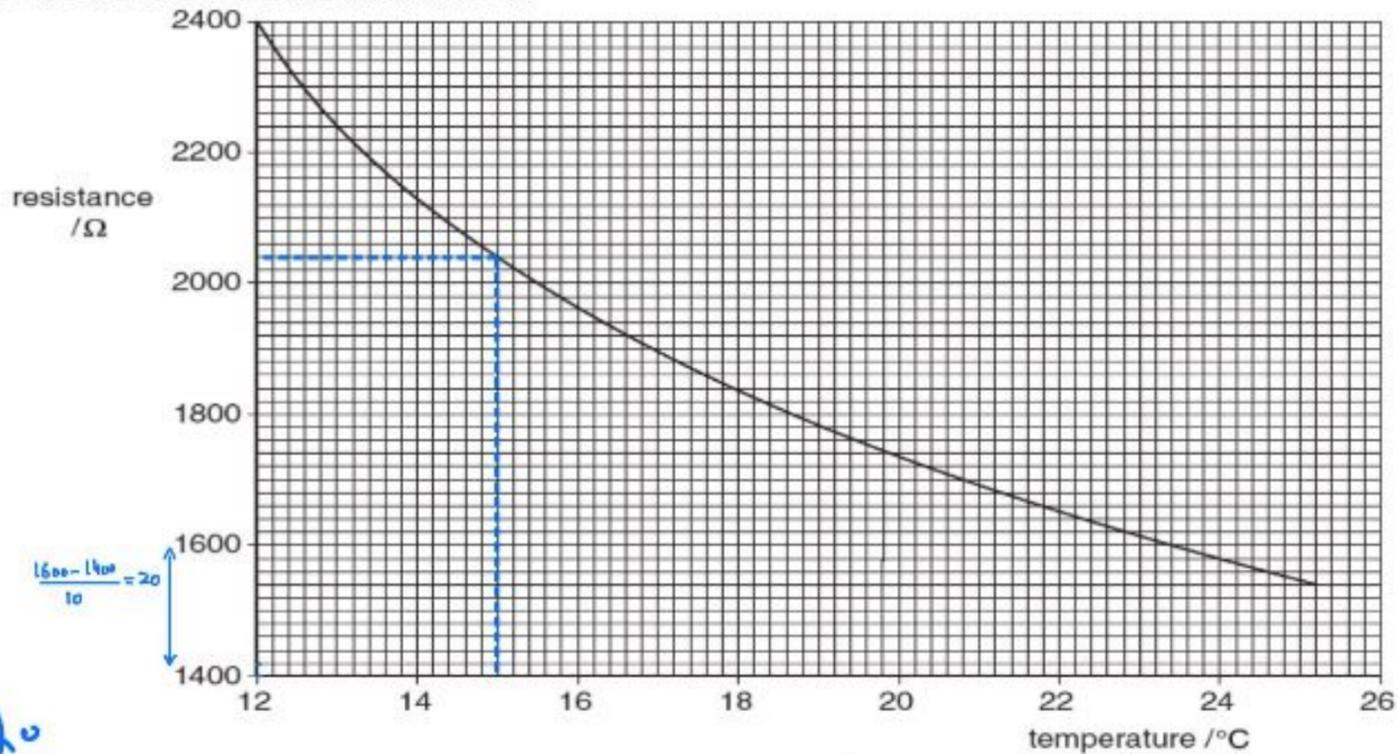**(a)** State and explain the feature of Fig. 5.1 which shows that the thermometer has a sensitivity that varies with temperature.

Sensitivity $= \frac{\Delta R}{\Delta \theta}$ = Gradient of graph

Since Gradient of graph varies with temperature and so is the sensitivity.

.... [2]

(b) At one particular temperature, the resistance of the thermistor is 2040 ± 20Ω. Determine this temperature, in kelvin, to an appropriate number of decimal places.

$$\theta/\overset{\circ}{c} = 15.0 \pm 0.2 \overset{\circ}{c}$$

$$T/K = \theta/\overset{\circ}{c} + 273.15$$

$$= 15.0 + 273.15$$

$$= 288.15 \text{ K}$$

$$or = 288.2 \text{ K}$$

temperature = ... K [3]

TEMPERATURE

Akhtar Mahmood (0333-4281759)
LGS, BLL, ALJT, ALBT, TCS Ravi,
TCS ALCG, TMS, SALT Academy
teacher_786@hotmail.com

Marking Keys:

Q.1 {*Ref. Q.3/ June 2016 /42 variant*}
(a) no <u>net</u> energy transfer between the bodies
    or
    bodies are at the same temperature   B1 [1]

(b) (i) thermocouple, platinum/metal resistance thermometer, pyrometer   B1 [1]

   (ii) thermistor, thermocouple   B1 [1]

(c) (i) change = 11.5 K   B1 [1]

   (ii) final temperature = 311.2 K   B1 [1]

Q. 2 {*Ref.Q.2/ Nov. 2011 /43 variant*}
(a) temperature scale calibrated assuming linear change of property with
    temperature   B1
    neither property varies linearly with temperature   B1 [2]

(b) (i) does not depend on the property of a substance   B1 [1]

   (ii) temperature at which atoms have minimum/zero energy   B1 [1]

(c) (i) 323.15 K   A1 [1]

   (ii) 30.00 K   A1 [1]

Q. 3 {*Ref: Q.3/ June 2010 /42& 43 variant*}
(a) (i) 1 deg C corresponds to (3840 – 190) / 100 Ω   C1
    for resistance 2300 Ω, temperature is 100 × (2300 – 3840) / (190 – 3840)
    temperature is 42°C   A1 [2]

   (ii) *either* 286 K ≡ 13°C *or* 42°C ≡ 315 K   B1
    thermodynamic scale does not depend on the property of a substance   M1
    so change in resistance (of thermistor) with temperature is non-linear A1 [3]

Q. 4 {*Ref.Q.7/ Nov 2004 / 9702-4*}
   (a) variation is non-linear   1
       two possible temperatures   1   [2]

   (b) e.g. **1.** small thermal capacity/measure $\Delta\theta$ of small object /short response time
        2. readings taken at a point/physically small
        3. can be used to measure temperature difference
        4. no power supply required
                etc. (any two, 1 mark each)   2   [2]

Q.5 (a) gradient of graph is (a measure of) the sensitivity
       the gradient varies with temperature   [2]

   (b) 2040 ± 20 Ω corresponds to 15.0 ± 0.2 °C
       T / K = T / °C + 273.15 (allow 273.2)
       temperature is 288.2 K   [3]

TEMPERATURE

Akhtar Mahmood (0333-4281759)
LGS, BLL, ALJT, ALBT, TCS Ravi,
TCS ALCG, TMS, SALT Academy
teacher_786@hotmail.com

Calculation sheet:

Specific Heat Capacity: c

$$Q = mc\,\Delta\theta \implies C = \frac{Q}{m\,\Delta\theta}$$

Def: Amount of heat energy per unit mass required to raise its temperature by unit degree is sp. heat capacity.

P.S   Scalar

Units $J\,kg^{-1}\,K^{-1}$ or $J\,kg^{-1}\,(°c)^{-1}$

Importance:

$$C = \frac{\frac{Q}{m}}{\Delta\theta}$$

$(\Delta\theta)\uparrow$ if $c\downarrow$ for constant $\left(\frac{Q}{m}\right)$

materials with smaller value of specific heat capacity suffer a rapid change of temperature i.e their temperature increases and decreases rapidly. For example, thermocouple thermometer measure rapid change of temperature due to smaller value of specific heat capacity of metallic wires used.

Note: Water is used as a cooling agent in engines / radiators / nuclear reactors due to its greater specific heat capacity (fresh water, $C = 4200\,J\,kg^{-1}\,K^{-1}$; sea water, $C = 3900\,J\,kg^{-1}\,K^{-1}$)

Specific Latent Heat :-

     ↓
Hidden → no change of temperature

$$Q = ml \implies l = \frac{Q}{m}$$

<u>Def.</u> Amount of heat energy per unit mass required to change the state of matter at constant temperature.

<u>P.S:</u>   Scalar

<u>Units:</u> $J kg^{-1}$

<u>Dependance:</u> Nature of material

<u>Note:</u> $Q = ml$

    $\longrightarrow$ changed state of matter

<u>Types:</u>

(i) <u>Sp. latent heat of Fusion</u>:-

<u>Def.</u> Amount of heat energy per unit mass required to change a solid to liquid at its melting point

<u>Symbol:</u> l_f

<u>Formula</u> $Q = ml_f$

<u>Units:</u> $J kg^{-1}$

<u>P.S:</u>   Scalar

<u>Kinetic theory explanation</u>:- In sp. latent heat of fusion, the heat provided is used to break the bonds but there is no significant increase in average separation between particles.

Here chemical/electrical potential energy increases but kinetic energy remain constant due to constant temperature. Therefore, internal energy of liquid obtained increases.

Experiment to determine specific latent heat of fusion of ice :-

— Beaker initially empty
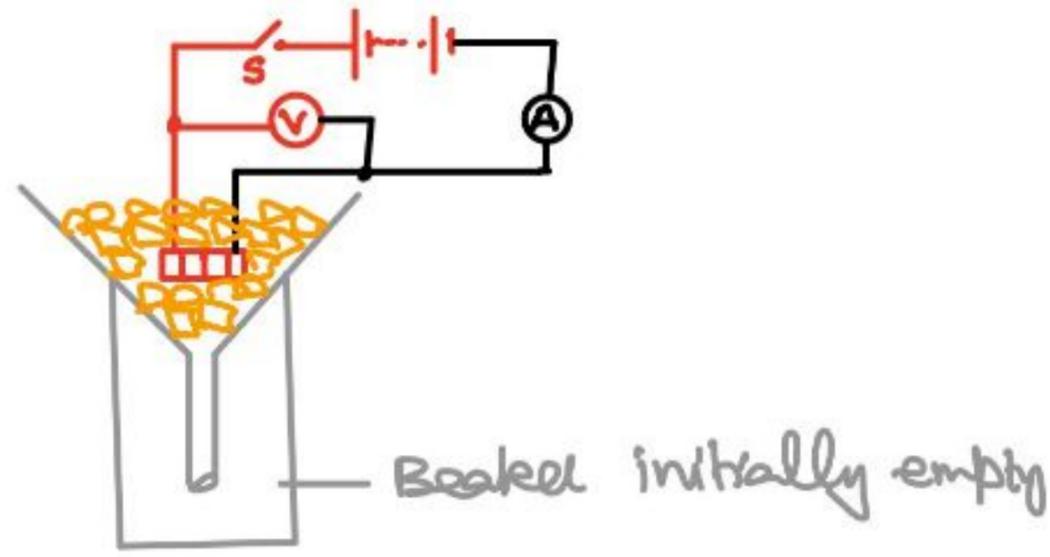
1- Switch on the electrical supply for a known time t and measure the mass of melted ice by absorbing heat from heater as well as from surrounding. By Principle of Conservation of energy.

Heat from heater + Heat from surrounding = Heat to melt ice

$$VIt \quad + \quad R \quad = \quad m_1 \, l_f \quad \text{------------------ (1)}$$

2- To eliminate the error caused by absorbing heat from surrounding, the whole experiment is repeated for the same time interval 't' with same initial design features but keep the switch s opened. Now ice is melted only by absorbing heat from surrounding.

Heat from surrounding = Heat to melt ice

$$R \quad = \quad m_2 \, l_f \quad \text{------------------ (2)}$$

(3) Subtract (2) from (1)

$$(VIt + h) - h = m_1 l_f - m_2 l_f$$

$$VIt = (m_1 - m_2) l_f$$

$$\boxed{l_f = \frac{VIt}{m_1 - m_2}}$$

Sp. latent heat of vaporisation:-

Def Amount of heat energy per unit mass required to change a liquid to vapour state at its boiling point
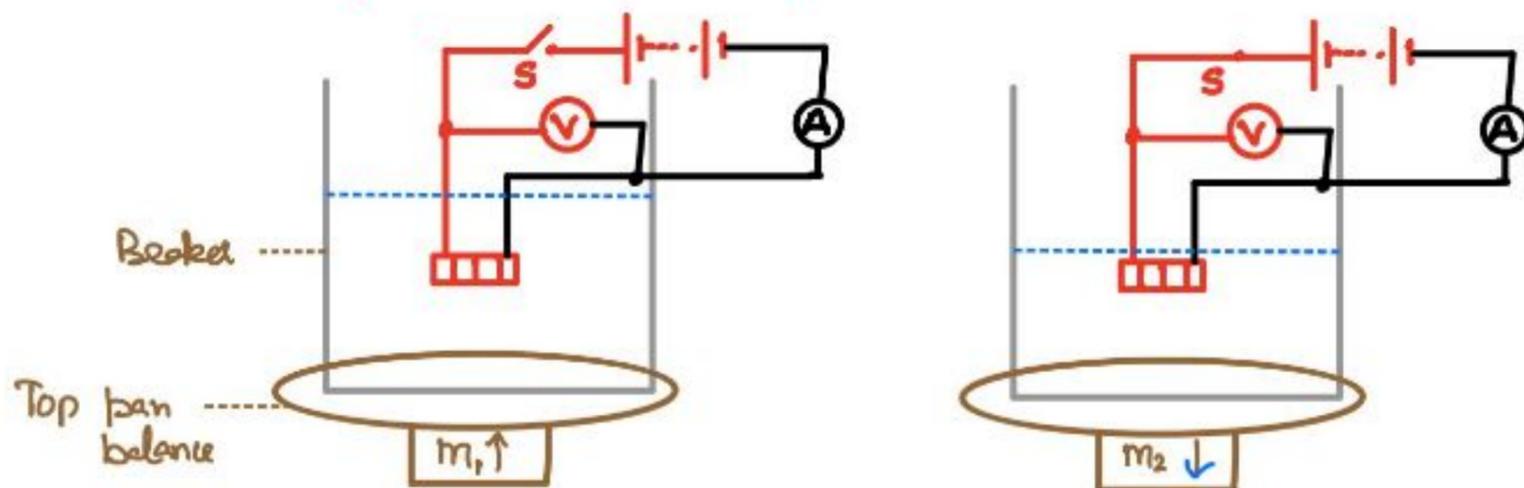
Symbol: l_v

Formula $Q = m l_v$

Units : $J\,kg^{-1}$

P.S :   Scalar

Kinetic theory explanation:- $Q = +ve$, $(\Delta E_k \propto T) = 0$

but $\Delta E_p \uparrow$ due to breaking of bonds and 10^{-} times increase in average separation between particles. So internal energy increases.

Experiment to determine specific latent heat of vaporisation of water :-
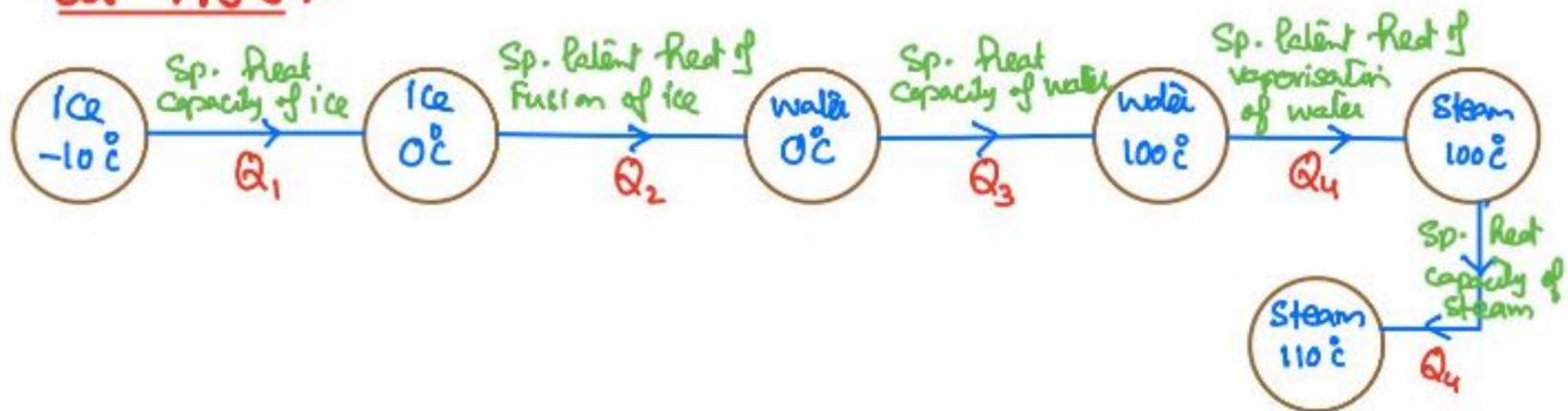
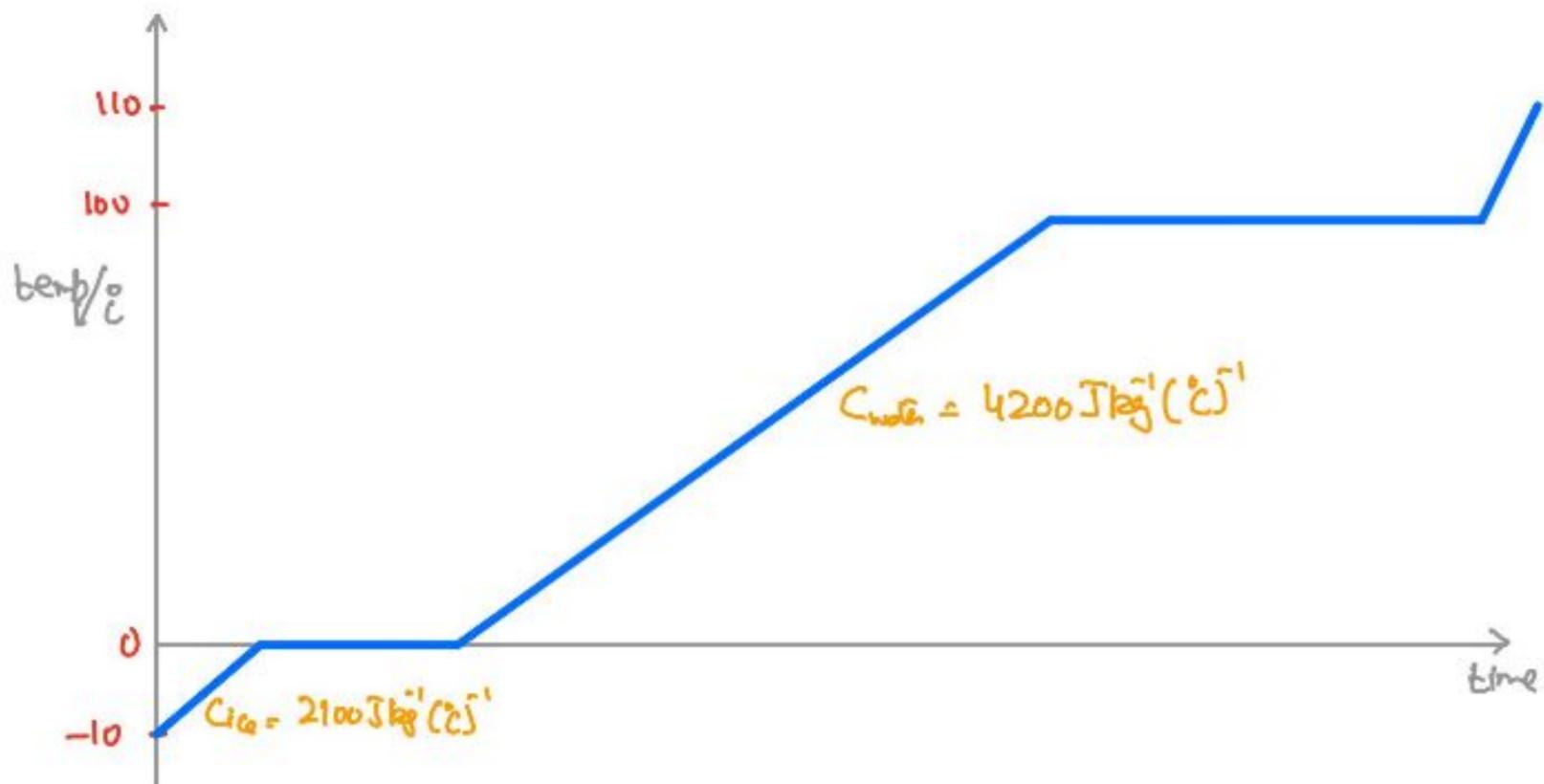Difference of mass of liquid vaporised due to heat energy: $m = m_1 - m_2$

$$Q = m \, l_v$$

$$V I t = (m_1 - m_2) \, l_v$$

$$\boxed{l_v = \frac{V I t}{m_1 - m_2}}$$

Total heat required to convert ice at $-10°c$ to steam at $110°c$:-

Ice $-10°c$ →[Sp. Heat capacity of ice] Q_1 → Ice $0°c$ →[Sp. latent Heat of Fusion of ice] Q_2 → Water $0°c$ →[Sp. Heat capacity of water] Q_3 → Water $100°c$ →[Sp. latent Heat of vaporisation of water] Q_4 → Steam $100°c$ →[Sp. Heat capacity of steam] Q_4 → Steam $110°c$

$$Q_{total} = Q_1 + Q_2 + Q_3 + Q_4 + Q_5$$

$C_{water} = 4200 \, J\,kg^{-1}(°c)^{-1}$

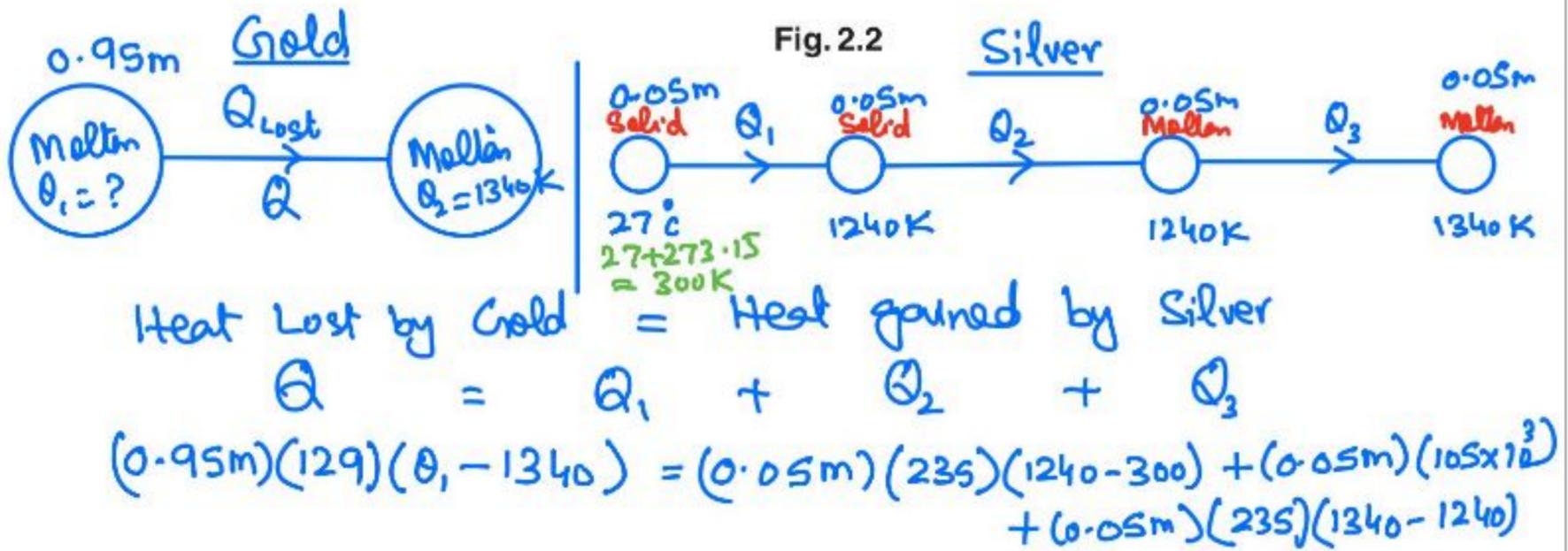$C_{ice} = 2100 \, J\,kg^{-1}(°c)^{-1}$

2 **(a)** On Fig. 2.1, place a tick (✓) against those changes where the internal energy of the body is increasing. [2]

water freezing at constant temperature	$\Delta u \downarrow$
a stone falling under gravity in a vacuum	$\Delta u = 0$
water evaporating at constant temperature	$\Delta u \uparrow$ as $\Delta E_p \uparrow$ and $(\Delta E_k \propto T) 0$
stretching a wire at constant temperature	$\Delta u \uparrow$ as $\Delta E_p \uparrow$

Fig. 2.1

(b) A jeweller wishes to harden a sample of pure gold by mixing it with some silver so that the mixture contains 5.0% silver by weight. The jeweller melts some pure gold and then adds the correct weight of silver. The initial temperature of the silver is 27 °C. Use the data of Fig. 2.2 to calculate the initial temperature of the pure gold so that the final mixture is at the melting point of pure gold.

	gold	silver
melting point / K	1340	1240
specific heat capacity (solid or liquid) / J kg⁻¹ K⁻¹	129	235
specific latent heat of fusion / kJ kg⁻¹	628	105

Fig. 2.2

0.95m Gold

Melton $\theta_1 = ?$ Q_{Lost} Molten $\theta_2 = 1340K$

Silver

0.05m Solid 27°C 27+273.15 = 300K Q_1 0.05m Solid 1240K Q_2 0.05m Molten 1240K Q_3 0.05m Molten 1340K

Heat Lost by Gold = Heat gained by Silver

$Q = Q_1 + Q_2 + Q_3$

$(0.95m)(129)(\theta_1 - 1340) = (0.05m)(235)(1240-300) + (0.05m)(105\times10^3) + (0.05m)(235)(1340-1240)$

$\theta_1 = 1483K$

temperature = ... K [5]

(c) Suggest a suitable thermometer for the measurement of the initial temperature of the gold in **(b)**.

Thermocouple thermometer [1]

9702/4/M/J03

3 When a liquid is boiling, thermal energy must be supplied in order to maintain a constant temperature.

(a) State two processes for which thermal energy is required during boiling.

1. Heat supplied is used to break binding and to increase average separation b/w particles.

2. Volume of bubble/vapour increes as it rises up, so work is done by boiling water on atmosphere.

[2]

(b) A student carries out an experiment to determine the specific latent heat of vaporisation of a liquid.
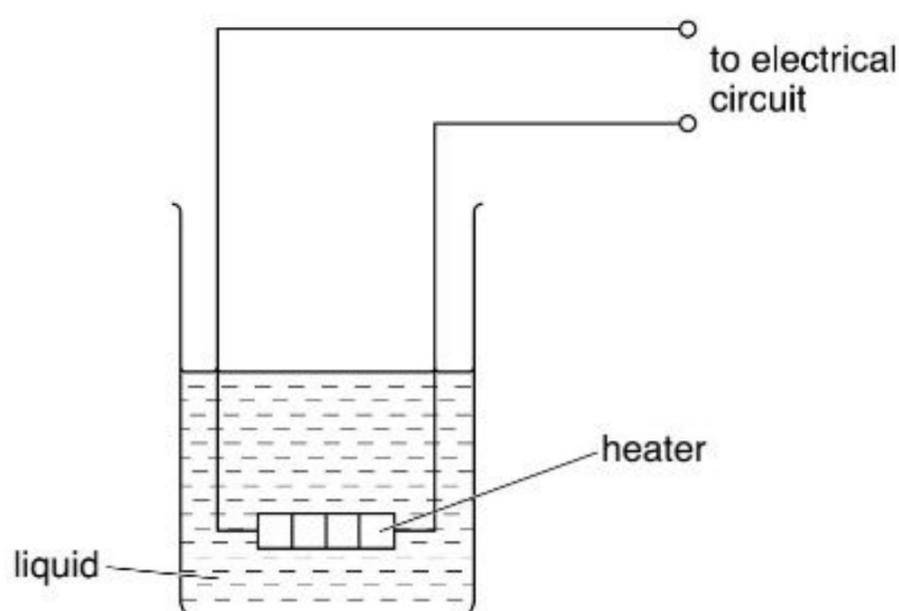Some liquid in a beaker is heated electrically as shown in Fig. 3.1.

Fig. 3.1

Energy is supplied at a constant rate to the heater. When the liquid is boiling at a constant rate, the mass of liquid evaporated in 5.0 minutes is measured.
The power of the heater is then changed and the procedure is repeated.
Data for the two power ratings are given in Fig. 3.2.

power of heater /W	mass evaporated in 5.0 minutes /g
50.0	6.5
70.0	13.6

Fig. 3.2

Electrical energ = Heat a boil + Heat loss a surround

$$P_2 t = m_2 l_v + h_2$$

$$-P_1 t = m_1 l_v + -h_1$$

$$\overline{(P_2 - P_1) t = (m_2 - m_1) l_v + (h_2 - h_1)}$$
$$\approx 0$$

(i) Suggest

    1. how it may be checked that the liquid is boiling at a constant rate,

    constant decrease in the mass of liquid

    .... [1]

    2. why the rate of evaporation is determined for two different power ratings.

    *to eliminate / reduce the loss of heat energy
to the atmosphere.* [1]

(ii) Calculate the specific latent heat of vaporisation of the liquid.

$$Q = m\, l_v$$

$$P_2 t - P_1 t = (m_2 - m_1)\, l_v$$

$$(70.0 - 50.0)(5 \times 60) = (13.6 - 5.6)\, l_v$$

$$l_v = \underline{\hspace{2cm}} J\,g^{-1}$$

specific latent heat of vaporisation = ... $J\,g^{-1}$ [3]

2 (a) Define *specific latent heat of fusion.*

$Q = m l_f$

Amount of heat energy per unit mass required to change a solid to liquid state at constant temperature. [2]

(b) Some crushed ice at 0 °C is placed in a funnel together with an electric heater, as shown in Fig. 2.1.
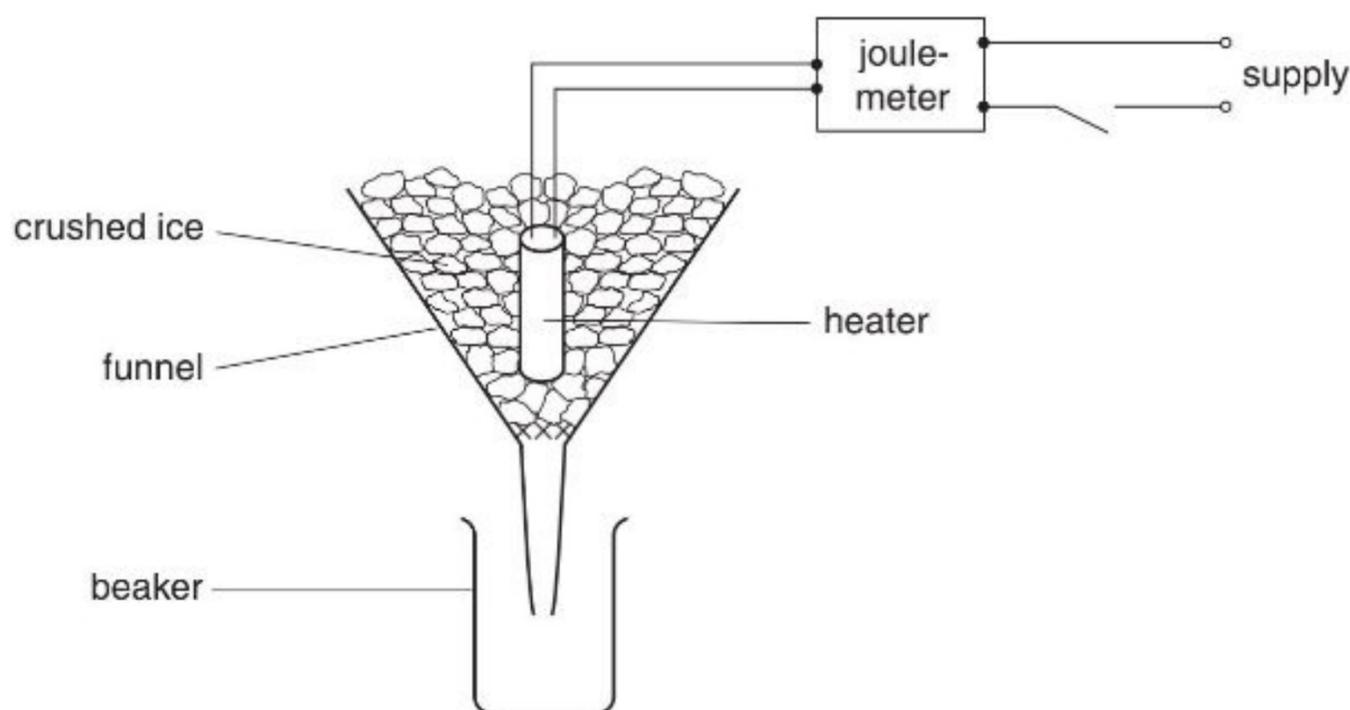

Fig. 2.1

The mass of water collected in the beaker in a measured interval of time is determined with the heater switched off. The mass is then found with the heater switched on. The energy supplied to the heater is also measured.
For both measurements of the mass, water is not collected until melting occurs at a constant rate.
The data shown in Fig. 2.2 are obtained.

	mass of water / g	energy supplied to heater / J	time interval / min
heater switched off	16.6	0	10.0
heater switched on	64.7	18000	5.0

Fig. 2.2

(i) State why the mass of water is determined with the heater switched off.

because ice is also melting by absorbing heat from surrounding. [1]

(ii) Suggest how it can be determined that the ice is melting at a constant rate.

increase in the mass/volume of water collected in beaker is uniform in equal time interval ......[1]

(iii) Calculate a value for the specific latent heat of fusion of ice.

latent heat = ... kJ kg^{-1} [3]

[Turn over