SECTIONB: HEAT AND THERMO DYNAMIC

CHAPTER1: THERMOMETRY

Heat is the amount of energy which moves from hotter to colder region.

Temperature is a number that expresses the degree of hotness of a body on a given scale.

Temperature is measured using a thermometer which has a scale on it.

Thermometers use a physical property which is called thermometric property to measure temperature.

Definition A thermometric property is a physical property which varies linearly and continuously with temperature.

1.1: QUALITIES OF A GOOD THERMOMETRIC PROPERTY

- It should vary linearly with temperature
- It should vary continuously with temperature
- It should be measurable over a wide range of temperature
- It should be sensitive to temperatures changes

TYPES OF THERMOMETERS AND THEIR THERMOMETRIC PROPERTY

Thermometer	Thermometric property
Liquid in glass	Length L of liquid column
Thermocouple	E.M.F " E"
Resistance eg Platinum	Electrical resistance "R" of a wire
Constant Volume gas	Pressure "P" of a fixed mass of a gas
Constant pressure gas	Volume "V" of afixed mass of a gas
Pyrometer	Wavelength λ(quality)

1.1.0: FIXED POINT

This is temperature at which a substance changes states under specific conditions.

1.1.1: ICE POINT

Ice point is temperature at which pure ice can exist in dynamic equilibrium with pure water at standard atmospheric pressure of 760mmHg. Ice point corresponds to 0℃

1.1.2: STEAM POINT

This is temperature at which pure water can exist in dynamic equilibrium with pure vapour at standard atmospheric pressure (760mmHg). Steam point corresponds to 100℃

1.1.3: TRIPLE POINT OF WATER

This is a temperature at which pure ice, pure water and pure vapour can exist together in dynamic equilibrium.

The triple point of water is chosen at fixed point and is defined as 273.16 K.

1.2.1: TYPES OF TEMPERATURE SCALE

Centigrade or Celsius temperature scale

Kelvin or absolute temperature or abnormal or thermodynamic temperature scale

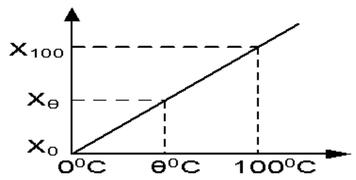
1.2.2: CENTIGRADE/ CELSIUS TEMPERATURE SCALE

Is a temperature scale which uses ice point (0°C) as it lower fixed point and steam point (100°C) as its upper fixed point

1.2.3: STEPS IN SETTING UP CELSIUS TEMPERATURE SCALE

- Choose a thermometric properly of substance and let it be X
- Measure the value of the property at ice point, steam point and let values be X_0, X_{100} respectively.
- Measure the value of the properly at unknown temperature θ and let it be X_θ
- Unknown temperature is determined from $\theta = \left(\frac{X_\theta - X_0}{X_{100} - X_0}\right) x 100℃$

A graph of property value against temperature.



Slope $=\frac{\Delta y}{\Delta x}$

$\frac{X_{100}-X_\theta}{100-0} = \frac{X_\theta-X_0}{\theta-0}$

$\theta=(\frac{X_\theta-X_0}{X_{100}-X_0})$ X100°C

Equation above is a defining equation of Celsius scale of temperature

Definition of a celcious scale of temperature for different thermometers

Thermo couple

θ= $(\frac{E_\theta-E_0}{E_{100}-E_0})$ X100°C

Platinum resistance

θ= $(\frac{R_\theta-R_0}{R_{100}-R_0})$ x100°c

Constant volume gas

θ= $(\frac{P_\theta-P_0}{P_{100}-P_0})$ x100°c

Constant pressure gas

θ= $(\frac{V_\theta-V_0}{V_{100}-V_0})$ x100°c

Liquid in glass

θ= $(\frac{L_\theta-L_0}{L_{100}-L_0})$ x100°c

1.2.4: KELVIN / THERMODYNAMIC TEMPERATURE SCALE

This is a temperature scale which uses triple point of water as a fixed point.

Kelvin is defined as $\frac{1}{273.16}$ of the thermodynamic temperature of the triple point of water

Steps to establish Kelvin scale

- ✓ Select thermometric property X of substance
- ✓ Measure the property at triple point of water, let it be X_{tr}
- ✓ Measure the property at un known temperature T, let it be X_T
- ✓ Assuming a linear variation of X with temperature then the un known temperature can be determined from

$$\boxed{T=\frac{X_T}{X_{tr}}x273.16K}$$

Definition of a thermodynamic scale of temperature for different thermometers

Thermo couple

$T=\frac{E_T}{E_{tr}}x273.16K$

Platinum resistance

$T=\frac{R_T}{R_{tr}}x273.16K$

Constant volume gas

$T=\frac{P_T}{P_{tr}}x273.16K$

Constant pressure gas

$T=\frac{V_T}{V_{tr}}x273.16K$

Liquid in glass

$T=\frac{L_T}{L_{tr}}x273.16K$

1.2.5: DISAGREEMENT OF TEMPERATURE SCALES

Different thermometers give different readings when measuring temperature of the same body except at fixed points where they must agree and this is because different thermometric properties vary differently with temperature but agree at fixed points.

Example

1) A resistance thermometer has a resistance of 21.42Ω at ice point, 29.10 Ω at steam point and 28.11 Ω at un known temperature θ. calculate θ on scale of this thermometer.

Solution

θ= $(\frac{R_\theta-R_0}{R_{100}-R_0})$ x100°C

θ= $\left(\frac{28.11-21.42}{29.10-21.42}\right)x100°C$

θ=87.11°C

2) The resistance of the wire is measured at ice point, steam point and at un known temperature θ and the following values were obtained 2.00 Ω, 2.48 Ω, 2.60 Ω respectively. Determine θ

θ= $(\frac{R_\theta-R_0}{R_{100}-R_0})$ x100°C

θ= $(\frac{2.60-2.00}{2.48-2.00})$ x100

θ =125°C

3) The length of mercury column is 2.00cm at ice point, 2.73cm at steam point.

   (i) What temperature on the mercury in glass thermometer corresponds to the value of 8.43cm?

   (ii) When the above temperature is measured on gas thermometer scale it correspond to a value of 1020°C.Explain the discrepancy

Solution

i) L_θ=2.00

L_θ=8.43, L_{100}=2.73

θ= $(\frac{L_\theta - L_0}{L_{100} - L_0})$ x100°C

θ= $(\frac{8.43-200}{2.73-2.00})$ x100°C

θ= 880.8°C

(ii) Different thermometric properties vary differently with temperature but agree at fixed points

4) A particular resistance thermometer has resistance of 30Ω at ice point, 41. 58Ω at steam point and 34.58Ω when immersed in a boiling liquid. A constant volume gas thermometer gives readings, $1.333x10^5$Pa, $1.821x10^5$Pa and $1.528x10^5$Pa at the same temperatures. Calculate the temperature at which the liquid is boiling on scale of;

   (i) Resistance thermometer

   (ii) Gas thermometer .

Solution

i) R_0=30 Ω R_θ=31.58 Ω, R_{100}=41.58 Ω

$\theta = (\frac{R_\theta - R_0}{R_{100} - R_0})$ x100°C= $[\frac{34.58-30}{41.58-30}]$ x100°C

θ=39.55°C

ii) P_θ=$1.333x10^5$Pa P_{100}=$1.821X10^5$Pa

P_θ=$1.628x10^5$Pa

θ= $(\frac{P_\theta - P_0}{P_{100} - P_0})$ x100°C

θ= $(\frac{1.528x10^5 - 1.333x10^5}{1.821x10^5 - 1.333x10^5})$ x100°C

θ= 39.959°C

Example on triple point of water or Kelvin scale

5) Pressure recorded by constant volume thermometer at Kelvin temperature T is given by $4.8x10^4Nm^{-2}$. Calculate T if the pressure at triple point of water is $4.2x10^4Nm^{-2}$

Solution

T=$\frac{P_T}{P_{tr}}$x273.16K

P_T=$4.8x10Nm^{-2}$

P_{tr} =$42x10^4Nm^{-2}$

T= $\frac{4.8x10^4}{4.2x10^4}$x273.16K

T= 312.18K

6) The resistance of platinum wire at triple point of water is 5.16Ω. what will be the resistance at 100°C

Solution

T= $\frac{R_T}{R_{tr}}$x273.16K

(273+100)= $\frac{R_T}{5.16}$X273.16

R_T= 7.045Ω

Determining temperature on a scale of one thermometer as read by another

1) The resistance, $R_\theta$of a particular resistance thermometer at Celsius temperature θ as measured by a constant volume gas thermometer is. $R_\theta = 50 + 0.17\theta + 3x10^{-4}\ \theta^2$ Calculate the temperature as measured on a scale of a resistance thermometer which corresponds to a temperature of 60°C at a gas thermometer.

Solution

θ= $(\frac{R_\theta - R_0}{R_{100} - R_0})$ x100°C

$R_\theta = 50 + 0.17\theta + 3x10^{-4}\ \theta^2$

$R_0 = 50 + 0.17x0 + 3x10^{-4}x\ 0^2$

$R_0 = 50$

R_{100}=50+0.17x100+$3x10^{-4}x100^2$

R_{100}= 70Ω

R_{60}=50+0.17x60+$3x10^{-4}x60^2$

R_{60}=61.28Ω

θ= $(\frac{61.28-50}{70-50})$ x100°C

θ= 56.4°C

2) The value of property X of certain substance X_t is given by $X_t = X_0 + 0.5t + 2x10^{-4}t^2$

Where t =temperature in °C measured in gas thermometer scale. What will be the Celsius temperature at 50°C on this thermometer scale?

Solution

X_{100}=X_0+52

X_0=X_0

X_{50} =X_0+25.5

θ= $(\frac{X_{50} - X_0}{X_{100} - X_0})$ x100°C

θ= $(\frac{X0+25.5-X0}{X0+52-X0}) x 100°C$

θ= $(\frac{25.5}{52})$ x100°C

θ= 49.04°C

3) The resistance of the wire as measured by gas thermometer varies with temperature θ according to the equation. $R_\theta = R_0\ (1 + 50\alpha\theta + 200\alpha\theta^2)$.Determine temperature on resistance thermometer that corresponds to 40°Con the gas scale

Solution

R_{100}= R_0 (1+50xαx100+200$\alpha$$100^2$)

R_{100} = R_0 [1+α(2005000)]

R_0=R_0

R_{40}= R_0 (1+50αx40+200x$\alpha$$40^2$)

R_{40}= R_0 [1+α (322000)]

θ= $[\frac{R_{40}-R_0}{R_{100}-R_0}]$ x100°C

θ= $(\frac{R0[1+\alpha(322000)]-R0}{R0[1+\alpha(2005000)]R0})$

θ= $[\frac{322000}{2005000}]$ x100°C

θ= 16.059°C

Exercise: 33

1) The resistance of the element in a platinum resistance thermometer is 6.75 Ω at triple point of water and 7.166 Ω at room temperature. What is the temperature of the room on a scale of resistance thermometer?. state one assumption you have made. **An[290K]**
2) A particular constant –volume gas thermometer registers a pressure of 1.937x10^4Pa at the triple point of water and 2.618x10^4Pa at the boiling of a liquid. What is the boiling point of the liquid according to this thermometer? **An[369.2K]**
3) The resistance of platinum thermometer is 2.04Ω at ice point and 3.02Ω at the steam point.
   i) What should be the temperature of platinum wire so as to have a resistance of 9.24Ω?
   ii) If a constant-pressure thermometer had been used, the same temperature would correspond to 1040°C. Explain the deviation. **An**[734.7°C]
4) The resistance R of platinum wire at temperature θ°C as measured by mercury-in-glass thermometer is given by; $R_\theta = R_0(1 + a\theta + b\theta^2)$ where $a = 3.8x10^{-3}K^{-1}$ and $b = -5.6x10^{-7}K^{-2}$. Calculate the temperature of platinum thermometer corresponding to 200°C on glass scale. **An**[197°C]
5) The resistance R of platinum wire at temperature θ°C as measured by a constant volume thermometer is given by; $R_\theta = R_0(1 + 8000\alpha\theta - \alpha\theta^2)$ where α is a constant. Calculate the temperature of platinum thermometer corresponding to 400°C on glass scale. **An**[384.8°C]

1.3.0: TYPES OF THERMOMETERS

a)-Liquid in glass thermometer;

measurement of temperature using a liquid in glass thermometer

- ❖ Place the bulb in pure melting ice and the length of the mercury column in capillary tube, L_0 is measured and recorded
- ❖ Place the bulb in steam from boiling water and the length of the mercury column in capillary tube, L_{100} is measured and recorded
- ❖ Place the bulb in contact with the body of an unknown temperature θ and the length of mercury column L_θ is measured and recorded
- ❖ Unknown temperature is determined from $\theta = \left(\frac{L_\theta - L_0}{L_{100} - L_0}\right) x 100°C$

Advantages of a Liquid in Glass Thermometer

- It is easy to use
- It is very cheap
- It is very portable
- It has direct readings

Disadvantages of a Liquid in Glass Thermometer

- It has small range of temperature
- It is not very accurate
- Its fragile so care is needed
- It is not very sensitive
- It can not measure temperature at a point
- It can not meaures rapidily changing temperatures

N.B:

A liquid in glass thermometer is not very accurate because of the following;

1. Parallax errors which contribute about $\pm 0.1°C$
2. Non uniformity of the bore of capillary tube limits accuracy to about 0.1°C
3. The glass contracts and expands and takes long hours to recover its correct size and shape and therefore spoils the calibration

Reasons why mercury is used as thermometric property .

- It doesn't wet the glass
- It is opaque
- It expands uniformly
- It is a good conductor of heat

Reasons why water is not used as thermometric property

- It wets the glass
- It is not opaque
- It is a bad conductor of heat
- It is has non uniform expansitivity.

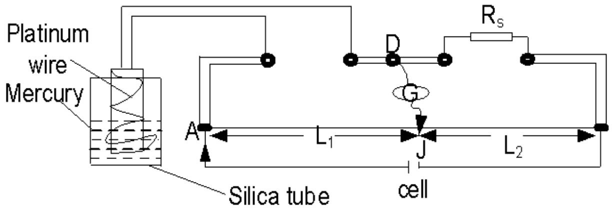
b)-RESISTANCE THERMOMETER [PLATINUM RESISTANCE THERMOMETER]

A resistance thermometer uses resistance(R) of a metal wire as a thermometric property.

QUALITIES OF A METAL TO BE USED IN A RESISTANCE THERMOMETER

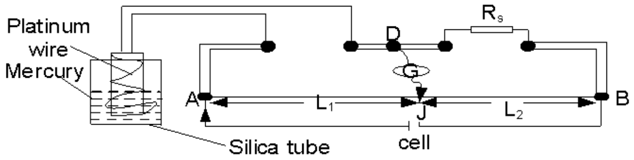
- Material of the wire should have a high temperature co-efficient of resistance (R) so that a small change in temperature causes a measurable change in resistance.
- The variation of resistance with temperature should be linear. Platinum is chosen to be used because it satisfies above 2 conditions.

MEASUREMENT OF CELCIUS SCALE TEMPERATURE OF A BODY USING PLATINUM RESISTANCE THERMOMETER



- A standard resistor R_S is connected to the right hand gap and silica tube leads on the left hand gap of a meter bridge
- With the silica tube immersed in ice, J is adjusted along the slide wire until G reads zero. The length l_1 and l_2 are read and recorded, $R_0 = \frac{l_1}{l_2} R_S$
- The above procedure is repeated with silica tube separately in steam and unknown temperature θ and resistances R_{100} and R_θ respectively calculated
- Unknown temperature, $\theta = (\frac{R_\theta - R_0}{R_{100} - R_0})$ x100°C

MEASUREMENT OF A BSOLUTE TEMPERATURE OF A BODY USING PLATINUM RESISTANCE THERMOMETER



- A standard resistor R_S is connected to the right hand gap and silica tube leads on the left hand gap of a meter bridge
- With the silica tube immersed in amixture of ice, pure vapour and pure water, J is adjusted along the slide wire until G reads zero. The length l_1 and l_2 are read and recorded, $R_{tr} = \frac{l_1}{l_2} R_S$
- The above procedure is repeated with silica tube in unknown temperature T and resistance R_T calculated
- Unknown temperature, $T = \frac{R_T}{R_{tr}} x 273.16K$

ADVANTAGES OF PLATINUM RESISTANCE THERMOMETER

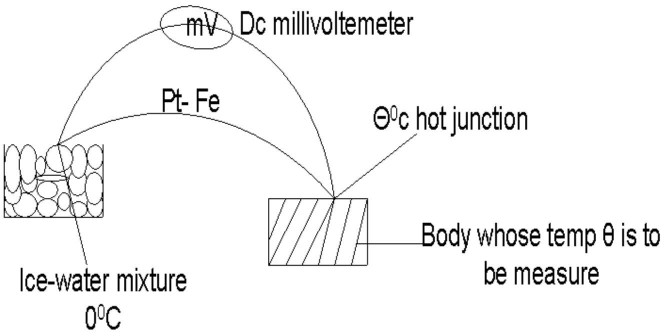
- It is used for measuring small unit temperature.
- It is very accurate. It is because the resistance of platinum wire varies linearly with temperature.
- It has a wide range of temperature i.e. from -200℃ to 1200℃
- It is very sensitive to small unit temperatures.

DISADVANTAGES OF PLATINUM RESISTANCE THERMOMETERS

- It cannot measure very rapidly changing temperature. This is because it has low -thermal conductivity and high heat capacity.
- It cannot measure temperature at a point due to size of silica tube.
- Its heavy and not portal

C) -THERMO COUPLE THERMOMETER

When two wires of different materials are joined together to form two junctions and their junctions maintained at different temperatures, a small E.M.f is created between the junctions. These effects is called thermo electric or **see beck effect** and such an arrangement gives a thermo couple.



- One junction is placed on the water-ice mixture and the other junction is put in steam and the Emf set up is m measured on milivoltmeter E_{100}
- With the other junction still in the water-ice mixture, and the other junction now put in contact with a body of unknown temperature,θ and the Emf set up is m measured on milivoltmeter E_θ
- The temperature of the body can then be calculated from

$$\theta = \left(\frac{E_\theta}{E_{100}}\right) X100°C$$

ADVANTAGES OF THERMO COUPLE

- It measures temperature at a point e.g. temperature of crystal since the wires can be made thin.
- It is used to measure rapidly changing temperatures. This is because of its small heat capacity and high thermal conductivity.
- It is portable
- It has a wide range of temperature between -250℃ to 1600℃ and this can be achieved by using different metals.
- It can be used to determine direct readings if connected to galvanometer which has been calibrated to read temperatures directly.

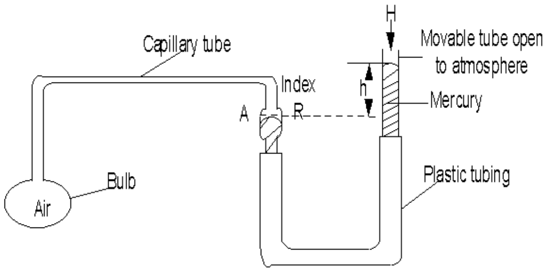
DISADVANTAGES OF THERMO COUPLE

- It cannot measure slowly changing temperatures.
- It is inaccurate because $E.m.f$ doesn't vary linearly with temperature.

N.B an $E.m.f$ can be generated from junction if.

- ✓ The junctions are made from different metals.
- ✓ The junctions are kept at different temperatures.

d)-CONSTANT VOLUME GAS THERMOMETER



- ➢ The bulb with air is immersed in a substance whose temperature is required.
- ➢ The substance warms up the bulb and the gas (air) expands forcing mercury up in a movable tube.
- ➢ By adjusting the plastic tubing up and down, the level in A is restored keeping the volume constant.
- ➢ The difference in mercury levels h is determined and the thermometer reading H due to atmosphere in the open limb is recorded
- ➢ The total pressure, P_θ exerted by the gas at temperature, θ is obtained from $P_\theta = H + h$.
- ➢ The pressure is then measured at the point P_0, at steam point P_{100}, by the same procedure
- ➢ Therefore the celecius temperature, θ on this thermometer is obtained from

$$\theta = \left(\frac{P_\theta - P_0}{P_{100} - P_0}\right) x100^\circ\text{C}$$

ADVANTAGES OF CONSTANT VOLUME GAS THERMOMETER

- It is very sensitive
- It has wide range of temperature from-270°C to 1500°C
- It is very accurate since the pressure of fixed mass of gas at constant volume varies linearly with temperature.
- It is used as a standard to calibrate other thermometer e.g. thermo couple thermometer.

DISADVANTAGES OF CONSTANT VOLUME GAS TERMOMETER

- It is bulky i.e. is not portable.
- It has no direct readings; therefore it requires skills to be read it.
- It cannot measure rapidly changing temperatures as the bulb needs time to reach steady states.

Corrections in a constant volume gas thermometer include;

- ❖ The temperature of the gas in the dead space because its temperature lies between that of the bulb and the room temperature.
- ❖ Thermal expansion of the bulb
- ❖ The capillary effect at the mercury surface.

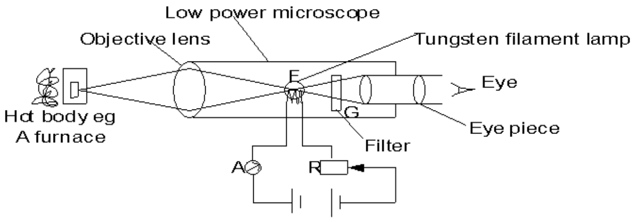
e)-PYROMETERS

They are used to measure very high temperatures e.g. temperature of furnace

They are divided into two;

- ➢ Total radiation pyrometer which responds to total radiation i.e. heat and light produced.
- ➢ Optical radiation pyrometer which responds to only light produced.

OPTICAL RADIATION PYROMETER



- ➢ A hot body whose temperature is to be measured is focused by objective lens so that its image of the object lies in the <u>same plane</u> as the fillament.
- ➢ The light from both the filament and the body pass through red filter and viewed by the eye.
- ➢ If the image of the hot body is brighter than the filament, the filament appears dark on bright background.
- ➢ If the filament is brighter than the image of the hot body, the filament appears bright on a dark background.
- ➢ Using the reheostat R, the current through filament is adjusted until the filament cannot be distinguished in the background. At that point, the temperature of hot body is then equals that of the filament. And this temperature can then be read from the ammeter (previously calibrated in °C.

UNEB 2017 Qn5

(a) **(i)** State the thermometric property used in the constant-volume gas thermometer (1marks)

(ii) Give **two** characteristics of a good thermometric property (02marks)

(b) **(i)** Describe the steps taken to set up a celcius scale of temperature for a mercury-in-glass thermometer (04marks)

(ii) State four disadvantages of mercury-in-glass thermometer. (02marks)

(c) Describe with the aid of a labellled diagram the operation of an optical pyrometer. (06marks)

(d) When oxygen is withdrawn from a tank of volume $50l$, the reading of a pressure gauge attached to the tank drops from $21.4x10^5Pa$ to $7.8x10^5Pa$. If the temperature of gas remaining in the tank falls from $30°C$ to $10°C$, calculate the mass of oxygen withdrawn. **An(828.8g)** (05marks)

UNEB 2015 Qn5

(e) **(i)** State four desirable properties a material; must have to be used as a thermometric substance

(ii) State why scales of temperature based on different thermometric property may not agree

UNEB 2014 Qn7

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

(ii) A platinum resistance thermometer has a resistance of 5.42 Ω at triple point of water. Calculate its resistance at a temperature of 50.0°C $An[6.41\,\Omega]$ (02marks)

UNEB 2011 Qn 5

(b) (i)Define the term thermometric property and give four examples (02marks)

(ii) State two qualities of a good thermometer property (01marks)

(c) (i)With reference to the a liquid in glass thermometer, describe the steps involved in setting up a Kelvin scale of temperature (03marks)

(ii) State one advantage and disadvantage of the resistance thermometer. (01mk)

(d)A resistance thermometer has a resistance of 21.42Ω at ice point, 29.10Ω at steam point and 28.11Ω at some unknown temperature θ. Calculate θ on the scale of this thermometer. **An[87.11°C]** (03mk)

UNEB 2007 Qn 5

(a) (i) Define a thermometric property and give two examples (02marks)

(ii) When is the temperature **0 K** attained (02marks)

(b) (i) With reference to a constant-volume gas thermometer define temperature on the Celsius scale

(ii) State two advantages and two disadvantages of constant-volume gas thermometer. (02marks)

(c) (i) Define the triple point of water (01mark)

(ii) Describe how you would measure the temperature of a body on thermodynamic scale using a thermo couple. (03marks)

UNEB 2005 Qn 5

(a) (i)What is meant by the term fixed points in thermometry. Give two examples of such points

(ii) How is temperature on a Celsius scale defined on a platinum resistance thermometer?

(b) Explain the extent to which thermometer based on different properties but calibrate using the same fixed points are likely to agree when used to measure a temperature

(i) Near one of the fixed points (02marks)

(ii) Midway between the two fixed points (02marks)

(d) What are the advantages of a thermocouple over a constant volume gas thermometer in measuring temperature.

Solution

b)i) They may agree, because for points near the fixed points the values of the thermometric properties vary almost in step for points close to the fixed points.

ii) They may not agree for temperature midway between fixed points the different thermometric properties vary differently with temperature.

UNEB 2004 Q5

(a) What is meant by

(i) Thermometric property (01mark)

(ii) Triple point of water (01mark)

(b) (i)Describe the steps taken to establish a temperature scale (05marks)

(ii) Explain why the thermometers may give different values for the same unknown the temperature.

(c) (i)Describe with the aid of a diagram, how a constant volume gas thermometer may be used to measure temperature (06marks)

(ii) State three corrections that need to be made when using the thermometer in c(i) above.

(iii)State and explain the sources of in accuracies in using mercury-in-glass thermometer.

In Accuracies rise Because

The none uniformity of the capillary tube from which the thermometer was made. This causes equal changes in volume of the liquid not producing equal changes in the length of the liquid column.

UNEB 2000 Q7

(a) (i) State the desired properties a material must have to be used as a thermometric liquid substance.

(ii) Explain why scales of temperature based on different thermometer properties may not agree

(b) (i) Draw a labelled diagram to show the structure of a simple constant volume gas thermometer.

(ii) Describe how a simple-constant volume gas thermometer can be used to establish a Celsius scale of temperature. (05marks)

(iii) State the advantage and disadvantage of mercury in glass thermometer and a constant volume gas (03marks)

(c) The resistance of the element of a platinum resistance thermometer is 4Ω at the point and 5.46Ω at the steam point. What temperature on the platinum resistance scale would correspond to a resistance of a 9.84Ω **An[400°C]** (03marks)

CHAPTER2: CALORIMETRY

The heat energy of a system is its internal energy and it can be either heat capacity or latent heat.

2.1.0: HEAT CAPACITY AND SPECIFIC HEAT CAPACITY

- **Specific heat capacity** of substance is quantity of heat required to raise the temperature of 1kg mass of substance by 1kelvin.
  Its S.I units are joules per kilogram per Kelvin [$Jkg^{-1}K^{-1}$].
- **Heat capacity** is the amount of heat required to raise the temperature of any mass of the a substance by 1Kelvin.
  Its units are joules per Kelvin [JK^{-1}]
  The heat gained Q or lost by the substance is given by

$$Q = mass\ x\ S.H.C\ x\ temp\ change$$

$$\boxed{Q = m\,c\,\Delta\,\theta}$$

Where $\Delta\theta = \theta_1 - \theta_2$ $\quad c = S.H.C$

Heat capacity = mass x S.H.C, which implies

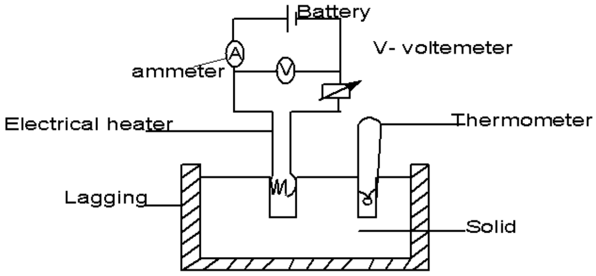
$$\boxed{\text{Q = Heat capacity x temperature change}}$$

EXERCISE:33

1) Calculate the quantity of heat required to raise the temperature of a metal block with a heat capacity of $23.1J^{\circ}C^{-1}$ by 30.0°C. **An [693J]**
2) An electrical heater supplies 500J of heat energy to a copper cylinder of mass 32.4g. Find the increase in temperature of the cylinder (specific heat capacity of copper = $385Jkg^{-1}\,{}^{\circ}C^{-1}$) **An[40.1°C]**
3) How much heat must be removed from an object with a heat capacity of $150J^{\circ}C^{-1}$, in order to reduce its temperature from 80.0°C to 20.0°C. **An [$9x10^3$J]**

2.1.2: METHODS OF DETERMINING S.H.C

a) Determination of S.H.C of a solid by electrical method



- A solid block of a metal is drilled with two holes, one for thermometer and other for an electric heater filled with mercury for good thermal contact
- The mass, m of the block is found and its initial temperature θ_1 recorded.
- A suitable steady current is switched on and stop clock is started simultaneously
- Ammeter and voltage readings I and V from the voltmeter are noted.
- When the temperature has risen appreciably, the current is stopped and the time, t of heating is noted and also the final temperature θ_2 is read and recorded.
- Assuming no heat loss to the surrounding, heat supplied by the heater = heat gained by the block.

$$Ivt = mC[\theta_2 - \theta_1]$$

- Therefore the specific heat capacity, C of the metal is got from

$$C = \frac{Ivt}{m[\theta_2 - \theta_1]}$$

Examples

1. A steady current of $12\,A$ and $p.d$ of $240\,V$ is passed through a block of mass $1500g$ for $1\frac{1}{2}\ minutes$. If the temperature of the block rises from 25°C to 80°C. Calculate;

(i) S.H.C of the block

(ii) The heat capacity of 4 kg mass of the block

Solution

i) $t = 1\frac{1}{2}\ minutes = 1\frac{1}{2}x60s = 90\ s,$

$m\ =\ 1500g\ = \dfrac{1500}{1000} = 1.5\ kg$

$Q = m\ C\ \Delta\theta$

$I\ V\ t = m\ C\ \Delta\theta$

$12x240x90 = 1.5x\ C\ \ (80 - 25)$

$C = \dfrac{12x240x90}{1.5x55}$

$C = 3141.82J\ kg^{-1}\ K^{-1}$

$ii)\qquad H = m\ C$

$H = 4\ x\ 3141.82$

$H = 12567.28J\ \ K^{-1}$

2. A heater rated 2 k W is used for heating the solid of mass 6 kg, if its temperature rises from 30°C to 40°C. In 12 s, find the S.H.C of the solid.

Solution

$Q = m\ C\ \Delta\theta$

$I\ V\ t = m\ C\ \Delta\theta$

$Px\ t = m\ C\ \Delta\theta$

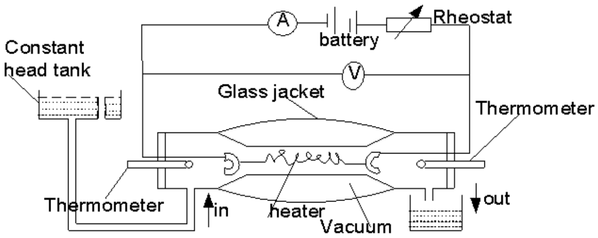
$2x1000x12 = 6x\ C\ \ (40 - 30)$

$C = \dfrac{2x1000x12}{6x10}$

$C = 400J\ kg^{-1}\ K^{-1}$

b)-Determination of S.H.C of a liquid

i)-Using continuous flow method



- ❖ A steady flow of the liquid is set and system left to run until thermometers indicate steady temperatures.
- ❖ The inflow temperature θ_1 and out flow temperature θ_2 are read and recorded
- ❖ The Ammeter reading I_1 and Voltmeter reading V_1 are read and recorded
- ❖ The mass m_1 which flows per second is measured and recorded
- ❖ At steady state $I_1V_1 = m_1c(\theta_2 - \theta_1) + h$-- [1] where h is rate of heat loss to surrounding.
- ❖ The experiment is repeated for different flow rate. The current and voltage are adjusted until the inflow and outflow temperatures are the same as before
- ❖ The Ammeter reading I_2 and Voltmeter reading V_2 are read and recorded
- ❖ The new mass m_2 which flows per second is measured and recorded
- ❖ At steady state $I_2V_2 = m_2c(\theta_2 - \theta_1) + h$ - [2] Therefore specific heat capacity of a liquid, c is got from

$$C = \frac{I_2V_2 - I_1V_1}{(m_2 - m_1)(\theta_2 - \theta_1)}$$

MERITS OF CONTINUOUS FLOW METHOD

- ➢ The heat capacity of apparatus is not required since at steady states, the apparatus does not absorb any more heat.
- ➢ No cooling correction is required since the heat lost to the surrounding is taken care by repeating the experiment.
- ➢ The temperature to be measured θ_1 and θ_2 are constant at steady state.
- ➢ They can therefore be measured at leisure and accurately using platinum resistance thermometer.
- ➢ There are no heat losses by convection since apparatus has vacuum.

DEMERITS OF CONTINUOUS FLOW METHOD

- It can't be used to determine S.H.C of solid
- It requires a large quantity of liquid and therefore it is expensive

Questions

1) In the flow method to determine the S.H.C of the liquid, the following two sets of results were obtained.

	Experiment 1	Experiment 2
P.d across water (V)	5.0	3.0
Current through heater (A)	0.3	0.2
Temperature of liquid at inlet (^{0}C)	25	25
Temperature of liquid at outlet (^{0}C)	41	41
Mass of liquid (kg)	0.15	0.07
Time taken (s)	200	120

a) Calculate the S.H.C of the liquid

b) Heat lost per second

Solution

a) $I_1V_1 = m_1\mathbf{c}(\theta_2 - \theta_1) + h$

$I_2V_2 = m_2\mathbf{c}(\theta_2 - \theta_1) + h$

C= $\frac{I_2V_2 - I_1V_1}{(m_2-m_1)(\theta_2-\theta_1)}$

C= $\frac{5.0x0.3 - 3.0x0.2}{\left(\frac{0.15}{200}-\frac{0.07}{120}\right)(41-25)} =$ ***3.3x10^{2}Jkg^{-1}K^{-1}***

b) $I_1V_1 = m_1c(\theta_2 - \theta_1) + h$

$5.0x0.3 = \frac{0.15}{200}x330x(41-25) + h$

$h = -2.55J$

2) In continuous flow experiment it was found that when applied $p.d$ 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

(ii) Rate of heat loss to the surrounding

Solution

$I_1V_1 = m_1\mathbf{c}(\theta_2 - \theta_1) + h$

$I_2V_2 = m_2\mathbf{c}(\theta_2 - \theta_1) + h$

C= $\frac{I_2V_2 - I_1V_1}{(m_2-m_1)(\theta_2-\theta_1)} = \frac{12x1.5 - 16x1.6}{\left(\frac{50x10^{-3}}{60}-\frac{90x10^{-3}}{60}\right)(10)}$

$C =$ 1.14x10^{3}Jkg^{-1}K^{-1}

ii) $I_2V_2 = m_2\mathbf{c}(\theta_2 - \theta_1) + h$

$16x1.6 = \frac{90x10^{-3}}{60}x1.14x10^3x10 + h$

$h = 8.50watts$

3) Water flow at rate of 0.15kg/minute through a tube and is heated by a heater dissipating 25.2W. The inflow and outflow temperature are 15.2°C and 17.4°C respectively. When the rate of flow is increased to 0.232kg/minute and rate of heating to 37.8W. The inflow and outflow temperature are not altered. Find;

i) S.H.C of water

ii) Rate of loss of heat in the tube

solution

$I_1V_1 = m_1\mathbf{c}(\theta_2 - \theta_1) + h$

$I_2V_2 = m_2\mathbf{c}(\theta_2 - \theta_1) + h$

C= $\frac{I_2V_2 - I_1V_1}{(m_2-m_1)(\theta_2-\theta_1)} = \frac{25.2 - 37.8}{\left(\frac{0.15}{60}-\frac{0.232}{60}\right)(17.4-15.2)}$ =4200Jkg^{-1}K^{-1}

ii) $I_1V_1 = m_1c(\theta_2 - \theta_1) + h$

25.2 = $\frac{0.15}{60}$x4200x$(17.4 - 15.2)$+h

h=2.21watts

4) In an experiment to measure specific heat capacity of water, stream of water flows at rate of 5gs^{-1}over an electrical heater dissipating 135W and temperature rise of 5K is observed. On increasing the rate of flow to 10g$s^{-1}$the same temperature rises is produced with dissipation of 240W.

Solution

$I_1V_1 = m_1\mathbf{c}(\theta_2 - \theta_1) + h$

$I_2V_2 = m_2\mathbf{c}(\theta_2 - \theta_1) + h$

C= $\frac{I_2V_2 - I_1V_1}{(m_2-m_1)(\theta_2-\theta_1)}$

C= $\frac{240 - 135}{(10x10^{-3}-5x10^{-3})(5)}$

C= 4200 Jkg^{-1}K^{-1}

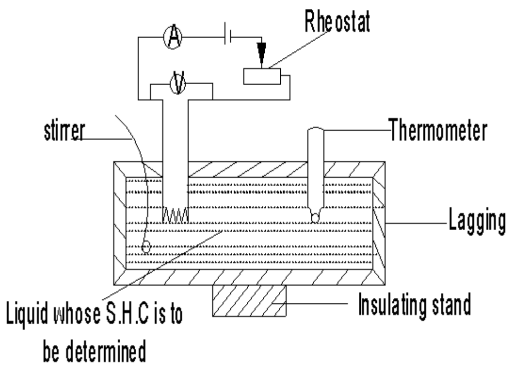
EXERCISE: 34

1) In an electrical constant flow experiment to determine the specific heat capacity of a liquid, heat is supplied to the liquid at a rate of 12W. When the rate of flow is 0.060kgmin^{-1}, the temperature rise along the flow is 2.0K. Use these figures to calculate a value for the specific heat capacity of the liquid. If the true value of the specific heat capacity is 5400Jkg^{-1}K^{-1}, estimate the percentage of heat lost in the apparatus. **An [6000 Jkg^{-1}K^{-1} 11%]**

2) When water was passed through a continuous flow calorimeter the rise in temperature was from 16 to 20°C, the mass of water flowing was 100g in one minute, the $p.d$ across the heating coil was 20V and the current was 1.5A. Another liquid at 16.0°C was then passed through the calorimeter and to get the same change in temperature, the $p.d$ was changed to 13V, the current to 1.2A and the rate of flow to 120g in one minute. Calculate the S.H.C of the liquid if the S.H.C of water is 4200 $Jkg^{-1}{}^{\circ}C^{-1}$
An[1700 Jkg^{-1}K^{-1}]

3) With a certain liquid, the inflow and outflow temperatures were maintained at 25.20°C and 26.51°C respectively for a p.d of 12.0V and current 1.50A, the rate of flow was 90g per minute, with 16.0V and 2.00A, the rate of flow was 310g per minute. Find the S.H.C. of the liquid and also the power lost to the surrounding. **An [2910 Jkg^{-1}K^{-1}, 12.3W]**

ii)Electrical method



- ❖ When $d.c$ is switched on for time t, the temperature of the liquid and calorimeter changes from θ_1 to θ_2.
- ❖ The resistant is then adjusted to get a suitable value of I and V when the mixture is uniform after stirring. Assuming that there is not heat gained by the thermometer, then there is no heat lost to the surrounding.
- ❖ The electric energy supplied by heater=heat gain by calorimeter and liquid.

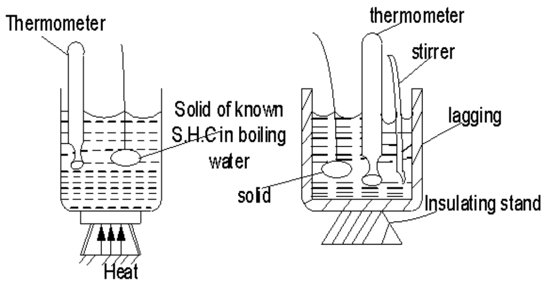
$$Ivt = M_L C_L(\theta_2-\theta_1) + M_C C_C(\theta_2-\theta_1)$$

$$C_L = \frac{Ivt - Mc\ Cc\ (\theta 2-\theta 1)}{ML(\theta 2-\theta 1)}$$

M_C = mass of calorimeter
M_L = mass of liquid
C_c = S.H.C of calorimeter, C_L = S.H.C of liquid

iii)USING METHOD OF MIXTURES

This S.H.C of liquid can be determined using method of mixture as follows



- ➢ The solid of mass M_s and S.H.C C_s in boiling water at temperature θ_1 is transferred to liquid of mass M_L whose S.H.C [C_L] is to be determined in calorimeter of mass M_c and S.H.C C_c both at temperature θ_2.
- ➢ The mixture is stirred uniformly until final steady temperature θ_3 is obtained
- ➢ Assuming there is no heat gained by the stirrer and thermometer and no heat is lost to the surrounding.
- ➢ Heat lost by solid= heat gained by calorimeter +heat gained by liquid

$$M_S C_S(\theta_1-\theta_3) = M_L C_L(\theta_2-\theta_3) + M_c C_c(\theta_2-\theta_3)$$

$$C_L = \frac{M_S C_S(\theta 1-\theta 3) - McCc(\theta 2-\theta 3)}{M_L(\theta 2-\theta 3)}$$

PRECAUTIONS TAKEN IN DETERMINING S.H.C BY METHOD OF MIXTURES

- The solid should be transferred as soon as possible to liquid in calorimeter.
- The liquid in calorimeter should be well stirred to ensure uniformly of temperature.
- The calorimeter should be supported on an insulated stand and should also be lagged to reduce heat loss by conduction.
- The calorimeter should be well polished to minimize heat loss by radiation.

DISADVANTAGES OF METHODS OF MIXTURE

- Some heat is lost to the surrounding
- Some heat is absorbed by stirrer and thermometer.
- Some heat losses by conduction and convection

N.B: heat losses that cannot be eliminated can be catered for by a cooling correction

Examples

1. What is the final temperature of the mixture if 100g of water at $70°C$ is added to 200g of cold water at $10°C$. And well stirred (Neglect the heat absorbed by the container and S.H.C of water is 42000$J\,kg^{-1}\,K^{-1}$).

Solution

Heatlost by hot water = heat gained by cold water

$$M_HC_H(\theta_1-\theta_3)=M_CC_C(\theta_2-\theta_3)$$

$$\frac{100}{1000}x\ 4200x(70-\theta)=\frac{200}{1000}x4200x(\theta-10)$$

$$0.1x(70-\theta)=0.2x(\theta-10)$$

$$7-0.1\theta=0.2\theta-2$$

$$\theta=30°C$$

2. The temperature of 500g of a certain metal is raised to 100°C and it is then placed in 200g of water at 15°C. If the final steady temperature rises to 21°C, calculate the S.H.C of the metal.

Solution

Heat lost by metal = heat gained by water

$$M_mC_m(\theta_1-\theta_3)=M_wC_w(\theta_2-\theta_3)$$

$$\frac{500}{1000}x\ C_mx(100-21)=\frac{200}{1000}x4200x(21-15)$$

$$0.5xC_mx\ 89=0.2x4200x6$$

$$C_m=\frac{0.2x4200x6}{0.5x89}=128J\,kg^{-1}\,K^{-1}$$

3. The temperature of a piece of copper of mass 250g is raised to 100°C and it is then transferred to a well– lagged aluminum can of mass 10.0g containing 120g of methylated spirit at 10.0°C. calculate the final steady temperature after the spirit has been well stirred. Neglect the heat capacity of the stirrer and any losses from evaporation. (S.H.C of copper, aluminum and spirit respectively= $400J\,kg^{-1}\,K^{-1},=900J\,kg^{-1}\,K^{-1},=2400J\,kg^{-1}\,K^{-1}$)

Solution

Heat lost by copper = heat gained by aluminum + heat gained by spirit

$$M_CC_C(\theta_1-\theta_3)=M_AC_A(\theta_2-\theta_3)+M_SC_S(\theta_2-\theta_3)$$

$$0.25x400(100-\theta)=0.1x900(\theta-10)+0.12x2400(\theta-10)$$

$$10000-100\theta=297\theta-2970$$

$$\theta=\frac{12970}{397}=32.7°C$$

4. A liquid of mass 200g in a calorimeter of heat capacity 500$J\ K^{-1}$ is heated such that its temperature changes from 25°C to 50°C. Find the S.H.C of the liquid if the heat supplied was 14,000J.

Solution

Heat supplied = heat gained by liquid + heat gained by calorimeter

$$Q=M_LC_L(\theta_2-\theta_3)+M_CC_C(\theta_2-\theta_3)$$

$$14000=0.2xC_L(50-25)+500x(50-25)$$

$$14000=5xC_L+12500$$

$$C_L=300J\,kg^{-1}\,K^{-1}$$

5. A metal of mass 0.2kg at 100°C is dropped into 0.08kg of water at 13°C contained in calorimeter of mass 0.12kg and S.H.C 400$J\,kg^{-1}\,K^{-1}$. The final temperature reached is 35°C. Determine the S.H.C of the solid.

Solution

$M_s=0.2kg$
$\theta_1=100°C$
$M_w=0.08kg$
$\theta_2=15°C$
$M_c=0.12$
$C_c=400Jkg^{-1}K^{-1}$
$C_w=4200Jkg^{-1}K^{-1}$
$\theta_3=35°C$

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

$M_sC_s(\theta_1-\theta_2)= M_cC_c(\theta_3-\theta_2)+M_wC_w(\theta_3-\theta_2)$

$0.2x\ C_s\ (100-35)= 0.12x\ 400\ (35-15)+0.08x4200(35-15)$

$13C_s = 960 + 6120$

$C_s=590.769\ J\ kg^{-1}\ K^{-1}$

6. Hot water of mass 0.4kg at 100°C is poured into calorimeter of mass 0.3kg and S.H.C 400Jkg^{-1}K^{-1} and contains 0.2kg of a liquid at 10°C. The final temperature of mixture is 40°C determines the S.H.C of a liquid.

Solution

$M_w=0.4kg$
$\theta_1=100°C$
$M_c=0.3kg$
$C_c=400\ J\ kg^{-1}\ K^{-1}$
$M_L=0.2kg$ $\theta_2=10°C$
$\theta_3= 40°C$

Heat lost by the hot water =heat gained by the colorimeter +heat gain by liquid

$M_wC_s(\theta_3-\theta_1)= M_cC_c(\theta_3-\theta_2)+ M_LC_L(\theta_3-\theta_2)$

$0.4x\ 4200(100-40)=0.3x400(40-10) +0.2xC_L(40-10)$

$100800 = 3600 + 6C_L$

$C_L=16200\ J\ kg^{-1}\ K^{-1}$

7. A 15W heating coil is immersed in 0.2kg of water and switched on for 560 seconds during which time; the temperature rises by 10°C. When water was replaced by some volume of another liquid of mass 0.15kg, the power required for same time is 8.3W. Calculate the S.H.C of the liquid.

Solution

$Ivt = M_LC_L\Delta\theta$

$8.3x\ 560=0.15xC_Lx10$

$C_L=[\frac{8.3x560}{0.15x10}]$

$C_L=3.1x10^3\ J\ kg^{-1}\ K^{-1}$

Assumption, same temperature rise occurs.

8. When a block of metal of mass 0.11kg and S.H.C 400 $J\ kg^{-1}\ K^{-1}$ 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;
   a) S.H.C of the liquid
   b) Thermal capacity of the container.

Solution

$M_S = 0.11kg$, $C_s=400\ J\ kg^{-1}\ K^{-1}$
$\theta_1 = 100°C$ $\theta_2=10°C$ $\theta_3=18°C$
$M_L=0.2kg$ $M_L=0.4kg$
$\theta_2=10°C$
$\theta_3=14.5°C$

Heat lost by solid = heat gained by liquid + heat gained by container

$M_sC_s(\theta_1-\theta_3) =M_LC_L(\theta_3-\theta_2) + M_cC_c(\theta_3-\theta_2)$

$0.11x400(100-18) =0.2xC_L(18-10) + H(18-10)$

$3608 = 1.6C_L+8H$ ....(1)

$M_sC_s(\theta_1-\theta_3) = M_LC_L(\theta_3-\theta_2) + M_cC_c(\theta_3-\theta2)$

$0.11x400(100-14.5) = 0.4\ x\ C_L(145-10) + H(14.5-10)$

$3762 =1.8\ C_L + 4.5H$ ....(2)

Solving equation1 and equation2 simultaneously

$C_L = 1925\ J\ kg^{-1}\ K^{-1}$

$H= 66\ J\ K^{-1}$ [thermal capacity of the container]

EXERCISE :35

1) 400g of a liquid at a temperature 70°C is mixed with another liquid of mass 200g at a temperature of 25°C. Find the final temperature of the mixture, if the S.H.C of the liquid is 4200 $J\ kg^{-1}\ K^{-1}$.
An[=55°C]

2) 60 kg of hot water at 82°C was added to 300 kg of cold water at 10°C. Calculate the final temperature of the mixture (S.H.C of water =4200 $J\,kg^{-1}\,K^{-1}$) **An[=22°C].**

3) Calculate the final steady temperature obtained when 0.8 kg of glycerine at 25°C is put into a copper calorimeter of mass 0.5 kg at 0°C (S.H.C of copper =400 $J\,kg^{-1}\,K^{-1}, S.H.C\ of\ glycerine = 250\,J\,kg^{-1}\,K^{-1}$). **An[12.5°C]**

4) A copper block of mass 250g is heated to a temperature of 145°C and then dropped into a copper calorimeter of mass 250g which contains 2500m^3 of water at 20°C. Calculate the final temperature of water. (S.H.C of copper = 400 $J\,kg^{-1}\,°C^{-1}$, S.H.C of water = 4200 $J\,kg^{-1}\,°C^{-1}$). **An[30°C]**

5) The temperature of heat which raises the temperature of 0.1 kg of water from 25°C to 60°C is used to heat a metal rod of mass 1.7 kg and S.H.C of the rod was 20°C. Calculate the final temperature of the rod. An [48.8°C]

6) A piece of copper of mass 100g is heated to 100°C and is then transferred to a well lagged copper can of mass 50g containing 200g of water at 10°C. Neglecting heat loss, calculate the final steady temperature of water after it has been well stirred. Take S.H.C of copper and water to be 400 $J\,kg^{-1}\,K^{-1}$ and 4200 $J\,kg^{-1}\,K^{-1}$ respectively. **An[14**°C]

7) A block of metal of mass 0.5kg initially at a temperature of 100°C is gently lowered into an insulated copper container of mass 0.05kg containing 0.9kg of water at 20°C. Neglecting heat loss, calculate the specific het capacity of the metal block. (Take S.H.C of water to be 400 $J\,kg^{-1}\,K^{-1}$and 4200 $J\,kg^{-1}\,K^{-1}$respectively. **An[506.6** $J\,kg^{-1}\,K^{-1}$**]**

8) A heating coil is placed in thermal flask containing 0.6kg of water for 600s. The temperature of water rises by 25°C during this time. Water is replaced by 0.4kg of another liquid. And the same temperature rise occurs in 180s. Calculate the S.H.C of the liquid given that S.H.C of water is 4200 $J\,kg^{-1}\,K^{-1}$. State any assumption. **An [1890** $J\,kg^{-1}\,K^{-1}$**]**

9) Copper calorimeter of mass 120g contains 100g of paraffin at 15°C. If 45g of aluminum at 100°C is transferred to the liquid and the final temperature is 27°C. Calculate the S.H.C of paraffin [S.H.C of aluminum and copper are 1000 and 400 $J\,kg^{-1}\,K^{-1}$ respectively]**. Ans. 2.4 x10^3Jkg^{-1}K^{-1}**

10) A steady current of 12 A and $p.d$ of 240V is passed, through a block of mass 1500g for 1 ½ minutes. If the temperature of the block rises from 25°C to 80°C, calculate
    (i) The specific heat capacity of the block
    (ii) The heat capacity of 4kg mass of the block**. An [3141.82** $J\,kg^{-1}\,K^{-1}$**, 12567.28** $J\,K^{-1}$**]**

11) A liquid of mass 250g is heated to 80°C and then quickly transferred to a calorimeter of heat capacity 380JK^{-1} containing 400g of water at 30°C. If the maximum temperature recorded is 55°C and specific heat capacity of water is 4200 $J\,kg^{-1}\,K^{-1}$. Calculate the S.H.C of the liquid. **An [8240** $J\,kg^{-1}\,K^{-1}$**]**

12) 500g of water is put in a calorimeter of heat capacity 0.38Jk^{-1} and heated to 60°C. It takes 2minute for the water to cool from 60°C to 55°C. When the water is replaced with 600g of a certain liquid, it takes 1 ½ minute for the liquid to cool from 60°C to 55°C. Calculate the S.H.C of the liquid. **An [2624.8** $J\,kg^{-1}\,K^{-1}$**]**

13) When a metal cylinder of mass 2.0x10^{-2}kg and specific heat capacity 500 $J\,kg^{-1}\,K^{-1}$ is heated by an electrical heater working at a constant power, the initial rate of rise of temperature is 3.0Kmin^{-1}.After a time the heater is switched off and the initial rate of fall of temperature is 0.3Kmin^{-1}. What is the rate at which the cylinder gains heat energy immediately before the heater is switched off? **An[0.45W]**

14) A copper block has a conical hole bored in it into which a conical copper plug just fits. The mass of the block is 376g and that of the plug is 18g. The block and plug are initially at room temperature 10°C and almost completely surrounded by a layer of insulating material. The plug is removed from the block, cooled to a temperature of -196°C and then quickly inserted into the block again. The temperature of the block falls to 3°C and then slowly rises. Calculate the value of the mean specific heat capacity of copper (in the range -196°C to 3°C) obtained by ignoring heat flow into the block from the surrounding. (S.H.C of copper to the temperature range 3°C to 10°C is 380 $J\,kg^{-1}\,K^{-1}$^{1}). **An [279** $J\,kg^{-1}\,K^{-1}$**]**

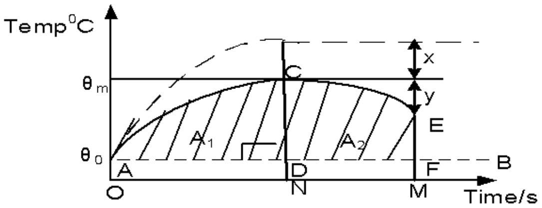
2.1.3: COOLING CORRECTION

Is the number of degree Celsius that should be added to the observed maximum temperature to cater for heat losses during rise or fall.

OR

Is the extra temperature that is added to the observed maximum temperature to compensate for the heat lose to the surrounding.

2.1.4: DETERMINATION OF COOLING CORRECTION OF A POOR CONDUCTOR E.G. RUBBER



- Pour a liquid in a calorimeter and place it on a table. Place a thermometer into the liquid and after some time record the temperature of the surrounding θ_0
- Gently place the heated solid into the liquid and stirr
- Temperature of mixture is recorded at different time interval until the temperature of the mixture has fallen by about 1°C below the observed maximum temperature θ_m.
- A graph of temperature against time is plotted.
- Draw a line AB through θ_0 parallel to the time axis
- Draw a line CD through θ_m parallel to the temperature axis
- Draw a line EF beyond CD parallel to the temperature axis and note y
- Areas A_1 and A_2 are estimated by counting squares of the graph paper.
- The cooling correction x, then determined from. $\frac{A_1}{A_2} = \frac{x}{y}$ $\therefore$ $x = \frac{A_1}{A_2} y$ and added to θ_m

2.1.5: NEWTON'S LAWS OF COOLING

It states that under conditions of forced convection, the rate of heat loss is directly proportioned to excess temperature over the surrounding

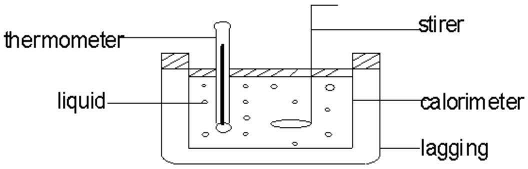
$$\frac{dQ}{dt} \propto (\theta - \theta_R),$$

$$\frac{dQ}{dt} = -k(\theta - \theta_R),$$

$$\text{But } \frac{dQ}{dt} = mc\frac{d\theta}{dt}$$

$$\therefore \frac{d\theta}{dt} = -k(\theta - \theta_R)$$

EXPERIMENT TO VERIFY NEWTON'S LAW OF COOLING



- ❖ Hot water in a calorimeter is placed near an open window.
- ❖ Temperature θ of the water is recorded at equal time interval for about 20 minutes.
- ❖ A graph of temperature θ against time t is plotted.
- ❖ Different slopes at different temperatures $\theta_1, \theta_2, \theta_3$ are determined.
- ❖ For each temperature the excess temperature, $\theta - \theta_R$ is calculated, where θ_R is room temperature
- ❖ A graph of slope against excess temperature is plotted
- ❖ A straight line graph through the origin verifies Newton's law of cooling.

2.1.6: HEAT LOSS AND TEMPERATURE CHANGE

The rate of heat loss also depends on;

- Excess temperature $(\theta - \theta_R)$,
- Surface area of the body
- The nature of the surface of the body i.e. Dull surface lose heat faster than shining

A body having a uniform surface area and uniform temperatures, heat loss per second is given by $\frac{d\theta}{dt}$.

Since $Q = m\, l\Delta\theta$

$$\frac{dQ}{dt} = -mc\frac{d\theta}{dt}$$

$$\frac{d\theta}{dt} = -\frac{dQ}{dt}/mc$$

But $m = \rho v$

$$\frac{d\theta}{dt} = \frac{dQ}{dt}/\rho vc$$

$$\frac{d\theta}{dt} = \frac{1}{\rho vc}\frac{dQ}{dt}$$

Question: Explain why a small body cools faster than larger bodies of the same material.

Rate of heat loss $\propto \frac{surface\ area}{volume}$. This implies that heat loss$\propto \frac{1}{length}$. Since $\frac{d\theta}{dt} = -{}^{1}/_{mc}\frac{dQ}{dt}$ and mass$\propto$ $volume$, a small body cools faster than a large body

92.2.0: LATENT HEAT

This is the amount of heat required for the substance to change state at constant temperature.

Why temperature remains constant during change of state (phase)

- During melting (change of state from solid to liquid), the heat energy supplied is used to weaken the intermolecular forces and increase separation between molecules. This increases the potential energy of the molecules but the mean kinetic energy of the molecules remain constant . Further increase in separation between molecules causes the regular patterns to collapse as the solid changes to a liquid, until the process is complete the temperature remains constant.
- During boiling (change from liquid to vapour state) the heat supplied is used to break the intermolecular forces and increases separation between molecules. This increases the potential energy of the molecules but the mean kinetic energy of the molecules remain constant . Also some of the energy is used in doing work during expansion against atmospheric pressure, hence no temperature change occurs.

Significance of latent heat on regulation of body temperautre

On a hot day the body sweats. Evaporation occurs at the surface of the body. The temperature of the sweat falls to maintain evaporation. Latent heat is constantly drawn from the body and the body cools.

LATENT HEAT OF FUSION

This is heat required to change any mass of substance from solid to a liquid at constant temperature.

SPECIFIC LATENT HEAT OF FUSION

Is the quantity of heat required to change **1kg** mass of a solid to a liquid at **constant temperature**. It is measured in Jkg^{-1}

LATENT HEAT OF VAPOURIZATION

Is the quantity of heat required to change any mass of substance from liquid to gas at a constant temperature.

SPECIFIC LATENT HEAT OF VAPOURIZATION

Is the quantity of heat required to change **1kg** mass of liquid to gas at **a constant temperature.** It is measured in Jkg^{-1}

2.2.1: WHY LATENT HEAT OF VAPOURIZATION IS HIGHER THAN LATENT HEAT OF FUSION

- In fusion, heat is required to weaken the intermolecular bonds accompanied with a small increase in volume hence negligible work done against atmospheric pressure.
- While in vaporization, heat is required to break intermolecular attractions and form a gas followed by a large increase in volume and more work is done against atmospheric pressure in expanding the gas.

Example

1. Ice has a mass of 3 kg. Calculate the heat required to melt it at 0°C. (S.L.H of fusion = $3.36x10^{5}Jkg^{-1}$).

Solution | $Q = m\,l = 3\ x\ 3.36x10^{5} = 1.008x10^{6}\,J$

2. **Find the heat required to change 2 kg of ice at 0°C into water at 50°C.(S.L.H of fusion of ice = $3.36x10^5 Jkg^{-1}$, $S.H.C\ of\ water = 4200\ J\ kg^{-1}\ K^{-1}$).**

Solution

$\boxed{\text{Ice at } 0^\circ C} \longrightarrow \boxed{\text{Water } 0^\circ C} + \boxed{\text{Water } 50^\circ C}$

$Q = m\,l + m\,C\,\Delta\theta$

$Q = 3\ x\ \ 3.36x10^5 + 2x4200x(50-0)$

$Q = 1.008x10^6\ + 4.2x10^6 = 1.092x10^6\ J$

3. **An ice making machine removes heat from water at a rate of 20 Js^{-1}. How long will it take to convert 0.5 kg of water at 20 °C to ice at 0°C°C. (S.L.H of fusion of ice = $3.36x10^5 Jkg^{-1}$, S.H.C of water=4200$J\ kg^{-1}\ K^{-1}$).**

Solution

$\boxed{\text{water } 20^\circ C} \longrightarrow \boxed{\text{Water } 0^\circ C} + \boxed{\text{Ice } 0^\circ C}$

$Q = m\,C\,\Delta\theta + \ m\,l$

$P\,x\,t\ = m\,C\,\Delta\theta + \ m\,l$

$20\ x\ t = 0.5x4200x(20-0) + 0.5x\ \ 3.36x10^5$

$20\,t = 42000\ + 168000$

$t = \frac{210000}{20}\ = 1.05x10^4$ s

4. **A calorimeter with heat capacity of $80J{}^\circ C^{-1}$contains 50g of water at 40°C what mass of ice at 0°C needs to be added in order to reduce the temperature to 10°C. Assume no heat is lost to the surround (S.H.C of water = 4200J$kg^{-1}{}^\circ C^{-1}$, S.L.H of the of ice = $3.4x10^5Jkg^{-1}$).**

Solution

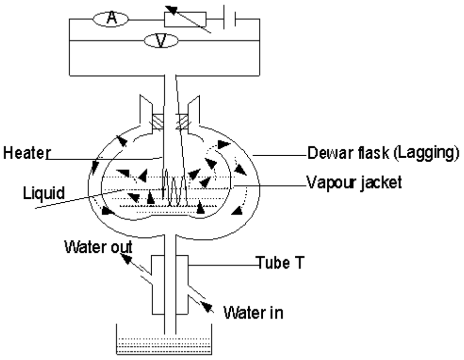
$$\begin{pmatrix}Heat\ lost\ by\\ calorimeter\\ from\\ 40^\circ C\ to\ 10^\circ C\end{pmatrix} + \begin{pmatrix}Heat\ lost\ by\\ water\\ from\\ 40^\circ C\ to\ 10^\circ C\end{pmatrix} = \begin{pmatrix}Heat\ gained\\ by\ ice\\ at\ 0^\circ C\end{pmatrix} + \begin{pmatrix}Heat\ gained\\ by\ melting\\ ice\\ from\ 0^\circ C\ to\ 10^\circ C\end{pmatrix}$$

$$M_c C_c (40-10) + M_w C_w (40-10) = M_I L + C + M_I C_I x\ (10-0)$$

$$80\,x\,30\ + \frac{50}{1000}x4200x30\ = M_I(3.4x10^5 + 4200x10)$$

M_I = 0.023kg   Mass of ice required = 23g

2.2.2: DETERMINATION OF THE S.L.H OF VAPOURIZATION (L$_v$) OF LIQUID BY a)ELECTRIC METHOD [DEWAR FLASK METHOD]



- Switch k is closed and liquid is heated until it starts boiling
- A stop clock is started and mass m_1 of liquid collected in a time in a time t. noted
- The Ammeter reading, $I_1$and Voltmeter reading V_1 are recorded.

- At steady state, $I_1\ V_1\ t\ = m_1 x\ l_V + h$ ...(1) where $h = ht$ heat lost to surrounding
- The Rheostat is adjusted and a new Ammeter reading I_2 and Voltmeter reading V_2 are recorded
- New mass m_2 of the liquid collected in the same time t is obtained

$I_2\ V_2\ t\ = m_2 x\ l_V + h$ ....(2)

The specific latent heat of vapourization is obtained from

$$\boxed{L_V = \frac{(I_2V_2 - I_1V_1)t}{(M_2 - M_1)}}$$

EXAMPLES

1) When electrical energy is supplied at a rate of 12W to a boiling liquid 5.0x10^{-3} Kg of the liquid evaporates in 30 min .On reducing the electrical power to 7W, 1.0x10^{-3} Kg of the liquid evaporates in the same time. Calculate;

a) S.L.H of vapouration

b) Power loss to the surrounding

Solution

$I_1\,V_1\,t\ = m_1 \text{x}\, l_V + h,\ I_2\,V_2\,t\ = m_2 \text{x}\, l_V + h$

$$L_V = \frac{(I_2V_{2-}\,I_1V_1)t}{(M_{2-}\,M_1)} = \frac{(7-12)x30x60}{(1x10^{-3}-5x10^{-3})}$$

$Lv = 2.25x10^6 Jkg^{-1}$

b) $I_1\,V_1\ = \frac{m_1}{t}\text{x}\, l_V + h$

$12\ = \frac{5x10^{-3}}{30x60}\,x\,2.25x10^6 + h$

h= $5.75W$

2) An experiment to determine S.L.H of vapourization of alcohol using dewar flask gave the following results.

Experiment 1	Experiment 2
V_1=7.4V	V_2=10.0V
I_1=2.6A	I_2=6.6A
m_1=5.8x10^{-3}kg	m_2=11.3x10^{-3}kg
t_1=300s	t_2=300s

a) Find S.L.H of vapourization of alcohol

b) Heat lost to surrounding per unit time.

Solution

a) $I_1\,V_1\,t\ = m_1 \text{x}\, l_V + h,$

$I_2\,V_2\,t\ = m_2 \text{x}\, l_V + h$

$$L_V = \frac{(I_2V_{2-}\,I_1V_1)t}{(M_{2-}\,M_1)} = \frac{(10x6.6-7.4x2.6)x300}{(11.3x10^{-3}-5.8x10^{-3})}$$

$Lv = 2.55\text{x}10^6 Jkg^{-1}$

b)- $I_1\,V_1\ = \frac{m_1}{t}\text{x}\, l_V + h$

$7.4x2.6\ = \frac{5.8x10^{-3}}{300}\text{x}\ 2.55\text{x}10^6 + h$

h= $30W$

3) When electrical power is supplied at rate of 12W, mass of liquid of 8.6x10^{-3} kg evapourates in 30minutes. On reducing the power to 7W, 5x10^{-3}kg of the liquid evapouration in same time. Calculate;

(i) S.L.H of evapouration of liquid. **An 2.25x10^6 Jkg^{-1}**

(ii) Power lost to the surrounding. **An 1Js^{-1}**

4) In an experiment to determine S.L.H.V of a liquid using Dewar flask in 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 to evaporate 3.0g of water in 2 minutes.

Solution

$I_1\,V_1\,t\ = m_1 \text{x}\, l_V + h,$

$I_2\,V_2\,t\ = m_2 \text{x}\, l_V + h$

$$Lv = \frac{I_2V_2 - I_1V_1}{M_2 - M_1} = \frac{10x3.6-7.4x2.6}{(11.3-5.8)x\frac{1}{300}x10^{-3}}$$

$Lv = 9.14x\ 10^5\ Jkg^{-1}$

Put into equation (2)

$I_2\,V_2\,t\ = m_2 \text{x}\, l_V + h$

$10x\,3.6\ = \frac{11.3}{300}x10^{-3}x9.14x10^5\ +\ h$

$h =\ 1.57w$

$I_3\ V_3 = M_3\,Lv + h$

$P_3 = (\frac{3x10^{-3}}{2x60}\,x\ 9.14x\ 10^5) + 1.57$

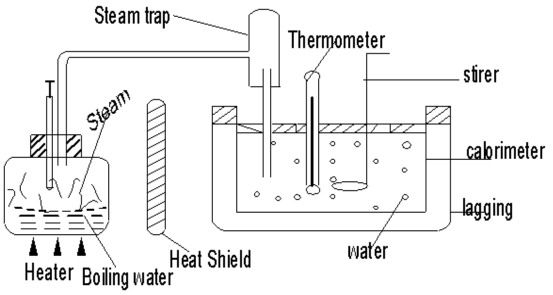
$P_3 =\ 24.42W$

5) In an experiment to determine S.L.H.V of a liquid using Dewar flask in the following results were obtained.

Voltage V(V)	Current I(A)	Mass collected in 400s/g
10.0	2.00	14.6
11.2	250	30.6

Calculate the heat lost to surrounding 400s.**An(5080J)**

b)DETERMINATION OF S.L.H.V BY METHOD OF MIXTURE



- The mass m_1 of water and the calorimeter is measured and noted
- The initial temperature, θ_1 of water in the calorimeter is noted
- Steam from boiling water is then passed into the water in the calorimeter through a steam trap.
- After a measurable temperature rise, the final temperature, θ_2 of the water in calorimeter is measured and noted.
- The new mass, m_2 of the water in the calorimeter is again measured and the mass, m_s of condensed steam is calculated from $m_s = m_2 - m_1$
- Temperature θ_3 of steam is measured by thermometer T and recorded
- The mass m_c of the empty calorimeter is obtained by weighing

$$\begin{pmatrix}\text{Heat given by}\\ \text{steam condensing}\end{pmatrix} + \begin{pmatrix}\text{heat given by}\\ \text{condensed water}\\ \text{from }\theta_3\text{ to }\theta°\text{C}\end{pmatrix} = \begin{pmatrix}\text{heat taken}\\ \text{by calorimeter}\end{pmatrix} + \begin{pmatrix}heat\ taken\\ by\ water\end{pmatrix}$$

$$m_s\, l_v + m_s\, C_w\,(\theta_3 - \theta_2) = (m_c C_c + m_w C_w)(\theta_3 - \theta_2)$$

C_w = S.H.C of water

m_w = mass of water $where\ m_w = m_1 - m_c$

C_c = S.H.C of calorimeter

- l_v can be obtained

EXAMPLE

1) An electric kettle with a 2.0kW heating element has a heat capacity of 400JK. 1.0kg of water at 20°C is placed in the kettle. The kettle is switched on and it is found that 13 minutes later the mass of water in it is 0.5kg. Ignoring heat losses calculate a value for the specific latent heat of vaporization of water. (specific heat capacity of water is 4200 $Jkg^{-1}K$)

Solution

$Pt = M_f C_f(\theta_2 - \theta_1) + M_w C_w(\theta_2 - \theta_1) + MsL$

$$2x1000x13x60 = 400\,(100 - 20) + 1x4200[100 - 20] + (1 - 0.5)\,L$$

$$l = 2.38x10^6 Jkg^{-1}$$

2) An electrical heater rated 500W is immersed in liquid of mass 2.0kg contained in large thermal flask of heat capacity 840Jkg^{-1} at 28°C. Electrical power is supplied to heater for 10minutes. If S.H.C of liquid is $2.5x10^3$ $Jkg^{-1}K^{-1}$. Its **S.L.H.V** is $8.54x10^3$ $Jkg^{-1}k$ and its boiling point is 78°C. Estimate the amount of liquid which boils off.

Solution

Heat supplied by heater = heat gained by flask + heat gained by liquid + heat used for evaporating the liquid.

$Ivt = M_f C_f(\theta_2 - \theta_1) + M_L C_L(\theta_2 - \theta_1) + MsLv$

$500x10x60 = 840\,(78-28) + 2x2.5x10^3\,[78-28] + M_s\,(8.54x10^3)$

Ms = 0.936kg

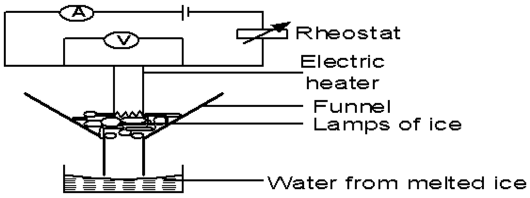
Excersise:36

1) Ice at 0°C is added to 200g of water initially at 70°C in a vacuum flask. When 50g of ice is added and has all melted, the temperature of the flask and content is 40°C. When further 80g of ice has been added and has been melted, the temperature of the whole becomes 10°C. Calculate the S.L.H of fusion of the neglecting any heat loss of surrounding. **Ans $3.78x10^5$ Jkg^{-1}**
2) A calorimeter of mass 20g and specific heat capacity 800 $J\,kg^{-1}K^{-1}$ contains 500 g of water at 30 °C. Dry steam at 100°C is passed through the water in the calorimeter until the temperature of water rises to 70°C. If the specific latent heat of vaporization of water is 2260000 $J\,kg^{-1}$, calculate the mass of steam condensed
3) A calorimeter of mass 35.0 g and specific heat capacity 840 $J\,kg^{-1}K^{-1}$ contains 143.0 g of water at 7 °C. Dry steam at 100°C is bubbled through the water in the calorimeter until the temperature of water rises to 29°C. If the mass of steam condensed is 5.6 g, find the specific latent heat of vaporization of water
4) A copper container of heat capacity 60 $J\,kg^{-1}$ contains 0.5 kg of water at 20 °C. Dry steam is passed into the water in the calorimeter until the temperature of water rises to 50°C. Calculate the mass of steam condensed

Explain why specific latent heat of vaporization of water is higher at 20°C than at 100°C

- At 20°C the molecules of the liquid are closer together than at 100°C. The intermolecular forces of attraction are stronger at 20°C than at 100°C.
- More energy is required to break the bonds at 20°C than the heat needed at 100°C

c) DETERMINATION OF S.L.H.F OF ICE BY ELECTRICAL METHOD



- The rheostat is adjusted until suitable values of I and V are obtained
- The heat supplied by the heater is used to melt the ice and water, and water from melted ice is collected and weighed per unit time.

$$\begin{pmatrix}\text{Heat supplied by}\\ \text{heater per second}\end{pmatrix}+\begin{pmatrix}\text{heat absorbed from}\\ \text{surrouding per second}\end{pmatrix}=$$

latent heat absorbed by ice

$IV + h = ML_F$ ………… (1)

- The experiment is repeated with values of I_1V_1 and M_1 is also determined by

$I_1V_1 + h = M_1L_F$………… (2)

- l_f can be obtained from

$$\boxed{L_f = \frac{IV - I_1V_1}{M - M_1}}$$

Exercise: 37

1) Calculate the heat required to melt 200g of ice at 0°C . (S.L.H of ice= $3.4\text{x}10^5$Jkg^{-1}) **An $6.8\text{x}10^4$ J**
2) Calculate the heat required to turn 500g of Ice at 0°C into water at 100°C. (S.L.H of ice= $3.4\text{x}10^5$Jkg^{-1} S.H.C of water = 4200Jkg^{-1}) **An [$3.8\text{x}10^5 J$]**
3) Calculate the heat given out when 600g of steam at 100°C condenses to water at 20°C [S.L.H of steam = $2.26\text{x}10^6$ Jkg^{-1}, S.H.C of water = 4200 Jkg^{-1}]. **An [$1.56\text{x}10^6$J]**
4) 1kg of vegetables, having a specific heat capacity 2200 Jkg^{-1} at a temperature 373K are plugged into a mixture of ice and water at 273K. How much is melted.
[S.L.H of fusion of the = $3.3\text{x}10^5$ Jkg^{-1}] **An [0.67kg]**
5) 3kg of molten lead (melting point 600K) is allowed to cool down until it has solidified. It is found that the temperature of the lead falls from 605K to 600K in 10s, remains constant at 600K for 300s, and then fall to 595K in a further 8. 4s. Assuming that the rate of loss of energy remains constant and that the specific heat capacity of solid lead is 140Jkg^{-1}K^{-1}. Calculate.
   (a) Rate of loss of energy from the lead.
   (b) The specific latent heat of fusion of lead.
   (c) The specific heat capacity of liquid lead
An [250W, $2.5\text{x}10^4$Jkg^{-1}, 167Jkg^{-1}K^{-1}]
6) 0.02kg of ice and 0.10kg water at 0°C are in a container. Steam at 100°C is passed in until all the ice is just melted. How much water is now in the container?
S.L.H of steam = $2.3\text{x}10^6$Jkg^{-1}, S.L.H of ice = $3.4\text{x}10^5$Jkg^{-1},
S.H.C of water = $4.2\text{ x}10^3$Jkg^{-1}K^{-1} **An [0.1225kg]**
7) When apiece of ice of mass $6\text{x}10^{-4}$kg at a temperature of 272K is dropped into liquid nitrogen boiling at 77K in a vacuum flask $8\text{x }10^{-4}$m^3 of nitrogen, measured at 294K and 0.75m mercury pressure are produced. Calculate the mean specific heat capacity of ice between 272K and 77K. Assume that the S.L.H of vaporization of nitrogen is $2.13\text{x}10^5$Jkg^{-1} and that the density of nitrogen at S.T.P is 1.25kgm^{-3} **.An $1.67\text{x}10^3$Jkg^{-1}K^{-1}**
8) Wet clothing at a temperature of 0°C is hung out to dry when the air temperature is 0°C and there is a dry wind blowing. After some time, it is found that some of the water has evaporated and the remainder has frozen. What is the source of the energy required to evaporate the water. Estimate the proportion of the water originally in the clothing which remains as ice, state any assumptions you make.
(S.L.H of fusion of ice at 273K = 333k Jkg^{-1}
S.L.H of vaporization of water at 273K = 2500k Jkg^{-1}) **An [88%]**

9) In a factory heating system water enters the radiators at 60°C and leaves at $38°C. The$ system is replaced is by one in which steam at 100°C is condensed in the radiators, the condensed steam leaving at 82°C. What mass of steam will supply the same heat as 1.00kg of hot water in the first instance.(The S.L.H of vapourisation of water is 2.26 $x10^6Jkg^{-1}$ at 100°C. The S.H.Cof water is $4.2x10^3Jkg^{-1}°C^{-1}$) **An [0.0396kg]**

10) A beaker containing ether at a temperature of 13°C is placed in a large vessel in which the pressure can be reduced so that the ether boils, this results in cooling of the remaining ether. What proportion of the ether has evaporated when the temperature of the remainder has been reduced to 0°C (assume no interchange of heat between the ether and its surrounding)

(Mean S.H.C of ether over the temperature range 0-13°C = $2.4x10^3Jkg^{-1}°C^{-1}$)

(Mean S.L.H of vapourisation of ether in the temperature range 0-13°C = $3.9x10^5Jkg^{-1}°C^{-1}$)

An[7.4%]

11) In an express coffee machines, steam at 100°C is passed into milk to heat it. Calculate

(i) The energy required to heat 150g of milk from room temperature (20°C) to 80°C.

(ii) The mass of steam condensed. **An [$3.6x10^6$J, 15.8g]**

UNEB 2016 Q5

(a) (i) Define **specific latent heat of fusion** (01mark)

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

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

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

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

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

Calculate the;

(i) Specific latent heat of fusion of ice. **An [$3.36x10^5Jkg^{-1}$]** (04marks)

(ii) Energy gained in the course of obtaining the first set of readings **An [500J]** (03marks)

(e) Why are two sets of readings necessary in (d) above. (01mark)

UNEB 2015 Q5

(c) Describe with the aid a diagram an experiment to determine specific latent heat of vaporization of steam using the method of mixtures (07marks)

(d) A 600W electric heater is used to raise the temperature of a certain mass of water in a thermos flask from room temperature to 80°C. The same temperature rise is obtained when steams from a boiler is passed into an equal mass of water at room temperature in the same time. If 16g of water were being evaporated every minute in the boiler, find the specific latent heat of vaporisation of steam, assumption no heat loses. **An($2.26x10^6$ Jkg^{-1})** (04marks)

UNEB 2014 Q7

(a) Define specific latent heat of vaporisation (01mark)

(b) With the aid of a labelled diagram, describe an experiment to measure the specific latent of vaporisation of a liquid using an electrical method (07mark)

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

(d) A liquid of specific heat capacity $2.8x10^3Jkg^{-1}K^{-1}$ and specific latent hate of vaporisation $9.00x10^5Jkg^{-1}$ is contained in a flask of heat capacity 800JK^{-1} at a temperature of 32°C. An electric heater rated 1 kW is immersed in 2.5kg of the liquid and switched on for 12 minutes, calculate the amount of liquid that boils off, given that boiling point of the liquid is 80°C

$An(3.84x10^{-1}kg)$ (06mark)

UNEB 2013 Q5

(a) Define

(i) Specific heat capacity (01mark)

(ii) Specific latent heat of vaporization of a liquid (01mark)

(b) With the aid of a labelled diagram, describe an electrical method of determining the specific heat capacity of a solid (07marks)

(c) An electrical heater rated 48W, 12V, is placed in a well insulated metal of mass 1.0kg at a temperature of 18°C. When the power is switched on for 5minutes, the temperature of the metal rises to 34°C. Find the specific heat of the metal. **An (900 $Jkg^{-1}K^{-1}$,)** (04marks)

(d) (i) State **Newton's law of cooling** (01marks)

(ii) Use Newton's law of cooling to show that

$$\frac{d\theta}{dt} = -k(\theta - \theta_R)$$

Where $\frac{d\theta}{dt}$ is the rate of fall of temperature and θ_R is the temperature of the surrounding

(e) Explain why evaporation causes cooling (03marks)

UNEB 2012 Q5

(a) (i) Define the terms specific heat capacity and specific latent heat of fusion (2mk)

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

c) With the aid of a labelled diagram describe an experiment to determine the S.H.C of a liquid using the continuous flow method (08marks)

d) Steam at 100°C is passed into a copper calorimeter of mass 150g containing 340g of water at 15°C. This is done until the temperature of the calorimeter and its content is 71°C. If the mass of the calorimeter and its contents is found to be 525g. Calculate the specific latent heat of vaporization of water.

Solution

Mass of calorimeter Mc = 150g

Mass of water Mw = 340g

Mass of steam Ms = 525 – (150+340) = 35g

$$\begin{pmatrix}\text{Heat supplied}\\ \text{by steam}\\ \text{at } 100°\text{C}\end{pmatrix} + \begin{pmatrix}\textit{Condensing steam}\\ \textit{from}\\ 100°\text{C } \textit{to } 71°\text{C}\end{pmatrix} = \begin{pmatrix}\text{heat gained by}\\ \text{calorimeter}\\ \text{from}\\ 15°\text{C to}71°\text{C}\end{pmatrix} + \begin{pmatrix}\textit{heat gained by}\\ \textit{water from}\\ 15°\text{C } \textit{to } 71°\text{C}\end{pmatrix}$$

Ms Lv + MsCs (100-71) = McCc (71-15) + Mw Cw (71-15)

$\frac{35}{1000}$Lv + $\frac{35}{1000}$x 4200x29 =$\frac{150}{1000}$ x400x56 +$\frac{340}{1000}$ x 4200 x56

Lv= 2.26X10^6 Jkg^{-1}

UNEB 2011 QN. 6

a) Define S.H.C of a substance and states its units (02marks)

b) (i) Describe how S.H.C of a liquid can be obtained by the continuous flow method (07marks)

(ii) State one disadvantage of this method (01mark)

c) An electric kettle rated 1000W, 240V is used on 220Vmains to boil 0.52kg of water. If the heat capacity of the kettle is 400Jkg^{-1} and the initial temperature of the water is 20°Chow long will the water take to boil. **An[246s]** (04marks)

UNEB 2009 QN 5

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

(ii)Hot water at 85°C and cold water at 10°C are run into a bath at a rate of 3.0x$10^{-2}m^3min^{-1}$ and V respectively. At the point of filling the bath the temperature of the mixture of water was 40°C. Calculate the time taken to fill the bath if its capacity is 1.5m^3 (05marks)

(c) The specific latent heat of fusion of a substance is significantly different from its specific latent heat of vaporization at the same pressure. Explain how the difference arises (04marks)

(d) Explain in terms of S.H.C why water is used in a car radiator than any other liquid. (02marks)

Solution

Let M_h = be mass of hot water

Mc = be mass of cold water

Heat supplied by hot water = heat gained by cold water

M_h C (85-40) = Mc (40-10)

M_h = $\frac{30}{45}$ Mc .... (1)

Let t be the time taken to fill

But M_h = ρ x volume

$M_h = \rho x$ (3x10^{-2}) t ....(2)

Also Mc = $\rho\, xV\, t$ ....(3)

Put equation (2) and equation (3) to equation (1)

$\rho x\,(3\times10^{-2})\,t = \frac{30}{45}\rho vt$

$V = 4.5\times10^{-2}\ m^3\ min^{-1}$

If the total volume = $1.5m^3$

If the volume of cold and hot water at filling temperature are V_1 and V_2 respectively.

$V_1+V_2 = 1.5m^3$

$3\times10^{-2}\,t + 4.5\times10^{-2}\,t = 1.5$

t=20minutes

c) Water has a very high S.H.C hence a small amount of water can absorb a lot of heat energy. Other liquids have low S.H.C so a large amount of these liquids are needed to carry away the heat consequently this wound require a larger radiator which is un economical.

UNEB 2008 Q 5

(a) Define the following terms
- (i) S.H.C of vaporization of a liquid (01mark)
- (ii) Coefficient of thermal conductivity (01mark)

(b) With the aid of a well labelled diagram describe an experiment to measure the S.L.H of vaporization of water by an electrical method (07marks)

(c) An appliance rated 240V, 200W evaporates 20g of water in the 5minutes. Find the heat loss if S.L.H of vaporization is $2.26\times10^6Jkg^{-1}$ (03marks) **An[14800J]**

(d) Explain why at a given external pressure a liquid boils at a constant temperature (4marks)

(e) With the aid of a suitable sketch graph explain the temperature distribution a long a lagged and un lagged metal rods, heated at one end (04marks)

UNEB 2007 Q 6

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

(ii)Explain the significance of latent heat in regulation of body temperature (3marks)

(b) (i)Using kinetic theory, explain boiling of a liquid. (03marks)

(ii)Describe how you would determine the S.L.H of vaporization of water using the method of mixtures.

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

Solution

UNEB 2006 Q 6

(a) (i) Define S.H.C of a substance (01mark)

(ii) State three advantages of the continuous flow method over the method of mixtures in the determination of S.H.C of a liquid (03marks)

(b) In a continuous flow experiment, a steady difference of temperature of 1.5°C is maintained when the rate of liquid flow is $45gs^{-1}$ and the rate of electrical heating is 60.5W. On reducing the liquid flow rate to $15gs^{-1}$, 36.5W is required to maintain. Calculate the;
- (i) S.H.C of the liquid (04marks)
- (ii) Rate of heat loss to the surrounding (3marks)**An [533.3Jkg^{-1}k^{-1}, 24.5W]**

(c) (i) Describe an electrical method for the determination of the S.H.C of a metal (06marks)

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

(iii) Comment about the accuracy of the result of the experiment in C (i) above (01mark)

Solution

C (i) assumption
- There is no heat loss to the surrounding
- The quantity of heat gained by the thermometer and the heater is negligible
- The volume of the metal is constant hence no work is done against the atmospheric pressure.

ii) Due to heat loss to the surrounding, it implies that more heat was supplied than as required to causes the observed temperature change. Hence the value of C is greater than the actual value.

UNEB 2005 QN 5

(c) The continuous flow method is used in the determination of the S.H.C of the liquid.

(i) What are the principle advantages of this method compared to the method of mixture

(ii) In such a method, 50g of water is collected in 1minute, the voltmeter and ammeter readings are 12.0V and 2.50A respectively. While the inflow and outflow temperatures are 20°Cand 28°C respectively. When the flow rate is reduced to $25gmin^{-1}$, the voltmeter and ammeter read 8.8V and 1.85A respectively while the temperatures remain constant. Calculate the S.H.C of water (5marks) **An[4.116x10^{3}Jkg^{-1}k^{-1}]**

UNEB 2002 QN 7

(a) (i) Define S.H.C of a substance (01mark)

(ii) State how heat losses are minimized in Calorimetry

(b) (i) What is meant by a cooling correction (02marks)

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

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

(c) Describe how you would determine the S.H.C of a liquid by the continuous flow method. (07marks)

UNEB 2001 QN 7

(a) Explain why temperature remains constant during change of phase (04marks)

(b) Describe with the aid of a labelled diagram, an electrical method for determination of S.L.H of vaporization of a liquid. (07marks)

(c) Water vapour and liquid water are confirmed in a air tight vessel. The temperature of the water is raised until all the water has evaporated, draw a sketch graph to show how the pressure of the water vapour changes with temperature and account for its main features (06 marks)

UNEB 1999 Q7

(a) Define S.H.C (01 mark)

(b) Describe an electrical method of measuring S.H.C of a metal. (06 marks)

(c) In a continuous flow calorimeter for measurement of S.H.C of a liquid, $3.6\times10^{-3}m^3$ of a liquid flows through the apparatus in 10 minutes. When electrical energy is supplied to the heating coil at the rate of 44W, a steady difference of 4k is obtained between the temperature of the out-flowing and inflowing liquid. When the flow rate is increased to $4.8\times10^{-3}m^3$ of liquid in 10 minutes, the electrical power required to maintain the temperature difference is 58W. Find the

(i) S.H.C of the liquid (06 marks)

(ii) Rate of loss of heat to the surrounding (02 marks)

[Density of liquid = $800kgm^{-3}$]

CHAPTER3: GAS LAWS

Boyle's law:

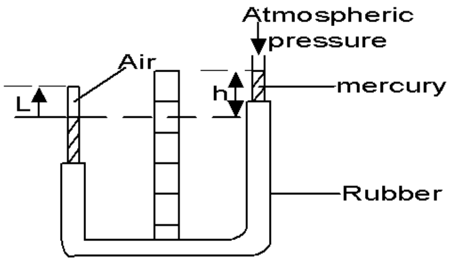
it states that the pressure of fixed mass of a gas is inversely proportional to its volume at constant temperature i.e.

$P \propto \frac{1}{v}$

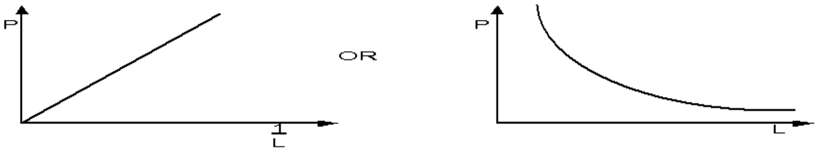
PV = constant

$\boxed{P_1V_1 = P_2V_2}$

EXPERIMENT TO VARIFY BOYLES LAW



- ❖ A fixed mass of the gas is trapped inside J tube of uniform cross section using mercury.
- ❖ Measure and record the atmospheric pressure H using a barometer
- ❖ Adjust the flexible tube by lowering or raising the open end.
- ❖ Measure and record the difference in mercury levels h
- ❖ Record the length l of the air column trapped in the closed tube
- ❖ Obtain the air pressure, $P = H \pm h$.
- ❖ Repeat the procedure and obtain a series of values P and l , $l \propto volume$
- ❖ Plot a graph of P against $\frac{1}{l}$ and a straight line graph passing through origin verifies Boyles law



This verifies Boyle's law

1. A given mass of a gas has a volume of 100 cm^3 at 75 $N\ m^{-2}$. At what pressure is it when the volume decreases to 60cm^3

Solution

$P_1V_1 = P_2V_2$

$75\ x\ 100 = P_2\ x\ 60$

$P_2 = \frac{75\ x\ 100}{60}$

$P_2 = 125N\ m^{-2}$

2. The cylinder of an exhaust pump has a volume of $25cm^3$. If it is connected through a valve to a flask of volume $225cm^3$ contianing air at a pressure of 75cmHg, calculate the pressure of the air I the flask after two strokes of the pump, assuming that the temperature of the air remains constant (04marks)

An(60.8cmHg)

Solution

1st stroke: $P_1V_1 = P_2V_2$

$75\ x\ 225 = P_2\ x\ (225 + 25)$

$P_2 = 67.5cmHg$

2nd stroke: $P_2V_2 = P_3V_3$

$67.5\ x\ 225 = P_3\ x\ (225 + 25)$

1st stroke: $P_1V_1 = P_2V_2$

$75\ x\ 225 = P_2\ x\ (225 + 25)$

$P_3 = 60.8cmHg$

Alternatively

$$\boldsymbol{P_1} = \left(\frac{V_1}{V_1 + V_2}\right)^n \boldsymbol{P}$$

$$\boldsymbol{P_1} = \left(\frac{225}{225 + 25}\right)^2 75$$

$$\boldsymbol{P_1} = 60.8cmHg$$

CHARLES LAW:

It states that the volume of fixed mass of gas is directly proportional to its absolute temperature at constant pressure i.e

V∝T

$\frac{V}{T}$ = constant

$\boxed{\frac{V_2}{T_2} = \frac{V_1}{T_1}}$

Absolute zero temperature (0K) is the temperature attained when molecules slow down and acquire their minimum possible energy.

Molecular explanation for existence of absolute zero temperature

When a gas is cooled, its molecules loose kinetic energy continuously since it depends directly on temperature. As molecules loose kinetic energy they move closer into close proximity until when they cease to have kinetic energy. At this point the gas is said to occupy a negligible volume and its temperature at this point is called the absolute zero temperature and the pressure the gas exerts on the walls of the container occupied is negligible.

Example

1. When the temperature of a gas is at 0°C, its volume is 75 cm^3. Find its volume when the gas is heated up to 273°C.

Solution

$V_1 = 75\,cm^3$, $V_2 = ?$,

$$\frac{V_2}{T_2} = \frac{V_1}{T_1}$$

$$\frac{V_2}{273+273} = \frac{75}{0+273}$$

$V_2 = 150cm^3$

2. The volume of a fixed mass of a gas at 27°C is 150 cm^3. What is its temperature at 200cm^3

Solution

$V_1 = 150\,cm^3, V_2 = 200cm^3$,

$$\frac{V_2}{T_2} = \frac{V_1}{T_1}$$

$$\frac{200}{T_2} = \frac{150}{27+273}$$

$$T_2 = \frac{300\,x\,200}{150}$$

$T_2 = 400\,K$

Temperature = 400 -273

=127°C

PRESSURE LAW/ GAY LUSSAC LAW

It states that the pressure of fixed mass of gas is directly proportional to its absolute temperature at constant volume i.e.

P∝T

$\frac{P}{T}$ = constant

$$\boxed{\frac{P_1}{T_1} = \frac{P_2}{T_2}}$$

EXAMPLE

1. The pressure of a gas is 75$N\ m^{-2}$ at −73°C. What is its pressure when a gas is heated up to 127°C

Solution

$P_1 = 75\,N\,m^{-2}, P_2 = ?,$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{75}{-73+273} = \frac{P_2}{127+273}$$

$P_2 = 150\,N\,m^{-2}$

2. A sealed flask contains a gas at a temperature of 27°C and a pressure of 90 kPa. If the temperature rises to 127°C. What will be the new pressure?

Solution

$P_1 = 90\,kPa, P_2 = ?, \frac{P_1}{T_1} = \frac{P_2}{T_2}$

$$\frac{90}{27+273} = \frac{P_2}{127+273}$$

$P_2 = 120\,kPa$

3.1: EQUATION OF STATE

This an equation relating pressure, volume and temperature.

$$\boxed{\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}}$$

Examples

1. When the pressure of 1m^3 of a gas at −73 °C is increased to 3 times its original value, the temperature becomes 27 °C. Find the new volume of the gas

Solution

$P_1 = P\,N\,m^{-2}, V_1 = 1m^3$,

$P_2 = 3\,P$, V_2 =?,

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{P\,x\,1}{-73+273} = \frac{3\,PxV_2}{27+273}$$

$V_2 = 0.5m^3$

2. A litre of gas at $0°C$ and $10^5\ Nm^{-2}$ pressure is suddenly compressed to $\frac{1}{4}$ of its volume and its temperature rises to 273°C. Calculate the resulting pressure of the gas.

Solution

$P_1 = 10^5\ Nm^{-2}, V_1 = 1\ l,$

$P_2 = ?\ ,\ V_2 = \frac{l}{4},$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{10^5\ x\ 1}{273} = \frac{P_2 x\ ^1/_4}{546}$$

$P_2 = 800000\ Nm^{-2}$

Note:

At standard temperature and pressure (s.t.p) a gas has an absolute temperature and normal pressure ie. T = 273 K, P = 76 cmHg

Example

1. 240 cm^3 of oxygen gas was collected when a temperature is 20℃ at a pressure of 50 cmHg. Calculate its volume at s.t.p.

Solution

$P_1 = 50\ cmHg, V_1 = 240\ cm^3,$

$P_2 = 76\ cmHg\ ,\ V_2 = ?,$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{50\ x\ 240}{20 + 273} = \frac{V_2\ x\ 76}{273}$$

$V_2 = 147.12\ cm^3$

2. The volume of hydrogen at 273℃ is 10 cm^3 at a pressure of 152 cmHg. What is its volume at s.t.p

Solution

$P_1 = 152cmHg, V_1 = 10\ cm^3,$

$P_2 = 76\ cmHg\ ,\ V_2 = ?,$

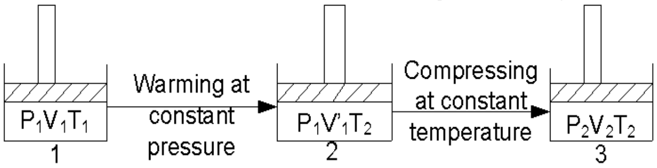
$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{152\ x\ 10}{273 + 273} = \frac{V_2\ x\ 76}{273}$$

$V_2 = 10\ cm^3$

Derivation of equation of state

Consider fixed mass of gas with pressure P_1, V_1 and temperature T_1 enclosed in piston cylinder system.



Moving from 1 to 2, Charles law applies

$$\frac{V_1}{T_1} = \frac{V_1'}{T_2}$$

$V_1' = V_1 \frac{T_2}{T_1}$ .... (1)

Moving from 2 to 3, Boyle's law apples

$P_1 V_1' = P_2 V_2$ .... (2)

Putting V_1 into equation (2)

$$P_1 V_1 \frac{T_2}{T_1} = P_2 V_2$$

$$\boxed{\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}}$$

$\frac{PV}{T}$ = Constant

PV= constant XT

$$PV = nRT$$

$$\boxed{PV = n\,R\,T}$$

This is an equation of state or ideal gas equation.

Where n= number of moles of gas

$$n = \frac{mass\ given\ (m)}{relative\ molecular\ mass(M)}$$

R= molar gas constant [8.31Jmol^{-1}k^{-1}]

To determine R, we consider the standard condition at $s.t.p$

Volume at $s.t.p$ = 22.4x10^{-3} m^3

Pressure at $s.t.p$ = 1.01325x10^{5}Nm^{-2}

$$PV = nRT$$

$$R = \frac{PV}{nT}$$

Temperature at $s.t.p$ =273K

Number of mole n = 1

$$R = \frac{1.01325x10^5\ x\ 22.4x10^{-3}}{1X273}$$

R= 8.31Jmol^{-1}K^{-1}

EXAMPLES

1) A gas is confined in the container of volume 0.1m^3 at pressure of 1.0x10^{5}Nm^{-2} And temperature of 300K. If the gas is found to be ideal gas, calculate the density of the gas [Rmm=32]

Solution

PV= nRT ∴n= $\frac{pv}{RT}$

n=$\frac{1.0x10^5x0.1}{8.31x300}$=

4.01moles

But n=$\frac{m}{M}$

4.01= $\frac{mass}{32x10^{-3}}$

Mass = 0.128kg

But $\rho = \frac{M}{V} = \frac{0.128}{0.1}$

$\rho = 1.28kg/m^{-3}$

2) Calculate the molecular mass of hydrogen of the density of hydrogen at s.t.p is $0.09kgm^{-3}$

Solution

$Pv = \frac{m}{M}RT \therefore M = \frac{mRT}{Pv}$ but $m = \rho v$

$M = \frac{\rho vRT}{Pv}$

$M = \frac{0.09x8.314x273}{1.013x10^5} = 2.02x10^{-3}kg$

Calculation involving loss of gas

1) Oxygen gas is contained in cylinder of volume $1x10^{-2}$ m^3 at temperature of 300K and pressure $2.5x0^5Nm^{-2}$. After some oxygen is used at constant temperature, pressure falls to $1.3x10^5$ Nm^{-2}. Calculate the mass of oxygen used.

Solution

$V_1 = 1x10^{-2}$ m^3

$T_1 = 300K$, $P_1 = 2.5x10^5Nm^{-2}$

$P_1V_1 = \frac{m}{M}RT_1 \quad \therefore m_1 = \frac{P_1V_1M}{RT_1}$

$m_1 = \frac{2.5x10^5x1x10^{-2}x32x10^{-3}}{8.31x300} = 0.032kg$

$m_2 = \frac{1.3x10^5x1x10^{-2}x32x10^{-3}}{8.31x300} = 0.0166kg$

Therefore mass of oxygen = $[m_1 - m_2]$ kg

= [0.032-0.0166] kg

= 0.0154 kg

2) A cylinder of gas has mass of gas 10kg and pressure of 8 atmospheres at 27°C when some gas is used in cold room at -3°C. The remaining gas in the cylinder at its temperature has a pressure of 6.4 atmospheres. Calculate the mass of the gas used.

Solution

$m_1 = 10kg \qquad m_2 = ?$

$P_1 = 8atm \qquad P_2 = 6.4atm$

$T_1 = 27+273 = 300K \qquad T_2 = (-3+273) = 270K$

$Pv = \frac{m}{M}RT \quad \therefore M = \frac{mRT}{PV}$

$M = \frac{10x\ 8.31x300}{8xv}$ ……… (1)

$M = \frac{m_2x8.31x270}{6.4xv}$ ……… (2)

Equating equation (1) to (2)

$\frac{10x8.31x300}{8V} = \frac{m_2x8.31x270}{6.4V}$

$m_2 = 8.89kg$

Therefore mass of gas = $m_1 - m_2$

= [10-8.89] kg

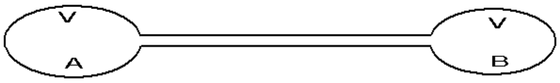
= 1.11kg

Connected containers

In closed containers the total number of molecules remains constant

1) Two glass bulbs of equal volume are joined by another tube and are filled with a gas at $s.t.p$. When one of the bulbs is kept in melting ice and another place in as hot bath the new pressure is 877.6mmHg. Calculate the temperature of bath

Solution



$P_A = 760mmHg \qquad P_B = 760mmHg$

$T_A = 273k \qquad T_B = 273K$

Since cylinders are enclosed, the number of moles is both cylinders before cooling will be the same after cooling (heating).

$n_A + n_B = n_A^1 + n_B^1$

$\frac{P_AV_A}{RT_A} + \frac{P_BV_B}{RT_B} = \frac{P'_AV'_A}{RT'_A} + \frac{P'_BV'_B}{RT'_B}$

$P'_A = P'_B = 877.6mmHg$

$T'_A = (0+273) = 273K \quad T'_B = ?$

$\frac{760xV}{8.31x273} + \frac{760xV}{8.31x273} = \frac{877.6xV}{8.31x273} + \frac{877.6xV}{8.31xT'_B}$

$\frac{642.4}{2268.63} = \frac{877.6}{8.31T'_B}$

$T'_B = 372.95K$

3) Two containers A and B of volume $3x10^3cm^3$ and $6x10^3cm^3$ respectively contain helium gas at a pressure of $1.0x10^3$ pa and temperature 300K. Container A is heated to 373K while container B is cooled 273K. Find the final pressure of the helium gas.

Solution

$V_A = 3x10^3cm^3 \qquad P_A = 1.0x10^3pa \qquad T_A = 300K \qquad V_B = 6x10^3cm^3$

$P_B = 1.0x10^3Pa \qquad T_B = 300K$

$T'_A = 373K \qquad T'_B = 273K$

$n_A + n_B = n_A^1 + n_B^1$

$\frac{P_AV_A}{RT_A} + \frac{P_BV_B}{RT_B} = \frac{P'_AV'_A}{RT'_A} + \frac{P'_BV'_B}{RT'_B}$

$$\frac{1.0x10^3x3x10^3}{8.31x300}+\frac{1.0x10^3x6x10^3}{8.31x300}=\frac{P_A'x3x10^3}{8.31x373}+\frac{P_B'x6x10^3}{8.31x273}$$

$P_A' = P_B'$=P

$$916461 = 2493\,(819000 + 2238000P)$$

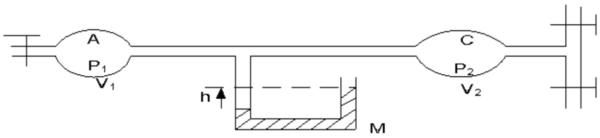
$$P = 999.3Pa$$

3.2: DALTONS LAW OF PARTIAL PRESSURE

It states that the total pressure of a mixture of gases that do not react chemically is the sum of partial pressure of the constituents

DEFINITION. Partial pressure of gas is the pressure the gas would exert if it was to occupy the whole container alone.

3.2.1: EXPERIMENT TO DEMONSTRATE DALTON'S LAW



- The apparatus above can be used to study the pressure of mixture of gases
- A is a bulb of volume V_1 containing air at atmospheric pressure P_1
- C is another bulb of volume V_2 containing carbon dioxide at atmospheric pressure P_2
- When the bulbs are connected by opening the taps, the gases mix and reach the same pressure P

$$P = \frac{P_1 \cdot V_1}{V_1+V_2} + \frac{P_2V_2}{V_1+V_2}$$

EXAMPLE

1) Two containers A and B of volume $3x10^3cm^3$ and $6x10^3cm^3$ respectively contain helium gas at pressure $1x10^3$Pa and temperature 300K. Container A is heated to 373Kwhile container B is cooled to 273K. Find the final pressure of the helium gas.

Solution

$$P = \frac{P_1 \cdot V_1}{V_1+V_2} + \frac{P_2V_2}{V_1+V_2}$$

$P_2 = P_1$

$$P = \frac{1x10^3x3x10^{-3}}{3x10^{-3}+6x10^{-3}} + \frac{1x10^3x6x10^{-3}}{3x10^{-3}+6x10^{-3}}$$

P= $1000Nm^{-2}$

2) Two bulbs A of volume $100cm^3$ and B of volume $50cm^3$ connected to freeway tap which enables them to be filled with gas or evacuated. Initially bulb A is filled with an ideal gas at 10°Cto pressure of $3.0x10^5$Pa. Bulb B is filled with an I deal gas at 100°C to a pressure of $1.0x10^5$Pa . Two bulbs and connected with A maintained at 10°C and B at 100°C .Calculate the pressure at equilibrium

Solution

$$P = \frac{P_A \cdot V_A}{V_A+V_B} + \frac{P_BV_B}{V_A+V_B}$$

$$P = \frac{3x10^5x100}{100+50} + \frac{1x10^5x50}{100+50}$$

P= $2.33x10^5$ Pa

Alternatively

$n_A + n_B = n_A^1 + n_B^1$

$$\frac{P_AV_A}{RT_A} + \frac{P_BV_B}{RT_B} = \frac{P_A'V_A'}{RT_A'} + \frac{P_B'V_B'}{RT_B'}$$

$$\left(\frac{3x10^5x100}{831x283}\right)+\left(\frac{1x10^5x50}{831x373}\right) = \frac{px100}{8.31x283} + \frac{px50}{8.31x373}$$

P = $2.33x10^5$ Pa

3) Two cylinder A and B of volume V and 3V respectively are separately filled with gas. The cylinders are connected with tap closed with pressure of gas A and B being P and 4P respectively. When tap is open, the common pressure becomes 60Pa. Find P

Solution

$$P = \frac{P_A \cdot V_A}{V_A+V_B} + \frac{P_BV_B}{V_A+V_B}$$

$$P = \frac{PxV}{V+3V} + \frac{4Px3V}{V+3V}$$

$$60 = \frac{PV}{V+3V} + \frac{4Px\,3V}{V+3V}$$

$$P = 18.46Pa$$

EXERCISE: 5