Thermometry, Thermal Expansion and Calorimetry

Temperature

Temperature is defined as the degree of hotness or coldness of a body. The natural flow of heat is from higher temperature to lower temperature.

Two bodies are said to be in thermal equilibrium with each other when no heat flows from one body to the other. That is when both the bodies are at the same temperature.

(1) Temperature is one of the seven fundamental quantities with dimension [θ]. It is a scalar physical quantity with S.I. unit Kelvin (K).

(2) When heat is given to a body and its state does not change, the temperature of the body rises and if heat is taken from a body its temperature falls, *i.e.*, temperature can be regarded as the effect of cause "heat".

(3) According to kinetic theory of gases, temperature (macroscopic physical quantity) is a measure of average translational kinetic energy of a molecule (microscopic physical quantity) *i.e* $T_k \propto (KE)_{molecule}$.

(4) Although the temperature of a body can be raised without limit, it cannot be lowered without limit and theoretically limiting low temperature is taken to be zero of the Kelvin scale.

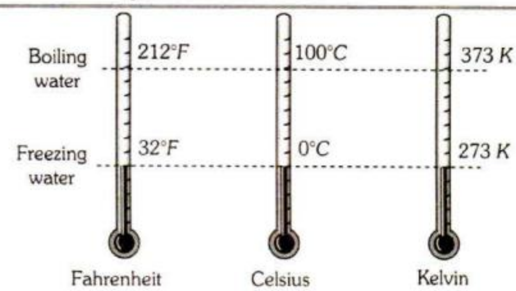
(5) Highest possible temperature achieved in laboratory is about $10^8 K$ while lowest possible temperature attained is $10^{-8} K$.

(6) Temperature of the core of the sun is $10^7 K$ while that of its surface is 6000 K.

(7) Normal temperature of human body is 310.15 K (37°C = 98.6°F).

(8) NTP or STP implies 273.15K (0°C = 32°F)

Scales of Temperature



The centigrade (°C), Fahrenheit (°F), Kelvin (K), Reaumer (R), Rankine (Ra) are commonly used temperature scales.

(1) To construct a scale of temperature, two fixed points are taken. First fixed point is the freezing point (ice point) of water, it is called lower fixed point (LFP). The second fixed point is the boiling point (steam point) of water, it is called upper fixed point (UFP).

(2) **Celsius scale :** In this scale LFP (ice point) is taken 0° and UFP (steam point) is taken 100°. The temperature measured on this scale all in degree Celsius (°C).

(3) **Fahrenheit scale :** This scale of temperature has LFP as 32°F and UFP as 212°F. The change in temperature of 1°F corresponds to a change of less than 1° on Celsius scale.

(4) **Kelvin scale :** The Kelvin temperature scale is also known as thermodynamic scale. The triple point of water is also selected to be the zero of scale of temperature. The temperature measured on this scale are in Kelvin (K).

The triple point of water is that point on a P-T diagram where the three phases of water; the solid, the liquid and the gas, can coexist in equilibrium.

Different measuring scales

Scale	Symbol for each degree	LFP	UFP	Number of divisions on the scale
Celsius	°C	0°C	100°C	100
Fahrenheit	°F	32°F	212°F	180
Reaumer	°R	0°R	80°R	80
Rankine	°Ra	460 Ra	672 Ra	212
Kelvin	K	273.15 K	373.15 K	100

(5) Temperature on one scale can be converted into other scale by using the following identity.

$$\frac{\text{Reading on any scale} - \text{LFP}}{\text{UFP} - \text{LFP}} = \text{Constant for all scales}$$

(6) All these temperatures are related to each other by the following relationship

$$\frac{C-0}{100} = \frac{F-32}{212-32} = \frac{K-273.15}{373.15-273.15} = \frac{R-0}{80-0} = \frac{Ra-460}{672-460}$$

$$\text{or } \frac{C}{5} = \frac{F-32}{9} = \frac{K-273}{5} = \frac{R}{4} = \frac{Ra-460}{10.6}$$

(7) The Celsius and Kelvin scales have different zero points but the same size degrees. Therefore any temperature difference is the same on the Celsius and Kelvin scales $(T_2 - T_1)°C = (T_2 - T_1)\,K$.

Thermometry

A branch of science which deals with the measurement of temperature of a substance is known as thermometry.

(1) The linear variation in some physical properties of a substance with change of temperature is the basic principle of thermometry and these properties are defined as thermometric properties (x) of the substance.

(2) Thermometric properties (x) may be as follows :

(i) Length of liquid in capillary

(ii) Pressure of gas at constant volume.

(iii) Volume of gas at constant pressure.

(iv) Resistance of a given platinum wire.

(3) In old thermometry, freezing point (0°C) and steam point (100°C) are taken to define the temperature scale. So if the thermometric property at temperature 0°C, 100°C and t°C are x_0, x_{100} and x respectively then

$$\frac{t-0}{100-0} = \frac{x-x_0}{x_{100}-x_0} \Rightarrow t°C = \frac{x-x_0}{x_{100}-x_0} \times 100°C$$

(4) In modern thermometry instead of two fixed points only one reference point is chosen (triple point of water 273.16 K) the other is itself 0 K where the value of thermometric property is assumed to be zero.

So if the value of thermometric property at 0 K, 273.16 K and TK are 0, x_{Tr} and x respectively then

$$\frac{T}{273.16} = \frac{x}{x_{Tr}} \Rightarrow T = 273.16\left[\frac{x}{x_{Tr}}\right]K$$

Thermometers

An instrument used to measure the temperature of a body is called a thermometer.

It works by absorbing some heat from the body, so the temperature recorded by it is lesser than the actual value unless the body is at constant temperature. Some common types of thermometers are as follows :

(1) **Liquid (mercury) thermometers :** In liquid thermometers mercury is preferred over other liquids as its expansion is large and uniform and it has high thermal conductivity and low specific heat.

(i) Range of temperature : $\underset{\text{(freezing point)}}{-50°C}$ to $\underset{\text{(boiling point)}}{350°C}$

(ii) Upper limit of range of mercury thermometer can be raised upto 550°C by filling nitrogen in space over mercury under pressure (which elevates boiling point of mercury).

(iii) Mercury thermometer with cylindrical bulbs are more sensitive than those with spherical bulbs.

(iv) If alcohol is used instead of mercury then range of temperature measurement becomes – 80°C to 350°C

(v) Formula : $t = \dfrac{l-l_0}{l_{100}-l_0} \times 100°C$

(2) **Gas thermometers :** These are more sensitive and accurate than liquid thermometers as expansion of gases is more than that of liquids. The thermometers using a gas as thermometric substance are called ideal gas thermometers. These are of two types.

(i) **Constant pressure gas thermometers**

(a) Principle : $V \propto T$ (if P = constant)

(b) Formula : $t = \frac{V - V_0}{V_{100} - V_0} \times 100°C$ or $T = 273.16 \frac{V}{V_{Tr}} K$

(ii) **Constant volume gas thermometers**

(a) Principle $P \propto T$ (if V = constant)

(b) Formula : $t = \frac{P - P_0}{P_{100} - P_0} \times 100°C$ or $T = 273.16 \frac{P}{P_{Tr}} K$

(c) Range of temperature :

Hydrogen gas thermometer : – 200°C to 500°C

Nitrogen gas thermometer : – 200°C to 1600°C

Helium gas thermometer : – 268°C to 500°C

(3) **Resistance thermometers :** Usually platinum is used in resistance thermometers due to high melting point and large value of temperature coefficient of resistance.

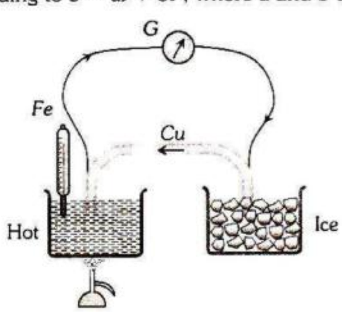
Resistance of metals varies with temperature according to relation $R = R_0(1 + \alpha t)$ where α is the temperature coefficient of resistance and t is change in temperature.

(i) Formula : $t = \frac{R - R_0}{R_{100} - R_0} \times 100°C$ or $T = 273.16 \frac{R}{R_{Tr}} K$

(ii) Temperature range : For Platinum resistance thermometer it is – 200°C to 1200°C

For Germanium resistance thermometer it is 4 to 77 K.

(4) **Thermoelectric thermometers :** These are based on "Seebeck effect" according to which when two distinct metals are joined to form a closed circuit called thermocouple and the difference in temperature is maintained between their junctions, an emf is developed. The emf is called thermo-emf and if one junction is at 0°C, thermoelectric emf varies with temperature of hot junction (t) according to $e = at + bt^2$; where a and b are constants.

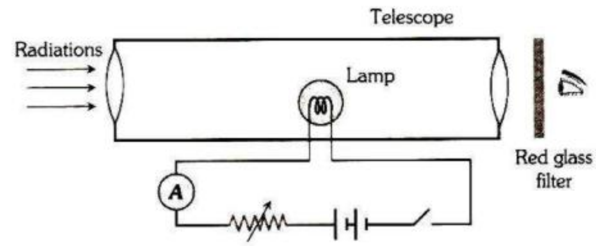


Thermoelectric thermometers have low thermal capacity and high thermal conductivity, so can be used to measure quickly changing temperature

Different temperature range

Thermo couple	Temperature range
Copper-iron thermocouple	0°C to 260°C
Iron-constantan thermocouple	0°C to 800°C
Tungsten-molybdenum thermocouple	2000°C to 3000°C

(5) **Pyrometers :** These are the devices used to measure the temperature by measuring the intensity of radiations received from the body. They are based on the fact that the amount of radiations emitted from a body per unit area per second is directly proportional to the fourth power of temperature (Stefan's law).



(i) These can be used to measure temperatures ranging from 800°C to 6000°C.

(ii) They cannot measure temperature below 800°C because the amount of radiations is too small to be measured.

(6) **Vapour pressure thermometer :** These are used to measure very low temperatures. They are based on the fact that saturated vapour pressure P of a liquid depends on the temperature according to the relation $\log P = a + bT + \frac{c}{T}$

The range of these thermometers varies from 0.71 K to 120 K for different liquid vapours.

Thermal Expansion

When matter is heated without any change in it's state, it usually expands. According to atomic theory of matter, a symmetry in potential energy curve is responsible for thermal expansion. As with rise in temperature the amplitude of vibration and hence energy of atoms increases, hence the average distance between the atoms increases. So the matter as a whole expands.

(1) Thermal expansion is minimum in case of solids but maximum in case of gases because intermolecular force is maximum in solids but minimum in gases.

(2) Solids can expand in one dimension (linear expansion), two dimensions (superficial expansion) and three dimensions (volume expansion) while liquids and gases usually suffer change in volume only.

(3) **Linear expansion :** When a solid is heated and it's length increases, then the expansion is called linear expansion.

(A) Before heating **(B)** After heating

(i) Change in length $\Delta L = L_0 \alpha \Delta T$

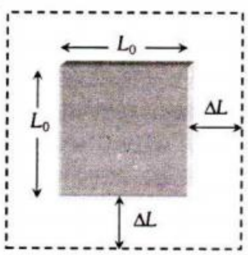
(L_0 = Original length, ΔT = Temperature change)

(ii) Final length $L = L_0 (1 + \alpha \Delta T)$

(iii) Co-efficient of linear expansion $\alpha = \dfrac{\Delta L}{L_0 \Delta T}$

(iv) Unit of α is $°C^{-1}$ or K^{-1}. It's dimension is $[\theta^{-1}]$

(4) **Superficial (aerial) expansion :** When the temperature of a 2D object is changed, it's area changes, then the expansion is called superficial expansion.



(i) Change in area is $\Delta A = A_0 \beta \Delta T$

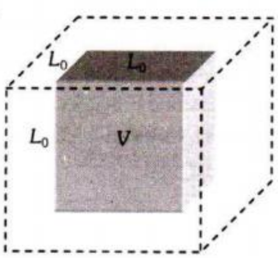
(A_0 = Original area, ΔT = Temperature change)

(ii) Final area $A = A_0(1 + \beta \Delta T)$

(iii) Co-efficient of superficial expansion $\beta = \dfrac{\Delta A}{A_0 \Delta T}$

(iv) Unit of β is $°C^{-1}$ or K^{-1}.

(5) **Volume or cubical expansion :** When a solid is heated and it's volume increases, then the expansion is called volume or cubical expansion.



(i) Change in volume is $\Delta V = V_0 \gamma \Delta T$

(V_0 = Original volume, ΔT = change in temperature)

(ii) Final volume $V = V_0(1 + \gamma \Delta T)$

(iii) Volume co-efficient of expansion $\gamma = \dfrac{\Delta V}{V_0 \Delta T}$

(iv) Unit of γ is $°C^{-1}$ or K^{-1}.

(6) **More about α, β and γ:** The co-efficients α, β and γ for a solid are related to each other as follows

$$\alpha = \frac{\beta}{2} = \frac{\gamma}{3} \Rightarrow \alpha : \beta : \gamma = 1 : 2 : 3$$

(i) Hence for the same rise in temperature

Percentage change in area = 2 × percentage change in length.

Percentage change in volume = 3 × percentage change in length.

(ii) The three coefficients of expansion are not constant for a given solid. Their values depend on the temperature range in which they are measured.

(iii) The values of α, β, γ are independent of the units of length, area and volume respectively.

(iv) For anisotropic solids $\gamma = \alpha_x + \alpha_y + \alpha_z$ where α_x, α_y, and α_z represent the mean coefficients of linear expansion along three mutually perpendicular directions.

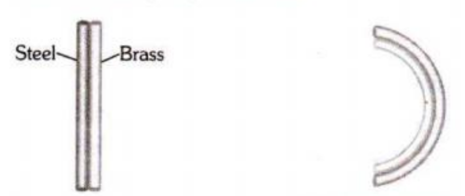
(7) **Contraction on heating :** Some rubber like substances contract with rising temperature, because transverse vibration of atoms of substance dominate over longitudinal vibration which is responsible for expansion.

α and γ for some materials

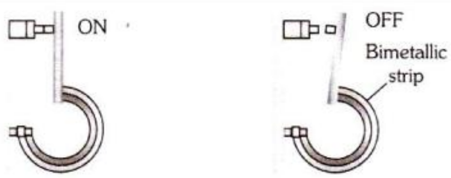
Material	α[K^{-1} or $(°C)^{-1}$]	γ[K^{-1} or $(°C)^{-1}$]
Steel	1.2×10^{-5}	3.6×10^{-5}
Copper	1.7×10^{-5}	5.1×10^{-5}
Brass	2.0×10^{-5}	6.0×10^{-5}
Aluminium	2.4×10^{-5}	7.2×10^{-5}

Application of Thermal Expansion in Solids

(1) **Bi-metallic strip :** Two strips of equal lengths but of different materials (different coefficient of linear expansion) when joined together, is called "bi-metallic strip", and can be used in thermostat to break or make electrical contact. This strip has the characteristic property of bending on heating due to unequal linear expansion of the two metals. The strip will bend with metal of greater α on outer side, *i.e.*, convex side.



Room temperature **(A)** Higher temperature **(B)**



At room temperature **(C)** At high temperature **(D)**

Fig. 12.7

(2) **Effect of temperature on the time period of a simple pendulum :** A pendulum clock keeps proper time at temperature θ. If temperature is increased to $\theta'(>\theta)$ then due to linear expansion, length of pendulum and hence its time period will increase.

Fractional change in time period $\frac{\Delta T}{T} = \frac{1}{2}\alpha\Delta\theta$

(i) Due to increment in its time period, a pendulum clock becomes slow in summer and will lose time.

Loss of time in a time period $\Delta T = \frac{1}{2}\alpha\ \Delta\theta\ T$

(ii) Time lost by the clock in a day (t = 86400 s)

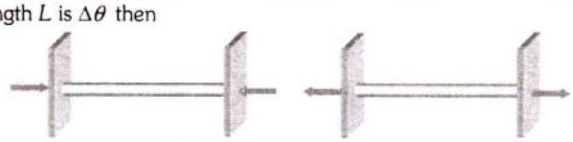
$$\Delta t = \frac{1}{2}\alpha\ \Delta\theta\ t = \frac{1}{2}\alpha\ \Delta\theta\ (86400) = 43200\alpha\ \Delta\theta\ s$$

(iii) The clock will lose time *i.e.* will become slow if $\theta' > \theta$ (in summer) and will gain time *i.e.* will become fast if $\theta' < \theta$ (in winter).

(iv) The gain or loss in time is independent of time period T and depends on the time interval t.

(v) Since coefficient of linear expansion (α) is very small for invar, hence pendulums are made of invar to show the correct time in all seasons.

(3) **Thermal stress in a rigidly fixed rod :** When a rod whose ends are rigidly fixed such as to prevent expansion or contraction, undergoes a change in temperature, due to thermal expansion or contraction, a compressive or tensile stress is developed in it. Due to this thermal stress the rod will exert a large force on the supports. If the change in temperature of a rod of length L is $\Delta\theta$ then



(A) Heating **(B)** Cooling

Fig. 12.8

Thermal strain $= \frac{\Delta L}{L} = \alpha\Delta\theta$ $\left[\text{As } \alpha = \frac{\Delta L}{L} \times \frac{1}{\Delta\theta}\right]$

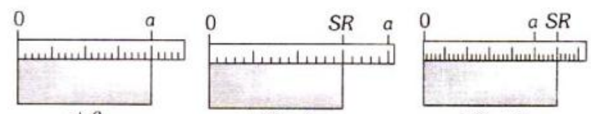
So Thermal stress $= Y\alpha\Delta\theta$ $\left[\text{As } Y = \frac{\text{stress}}{\text{strain}}\right]$

or Force on the supports $F = YA\alpha\,\Delta\theta$

(4) **Error in scale reading due to expansion or contraction :** If a scale gives correct reading at temperature θ, at temperature $\theta'(>\theta)$ due to linear expansion of scale, the scale will expand and scale reading will be lesser than true value so that,

True value = Scale reading $[1 + \alpha(\theta' - \theta)]$

i.e. TV $= SR[1 + \alpha\,\Delta\theta]$ with $\Delta\theta = (\theta' - \theta)$

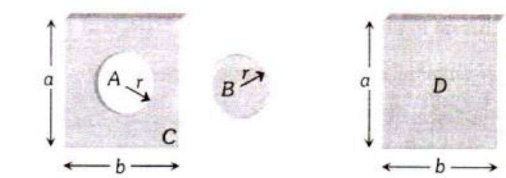


at θ $TV = SR$ at $\theta' > \theta$ $TV > SR$ at $\theta' < \theta$ $TV < SR$

Fig. 12.9

However, if $\theta' < \theta$, due to contraction of scale, scale reading will be more than true value, so true value will be lesser than scale reading and will still be given by above equation with $\Delta\theta = (\theta' - \theta)$ negative.

(5) **Expansion of cavity :** Thermal expansion of an isotropic object may be imagined as a photographic enlargement. So if there is a hole A in a plate C (or cavity A inside a body C), the area of hole (or volume of cavity) will increase when body expands on heating, just as if the hole (or cavity) were solid B of the same material. Also the expansion of area (or volume) of the body C will be independent of shape and size of hole (or cavity), *i.e.*, will be equal to that of D.



Expansion of A = Expansion of B Expansion of C = Expansion of D

Fig. 12.10

(6) **Some other applications**

(i) When rails are laid down on the ground, space is left between the ends of two rails.

(ii) The transmission cable are not tightly fixed to the poles.

(iii) Test tubes, beakers and crucibles are made of pyrex-glass or silica because they have very low value of coefficient of linear expansion.

(iv) The iron rim to be put on a cart wheel is always of slightly smaller diameter than that of wheel.

(v) A glass stopper jammed in the neck of a glass bottle can be taken out by warming the neck of the bottle

Thermal Expansion in Liquids

(1) Liquids do not have linear and superficial expansion but these only have volume expansion.

(2) Since liquids are always to be heated along with a vessel which contains them so initially on heating the system (liquid + vessel), the level of liquid in vessel falls (as vessel expands more since it absorbs heat and liquid expands less) but later on, it starts rising due to faster expansion of the liquid.

$PQ \rightarrow$ represents expansion of vessel

$QR \rightarrow$ represents the real expansion of liquid

$PR \rightarrow$ represent the apparent expansion of liquid

Fig. 12.11

(3) The actual increase in the volume of the liquid = The apparent increase in the volume of liquid + the increase in the volume of the vessel.

(4) Liquids have two coefficients of volume expansion.

(i) **Co-efficient of apparent expansion (γ_a) :** It is due to apparent (that appears to be, but is not) increase in the volume of liquid if expansion of vessel containing the liquid is not taken into account.

$$\gamma_a = \frac{\text{Apparent expansion in volume}}{\text{Initial volume} \times \Delta\theta} = \frac{(\Delta V)_a}{V \times \Delta\theta}$$

(ii) **Co-efficient of real expansion (γ_r) :** It is due to the actual increase in volume of liquid due to heating.

$$\gamma_r = \frac{\text{Real increase in volume}}{\text{Initial volume} \times \Delta\theta} = \frac{(\Delta V)_r}{V \times \Delta\theta}$$

(iii) Also coefficient of expansion of flask $\gamma_{Vessel} = \frac{(\Delta V)_{Vessel}}{V \times \Delta\theta}$

(iv) $\gamma_{Real} = \gamma_{Apparent} + \gamma_{Vessel}$

(v) Change (apparent change) in volume in liquid relative to vessel is

$$\Delta V_{app} = V\,\gamma_{app}\,\Delta\theta = V(\gamma_{Real} - \gamma_{Vessel})\Delta\theta = V(\gamma_r - 3\alpha)\Delta\theta$$

α = Coefficient of linear expansion of the vessel.

Table 12.4 : Different levels of liquid in vessel

γ	ΔV	Level
$\gamma_{Real} > \gamma_{Vessel} (=3\alpha) \Rightarrow \gamma_{app} > 0$	ΔV_{app} is positive	Level of liquid in vessel will rise on heating.
$\gamma_{Real} < \gamma_{Vessel} (=3\alpha) \Rightarrow \gamma_{app} < 0$	ΔV_{app} is negative	Level of liquid in vessel will fall on heating.
$\gamma_{Real} = \gamma_{Vessel} (=3\alpha) \Rightarrow \gamma_{app} = 0$	$\Delta V_{app} = 0$	level of liquid in vessel will remain same.

(5) **Anomalous expansion of water :** Generally matter expands on heating and contracts on cooling. In case of water, it expands on heating if its temperature is greater than 4°C. In the range 0°C to 4°C, water contracts on heating and expands on cooling, *i.e.* γ is negative. This behaviour of water in the range from 0°C to 4°C is called anomalous expansion.

This anomalous behaviour of water causes ice to form first at the surface of a lake in cold weather. As winter approaches, the water temperature increases initially at the surface. The water there sinks because of its increased density. Consequently, the surface reaches 0°C first and the lake becomes covered with ice. Aquatic life is able to survive the cold winter as the lake bottom remains unfrozen at a temperature of about 4°C.

At 4°C, density of water is maximum while its specific volume is minimum.

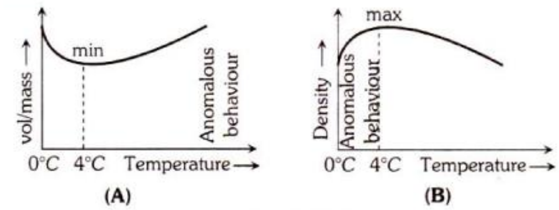


Fig. 12.12

(6) **Effect of temperature on upthrust :** The thrust on V volume of a body in a liquid of density σ is given by $Th = V\sigma g$

Now with rise in temperature by $\Delta\theta$ °C, due to expansion, volume of the body will increase while density of liquid will decrease according to the relations $V' = V(1 + \gamma_S \Delta\theta)$ and $\sigma' = \sigma/(1 + \gamma_L \Delta\theta)$

So the thrust $Th' = V'\sigma' g \Rightarrow \frac{Th'}{Th} = \frac{V'\sigma' g}{V\sigma g} = \frac{(1+\gamma_S \Delta\theta)}{(1+\gamma_L \Delta\theta)}$

and apparent weight of the body W_{app} = Actual weight–Thrust

As $\gamma_S < \gamma_L \therefore Th' < Th$ with rise in temperature thrust also decreases and apparent weight of body increases.

Variation of Density with Temperature

Most substances (solid and liquid) expand when they are heated, *i.e.*, volume of a given mass of a substance increases on heating, so the density should decrease $\left(\text{as } \rho \propto \frac{1}{V}\right)$. For a given mass $\rho \propto \frac{1}{V} \Rightarrow \frac{\rho'}{\rho} = \frac{V}{V'} = \frac{V}{V + \Delta V} = \frac{V}{V + \gamma V \Delta\theta} = \frac{1}{1 + \gamma\Delta\theta}$

$$\Rightarrow \rho' = \frac{\rho}{1 + \gamma\Delta\theta} = \rho(1 + \gamma\Delta\theta)^{-1} = \rho(1 - \gamma\Delta\theta)$$

Expansion of Gases

Gases have no definite shape, therefore gases have only volume expansion. Since the expansion of container is negligible in comparison to the gases, therefore gases have only real expansion.

(1) **Coefficient of volume expansion :** At constant pressure, the unit volume of a given mass of a gas, increases with 1°C rise of temperature, is called coefficient of volume expansion.

$$\alpha = \frac{\Delta V}{V_0} \times \frac{1}{\Delta \theta} \Rightarrow \text{Final volume } V' = V(1 + \alpha \Delta \theta)$$

(2) **Coefficient of pressure expansion :** $\beta = \frac{\Delta P}{P} \times \frac{1}{\Delta \theta}$

$\therefore$ Final pressure $P' = P(1 + \beta \Delta \theta)$

For an ideal gas, coefficient of volume expansion is equal to the coefficient of pressure expansion, *i.e.*, $\alpha = \beta = \frac{1}{273} {}^\circ C^{-1}$

Heat

(1) The form of energy which is exchanged among various bodies or system on account of temperature difference is defined as heat.

(2) We can change the temperature of a body by giving heat (temperature rises) or by removing heat (temperature falls) from body.

(3) The amount of heat (Q) given to a body depends upon it's mass (m), change in it's temperature ($\Delta\theta^\circ = \Delta\theta$) and nature of material, *i.e.*, $Q = m.c.\Delta\theta$; where c = specific heat of material.

(4) Heat is a scalar quantity. It's units are *joule, erg, cal, kcal etc.*

(5) The calorie (*cal*) is defined as the amount of heat required to raise the temperature of 1 *gm* of water from 14.5°C to 15.5°C.

Also 1 *kcal* = 1000 *cal* = 4186 *J* and 1 *cal* = 4.18 *J*

(6) **British Thermal Unit (BTU) :** One BTU is the quantity of heat required to raise the temperature of one pound (1 *lb*) of water from 63°F to 64°F

1 *BTU* = 778 *ft. lb* = 252 *cal* = 1055 *J*

(7) In solids thermal energy is present in the form of kinetic energy, in liquids, in the form of translatory energy of molecules. In gas it is due to the random motion of molecules.

(8) Heat always flows from a body of higher temperature to lower temperature till their temperature becomes equal (Thermal equilibrium).

(9) The heat required for a given temperature increase depends only on how many atoms the sample contains, not on the mass of an individual atom.

Specific Heat

When a body is heated it's temperature rises (except during a change in phase).

(1) **Gram specific heat :** The amount of heat energy required to raise the temperature of unit mass of a body through 1°C (or *K*) is called specific heat of the material of the body.

If Q heat changes the temperature of mass m by $\Delta\theta$ then specific heat $c = \frac{Q}{m\Delta\theta}$

(i) Units : *Calorie/gm* × °C (practical), *J/kg* × *K* (S.I.) Dimension : $[L^2T^{-2}\theta^{-1}]$

(ii) For an infinitely small temperature change $d\theta$ and corresponding quantity of heat dQ,

Specific heat $c = \frac{1}{m} \cdot \frac{dQ}{d\theta}$

(2) **Molar specific heat :** Molar specific heat of a substance is defined as the amount of heat required to raise the temperature of one gram mole of the substance through a unit degree, it is represented by (capital) C.

Molar specific heat (C) = $M \times$ Gram specific heat (c)

(M = Molecular mass of substance)

$$C = M\frac{Q}{m\Delta\theta} = \frac{1}{\mu}\frac{Q}{\Delta\theta} \quad \left(\text{where, Number of moles } \mu = \frac{m}{M}\right)$$

Units : *calorie/mole* × °C (practical); *J/mole* × *kelvin* (S.I.) Dimension : $[ML^2T^{-2}\theta^{-1}]$

Specific Heat of Solids

When a solid is heated through a small range of temperature, its volume remains more or less constant. Therefore specific heat of a solid may be called its specific heat at constant volume C_V.

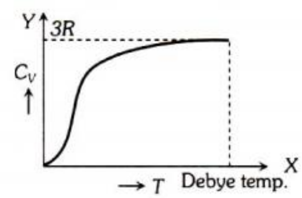


Fig. 12.13

(1) From the graph it is clear that at $T = 0$, C_V tends to zero

(2) With rise in temperature, C_V increases and at a particular temperature (called Debye's temperature) it becomes constant = $3R$ = 6 *cal/mole* × *kelvin* = 25 *J/mole* × *kelvin*

(3) For most of the solids, Debye temperature is close to room temperature.

(4) **Dulong and Petite law :** Average molar specific heat of all metals at room temperature is constant, being nearly equal to $3R$ = 6 *cal. mole*$^{-1}$ K^{-1} = 25 *J mole*$^{-1}$ K^{-1}, where R is gas constant for one mole of the gas. This statement is known as Dulong and Petite law.

(5) **Debye's law :** It was observed that at very low temperature molar specific heat $\propto T^3$ (exception are *Sn*, *Pb* and *Pt*)

(6) **Specific heat of ice :** In C.G.S. $c_{ice} = 0.5 \frac{cal}{gm \times {}^\circ C}$

In S.I. $c_{ice} = 500 \frac{cal}{kg \times {}^\circ C} = 2100 \frac{Joule}{kg \times {}^\circ C}$.

Specific heat of some solids at room temperature and atmospheric pressure

Substance	Specific heat ($J\text{-}kg^{-1}\,K^{-1}$)	Molar specific heat ($J\text{-}g\ mole^{-1}\,K^{-1}$)
Aluminium	900.0	24.4
Copper	386.4	24.5
Silver	236.1	25.5
Tungsten	134.4	24.9
Lead	127.7	26.5

Specific Heat of Liquid (Water)

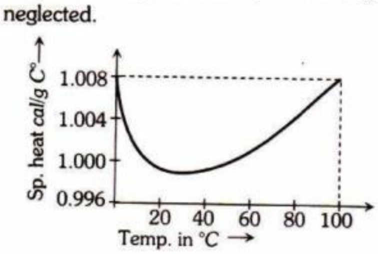
(1) Among all known solids and liquids specific heat of water is maximum, *i.e.*, water takes more time to heat and more time to cool *w.r.t.* other solids and liquids.

(2) It is observed that by increasing temperature, initially specific heat of water goes on decreasing, becomes minimum at 37°C and then it start increasing. Specific heat of water is –

$$\frac{1\,cal}{gm\times{}^\circ C}=1000\frac{cal}{kg\times{}^\circ C}=4200\frac{J}{kg\times{}^\circ C}$$

(This value is obtained between the temperatures 14.5°C to 15.5°C)

(3) The variation of specific heat with temperature for water is shown in the figure. Usually this temperature dependence of specific heat is neglected.



(4) As specific heat of water is very large; by absorbing or releasing large amount of heat its temperature changes by small amount. This is why, it is used in hot water bottles or as coolant in radiators.

Specific Heat of Gases

(1) In case of gases, heat energy supplied to a gas is spent not only in raising the temperature of the gas but also in expansion of gas against atmospheric pressure.

(2) Hence specific heat of a gas, which is the amount of heat energy required to raise the temperature of one gram of gas through a unit degree shall not have a single or unique value.

(3) If the gas is compressed suddenly and no heat is supplied from outside, *i.e.*, $\Delta Q = 0$, but the temperature of the gas raises on the account of compression.

$$\Rightarrow\ c=\frac{Q}{m(\Delta\theta)}=\frac{0}{m\Delta\theta}=0$$

(4) If the gas is heated and allowed to expand at such a rate that rise in temperature due to heat supplied is exactly equal to fall in temperature due to expansion of the gas, *i.e.*, $\Delta\theta = 0$

$$\Rightarrow\ c=\frac{Q}{m(\Delta\theta)}=\frac{Q}{0}=\infty$$

(5) If rate of expansion of the gas was slow, the fall in temperature of the gas due to expansion would be smaller than the rise in temperature of the gas due to heat supplied. Therefore, there will be some net rise in temperature of the gas, *i.e.*, ΔT will be positive.

$$\Rightarrow\ c=\frac{Q}{m(\Delta\theta)}=\text{Positive}$$

(6) If the gas were to expand very fast, fall of temperature of gas due to expansion would be greater than rise in temperature due to heat supplied. Therefore, there will be some net fall in temperature of the gas, *i.e.*, $\Delta\theta$ will be negative.

$$\Rightarrow\ c=\frac{Q}{m(-\Delta\theta)}=\text{Negative}$$

Hence the specific heat of gas can have any positive value ranging from zero to infinity. Further it can even be negative. The exact value depends upon the mode of heating the gas. Out of many values of specific heat of a gas, two are of special significance, namely C_P and C_V, in the chapter "Kinetic theory of gases" we will discuss this topic in detail.

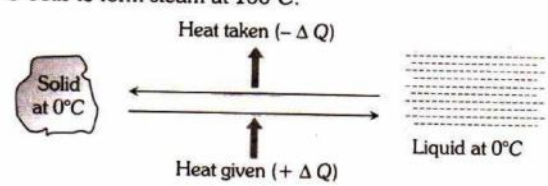
Specific heat of steam : $c_{steam} = 0.47\,cal/gm\times{}^\circ C$

Phase Change and Latent Heat

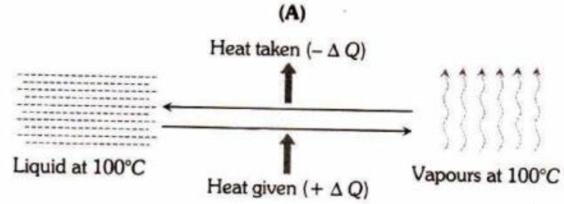
(1) **Phase :** We use the term phase to describe a specific state of matter, such as solid, liquid or gas. A transition from one phase to another is called a phase change.

(i) For any given pressure a phase change takes place at a definite temperature, usually accompanied by absorption or emission of heat and a change of volume and density.

(ii) In phase change ice at 0°C melts into water at 0°C. Water at 100°C boils to form steam at 100°C.



(A)



(B)

(iii) In solids, the forces between the molecules are large and the molecules are almost fixed in their positions inside the solid. In a liquid, the forces between the molecules are weaker and the molecules may move freely inside the volume of the liquid. However, they are not able to come out of the surface. In vapours or gases, the intermolecular forces are almost negligible and the molecules may move freely anywhere in the container. When a solid melts, its molecules move apart against the strong molecular attraction. This needs energy which must be supplied from outside. Thus, the internal energy of a given body is larger in liquid phase than in solid phase. Similarly, the internal energy of a given body in vapour phase is larger than that in liquid phase.

(iv) In case of change of state if the molecules come closer, energy is released and if the molecules move apart, energy is absorbed.

(2) **Latent heat :** The amount of heat required to change the state of the mass m of the substance while its temperature remaining constant is written as : $Q = mL$, where L is the latent heat. Latent heat is also called as Heat of Transformation. It's unit is *cal/gm* or *J/kg* and Dimension: $[L^2T^{-2}]$

(i) **Latent heat of fusion :** The latent heat of fusion of a substance is the quantity of heat required to change unit mass of the solid substance from solid state to liquid state, while temperature remaining constant.

In case of ice the latent heat of fusion of ice is 80 *cal/gm*.

(ii) **Latent heat of vaporisation :** The latent heat of vaporisation of a substance is the quantity of heat required to change unit mass of liquid substance into vapour state while temperature remaining constant.

In case of water the latent heat of vaporisation is 536 *cal/gm*.

(iii) Latent heat of vaporisation is more than the latent heat of fusion. This is because when a substance gets converted from liquid to vapour, there is a large increase in volume. Hence more amount of heat is required. But when a solid gets converted to a liquid, then the increase in volume is negligible. Hence very less amount of heat is required.

Thermal Capacity and Water Equivalent

(1) **Thermal capacity :** It is defined as the amount of heat required to raise the temperature of the whole body (mass m) through 1°C or 1K.

$$\text{Thermal capacity} = mc = \mu C = \frac{Q}{\Delta\theta}$$

The value of thermal capacity of a body depends upon the nature of the body and its mass.

Dimension : $[ML^2T^{-2}\theta^{-1}]$, Unit : *cal/°C* (practical) *Joule/K* (S.I.)

(2) **Water Equivalent :** Water equivalent of a body is defined as the mass of water which would absorb or evolve the same amount of heat as is done by the body in rising or falling through the same range of temperature. It is represented by W.

If m = Mass of the body, c = Specific heat of body, $\Delta\theta$ = Rise in temperature.

Then heat given to body $\Delta Q = mc\Delta\theta$ ..... (i)

If same amount of heat is given to W *gm* of water and its temperature also rises by $\Delta\theta$, then

heat given to water $Q = W\times 1\times\Delta\theta$ ... (ii) [As $c_{water} = 1$]

From equation (i) and (ii) $\Delta Q = mc\Delta\theta = W\times 1\times\Delta\theta$

$\Rightarrow$ Water equivalent (W) = mc *gm*

(i) Unit : Kg (S.I.) Dimension : $[ML^0T^0]$

(ii) Unit of thermal capacity is *J/kg* while unit of water equivalent is *kg*.

(iii) Thermal capacity of the body and its water equivalent are numerically equal.

(iv) If thermal capacity of a body is expressed in terms of mass of water it is called water-equivalent of the body.

Some Important Terms

(1) **Evaporation :** Vaporisation occurring from the free surface of a liquid is called evaporation. Evaporation is the escape of molecules from the surface of a liquid. This process takes place at all temperatures and increases with the increase of temperature. Evaporation leads to cooling because the faster molecules escape and, therefore, the average kinetic energy of the molecules of the liquid (and hence the temperature) decreases.

(2) **Melting (or fusion)/freezing (or solidification) :** The phase change of solid to liquid is called melting or fusion. The reverse phenomenon is called freezing or solidification.

When pressure is applied on ice, it melts. As soon as the pressure is removed, it freezes again. This phenomenon is called **regelation**.

(3) **Vaporisation/liquefication (condensation) :** The phase change from liquid to vapour is called vaporisation. The reverse transition is called liquefication or condensation.

(4) **Sublimation :** Sublimation is the conversion of a solid directly into vapours. Sublimation takes place when boiling point is less than the melting point. A block of ice sublimates into vapours on the surface of moon because of very very low pressure on its surface. Heat required to change unit mass of solid directly into vapours at a given temperature is called heat of sublimation at that temperature.

(5) **Hoar frost :** Direct conversion of vapours into solid is called hoar frost. This process is just reverse of the process of sublimation, *e.g.*, formation of snow by freezing of clouds.

(6) **Vapour pressure :** When the space above a liquid is closed, it soon becomes saturated with vapour and a dynamic equilibrium is established. The pressure exerted by this vapour is called Saturated Vapour Pressure (S.V.P.) whose value depends only on the temperature – it is independent of any external pressure. If the volume of the space is reduced, some vapour liquefies, but the pressure is unchanged.

A saturated vapour does not obey the gas law whereas the unsaturated vapour obeys them fairly well. However, a vapour differs from a gas in that the former can be liquefied by pressure alone, whereas the latter cannot be liquefied unless it is first cooled.

(7) **Boiling :** As the temperature of a liquid is increased, the rate of evaporation also increases. A stage is reached when bubbles of vapour start forming in the body of the liquid which rise to the surface and escape. A liquid boils at a temperature at which the S.V.P. is equal to the external pressure.

It is a fast process. The boiling point changes on mixing impurities.

(8) **Dew point :** It is that temperature at which the mass of water vapour present in a given volume of air is just sufficient to saturate it, *i.e.*, the temperature at which the actual vapour pressure becomes equal to the saturated vapour pressure.

(9) **Humidity :** Atmospheric air always contains some water vapour. The mass of water vapour per unit volume is called absolute humidity.

The ratio of the mass of water vapour (m) actually present in a given volume of air to the mass of water vapour (M) required to saturate the same volume at the same temperature is called the relative humidity (R.H.). Generally, it is expressed as a percentage,

i.e., $R.H.(\%) = \frac{m}{M} \times 100(\%)$

R.H. may also be defined as the ratio of the actual vapour pressure (p) of water at the same temperature, *i.e.*,

$R.H.(\%) = \frac{p}{P} \times 100(\%)$

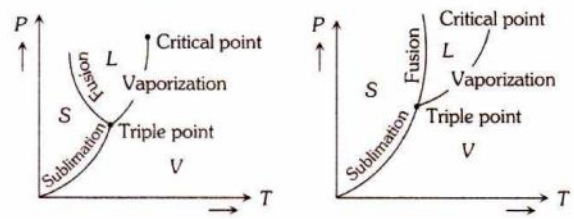
Thus R.H. may also be defined as

$$R.H.(\%) = \frac{\text{S.V.P. at dew point}}{\text{S.V.P. at given temperature}} \times 100$$

(10) **Variation of melting point with pressure :** For those substances which contract on melting (*e.g.* water and rubber), the melting point decreases with pressure. The reason is the pressure helps shrinking and hence melting. Most substances expand on melting. (*e.g.* max, sulphur *etc.*)

An increase of pressure opposes the melting of such substances and their melting point is raised.

(11) **Variation of latent heat with temperature and pressure :** The latent heat of vapourization of a substance varies with temperature and hence pressure because the boiling point depends on pressure. It increases as the temperature is decreased. For example, water at 1 *atm* boils at 100°*C* and has latent heat 2259 Jg^{-1} but at 0.5 *atm* it boils at 82°*C* and has latent heat 2310 Jg^{-1}



The latent heat of fusion shows similar but less pronounced pressure dependence.

The figures show the *P-T* graphs for (*a*) a substance (*e.g.*, water) which contracts on melting an (*b*) a substance (*e.g* wax) which expands on melting. The *P-T* graph consists of three curves.

(i) Sublimation curve which connects points at which vapour (*V*) and solid (*S*) exist in equilibrium.

(ii) Vapourization curve which shows vapour and liquid (*L*) existing in equilibrium.

(iii) Fusion curve which shows liquid and solid existing in equilibrium.

The three curves meet at a single point which is called the triple point. It is that unique temperature-pressure point for a substance at which all the three phases co-exist in equilibrium.

(12) **Freezing mixture :** If salt is added to ice, then the temperature of mixture drops down to less than 0°*C*. This is so because, some ice melts down to cool the salt to 0°*C*. As a result, salt gets dissolved in the water formed and saturated solution of salt is obtained; but the ice point (freeing point) of the solution formed is always less than that of pure water. So, ice cannot be in the solid state with the salt solution at 0°*C*. The ice which is in contact with the solution, starts melting and it absorbs the required latent heat from the mixture, so the temperature of mixture falls down.

Joule's Law (Heat and Mechanical Work)

Whenever heat is converted into mechanical work or mechanical work is converted into heat, then the ratio of work done to heat produced always remains constant, *i.e.*, $W \propto Q$ or $\frac{W}{Q} = J$

This is Joule's law and J is called mechanical equivalent of heat.

(1) From $W = JQ$ if $Q = 1$ then $J = W$. Hence the amount of work done necessary to produce unit amount of heat is defined as the mechanical equivalent of heat.

(2) J is neither a constant, nor a physical quantity rather it is a conversion factor which used to convert *Joule* or *erg* into *calorie* or *kilo calories* vice-versa.

(3) Value of $J = 4.2\frac{Joule}{cal} = 4.2\times10^7\frac{erg}{cal}$

$$= 4.2\times10^3\frac{Joule}{kcal}.$$

(4) When water in a stream falls from height h, then its potential energy is converted into heat and temperature of water rises slightly.

From $\quad W = JQ \Rightarrow mgh = J(mc\,\Delta\theta)$

[where m = Mass of water, c = Specific heat of water, $\Delta\theta$ = temperature rise]

$\Rightarrow$ Rise in temperature $\Delta\theta = \frac{gh}{Jc}\,°C$

(5) The kinetic energy of a bullet fired from a gun gets converted into heat on striking the target. By this heat, the temperature of bullet increases by $\Delta\theta$.

From $\quad W = JQ \Rightarrow \frac{1}{2}mv^2 = J(ms\,\Delta\theta)$

[where m = Mass of the bullet, v = Velocity of the bullet, c = Specific heat of the bullet]

$\Rightarrow$ Rise in temperature $\Delta t = \frac{v^2}{2Jc}\,°C$

If the temperature of bullet rises upto the melting point of the bullet and bullet melts then.

From $\quad W = J(Q_{\text{Temperature change}} + Q_{\text{Phase change}})$

$\Rightarrow \frac{1}{2}mv^2 = J(mc\,\Delta\theta + mL)$; $\quad L$ = Latent heat of bullet

$\Rightarrow$ Rise in temperature $\Delta\theta = \left[\frac{\left(\frac{v^2}{2J} - L\right)}{c}\right]°C$

(6) If m *kg* ice-block falls down through some height (h) and melts partially (m' *kg*) then its potential energy gets converted into heat of melting.

From $W = JQ \Rightarrow mgh = Jm'L \Rightarrow h = \frac{m'}{m}\left(\frac{JL}{g}\right)$

If ice-block melts completely then $m' = m \Rightarrow h = \frac{JL}{g}$ *meter*

Principle of Calorimetry

Calorimetry means 'measuring heat'.

When two bodies (one being solid and other liquid or both being liquid) at different temperatures are mixed, heat will be transferred from body at higher temperature to a body at lower temperature till both acquire same temperature. The body at higher temperature releases heat while body at lower temperature absorbs it, so that

Heat lost = Heat gained

i.e., principle of calorimetry represents the law of conservation of heat energy.

(1) Temperature of mixture (θ_{mix}) is always $\geq$ lower temperature (θ_L) and $\leq$ higher temperature (θ_H), *i.e.*, $\theta_L \leq \theta_{mix} \leq \theta_H$.

It means the temperature of mixture can never be less than lower temperatures (as a body cannot be cooled below the temperature of cooling body) and greater than higher temperature (as a body cannot be heated above the temperature of heating body). Furthermore usually rise in temperature of one body is not equal to the fall in temperature of the other body though heat gained by one body is equal to the heat lost by the other.

(2) **Mixing of two substances when temperature changes only** : It means no phase change. Suppose two substances having masses m_1 and m_2, gram specific heat c_1 and c_2, temperatures θ_1 and θ_2 $(\theta_1 > \theta_2)$ are mixed together such that temperature of mixture at equilibrium is θ_{mix}

Hence, Heat lost = Heat gained

$$\Rightarrow m_1c_1(\theta_1 - \theta_{mix}) = m_2c_2(\theta_{mix} - \theta_2) \Rightarrow \theta_{mix} = \frac{m_1c_1\theta_1 + m_2c_2\theta_2}{m_1c_1 + m_2c_2}$$

Temperature of mixture in different cases

Condition	Temperature of mixture
If bodies are of same material *i.e.*, $c_1 = c_2$	$\theta_{mix} = \frac{m_1\theta_1 + m_2\theta_2}{m_1 + m_2}$
If bodies are of same mass $m_1 = m_2$	$\theta_{mix} = \frac{\theta_1c_1 + \theta_2c_2}{c_1 + c_2}$
If $m_1 = m_2$ and $c_1 = c_2$	$\theta_{mix} = \frac{\theta_1 + \theta_2}{2}$

(3) **Mixing of two substances when temperature and phase both changes or only phase changes:** A very common example for this category is ice-water mixing.

Suppose water at temperature θ_W°C is mixed with ice at 0_i°C, first, ice will melt and then it's temperature rises to attain thermal equilibrium. Hence; Heat given = Heat taken

$$\Rightarrow m_W C_W(\theta_W - \theta_{mix}) = m_i L_i + m_i C_W(\theta_{mix} - 0°)$$

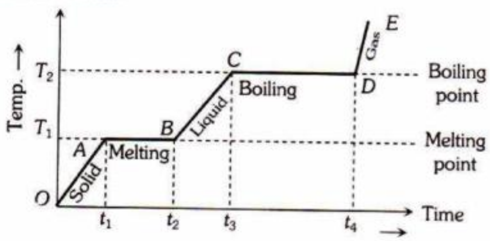
$$\Rightarrow \theta_{mix} = \frac{m_W\theta_W - \frac{m_i L_i}{C_W}}{m_W + m_i}$$

(i) If $m_W = m_i$ then $\theta_{mix} = \dfrac{\theta_W - \frac{L_i}{C_W}}{2}$

(ii) By using this formulae if $\theta_{mix} < \theta_i$ then take $\theta_{mix} = 0°C$

Heating Curve

If, to a given mass (m) of a solid, heat is supplied at constant rate P and a graph is plotted between temperature and time, the graph is as shown in figure and is called heating curve. From this curve, it is clear that



(1) In the region OA, temperature of solid is changing with time so, $Q = mc_S\Delta T \Rightarrow P\,\Delta t = mc_S\Delta T$ [as $Q = P\Delta t$]

But as $(\Delta T/\Delta t)$ is the slope of temperature-time curve

$$c_s \propto \frac{1}{\text{Slope of line } OA}$$

i.e., specific heat (or thermal capacity) is inversely proportional to the slope of temperature-time curve.

(2) In the region AB, temperature is constant, so it represents change of state, *i.e.*, melting of solid with melting point T_1. At A melting starts and at B all solid is converted into liquid. So between A and B substance is partly solid and partly liquid. If L_F is the latent heat of fusion. $Q = mL_F$ or $L_F = \dfrac{P(t_2 - t_1)}{m}$ [as $Q = P(t_2 - t_1)$]

or $L_F \propto$ length of line AB

i.e., Latent heat of fusion is proportional to the length of line of zero slope. [In this region specific heat $\propto \dfrac{1}{\tan 0} = \infty$]

(3) In the region BC, temperature of liquid increases so specific heat (or thermal capacity) of liquid will be inversely proportional to the slope of line BC

$$i.e.,\ c_L \propto \frac{1}{\text{Slope of line } BC}$$

(4) In the region CD, temperature is constant, so it represents the change of state, *i.e.*, boiling with boiling point T_2. At C all substances are in liquid state while at D in vapour state and between C and D partly liquid and partly gas. The length of line CD is proportional to latent heat of vaporisation

i.e., $L_V \propto$ Length of line CD [In this region specific heat $\propto \dfrac{1}{\tan 0} = \infty$]

(5) The line DE represents gaseous state of substance with its temperature increasing linearly with time. The reciprocal of slope of line will be proportional to specific heat or thermal capacity of substance in vapour state.

Tips & Tricks

✍ After snow falls, the temperature of the atmosphere becomes very low. This is because the snow absorbs the heat from the atmosphere to melt down. So, in the mountains, when snow falls, one does not feel too cold, but when ice melts, he feels too cold.

✍ There is more shivering effect of **ice-cream** on teeth as compared to that of water (obtained from ice). This is because, when ice-cream melts down, it absorbs large amount of heat from teeth.

✍ Branch of physics dealing with production and measurement of temperatures close to $0\,K$ is known as Cryogenics while that dealing with the measurement of very high temperature is called as Pyrometry.

✍ It is more painful to get burnt by steam rather than by boiling water at same temperature. This is so because when steam at 100°C gets converted to water at 100°C, then it gives out 536 *calories* of heat. So, it is clear that steam at 100°C has more heat than water at 100°C (*i.e.*, boiling of water).

✍ A solid and hollow sphere of same radius and material, heated to the same temperature then expansion of both will be equal because thermal expansion of isotropic solids is similar to true photographic enlargement. It means the expansion of cavity is same as if it has been a solid body of the same material. But if same heat is given to the two spheres, due to lesser mass, rise in temperature of hollow sphere will be more $\left\{As\left(\Delta\theta = \frac{\Delta Q}{mc}\right)\right\}$.

Hence its expansion will be more.

✍ Specific heat of a substance can also be negative. Negative specific heat means that in order to raise the temperature, a certain quantity of heat is to be withdrawn from the body.

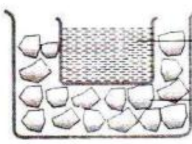
e.g. Specific heat of saturated vapours.

✍ Specific heat for hydrogen is maximum $(3.5\ cal/gm\times{}^{o}C)$ and it is minimum for radon and actinium $(\approx 0.022\,cal/gm\times{}^{\circ}C)$.

✍ The minimum possible temperature is $0\ K$.

✍ Amount of steam at $100°C$ required to just melt m gm of ice at $0°C$ is $m/8$ gm.

✍ If we put the beaker containing water in melting ice, the water in the beaker will cool to $0°C$ but will never freeze.



✍ A pressure in excess of 25 *atm* is required to make helium solidfy. At 1 *atm* pressure, helium remains a liquid down to absolute zero.

✍ Boiling temperature of water, if pressure is different from normal pressure, is $t_{Boiling} = [100°C - (760 - P \text{ in } mm) \times 0.037]°C$

✍ **Confusing S.I. and C.G.S. units**

It is advised to do questions on calorimetry in C.G.S. as calculations become simple. If the final answer is in joules, then convert cal into joules.

✍ Invar and quartz have very small values of co-efficient of linear expansion.

✍ In S.I. nomenclature " degree" is not used with the kelvin scale; *e.g.* $273°K$ is wrong while $273\ K$ is correct to write.

✍ Magnetic thermometer is recommended for measuring very low temperature ($2K$).

✍ The most sensitive thermometer is gas thermometer.

✍ Dew formation is more probable on a cloudiness calm night.

✍ In winters, generally fog disappear before noon. Because, the atmosphere warms up and tends to be unsaturated. The condensed vapours reevaporates and the fog disappears.

✍ Standardisation of thermometer is obtained with gas thermometer. Because coefficient of expansion of gas is very large.

✍ Dogs hang their tongues in order to expose a surface to the air for evaporation and hence, cooling. They do not sweat.

Thermometry

1. On the Celsius scale the absolute zero of temperature is at **[CBSE PMT 1994]**

(a) $0°C$ (b) $-32°C$

(c) $100°C$ (d) $-273.15°C$

2. In a mercury thermometer the ice point (lower fixed point) is marked as 10° and the steam point (upper fixed point) is marked as 130°. At $40°C$ temperature, what will this thermometer read **[WB-JEE 2012]**

(a) 78° (b) 66°

(c) 62° (d) 58°

3. The ratio of the coefficient of thermal conductivity of two different materials is 5 : 3. If the thermal resistance of the two rods of these materials of same thickness is same, then the ratio of the length of these rods will be **[MP PET 2013]**

(a) 5 : 3 (b) 3 : 5

(c) 9 : 25 (d) 25 : 9

4. When the room temperature becomes equal to the dew point, the relative humidity of the room is **[WB-JEE 2008]**

(a) 100% (b) 0%

(c) 70% (d) 85%

5. The correct value of $0°C$ on Kelvin scale will be **[RPMT 1999]**

(a) $273.15\ K$ (b) $273.00\ K$

(c) $273.05\ K$ (d) $273.63\ K$

6. On centigrade scale the temperature of a body increases by 30 degrees. The increase in temperature on Fahrenheit scale is **[UPSEAT 2005]**

(a) 50° (b) 40°

(c) 30° (d) 54°

7. The temperature of the sun is measured with **[Pb. PET 1997, 2001; Pb. PMT 1998; CPMT 1998; Similar KCET 1998]**
(a) Platinum thermometer
(b) Gas thermometer
(c) Pyrometer
(d) Vapour pressure thermometer

8. If temperature of an object is 140°*F*, then its temperature in centigrade is **[RPMT 1999; Similar BHU 2006]**
(a) 105°*C* (b) 32°*C*
(c) 140°*C* (d) 60°*C*

9. Thermoelectric thermometer is based on **[CPMT 1993, 95; AFMC 1998]**
(a) Photoelectric effect (b) Seebeck effect
(c) Compton effect (d) Joule effect

10. Maximum density of H_2O is at the temperature **[CPMT 1996; Pb. PMT 1996]**
(a) 32°*F* (b) 39.2°*F*
(c) 42°*F* (d) 4°*F*

11. On a new scale of temperature (which is linear) and called the *W* scale, the freezing and boiling points of water are 39° *W* and 239° *W* respectively. What will be the temperature on the new scale, corresponding to a temperature of 39° *C* on the Celsius scale **[CBSE PMT 2008]**
(a) 200° *W* (b) 139° *W*
(c) 78° *W* (d) 117° *W*

12. 'Stem Correction' in platinum resistance thermometers are eliminated by the use of **[AIIMS 1998]**
(a) Cells (b) Electrodes
(c) Compensating leads (d) None of the above

13. The absolute zero is the temperature at which **[AIIMS 1998]**
(a) Water freezes
(b) All substances exist in solid state
(c) Molecular motion ceases
(d) None of the above

14. Absolute scale of temperature is reproduced in the laboratory by making use of a **[SCRA 1998]**
(a) Radiation pyrometer
(b) Platinum resistance thermometer
(c) Constant volume helium gas thermometer
(d) Constant pressure ideal gas thermometer

15. The absolute zero temperature in Fahrenheit scale is **[DCE 1996; MP PMT 2009]**
(a) – 273°*F* (b) – 32°*F*
(c) – 460°*F* (d) – 132°*F*

16. On which of the following scales of temperature, the temperature is never negative **[EAMCET 1997]**
(a) Celsius (b) Fahrenheit
(c) Reaumur (d) Kelvin

17. The temperature on Celsius scale is 25°*C*. What is the corresponding temperature on the Fahrenheit scale **[AFMC 2001]**
(a) 40°*F* (b) 77°*F*
(c) 50°*F* (d) 45°*F*

18. One quality of a thermometer is that its heat capacity should be small. If *P* is a mercury thermometer, *Q* is a resistance thermometer and *R* thermocouple type then **[CPMT 1997]**
(a) *P* is best, *R* worst (b) *R* is best, *P* worst
(c) *R* is best, *Q* worst (d) *P* is best, *Q* worst

19. Two thermometers are used to record the temperature of a room. If the bulb of one is wrapped in wet hanky **[AFMC 1997]**
(a) The temperature recorded by both will be same
(b) The temperature recorded by wet-bulb thermometer will be greater than that recorded by the other
(c) The temperature recorded by dry-bulb thermometer will be greater than that recorded by the other
(d) None of the above

20. The temperature of a body on Kelvin scale is found to be *x* *K*. When it is measured by Fahrenheit thermometer, it is found to be *x*°*F*, then the value of *x* is **[UPSEAT 2000; Pb. CET 2004]**
(a) 40 (b) 313
(c) 574.25 (d) 301.25

21. A centigrade and a Fahrenheit thermometer are dipped in boiling water. The water temperature is lowered until the Fahrenheit thermometer registers 140°. What is the fall in temperature as registered by the Centigrade thermometer **[CBSE PMT 1992; AIIMS 1998]**
(a) 30° (b) 40°
(c) 60° (d) 80°

22. At what temperature the centigrade (Celsius) and Fahrenheit, readings are the same **[MNR 1992; CPMT 1995; RPMT 1997, 99, 2003; BHU 1997; DPMT 1998; UPSEAT 1999; KCET 2000]**
(a) – 40° (b) + 40°
(c) 36.6° (d) – 37°

23. Standardisation of thermometers is obtained with **[CPMT 1996]**
(a) Jolly's thermometer
(b) Platinum resistance thermometer
(c) Thermocouple thermometer
(d) Gas thermometer

24. What is rise in temperature of a collective drop when initially 1 *gm* and 2 *gm* drops travel with velocities 10 *cm/sec* and 15 *cm/sec* **[MP PMT 2009]**
(a) $6.6\times10^{-3}\,°C$ (b) $66\times10^{-3}\,°C$
(c) $660\times10^{-3}\,°C$ (d) 6.6°*C*

25. Mercury thermometers can be used to measure temperatures upto **[CBSE PMT 1992, 96; BHU 1998; UPSEAT 1998]**
(a) 100°*C* (b) 212°*C*
(c) 360°*C* (d) 500°*C*

26. A constant volume gas thermometer shows pressure reading of 50*cm* and 90*cm* of mercury at 0°*C* and 100°*C* respectively. When the pressure reading is 60 *cm* of mercury, the temperature is **[MNR 1991; UPSEAT 2000; Pb. CET 2004]**
(a) 25°*C* (b) 40°*C*
(c) 15°*C* (d) 12.5°*C*

27. Mercury boils at 367°C. However, mercury thermometers are made such that they can measure temperature up to 500°C. This is done by **[CPMT 2004; RPMT 2006]**

(a) Maintaining vacuum above mercury column in the stem of the thermometer
(b) Filling nitrogen gas at high pressure above the mercury column
(c) Filling nitrogen gas at low pressure above the mercury level
(d) Filling oxygen gas at high pressure above the mercury column

Thermal Expansion

1. A clock with a metal pendulum beating seconds keeps correct time at 0°C. If it loses 12.5 s a day at 25°C, the coefficient of linear expansion of metal pendulum is **[AIIMS 2010]**

(a) $\frac{1}{86400}/°C$ (b) $\frac{1}{43200}/°C$
(c) $\frac{1}{14400}/°C$ (d) $\frac{1}{28800}/°C$

2. The coefficient of volume expansion of a liquid is $49\times10^{-5}K^{-1}$. Calculate the fractional change in its density when the temperature is raised by 30°C. **[AMU (Engg.) 2010]**

(a) 7.5×10^{-2} (b) 3.0×10^{-2}
(c) 1.5×10^{-2} (d) 1.1×10^{-2}

3. Two solid spheres of the same material have the same radius but one is hollow while the other is solid. Both spheres are heated to same temperature. Then **[Odisha JEE 2010]**

(a) The solid sphere expands more
(b) The hollow sphere expands more
(c) Expansion is same for both
(d) Nothing can be said about their relative expansion if their masses are not given

4. The coefficient of apparent expansion of a liquid when determined using two different vessels A and B are γ_1 and γ_2 respectively. If the coefficient of linear expansion of the vessel A is α, the coefficient of linear expansion of the vessel B is **[EAMCET 2002]**

(a) $\frac{\alpha\gamma_1\gamma_2}{\gamma_1+\gamma_2}$ (b) $\frac{\gamma_1-\gamma_2}{2\alpha}$
(c) $\frac{\gamma_1-\gamma_2+\alpha}{3}$ (d) $\frac{\gamma_1-\gamma_2}{3}+\alpha$

5. A bar of iron is 10 cm at 20°C. At 19°C it will be (α of iron $= 11\times10^{-6}/°C$) **[EAMCET 1997]**

(a) 11×10^{-6} cm longer (b) 11×10^{-6} cm shorter
(c) 11×10^{-5} cm shorter (d) 11×10^{-5} cm longer

6. When a rod is heated but prevented from expanding, the stress developed is independent of **[EAMCET 1997]**

(a) Material of the rod (b) Rise in temperature
(c) Length of rod (d) None of above

7. Expansion during heating **[CBSE PMT 1994]**

(a) Occurs only in solids
(b) Increases the weight of a material
(c) Decreases the density of a material
(d) Occurs at the same rate for all liquids and solids

8. An iron bar of length l and having a cross-section A is heated from 0 to 100°C. If this bar is so held that it is not permitted to expand or bend, the force that is developed, is **[RPMT 2005]**

(a) Inversely proportional to the cross-sectional area of the bar
(b) Independent of the length of the bar
(c) Inversely proportional to the length of the bar
(d) Directly proportional to the length of the bar

9. Two rods, one of aluminum and the other made of steel, having initial length l_1 and l_2 are connected together to form a single rod of length l_1+l_2. The coefficients of linear expansion for aluminum and steel are α_a and α_s respectively. If the length of each rod increases by the same amount when their temperatures are raised by $t°C$, then find the ratio $\frac{l_1}{(l_1+l_2)}$ **[IIT-JEE (Screening) 2003]**

(a) $\frac{\alpha_s}{\alpha_a}$ (b) $\frac{\alpha_a}{\alpha_s}$
(c) $\frac{\alpha_s}{(\alpha_a+\alpha_s)}$ (d) $\frac{\alpha_a}{(\alpha_a+\alpha_s)}$

10. When a bimetallic strip is heated, it **[CBSE PMT 1990; Similar AIIMS 2006]**

(a) Does not bend at all
(b) Gets twisted in the form of an helix
(c) Bend in the form of an arc with the more expandable metal outside
(d) Bends in the form of an arc with the more expandable metal inside

11. A solid ball of metal has a concentric spherical cavity within it. If the ball is heated, the volume of the cavity will **[AFMC 1997; Odisha PMT 2004]**

(a) Increase (b) Decrease
(c) Remain unaffected (d) None of these

12. A *litre* of alcohol weighs **[AFMC 1994; Similar MNR 1996]**

(a) Less in winter than in summer
(b) Less in summer than in winter
(c) Same both in summer and winter
(d) None of the above

13. An ideal gas is expanding such that $PT^2=$ constant. The coefficient of volume expansion of the gas is **[IIT-JEE 2008]**

(a) $\frac{1}{T}$ (b) $\frac{2}{T}$
(c) $\frac{3}{T}$ (d) $\frac{4}{T}$

14. Water has maximum density at **[[illegible] PMT 1997; Kerala PET 2007]**

(a) 0°C (b) 32°F
(c) – 4°C (d) 4°C

15. At some temperature T, a bronze pin is a little large to fit into a hole drilled in a steel block. The change in temperature required for an exact fit is minimum when **[SCRA 1998]**

(a) Only the block is heated
(b) Both block and pin are heated together
(c) Both block and pin are cooled together
(d) Only the pin is cooled

16. If the length of a cylinder on heating increases by 2%, the area of its base will increase by [CPMT 1993; BHU 1997]
(a) 0.5% (b) 2%
(c) 1% (d) 4%

17. The volume of a gas at 20°C is 100 cm^3 at normal pressure. If it is heated to 100°C, its volume becomes 125 cm^3 at the same pressure, then volume coefficient of the gas at normal pressure is [DPMT 2001; Pb. PET 2002]
(a) 0.0015/°C (b) 0.0045/°C
(c) 0.0025/°C (d) 0.0033/°C

18. The coefficient of superficial expansion of a solid is 2×10^{-5}/°C. It's coefficient of linear expansion is [KCET 1999]
(a) 4×10^{-5}/°C (b) 3×10^{-5}/°C
(c) 2×10^{-5}/°C (d) 1×10^{-5}/°C

19. Density of substance at 0°C is 10 gm/cc and at 100°C, its density is 9.7 gm/cc. The coefficient of linear expansion of the substance will be [BHU 1996; DPMT 1998, 2003; Pb. PMT 1999; Similar NEET (Karnataka) 2013]
(a) 10^2 (b) 10^{-2}
(c) 10^{-3} (d) 10^{-4}

20. Coefficient of real expansion of mercury is 0.18×10^{-3}/°C. If the density of mercury at 0°C is 13.6 gm/cc, its density at 473K is [DPMT 1996]
(a) 13.11 gm/cc (b) 26.22 gm/cc
(c) 52.11 gm/cc (d) None of these

21. The real coefficient of volume expansion of glycerine is 0.000597 per°C and linear coefficient of expansion of glass is 0.000009 per°C. Then the apparent volume coefficient of expansion of glycerine is [AIIMS 2000]
(a) 0.000558 per°C (b) 0.00057 per°C
(c) 0.00027 per°C (d) 0.00066 per°C

22. A beaker is completely filled with water at 4°C. It will overflow if [EAMCET 1992; BHU 1994; AFMC 2005]
(a) Heated above 4°C
(b) Cooled below 4°C
(c) Both heated and cooled above and below 4°C respectively
(d) None of the above

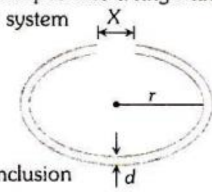
23. The volume of a metal sphere increases by 0.24% when its temperature is raised by 40°C. The coefficient of linear expansion of the metal is .... °C [Kerala PMT 2005]
(a) 2×10^{-5} per °C (b) 6×10^{-5} per °C
(c) 2.1×10^{-5} per °C (d) 1.2×10^{-5} per °C

24. Ratio among linear expansion coefficient (α), areal expansion coefficient (β) and volume expansion coefficient (γ) is [RPMT 2000]
(a) 1 : 2 : 3 (b) 3 : 2 : 1
(c) 4 : 3 : 2 (d) None of these

25. If on heating liquid through 80°C, the mass expelled is (1/100)th of mass still remaining, the coefficient of apparent expansion of liquid is [RPMT 2004]
(a) 1.25×10^{-4}/°C (b) 12.5×10^{-4}/°C
(c) 1.25×10^{-5}/°C (b) None of these

26. A piece of metal weighs 45 g in air and 25 g in a liquid of density $1.5 \times 10^3 kg - m^{-3}$ kept at 30°C. When the temperature of the liquid is raised to 40°C, the metal piece weighs 27 g. The density of liquid at 40°C, is $1.25 \times 10^3 kg - m^{-3}$. The coefficient of linear expansion of metal is [EAMCET 2009]
(a) 1.3×10^{-3} / °C (b) 5.2×10^{-3} / °C
(c) 2.6×10^{-3} / °C (d) 0.26×10^{-3} / °C

27. A cylindrical metal rod of length L_0 is shaped into a ring with a small gap as shown. On heating the system



(a) x decreases, r and d increase
(b) x and r increase, d decreases
(c) x, r and d all increase
(d) Data insufficient to arrive at a conclusion

28. Two uniform brass rods A and B of length l and 2l and radii 2r and r respectively are heated to the same temperature. The ratio of the increase in the volume of A to that of B is [AMU (Engg.) 2009]
(a) 1 : 1 (b) 1 : 2
(c) 2 : 1 (d) 1 : 4

29. A rod of silver at 0°C is heated to 100°C. It's length is increased by 0.19 cm. Coefficient of cubical expansion of the silver rod is [UPSEAT 2001; Similar UPCEAT 1999]
(a) 5.7×10^{-5}/°C (b) 0.63×10^{-5}/°C
(c) 1.9×10^{-5}/°C (d) 16.1×10^{-5}/°C

30. A brass disc fits simply in a hole of a steel plate. The disc from the hole can be loosened if the system [UPSEAT 2001]
(a) First heated then cooled
(b) First cooled then heated
(c) Is heated
(d) Is cooled

31. An iron bar of length 10 m is heated from 0°C to 100°C. If the coefficient of linear thermal expansion of iron is 10×10^{-6} / °C, the increase in the length of bar is [UPSEAT 2005; MP PET 2006]
(a) 0.5 cm (b) 1.0 cm
(c) 1.5 cm (d) 2.0 cm

32. If a cylinder of diameter 1.0 cm at 30°C is to be fitted into a hole of diameter 0.9997 cm in a steel plate at the same temperature, then minimum required rise in the temperature of the plate is : (Coefficient of linear expansion of steel $= 12 \times 10^{-6}$ / °C) [EAMCET 2001]
(a) 25°C (b) 35°C
(c) 45°C (d) 55°C

33. Surface of the lake is at 2°C. Find the temperature of the bottom of the lake [Odisha JEE 2002]
(a) 2°C (b) 3°C
(c) 4°C (d) 1°C

Calorimetry

1. 22320 cal of heat is supplied to 100 g of ice at 0° C. If the latent heat of fusion of ice is 80 $cal\ g^{-1}$ and latent heat of vaporization of water is 540 $cal\ g^{-1}$, the final amount of water thus obtained and its temperature respectively are [WB-JEE 2012]
(a) 8 g, 100° C (b) 100 g, 90° C
(c) 92 g, 100° C (d) 80 g, 100° C

2. At NTP water boils at 100°C. Deep down the mine, water will boil at a temperature [CPMT 1996]
(a) 100°C (b) > 100°C
(c) < 100°C (d) Will not boil at all

3. If specific heat of a substance is infinite, it means **[AIIMS 1997]**

(a) Heat is given out

(b) Heat is taken in

(c) No change in temperature takes place whether heat is taken in or given out

(d) All of the above

4. A gas in an airtight container is heated from 25°C to 90°C. The density of the gas will **[BCECE 1997]**

(a) Increase slightly (b) Increase considerably

(c) Remain the same (d) Decrease slightly

5. A quantity of heat required to change the unit mass of a solid substance, from solid state to liquid state, while the temperature remains constant, is known as **[AIIMS 1998]**

(a) Latent heat (b) Sublimation

(c) Hoar frost (d) Latent heat of fusion

6. The latent heat of vaporization of a substance is always **[SCRA 1998]**

(a) Greater than its latent heat of fusion

(b) Greater than its latent heat of sublimation

(c) Equal to its latent heat of sublimation

(d) Less than its latent heat of fusion

7. The factor not needed to calculate heat lost or gained when there is no change of state is **[AFMC 1997; BHU 1997]**

(a) Weight (b) Specific heat

(c) Relative density (d) Temperature change

8. 540 g of ice at 0°C is mixed with 540 g of water at 80°C. The final temperature of the mixture is **[AFMC 1994; DCE 2006]**

(a) 0°C (b) 40°C

(c) 80°C (d) Less than 0°C

9. Water is used to cool radiators of engines, because **[AFMC 2001]**

(a) Of its lower density (b) It is easily available

(c) It is cheap (d) It has high specific heat

10. How much heat energy is gained when 5 kg of water at 20°C is brought to its boiling point

(Specific heat of water = 4.2 $kJ\ kg^{-1}c^{-1}$) **[BHU 2001]**

(a) 1680 kJ (b) 1700 kJ

(c) 1720 kJ (d) 1740 kJ

11. Melting point of ice **[CBSE PMT 1993; JIPMER 1997]**

(a) Increases with increasing pressure

(b) Decreases with increasing pressure

(c) Is independent of pressure

(d) Is proportional to pressure

12. 19 g of water at $30°C$ and 5 g of ice at $-20°C$ are mixed together in a calorimeter. What is the final temperature of the mixture? Given specific heat of ice = 0.5 cal $g^{-1}\,(°C)^{-1}$ and latent heat of fusion of ice = 80 cal g^{-1} **[WB-JEE 2009]**

(a) $0°C$ (b) $-5°C$

(c) $5°C$ (d) $10°C$

13. 80 gm of water at 30°C are poured on a large block of ice at 0°C. The mass of ice that melts is **[CBSE PMT 1989]**

(a) 30 gm (b) 80 gm

(c) 1600 gm (d) 150 gm

14. The saturation vapour pressure of water at 100°C is **[EAMCET 1997]**

(a) 739 mm of mercury (b) 750 mm of mercury

(c) 760 mm of mercury (d) 712 mm of mercury

15. Two spheres made of same substance have diameters in the ratio 1 : 2. Their thermal capacities are in the ratio of **[JIPMER 1999]**

(a) 1 : 2 (b) 1 : 8

(c) 1 : 4 (d) 2 : 1

16. Work done in converting one gram of ice at –10°C into steam at 100°C is **[MP PET/PMT 1988; EAMCET (Med.) 1995; MP PMT 2003]**

(a) 3045 J (b) 6056 J

(c) 721 J (d) 616 J

17. If mass energy equivalence is taken into account, when water is cooled to form ice, the mass of water should **[AIEEE 2002]**

(a) Increase (b) Remain unchanged

(c) Decrease (d) First increase then decrease

18. Compared to a burn due to water at 100°C, a burn due to steam at 100°C is **[KCET 1999; UPSEAT 1999]**

(a) More dangerous

(b) Less dangerous

(c) Equally dangerous

(d) None of these

19. 50 gm of copper is heated to increase its temperature by 10°C. If the same quantity of heat is given to 10 gm of water, the rise in its temperature is (Specific heat of copper = 420 $Joule\text{-}kg^{-1}\,°C^{-1}$) **[EAMCET (Med.) 2000; Kerala PMT 2010]**

(a) 5°C (b) 6°C

(c) 7°C (d) 8°C

20. Assume that a drop of liquid evaporates by decrease in its surface energy, so that its temperature remains unchanged. What should be the minimum radius of the drop for this to be possible ? The surface tension is T, density of liquid is ρ and L is its latent heat of vaporization **[JEE (Mains) 2013]**

(a) $\rho L / T$ (b) $\sqrt{T / \rho L}$

(c) $T / \rho L$ (d) $2T / \rho L$

21. It is difficult to cook rice in an open vessel by boiling it a high altitudes because of **[WB-JEE 2009]**

(a) Low boiling point and high pressure

(b) High boiling point and low pressure

(c) Low boiling point and low pressure

(d) High boiling point and high pressure

22. Amount of heat required to raise the temperature of a body through 1K is called its **[KCET 1996; MH CET 2001; AIEEE 2002]**

(a) Water equivalent (b) Thermal capacity

(c) Entropy (d) Specific heat

23. A metallic ball and highly stretched spring are made of the same material and have the same mass. They are heated so that they melt, the latent heat required **[AIIMS 2002]**
(a) Are the same for both
(b) Is greater for the ball
(c) Is greater for the spring
(d) For the two may or may not be the same depending upon the metal

24. A lead bullet strikes against a steel plate with a velocity $200ms^{-1}$. If the impact is perfectly inelastic and the heat produced is equally shared between the bullet and the target, then the rise in temperature of the bullet is (specific heat capacity of lead $= 125 Jkg^{-1}K^{-1}$) **[Kerala PET 2011]**
(a) 80°C (b) 60°C
(c) 160°C (d) 40°C
(e) 120°C

25. Calorie is defined as the amount of heat required to raise temperature of 1g of water by 1°C and it is defined under which of the following conditions **[IIT-JEE (Screening) 2005]**
(a) From 14.5°C to 15.5°C at 760 *mm* of *Hg*
(b) From 98.5°C to 99.5°C at 760 *mm* of *Hg*
(c) From 13.5°C to 14.5°C at 76 *mm* of *Hg*
(d) From 3.5°C to 4.5°C at 76 *mm* of *Hg*

26. 0.1 m^3 of water at 80°C is mixed with $0.3 m^3$ of water at 60°C. The final temperature of the mixture is **[KCET 2009]**
(a) 65°C (b) 70°C
(c) 60°C (d) 75°C

27. A bubble of 8 mole of helium is submerged at a certain depth in water. The temperature of water increases by 30°C. How much heat is added approximately to helium during expansion **[Kerala PET 2008]**
(a) 4000 *J* (b) 3000 *J*
(c) 3500 *J* (d) 4500 *J*
(e) 5000 *J*

28. A closed bottle containing water at 30°C is carried to the moon in a space-ship. If it is placed on the surface of the moon, what will happen to the water as soon as the lid is opened **[RPMT 2002]**
(a) Water will boil
(b) Water will freeze
(c) Nothing will happen on it
(d) It will decompose into H_2 and O_2

29. The thermal capacity of 40 *g* of aluminium (specific heat = 0.2 *cal/g/°C*) is **[CBSE PMT 1990]**
(a) 40 *cal/°C* (b) 160 *cal/°C*
(c) 200 *cal/°C* (d) 8 *cal/°C*

30. An experiment takes 10 minutes to raise temperature of water from 0°C to 100°C and another 55 minutes to convert it totally into steam by a stabilized heater. The latent heat of vaporization comes out to be **[WB-JEE 2008]**
(a) 530 *cal/g* (b) 540 *cal/g*
(c) 550 *cal/g* (d) 560 *cal/g*

31. In a pressure cooker, the cooking is fast, because **[BCECE 2001]**
(a) The boiling point of water is raised by the increased pressure inside the cooker
(b) The boiling point of water is lowered by pressure
(c) More steam is available to cook the food at 100°C
(d) More pressure is available to cook the food at 100°C

32. If γ is the ratio of specific heats and R is the universal gas constant, then the molar specific heat at constant volume C_v is given by **[KCET 2008]**
(a) $\frac{R}{\gamma-1}$ (b) $\frac{\gamma R}{\gamma-1}$
(c) γR (d) $\frac{(\gamma-1)R}{\gamma}$

33. Two rigid boxes containing different ideal gases are placed on a table. Box A contains one mole of nitrogen at temperature T_0, while Box B contains one mole of helium at temperature (7/3) T_0. The boxes are then put into thermal contact with each other and heat flows between them until the gases reach a common final temperature (Ignore the heat capacity of boxes). Then, the final temperature of the gases, T_f, in terms of T_0 is **[AIEEE 2006; AIIMS 2008]**
(a) $T_f = \frac{7}{3}T_0$ (b) $T_f = \frac{3}{2}T_0$
(c) $T_f = \frac{5}{2}T_0$ (d) $T_f = \frac{3}{7}T_0$

34. Dry ice is **[CPMT 2000]**
(a) Ice cube (b) Sodium chloride
(c) Liquid nitrogen (d) Solid carbon dioxide

35. A liquid of mass *M* and specific heat *S* is at a temperature 2*t*. If another liquid of thermal capacity 1.5 times, at a temperature of $\frac{t}{3}$ is added to it, the resultant temperature will be **[EAMCET (Engg.) 1999]**
(a) $\frac{4}{3}t$ (b) t
(c) $\frac{t}{2}$ (d) $\frac{2}{3}t$

36. 300 *gm* of water at 25°C is added to 100 *g* of ice at 0°C. The final temperature of the mixture is **[MP PET 2004]**
(a) $-\frac{5}{3}$°C (b) $-\frac{5}{2}$°C
(c) – 5°C (d) 0°C

37. 0.93 *watt-hour* of energy is supplied to a block of ice weighing 10 *g*. It is found that **[DPMT 1999]**
(a) Half of the block melts
(b) The entire block melts and the water attains a temperature of 4°C
(c) The entire block just melts
(d) The block remains unchanged

38. The weight of a person is 60 *kg*. If he gets 10^5 calories heat through food and the efficiency of his body is 28%, then upto how much height he can climb (approximately) **[AFMC 1997]**
(a) 100 *m* (b) 200 *m*
(c) 400 *m* (d) 1000 *m*

39. The thermal capacity of a body is 80 *cal*, then its water equivalent is **[UPSEAT 2001]**
(a) 80 *cal / g* (b) 8 *g*
(c) 80 *g* (d) 80 *kg*

40. A vessel contains 110 g of water. The heat capacity of the vessel is equal to 10 g of water. The initial temperature of water in vessel is 10°C. If 220 g of hot water at 70°C is poured in the vessel, the final temperature neglecting radiation loss, will be **[UPSEAT 2000; Similar NSEP 1994]**

(a) 70°C (b) 80°C

(c) 60°C (d) 50°C

41. A stationary object at 4°C and weighing 3.5 kg falls from a height of 2000 m on a snow mountain at 0°C. If the temperature of the object just before hitting the snow is 0°C and the object comes to rest immediately $(g = 10\, m/s^2)$ and (latent heat of ice $= 3.5 \times 10^5$ $joule/s$), then the mass of ice that will melt is **[BHU 2001]**

(a) 2 kg (b) 200 g

(c) 20 g (d) 2 g

42. The SI unit of mechanical equivalent of heat is **[MP PMT/PET 1998]**

(a) $Joule \times Calorie$ (b) $Joule/Calorie$

(c) $Calorie \times Erg$ (d) $Erg/Calorie$

43. Of two masses of 5 kg each falling from height of 10 m, by which 2kg water is stirred. The rise in temperature of water will be **[RPET 1997]**

(a) 2.6°C (b) 1.2°C

(c) 0.32°C (d) 0.12°C

44. A lead ball moving with a velocity V strikes a wall and stops. If 50% of its energy is converted into heat, then what will be the increase in temperature (Specific heat of lead is S) **[RPMT 1996]**

(a) $\frac{2V^2}{JS}$ (b) $\frac{V^2}{4JS}$

(c) $\frac{V^2}{J}$ (d) $\frac{V^2 S}{2J}$

45. The mechanical equivalent of heat J is **[MP PET 2000]**

(a) A constant (b) A physical quantity

(c) A conversion factor (d) None of the above

46. Boiling water is changing into steam. At this stage the specific heat of water is **[UPSEAT 1998]**

(a) < 1 (b) ∞

(c) 1 (d) 0

47. A block of mass 100 gm slides on a rough horizontal surface. If the speed of the block decreases from 10 m/s to 5 m/s, the thermal energy developed in the process is **[UPSEAT 2002]**

(a) 3.75 J (b) 37.5 J

(c) 0.375 J (d) 0.75 J

48. Calculate the amount of heat (in calories) required to convert 5 g of ice at 0°C to steam at 100°C **[DPMT 2005; Similar Pb. PMT 1990; RPMT 1999]**

(a) 3100 cal (b) 3200 cal

(c) 3600 cal (d) 4200 cal

49. The point on the pressure temperature phase diagram where all the phases co-exist is called **[MH CET 2005]**

(a) Sublimation (b) Fusion point

(c) Triple point (d) Vaporisation point

50. In a water-fall the water falls from a height of 100 m. If the entire K.E. of water is converted into heat, the rise in temperature of water will be **[MP PMT 2001; Similar MP PET 1994; JIPMER 2002; Pb. PMT 2002; WB-JEE 2009]**

(a) 0.23°C (b) 0.46°C

(c) 2.3°C (d) 0.023°C

51. A lead bullet of 10 g travelling at 300 m/s strikes against a block of wood and comes to rest. Assuming 50% of heat is absorbed by the bullet, the increase in its temperature is (Specific heat of lead = 150$J/kg, K$) **[EAMCET 2001]**

(a) 100°C (b) 125°C

(c) 150°C (d) 200°C

52. The temperature at which the vapour pressure of a liquid becomes equals to the external (atmospheric) pressure is its **[Kerala (Engg.) 2001; MP PMT 2002]**

(a) Melting point (b) Sublimation point

(c) Critical temperature (d) Boiling point

53. When the pressure on water is increased the boiling temperature of water as compared to 100°C will be **[RPET 1999; Similar MP PMT 1984]**

(a) Lower (b) The same

(c) Higher (d) On the critical temperature

54. Calorimeters are made of which of the following **[AFMC 2000]**

(a) Glass (b) Metal

(c) Wood (d) Either (a) or (c)

55. Triple point of water is **[CPMT 2002]**

(a) 273.16°F (b) 273.16 K

(c) 273.16°C (d) 273.16 R

56. The sprinkling of water reduces slightly the temperature of a closed room because **[KCET 2006]**

(a) Temperature of water is less than that of the room

(b) Specific heat of water is high

(c) Water has large latent heat of vaporisation

(d) Water is a bad conductor of heat

57. The amount of work, which can be obtained by supplying 200 cal of heat, is **[Pb. PET 2001, 03; BHU 2004]**

(a) 840 $dyne$ (b) 840 W

(c) 840 erg (d) 840 J

58. How many grams of a liquid of specific heat 0.2 at a temperature 40°C must be mixed with 100 gm of a liquid of specific heat of 0.5 at a temperature 20°C, so that the final temperature of the mixture becomes 32°C **[Pb. PET 1999]**

(a) 175 gm (b) 300 g

(c) 295 gm (d) 375 g

59. 1 g of a steam at 100°C melts how much ice at 0°C (Latent heat of ice = 80 cal/gm and latent heat of steam = 540 cal/gm) **[Pb. PET 2000]**

(a) 1 gm (b) 2 gm

(c) 4 gm (d) 8 gm

60. Three liquids with masses m_1, m_2, m_3 are thoroughly mixed. If their specific heats are c_1, c_2, c_3 and their temperatures T_1, T_2, T_3 respectively, then the temperature of the mixture is

(a) $\frac{c_1T_1 + c_2T_2 + c_3T_3}{m_1c_1 + m_2c_2 + m_3c_3}$

(b) $\frac{m_1c_1T_1 + m_2c_2T_2 + m_3c_3T_3}{m_1c_1 + m_2c_2 + m_3c_3}$

(c) $\frac{m_1c_1T_1 + m_2c_2T_2 + m_3c_3T_3}{m_1T_1 + m_2T_2 + m_3T_3}$

(d) $\frac{m_1T_1 + m_2T_2 + m_3T_3}{c_1T_1 + c_2T_2 + c_3T_3}$

61. 10 g of ice at 0°C is mixed with 100 g of water at 50°C. What is the resultant temperature of mixture

[AFMC 2005; Similar AIIMS 1994; SCRA 1996; AMU 1999; KCET 2002; DCE 2002; Pb. PET 2003]

(a) 31.2°C (b) 32.8°C
(c) 36.7°C (d) 38.2°C

62. Which of the following has maximum specific heat **[RPMT 1999]**

(a) Water (b) Alcohol
(c) Glycerine (d) Oil

63. Which of the following is the unit of specific heat **[MH CET 2004]**

(a) $J\,kg\,°C^{-1}$ (b) $J/kg\,°C$
(c) $kg\,°C/J$ (d) $J/kg\,°C^{-2}$

64. 2g of steam condenses when passed through 40g of water initially at 25°C. The condensation of steam raises the temperature of water to 54.3°C. What is the latent heat of steam **[J & K CET 2005]**

(a) 540 cal/g (b) 536 cal/g
(c) 270 cal/g (d) 480 cal/g

65. Latent heat of 1gm of steam is 536 cal/gm, then its value in joule/kg is **[RPMT 1999]**

(a) 2.25×10^6 (b) 2.25×10^3
(c) 2.25 (d) None

66. The relative humidity on a day, when partial pressure of water vapour is $0.012 \times 10^5\,Pa$ at 12°C is (take vapour pressure of water at this temperature as $0.016 \times 10^5\,Pa$) **[AIIMS 1998]**

(a) 70% (b) 40%
(c) 75% (d) 25%

67. A hammer of mass 1kg having speed of 50 m/s, hit a iron nail of mass 200 gm. If specific heat of iron is 0.105 cal/gm°C and half the energy is converted into heat, the raise in temperature of nail is **[RPMT 1995; Kerala PET 2011]**

(a) 7.1°C (b) 9.2°C
(c) 10.5°C (d) 12.1°C

Critical Thinking

1. A glass flask is filled up to a mark with 50 cc of mercury at 18°C. If the flask and contents are heated to 38°C, how much mercury will be above the mark (α for glass is $9 \times 10^{-6}/°C$ and coefficient of real expansion of mercury is $180 \times 10^{-6}/°C$) **[EAMCET 1997; Similar MNR 1994]**

(a) 0.85 cc (b) 0.46 cc
(c) 0.153 cc (d) 0.05 cc

2. The coefficient of apparent expansion of mercury in a glass vessel is $153 \times 10^{-6}/°C$ and in a steel vessel is $144 \times 10^{-6}/°C$. If α for steel is $12 \times 10^{-6}/°C$, then that of glass is **[EAMCET 1997]**

(a) $9 \times 10^{-6}/°C$ (b) $6 \times 10^{-6}/°C$
(c) $36 \times 10^{-6}/°C$ (d) $27 \times 10^{-6}/°C$

3. A one litre flask contains certain quantity of mercury. If the volume of air inside the flask remains the same at all temperatures then the volume of mercury in the flask is (volume expansion coefficient of mercury is 20 times that of flask) **[Kerala PMT 2012]**

(a) 100cc (b) 50cc
(c) 200cc (d) 150cc
(e) 500cc

4. 10 g of ice at – 20°C is dropped into a calorimeter containing 10 g of water at 10°C; the specific heat of water is twice that of ice. When equilibrium is reached, the calorimeter will contain

(a) 20 g of water
(b) 20 g of ice
(c) 10 g ice and 10 g water
(d) 5 g ice and 15 g water

5. An electric kettle takes 4A current at 220 V. How much time will it take to boil 1 kg of water from temperature 20°C ? The temperature of boiling water is 100°C **[CBSE PMT 2008]**

(a) 12.6 min (b) 4.2 min
(c) 6.3 min (d) 8.4 min

6. A steel scale measures the length of a copper wire as 80.0 cm, when both are at 20°C (the calibration temperature for scale). What would be the scale read for the length of the wire when both are at 40°C? (Given $\alpha_{steel} = 11 \times 10^{-6}$ per°C and $\alpha_{copper} = 17 \times 10^{-6}$ per °C) **[CPMT 2004; RPMT 2006]**

(a) 80.0096 cm (b) 80.0272 cm
(c) 1 cm (d) 25.2 cm

7. When the temperature of a rod increases from t to $t + \Delta t$, its moment of inertia increases from I to $I + \Delta I$. If α be the coefficient of linear expansion of the rod, then the value of $\frac{\Delta I}{I}$ is **[Kerala PMT 2011]**

(a) $2\alpha\Delta t$ (b) $\alpha\Delta t$
(c) $\frac{\alpha\Delta t}{2}$ (d) $\frac{\Delta t}{\alpha}$
(e) $\frac{\Delta t}{2\alpha}$

8. Two metal strips that constitute a thermostat must necessarily differ in their **[IIT-JEE 1992]**

(a) Mass
(b) Length
(c) Resistivity
(d) Coefficient of linear expansion

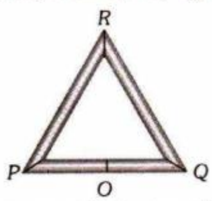
9. A metal ball immersed in alcohol weighs W_1 at 0°C and W_2 at 59°C. The coefficient of cubical expansion of the metal is less than that of alcohol. Assuming that the density of metal is large compared to that of alcohol, it can be shown that **[CPMT 1998]**

(a) $W_1 > W_2$ (b) $W_1 = W_2$
(c) $W_1 < W_2$ (d) $W_2 = (W_1 / 2)$

10. The coefficient of volumetric expansion of mercury is $18 \times 10^{-5}/°C$. A thermometer bulb has a volume $10^{-6}\ m^3$ and cross section of stem is $0.004\ cm^2$. Assuming that bulb is filled with mercury at 0°C then the length of the mercury column at 100°C is **[DPMT 1997, 2001; Pb. PMT 1998]**

(a) 18.8 *mm* (b) 9.2 *mm*
(c) 7.4 *cm* (d) 4.5 *cm*

11. Three rods of equal length l are joined to form an equilateral triangle PQR. O is the mid point of PQ. Distance OR remains same for small change in temperature. Coefficient of linear expansion for PR and RQ is same, *i.e.*, α_2 but that for PQ is α_1. Then



(a) $\alpha_2 = 3\alpha_1$
(b) $\alpha_2 = 4\alpha_1$
(c) $\alpha_1 = 3\alpha_2$
(d) $\alpha_1 = 4\alpha_2$

12. It is known that wax contracts on solidification. If molten wax is taken in a large vessel and it is allowed to cool slowly, then **[CBSE PMT 1994]**

(a) It will start solidifying from the top to downward
(b) It will start solidifying from the bottom to upward
(c) It will start solidifying from the middle, upward and downward at equal rates
(d) The whole mass will solidify simultaneously

13. A substance of mass m kg requires a power input of P watts to remain in the molten state at its melting point. When the power is turned off, the sample completely solidifies in time t sec. What is the latent heat of fusion of the substance **[IIT JEE 1992]**

(a) $\frac{Pm}{t}$ (b) $\frac{Pt}{m}$
(c) $\frac{m}{Pt}$ (d) $\frac{t}{Pm}$

14. Steam at 100°C is passed into 1.1 *kg* of water contained in a calorimeter of water equivalent to 0.02 *kg* at 15°C till the temperature of the calorimeter and its contents rises to 80°C. The mass of the steam condensed in *kg* is **[IIT 1995]**

(a) 0.130 (b) 0.065
(c) 0.260 (d) 0.135

15. 2 *kg* of ice at – 20°C is mixed with 5 *kg* of water at 20°C in an insulating vessel having a negligible heat capacity. Calculate the final mass of water remaining in the container. It is given that the specific heats of water and ice are 1 *kcal/kg per* °C and 0.5 *kcal/kg/°C* while the latent heat of fusion of ice is 80 *kcal/kg* **[IIT-JEE (Screening) 2003]**

(a) 7 *kg* (b) 6 *kg*
(c) 4 *kg* (d) 2 *kg*

16. Water of volume 2 *litre* in a container is heated with a coil of $1 kW$ at $27°C$. The lid of the container is open and energy dissipates at rate of $160 J/s$. In how much time temperature will rise from $27°C$ to $77°C$ [Given specific heat of water is $4.2 kJ/kg$] **[IIT-JEE (Screening) 2004]**

(a) 8 *min* 20 *s* (b) 6 *min* 2 *s*
(c) 7 *min* (d) 14 *min*

17. A lead bullet at 27°C just melts when stopped by an obstacle. Assuming that 25% of heat is absorbed by the obstacle, then the velocity of the bullet at the time of striking (M.P. of lead = 327°C, specific heat of lead = 0.03 *cal/g°C*, latent heat of fusion of lead = 6 *cal/g* and J = 4.2 *joule/cal*) **[IIT 1981]**

(a) 410 *m/s* (b) 1230 *m/s*
(c) 307.5 *m/s* (d) None of the above

18. We have seen that a gamma–ray dose of 3 Gy is lethal to half the people exposed to it. If the equivalent energy were absorbed as heat, what rise in body temperature would result **[AIIMS 2007]**

(a) $300\mu K$ (b) $700\mu K$
(c) $455\mu K$ (d) $390\mu K$

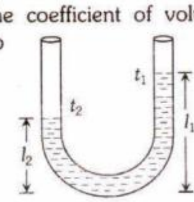
19. The temperature of equal masses of three different liquids A, B and C are 12°C, 19°C and 28°C respectively. The temperature when A and B are mixed is 16°C and when B and C are mixed is 23°C. The temperature when A and C are mixed is **[Kerala PET 2005]**

(a) 18.2°C (b) 22°C
(c) 20.2°C (d) 25.2°C

20. In an industrial process 10 *kg* of water per hour is to be heated from 20°C to 80°C. To do this steam at 150°C is passed from a boiler into a copper coil immersed in water. The steam condenses in the coil and is returned to the boiler as water at 90°C. How many *kg* of steam is required per hour (Specific heat of steam = 1 *calorie* per *g°C*, Latent heat of vaporisation = 540 *cal/g*)

(a) 1 *g* (b) 1 *kg*
(c) 10 *g* (d) 10 *kg*

21. In a vertical U-tube containing a liquid, the two arms are maintained at different temperatures t_1 and t_2. The liquid columns in the two arms have heights l_1 and l_2 respectively. The coefficient of volume expansion of the liquid is equal to



(a) $\frac{l_1 - l_2}{l_2 t_1 - l_1 t_2}$ (b) $\frac{l_1 - l_2}{l_1 t_1 - l_2 t_2}$
(c) $\frac{l_1 + l_2}{l_2 t_1 + l_1 t_2}$ (d) $\frac{l_1 + l_2}{l_1 t_1 + l_2 t_2}$

22. The coefficient of linear expansion of crystal in one direction is α_1 and that in every direction perpendicular to it is α_2. The coefficient of cubical expansion is

(a) $\alpha_1 + \alpha_2$ (b) $2\alpha_1 + \alpha_2$
(c) $\alpha_1 + 2\alpha_2$ (d) None of these

23. The pressure that has to be applied to the ends of a steel wire of length 10 *cm* to keep its length constant when its temperature is raised by 100°*C* is

(For steel Young's modulus is $2\times10^{11} Nm^{-2}$ and coefficient of thermal expansion is $1.1\times10^{-5} K^{-1}$) **[JEE (Mains) 2014]**

(a) $2.2\times10^{8} Pa$ (b) $2.2\times10^{9} Pa$

(c) $2.2\times10^{7} Pa$ (d) $2.2\times10^{6} Pa$

24. Steam at 100°*C* is passed into 20 *g* of water at 10°*C*. When water acquires a temperature of 80°*C*, the mass of water present will be [Take specific heat of water = 1 *cal g*–1°*C*$^{-1}$ and latent heat of steam = 540 *cal* g^{-1}]

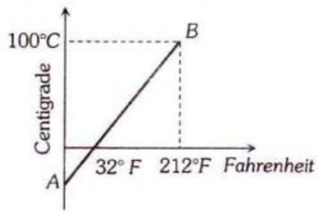
[SCRA 1994; CBSE PMT 2014]

(a) 42.5 *g* (b) 22.5 *g*

(c) 24 *g* (d) 31.5 *g*

Graphical Questions

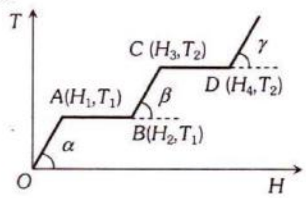
1. The graph *AB* shown in figure is a plot of temperature of a body in degree celsius and degree Fahrenheit. Then



(a) Slope of line *AB* is 9/5 (b) Slope of line *AB* is 5/9

(c) Slope of line *AB* is 1/9 (d) Slope of line *AB* is 3/9

2. The graph shows the variation of temperature (*T*) of one *kilogram* of a material with the heat (*H*) supplied to it. At *O*, the substance is in the solid state. From the graph, we can conclude that



(a) T_2 is the melting point of the solid

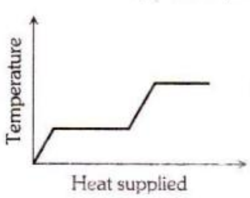
(b) *BC* represents the change of state from solid to liquid

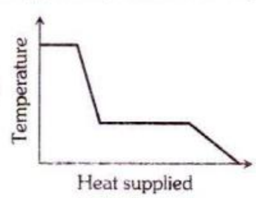
(c) $(H_2 - H_1)$ represents the latent heat of fusion of the substance

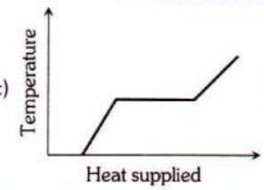
(d) $(H_3 - H_1)$ represents the latent heat of vaporization of the liquid

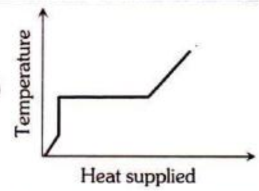
3. A block of ice at –10°*C* is slowly heated and converted to steam at 100°*C*. Which of the following curves represents the phenomenon qualitatively

[IIT-JEE (Screening) 2000; WB-JEE 2010]

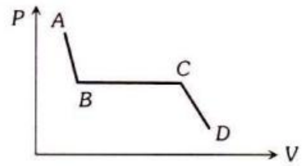
(a)


(b)


(c)


(d)


4. The portion *AB* of the indicator diagram representing the state of matter denotes



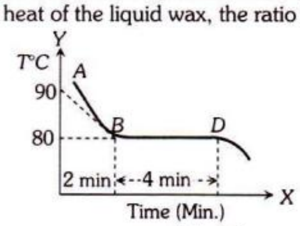
(a) The liquid state of matter

(b) Gaseous state of matter

(c) Change from liquid to gaseous state

(d) Change from gaseous state to liquid state

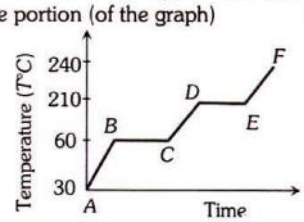
5. The figure given below shows the cooling curve of pure wax material after heating. It cools from *A* to *B* and solidifies along *BD*. If *L* and *C* are respective values of latent heat and the specific heat of the liquid wax, the ratio *L*/*C* is



(a) 40 (b) 80

(c) 100 (d) 20

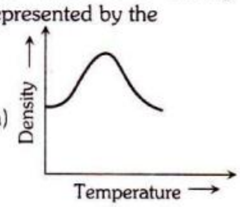
6. A solid substance is at 30°*C*. To this substance heat energy is supplied at a constant rate. Then temperature versus time graph is as shown in the figure. The substance is in liquid state for the portion (of the graph) **[RPET 1990, 94]**

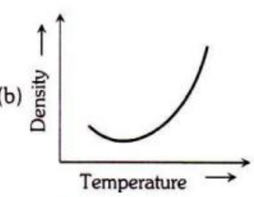


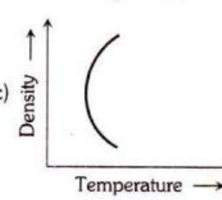
(a) *BC* (b) *CD*

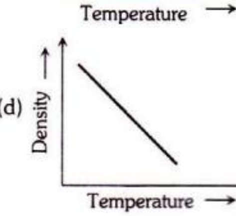
(c) *ED* (d) *EF*

7. The variation of density of water with temperature is represented by the

(a)


(b)


(c)


(d)


8. If a graph is plotted taking the temperature in Fahrenheit along Y-axis and the corresponding temperature in Celsius along the X-axis, it will be a straight line **[AIIMS 1997]**

(a) Having a $+ve$ intercept on Y-axis

(b) Having a $+ve$ intercept on X-axis

(c) Passing through the origin

(d) Having $a - ve$ intercepts on both the axis

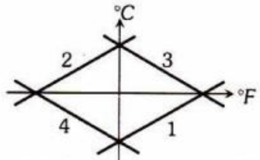
9. Which of the curves in figure represents the relation between Celsius and Fahrenheit temperatures

(a) 1

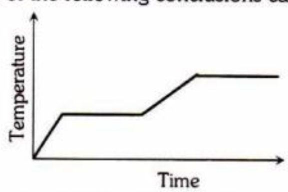
(b) 2

(c) 3

(d) 4



10. Heat is supplied to a certain homogenous sample of matter, at a uniform rate. Its temperature is plotted against time, as shown. Which of the following conclusions can be drawn



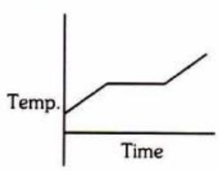
(a) Its specific heat capacity is greater in the solid state than in the liquid state

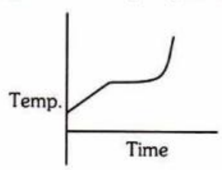
(b) Its specific heat capacity is greater in the liquid state than in the solid state

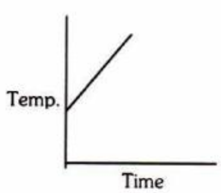
(c) Its latent heat of vaporization is greater than its latent heat of fusion

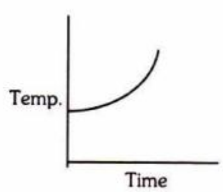
(d) Its latent heat of vaporization is smaller than its latent of fusion

11. Liquid oxygen at $50K$ is heated to $300K$ at constant pressure of 1 atm. The rate of heating is constant. Which one of the following graphs represents the variation of temperature with time **[CBSE PMT (Pre.) 2012]**

(a)


(b)


(c)


(d)


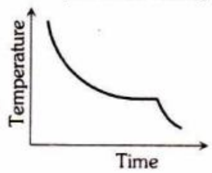
12. The graph signifies **[JIPMER 1999]**

(a) Adiabatic expansion of a gas

(b) Isothermal expansion of a gas

(c) Change of state from liquid to solid

(d) Cooling of a heated solid



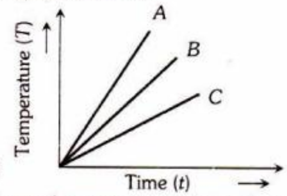
13. Which of the substances A, B or C has the highest specific heat ? The temperature vs time graph is shown

(a) A

(b) B

(c) C

(d) All have equal specific heat



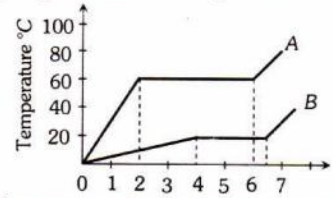
14. Two substances A and B of equal mass m are heated at uniform rate of 6 $cal\ s^{-1}$ under similar conditions. A graph between temperature and time is shown in figure. Ratio of heat absorbed H_A / H_B by them for complete fusion is

(a) 9/4

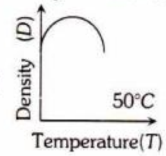
(b) 4/9

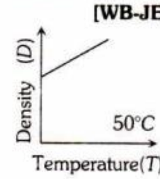
(c) 8/5

(d) 5/8



15. Which one of the figures gives the temperature dependence of density of water correctly **[WB-JEE 2008]**

(a)


(b)


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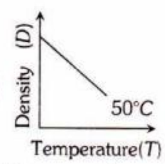
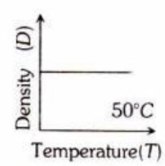


(d)


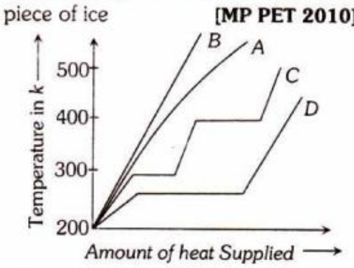
16. Which curve shows the rise of temperature with the amount of heat supplied, for a piece of ice **[MP PET 2010]**

(a) A

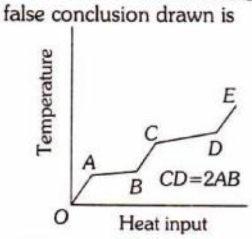
(b) B

(c) C

(d) D



17. A solid material is supplied with heat at constant rate and the temperature of the material changes as shown. From the graph, the false conclusion drawn is **[Kerala PMT 2011]**



(a) AB and CD of the graph represent phase changes

(b) AB represents the change of state from solid to liquid

(c) Latent heat of fusion is twice the latent heat of vaporization

(d) CD represents change of state from liquid to vapour

(e) Latent heat of vaporization is twice the latent heat of fusion

JEE Section

More than one correct answers

1. A bimetallic strip is formed out of two identical strips, one of copper and other of brass. The coefficients of linear expansion of the two metals are α_C and α_B. On heating, the temperature of the strip goes up by ΔT and the strip bends to form an arc of radius of curvature R. Then R is **[IIT-JEE (Screening) 1999]**

(a) Proportional to ΔT

(b) Inversely proportional to ΔT

(c) Proportional to $|\alpha_B - \alpha_C|$

(d) Inversely proportional to $|\alpha_B - \alpha_C|$

Reasoning type questions

Read the following statements carefully to mark the correct option out of the options given below

(a) Statement 1 is true, statement 2 is true ; statement 2 is a correct explanation for statement 1

(b) Statement 1 is true, statement 2 is true ; statement 2 is not a correct explanation for statement 1

(c) Statement 1 is true, statement 2 is false

(d) Statement 1 is false, statement 2 is true

2. **Statement-1** : Water is considered unsuitable for use in thermometers.

Statement-2 : This is due to small specific heat and high thermal conductivity.

3. **Statement-1** : The thermal resistance of a multiple layer is equal to the sum of the thermal resistances of the individual laminas.

Statement-2 : Heat transferred is directly proportional to the temperature gradient in each layer.

4. **Statement-1** : The earth without atmosphere would be inhospitably cold.

Statement-2 : All heat would escape in the absence of atmosphere.

Comprehension type questions

Passage - I

A calorimeter of mass m contains an equal mass of water in it. The temperature of the water and calorimeter is t_2. A block of ice of mass m and temperature $t_3 < 0°C$ is gently dropped into the calorimeter. Let C_1, C_2 and C_3 be the specific heats of calorimeter, water and ice respectively and L be the latent heat of ice.

5. The whole mixture in the calorimeter becomes ice if

(a) $C_1t_2 + C_2t_2 + L + C_3t_3 > 0$

(b) $C_1t_2 + C_2t_2 + L + C_3t_3 < 0$

(c) $C_1t_2 + C_2t_2 - L - C_3t_3 > 0$

(d) $C_1t_2 + C_2t_2 - L - C_3t_3 < 0$

6. The whole mixture in the calorimeter becomes water if

(a) $(C_1 + C_2)t_2 - C_3t_3 + L > 0$

(b) $(C_1 + C_2)t_2 + C_3t_3 + L > 0$

(c) $(C_1 + C_2)t_2 - C_3t_3 - L > 0$

(d) $(C_1 + C_2)t_2 + C_3t_3 - L > 0$

7. Water equivalent of calorimeter is

(a) mC_1 (b) $\frac{mC_1}{C_2}$

(c) $\frac{mC_2}{C_1}$ (d) None of these

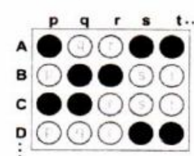
Integer type questions

This section contains some integer type questions. The answers to each of the questions is a **single-digit integer**, ranging from **0 to 9**.

8. 2 kg of ice at $-15°C$ is mixed with 2.5 kg of water at $25°C$ in an insulating container. If the specific heat capacities of ice and water are 0.5 $cal/g°C$ and 1 $cal/g°C$, find the amount of water present in the container (in kg nearest integer)

Matrix Match type questions

In this section each question has some statements (A, B, C, D,...) given in **Column-I** and some statements (p, q, r, s, t,...) in **Column-II**. Any given statement in **Column-I** can have correct matching with **ONE OR MORE** statement(s) in **Column-II**. For example, if for a given question, statement B matches with the statements given in q and r, then for that particular question against statement B, darken the bubbles corresponding to q and r in the ORS. *i.e.* answer will be q and r.



9. Match the conics in Column I with the statements/ expressions in Column II **[IIT-JEE 2007]**

	Column-I		Column-II
(A)	Bimetallic strip	(p)	Radiation from a hot body
(B)	Steam engine	(q)	Energy conversion
(C)	Incandescent lamp	(r)	Melting
(D)	Electric fuses	(s)	Thermal expansion of solids

10. A piece of metal of density ρ_1 floats on mercury density ρ_2. The coefficients of expansion of the metal and mercury are γ_1 and γ_2, respectively. The temperatures of both mercury and metal are increased by ΔT. Then match the following

	Column I		Column II
(A)	If $\gamma_2 > \gamma_1$	(p)	No effect on submergence
(B)	$\gamma_2 = \gamma_1$	(q)	Fraction of the volume of metal sub merged in mercury
(C)	If $\gamma_2 < \gamma_1$	(r)	The solid sinks
(D)	$(\gamma_2 - \gamma_1)\Delta T$	(s)	The solid lifts up

11. Match the following

	Column I		Column II
(A)	Anomalous expansion	(p)	Pyrometer
(B)	Radiation thermometry	(q)	Convection current
(C)	Surface temperature of sun	(r)	Expansion on cooling
(D)	Ventilation	(s)	$\simeq 6000\,K$

12. Match the following

	Column I		Column II
(A)	Lowest temperature of water in a lake	(p)	Less than 4°C
(B)	Rate of variation of density (ρ) is zero	(q)	Co-existence of three phases of a substance
(C)	Least volume of water	(r)	Surface tension is zero
(D)	Triple point	(s)	4°C

Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : The melting point of ice decreases with increase of pressure.
Reason : Ice contracts on melting. **[AIIMS 2004]**

2. Assertion : Fahrenheit is the smallest unit measuring temperature.
Reason : Fahrenheit was the first temperature scale used for measuring temperature. **[AIIMS 1999]**

3. Assertion : Melting of solid causes no change in internal energy.
Reason : Latent heat is the heat required to melt a unit mass of solid. **[AIIMS 1998]**

4. Assertion : Specific heat capacity is the cause of formation of land and sea breeze.
Reason : The specific heat of water is more than land. **[AIIMS 1995]**

5. Assertion : The molecules at 0°C ice and 0°C water will have same potential energy.
Reason : Potential energy depends only on temperature of the system.

6. Assertion : Water kept in an open vessel will quickly evaporate on the surface of the moon.
Reason : The temperature at the surface of the moon is much higher than boiling point of the water.

7. Assertion : The temperature at which Centigrade and Fahrenheit thermometers read the same is – 40°.
Reason : There is no relation between Fahrenheit and Centigrade temperature.

8. Assertion : Specific heat of a body is always greater than its thermal capacity.
Reason : Thermal capacity is the required for raising temperature of unit mass of the body through unit degree.

9. Assertion : A beaker is completely filled with water at 4°C. It will overflow, both when heated or cooled.
Reason : There is expansion of water below and above 4°C.

10. Assertion : Two bodies at different temperatures, if brought in thermal contact do not necessary settle to the mean temperature.
Reason : The two bodies may have different thermal capacities.

Answers

Thermometry

1	d	2	d	3	a	4	a	5	a
6	d	7	c	8	d	9	b	10	b
11	d	12	c	13	c	14	c	15	c
16	d	17	b	18	c	19	c	20	c
21	b	22	a	23	d	24	c	25	c
26	a	27	b						

Thermal Expansion

1	a	2	c	3	c	4	d	5	c
6	c	7	c	8	b	9	c	10	c
11	a	12	b	13	c	14	d	15	a
16	d	17	d	18	d	19	d	20	a
21	b	22	c	23	a	24	a	25	a
26	c	27	c	28	c	29	a	30	d
31	b	32	a	33	c				

Calorimetry

1	c	2	b	3	c	4	c	5	d
6	a	7	c	8	a	9	d	10	a
11	b	12	c	13	a	14	c	15	b
16	a	17	b	18	a	19	a	20	d
21	c	22	b	23	a	24	a	25	a
26	a	27	e	28	a	29	d	30	c
31	a	32	a	33	b	34	d	35	b
36	d	37	c	38	b	39	c	40	d
41	b	42	b	43	d	44	b	45	c
46	b	47	a	48	c	49	c	50	a
51	c	52	d	53	c	54	b	55	b
56	c	57	d	58	d	59	d	60	b
61	d	62	a	63	b	64	a	65	a
66	c	67	a						

Critical Thinking Questions

1	c	2	a	3	b	4	c	5	c
6	a	7	a	8	d	9	c	10	d
11	d	12	b	13	b	14	a	15	b
16	a	17	a	18	b	19	c	20	b
21	a	22	c	23	a	24	b		

Graphical Questions

1	b	2	c	3	a	4	a	5	d
6	b	7	a	8	a	9	a	10	bc
11	a	12	c	13	c	14	c	15	a
16	c	17	c						

JEE Section

1	bd	2	c	3	c	4	a	5	b
6	d	7	b	8	3				
9	A→ s; B→ q; C→ p, q; D→ q, r								
10	A→ q; B→ p; C→ s; D→ q								
11	A→ r; B→ p; C→ p, s; D→ q								
12	A→ s; B→ s; C→ s; D→ p, q								

Assertion and Reason

1	a	2	c	3	e	4	a	5	d
6	c	7	c	8	d	9	a	10	a

Answers & Solutions

Thermometry

1. (d) $T = 273.15 + t°C \Rightarrow 0 = 273.15 + t°C$

$\Rightarrow t = -273.15°C$

2. (d) Using $\frac{T_C - 0}{100 - 0} = \frac{T - 10}{130 - 10}$

$\frac{40 - 0}{100 - 0} = \frac{T - 10}{130 - 10}$

$\frac{40}{100} = \frac{T - 10}{120}$ or $\frac{2}{5} = \frac{T - 10}{120}$

$5T - 50 = 240 \Rightarrow 5T = 290 \Rightarrow T = \frac{290}{5} = 58°$.

3. (a) $R = \frac{\ell}{kA}$

R=same, ℓ = same

$\therefore \frac{\ell_1}{\ell_2} = \frac{k_1}{k_2} = \frac{5}{3}$.

6. (d) Difference of $100°C$ = difference of $180°F$

$\therefore$ Difference of $30° = \frac{180}{100} \times 30 = 54°$

7. (c) Pyrometer can measure temperature from $800°C$ to $6000°C$. Hence temperature of sun is measured with pyrometer.

8. (d) $\frac{C}{5} = \frac{F - 32}{9} \Rightarrow \frac{C}{5} = \frac{140 - 32}{9} \Rightarrow C = 60°C$.

9. (b) Thermoelectric thermometer is based on Seebeck Effect.

10. (b) Maximum density of water is at $4°C$

Also $\frac{C}{5} = \frac{F - 32}{9} \Rightarrow \frac{4}{5} = \frac{F - 32}{9} \Rightarrow F = 39.2°F$

11. (d) $\frac{X - LFP}{UFP - LFP}$ = constant

where X = Any given temperature on that scale

L.F.P. = Lower fixed point (Freezing point)

U.F.P. = Upper fixed point (Boiling point)

$\frac{W - 39}{239 - 39} = \frac{39 - 0}{100 - 0}$

$\Rightarrow \frac{W - 39}{200} = \frac{39}{100} \Rightarrow W = 78 + 39 \Rightarrow W = 117° W$.

13. (c) At absolute zero (*i.e.*, 0 K) v_{rms} becomes zero.

15. (c) $\frac{F - 32}{9} = \frac{K - 273}{5} \Rightarrow \frac{F - 32}{9} = \frac{0 - 273}{5}$

$\Rightarrow F = -459.4°F \approx -460°F$

16. (d) Zero kelvin $= -273°C$ (absolute temperature). As no matter can attain this temperature, hence temperature can never be negative on Kelvin scale.

17. (b) $\frac{C}{5} = \frac{F - 32}{9} \Rightarrow \frac{25}{5} = \frac{F - 32}{9} \Rightarrow F = 77°F$.

18. (c) Thermoelectric thermometer is used for finding rapidly varying temperature.

19. (c) Due to evaporation cooling is caused which lowers the temperature of bulb wrapped in wet hanky.

20. (c) $\frac{F - 32}{9} = \frac{K - 273}{5} \Rightarrow \frac{x - 32}{9} = \frac{x - 273}{5} \Rightarrow x = 574.25$

21. (b) $\frac{\Delta T_C}{100} = \frac{\Delta T_F}{180} = \frac{212 - 140}{180}$

i.e., $\Delta T_C = 100 \times \frac{72}{180} = 40°C$

$\therefore$ Fall in temperature = 40°.

22. (a) $\frac{C}{5} = \frac{F - 32}{9} \Rightarrow \frac{t}{5} = \frac{t - 32}{9} \Rightarrow t = -40°$

25. (c) The boiling point of mercury is 400°C. Therefore, the mercury thermometer can be used to measure the temperature upto 360°C.

26. (a) $t = \frac{(P_t - P_0)}{(P_{100} - P_0)} \times 100°C = \frac{(60 - 50)}{(90 - 50)} \times 100 = 25°C$

27. (b) By filling nitrogen gas at high pressure, the boiling point of mercury is increased which extends the range upto 500°C.

Thermal Expansion

1. (a) Number of seconds lost in a day

$$\Delta t = \frac{1}{2}\alpha\,\Delta\theta \times 86400$$

The coefficient of linear expansion of metal pendulum

$$\alpha = \frac{2\Delta t}{\Delta\theta \times 86400} = \frac{2\times 12.5}{25\times 86400}$$

$$\alpha = \frac{1}{86400}/^\circ C$$

2. (c) When the temperature of a liquid is increased by $\Delta T^\circ C$ the mass will remain unchanged while due to thermal expansion volume will increase and becomes V'.

$V' = V(1+\gamma\Delta T)$

where γ is the coefficient of volume expansion of liquid

$$\therefore\ \rho' = \frac{m}{V'} = \frac{m}{V(1+\gamma\Delta T)} = \frac{\rho}{1+\gamma\Delta T} \qquad \left[\because \rho = \frac{m}{V}\right]$$

Fractional change in density $= \dfrac{\rho-\rho'}{\rho}$

$$= \left(1-\frac{\rho'}{\rho}\right) = \left(1-\frac{1}{1+\gamma\Delta T}\right)$$

$$= \frac{\gamma\Delta T}{1+\gamma\Delta T} = \frac{49\times10^{-5}\times 30}{1+49\times10^{-5}\times 30}$$

$$= \frac{1470\times10^{-5}}{1+1470\times10^{-5}} = \frac{0.0147}{1.0147} = 0.0145 \approx 1.5\times10^{-2}$$

4. (d) $\gamma_{real} = \gamma_{app} + \gamma_{vessel}$; $\gamma_{vessel} = 3\alpha$

For vessel 'A' $\Rightarrow \gamma_{real} = \gamma_1 + 3\alpha$

For vessel 'B' $\Rightarrow \gamma_{real} = \gamma_2 + 3\alpha_B$

Hence, $\gamma_1 + 3\alpha = \gamma_2 + 3\alpha_B \Rightarrow \alpha_B = \dfrac{\gamma_1-\gamma_2}{3} + \alpha$

5. (c) $L = L_0(1+\alpha\Delta\theta) \Rightarrow \dfrac{L_1}{L_2} = \dfrac{1+\alpha(\Delta\theta)_1}{1+\alpha(\Delta\theta)_2}$

$$\Rightarrow \frac{10}{L_2} = \frac{1+11\times10^{-6}\times 20}{1+11\times10^{-6}\times 19} \Rightarrow L_2 = 9.99989$$

$\Rightarrow$ Length is shorten by

$10 - 9.99989 = 0.00011 = 11\times10^{-5}\ cm$.

6. (c) Stress $= Y\alpha\Delta\theta$; hence it is independent of length.

7. (c) Solids, liquids and gases all expand on being heated, as a result density (= mass/volume) decreases.

8. (b) $Y = \dfrac{FL}{Al}$ where Y is Young's modulus, A is area

$$\Rightarrow F = \frac{YAl}{L} \quad \text{... (i)}$$

From the formula for linear expansion

$$\alpha = \frac{l}{L\times 100} \quad \text{... (ii)}$$

According to the condition the bar should not bend or expand

Now from equations (i) and (ii)

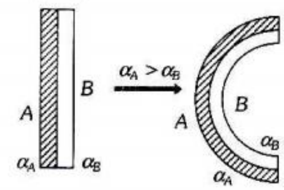
$$F = YA\times 100\,\alpha$$

Hence, force is independent of length L

9. (c) Given $\Delta l_1 = \Delta l_2$ or $l_1\alpha_a t = l_2\alpha_s t$

$$\therefore\ \frac{l_1}{l_2} = \frac{\alpha_s}{\alpha_a} \text{ or } \frac{l_1}{l_1+l_2} = \frac{\alpha_s}{\alpha_a+\alpha_s}.$$

10. (c) A bimetallic strip on being heated bends in the form of an arc with more expandable metal (A) outside (as shown).



11. (a) When the ball is heated, expansion of ball and cavity both occurs, hence volume of cavity increases.

12. (b) In summer alcohol expands, density decreases, so 1 litre of alcohol will weigh less in summer than in winter.

13. (c) From Ideal gas equation $PV = \mu RT \Rightarrow P = \dfrac{\mu RT}{V}$

Given $PT^2 = K \Rightarrow \dfrac{\mu RT}{V}.T^2 = K \Rightarrow \mu RT^3 = KV$ ... (i)

Differentiating both sides, we get $3\mu RT^2\,dT = K\,dV$ ... (ii)

Dividing equation (ii) by (i), we get $\dfrac{3}{T}dT = \dfrac{dV}{V}$

Coefficient of volume expansion $= \dfrac{dV}{V\,dT} = \dfrac{3}{T}$.

14. (d) Water has maximum density at 4°C.

15. (a) Since coefficient of expansion of steel is greater than that of bronze, hence with small increase in it's temperature the hole expands sufficiently.

16. (d) $A \propto L^2 \Rightarrow \dfrac{\Delta A}{A} = 2\cdot\dfrac{\Delta L}{L} \Rightarrow \dfrac{\Delta A}{A} = 2\times 2 = 4\%$.

17. (d) $\dfrac{V_1}{V_2} = \dfrac{1+\gamma t_1}{1+\gamma t_2} \Rightarrow \dfrac{100}{125} = \dfrac{1+\gamma\times 20}{1+\gamma\times 100}$

$\Rightarrow \gamma = 0.0033/^\circ C$

18. (d) $\alpha = \dfrac{\beta}{2} = \dfrac{2\times10^{-5}}{2} = 10^{-5}/^\circ C$

19. (d) Coefficient of volume expansion

$$\gamma = \frac{\Delta\rho}{\rho.\Delta T} = \frac{(\rho_1-\rho_2)}{\rho.(\Delta\theta)} = \frac{(10-9.7)}{10\times(100-0)} = 3\times10^{-4}$$

Hence, coefficient of linear expansion

$$\alpha = \frac{\gamma}{3} = 10^{-4}/^\circ C$$

20. (a) $\rho = \rho_0(1-\gamma.\Delta\theta) = 13.6[1-0.18\times10^{-3}(473-273)]$

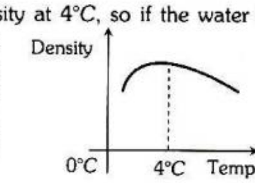
$= 13.6[1-0.036] = 13.11\ gm/cc$.

21. (b) As we know $\gamma_{real} = \gamma_{app} + \gamma_{vessel}$

$\Rightarrow \gamma_{app.} = \gamma_{glycerine} - \gamma_{glass}$

$= 0.000597 - 0.000027 = 0.00057/^\circ C$.

22. (c) Water has maximum density at 4°C, so if the water is heated above 4°C or cooled below 4°C density decreases, *i.e.*, volume increases. In other words, it expands so it overflows in both the cases.



23. (a) $\gamma = \frac{\Delta V}{V.\Delta T} = \frac{0.24}{100 \times 40} = 6 \times 10^{-5} / {}^\circ C$

$\Rightarrow \alpha = \frac{\gamma}{3} = 2 \times 10^{-5} / {}^\circ C$

24. (a) As $\alpha = \frac{\beta}{2} = \frac{\gamma}{3} \Rightarrow \alpha : \beta : \gamma = 1 : 2 : 3$

25. (a) $\gamma_{app.} = \frac{\text{Mass expelled}}{\text{Mass remained} \times \Delta T}$

$= \frac{x/100}{x \times 80} = \frac{1}{8000} = 1.25 \times 10^{-4} / {}^\circ C$.

26. (c) The Volume of the metal at $30^\circ C$ is

$V_{30} = \frac{\text{loss of weight}}{\text{Specific gravity} \times g} = \frac{(45-25)g}{1.5 \times g} = 13.33\, cm^3$

Similarly, Volume of metal at $40^\circ C$ is

$V_{40} = \frac{(45-27)g}{1.25 \times g} = 14.40\, cm^3$

Now, $V_{40} = V_{30}[1 + \gamma(t_2 - t_1)]$

$\Rightarrow \gamma = \frac{V_{40} - V_{30}}{V_{30}(t_2 - t_1)} = \frac{14.40 - 13.33}{13.33(40-30)} = 8.03 \times 10^{-3} / {}^\circ C$

$\therefore$ Coefficient of linear expansion of the metal is

$\alpha = \frac{\gamma}{3} = \frac{8.03 \times 10^{-3}}{3} \approx 2.6 \times 10^{-3} / {}^\circ C$.

27. (c) On heating the system; x, r, d all increases, since the expansion of isotropic solids is similar to true photographic enlargement.

28. (c) Let the original temperature be $0^\circ C$; Volume of $A = l \times \pi(2r)^2 = V_1$; $V'_1 = V_1(1 + \gamma\Delta T)$

$\frac{(V'_1 - V_1)}{V_1} = \gamma\Delta T \Rightarrow V'_1 - V_1 \propto V_1$

$\frac{(V'_2 - V_2)}{V_2} = \gamma\Delta T \Rightarrow V'_2 - V_2 \propto V_2$

$\therefore \frac{\Delta V_1}{\Delta V_2} = \frac{l(2r)^2}{2lr^2} = \frac{2}{1}$

29. (a) $\alpha = \frac{\Delta L}{L_0(\Delta\theta)} = \frac{0.19}{100(100-0)} = 1.9 \times 10^{-5} / {}^\circ C$

Now $\gamma = 3\alpha = 3 \times 1.9 \times 10^{-5}/{}^\circ C = 5.7 \times 10^{-5}/{}^\circ C$

30. (d) Since, the coefficient of linear expansion of brass is greater than that of steel. On cooling, the brass contracts more, so, it get loosened.

31. (b) Increase in length $\Delta L = L_0\, \alpha\, \Delta\theta$

$= 10 \times 10 \times 10^{-6} \times (100 - 0) = 10^{-2}\, m = 1\, cm$

32. (a) $\theta = \frac{\Delta L}{L_0 \Delta\alpha} = \frac{(1 - 0.9997)}{0.9997 \times 12 \times 10^{-6}} = 25^\circ C$

33. (c) The densest layer of water will be at bottom. The density of water is maximum at 4°C. So the temperature of bottom of lake will be 4°C.

Calorimetry

1. (c) 100 g of ice (0°C) convert into steam (100°C) in following three steps

$\underset{(0^\circ C)}{Ice} \rightarrow \underset{(0^\circ C)}{water} \rightarrow \underset{(100^\circ C)}{water} \rightarrow \underset{(100^\circ C)}{stream}$

$\because$ Total heat supplied $Q = 22320\, cal$

$\therefore Q = Q_1 + Q_2 + Q_3$

$22320\, cal = 100 g \times 80\, cal\, g^{-1}$

$+ 100 g \times 1(100 - 0)^\circ C + m_3 \times 540\, cal\, g^{-1}$

$22320 = 800 + 10000 + 540(m_3)$

$540(m_3) = 4320 \Rightarrow m_3 = 8$

Then mass of vapour steam = 8 g

The final amount water thus obtained at 100°C

$= (100 - 8)g = 92g$.

2. (b) Pressure inside the mines is greater than that of normal pressure. Also we know that boiling point increases with increase in pressure.

3. (c) $Q = m.c.\Delta\theta \Rightarrow c = \frac{Q}{m.\Delta\theta}$

when $\Delta\theta = 0 \Rightarrow c = \infty$

4. (c) Mass and volume of the gas will remain same, so density will also remain same.

6. (a) The latent heat of vaporization is always greater than latent heat of fusion because in liquid to vapour phase change there is a large increase in volume. Hence more heat is required as compared to solid to liquid phase change.

7. (c) When state is not changing $\Delta Q = mc\Delta\theta$.

8. (a) Heat taken by ice to melt at 0°C is

$Q_1 = mL = 540 \times 80 = 43200\, cal$

Heat given by water to cool upto 0°C is

$Q_2 = ms\Delta\theta = 540 \times 1 \times (80 - 0) = 43200\, cal$

Hence heat given by water is just sufficient to melt the whole ice and final temperature of mixture is 0°C.

Short trick : For these types of frequently asked questions you can remember the following formula

$\theta_{mix} = \frac{m_W\theta_W - \frac{m_i L_i}{c_W}}{m_i + m_W}$ (See theory for more details)

If $m_W = m_i$ then $\theta_{mix} = \frac{\theta_W - \frac{L_i}{c_W}}{2} = \frac{80 - \frac{80}{1}}{2} = 0^\circ C$

9. (d) Due to large specific heat of water, it releases large heat with very small temperature change.

10. (a) $Q = m.c.\Delta\theta = 5 \times (1000 \times 4.2) \times (100 - 20)$

$= 1680 \times 10^3\, J = 1680\, kJ$

11. (b) Melting point of ice decreases with increase in pressure (as ice expands on solidification).

12. (c) Here, specific heat of ice, $s_{ice} = 0.5 \text{ cal } g^{-1}\,^{\circ}C^{-1}$

Specific heat of water, $s_{water} = 1 \text{ cal } g^{-1}\,^{\circ}C^{-1}$

Latent heat of fusion of ice, $L_{f_{ice}} = 80 \text{ cal } g^{-1}$

Here ice will absorb heat while hot water will release it. Let T be the final temperature of the mixture.

Assuming water equivalent of calorimeter to be neglected.

Heat given by water, $Q_1 = m_{water} s_{water} \Delta T$

$= 19 \times 1 \times (30 - T) = 570 - 19T$ ...(i)

Heat absorbed by ice,

$Q_2 = m_{ice} \times s_{ice} \times [0 - (-20)] + m_{ice} \times L_{f\ ice} + m_{ice} \times s_{water} \times (T - 0)$

$= 5 \times 0.5 \times 20 + 5 \times 80 + 5 \times 1 \times T$

$= 450 + 5T$ ...(ii)

According to principle of calorimetry, $Q_1 = Q_2$

i.e., $570 - 19T = 450 + 5T \Rightarrow T = \dfrac{120}{24} = 5^{\circ}C$

13. (a) If m *gm* ice melts then

Heat lost = Heat gain

$80 \times 1 \times (30 - 0) = m \times 80 \Rightarrow m = 30\, gm$

14. (c) At boiling point saturation vapour pressure becomes equal to atmospheric pressure. Therefore, at 100°C for water. S.V.P. = 760 *mm* of *Hg* (atm pressure).

15. (b) Thermal capacity = Mass × Specific heat

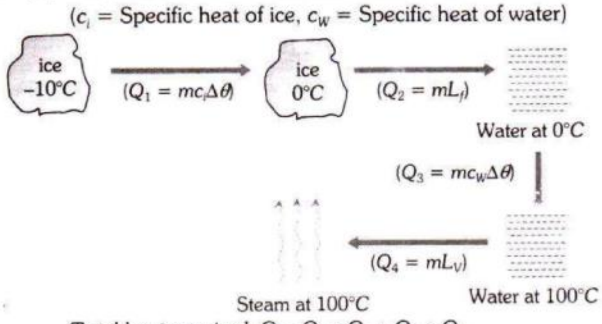
Due to same material both spheres will have same specific heat. Also mass = Volume (V) × Density (ρ)

∴ Ratio of thermal capacity

$$= \frac{m_1}{m_2} = \frac{V_1\rho}{V_2\rho} = \frac{\frac{4}{3}\pi r_1^3}{\frac{4}{3}\pi r_2^3} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{1}{2}\right)^3 = 1:8$$

16. (a) Ice (–10°C) converts into steam as follows

(c_i = Specific heat of ice, c_W = Specific heat of water)



Total heat required $Q = Q_1 + Q_2 + Q_3 + Q_4$

$\Rightarrow Q = 1 \times 0.5(10) + 1 \times 80 + 1 \times 1 \times (100 - 0) + 1 \times 540$

$= 725\, cal$

Hence work done $W = JQ = 4.2 \times 725 = 3045\, J$

17. (b) When water is cooled at 0°C to form ice then 80 *calorie/gm* (latent heat) energy is released. Because potential energy of the molecules decreases. Mass will remain constant in the process of freezing of water.

18. (a) Steam at 100°C contains extra 540 *calorie/gm* energy as compare to water at 100°C. So it's more dangerous to burn with steam than water.

19. (a) Same amount of heat is supplied to copper and water so $m_c c_c \Delta\theta_c = m_W c_W \Delta\theta_W$

$$\Rightarrow \Delta\theta_W = \frac{m_c c_c (\Delta\theta)_c}{m_W c_W} = \frac{50 \times 10^{-3} \times 420 \times 10}{10 \times 10^{-3} \times 4200} = 5^{\circ}C$$

20. (d) $\rho 4\pi R^2 \Delta R L = T 4\pi \left|R^2 - (R - \Delta R)^2\right|$

$\rho R^2 \Delta R L = T\left|R^2 - R^2 + 2R\Delta R - \Delta R^2\right|$

$\rho R^2 \Delta R L = T 2R\Delta R$ (ΔR is very small)

$\therefore R = \dfrac{2T}{\rho L}$

21. (c) With rise of altitude pressure decreases and boiling point decreases.

22. (b) $Q = m.c.\Delta\theta$; if $\Delta\theta = 1K$ then $Q = mc$ = Thermal capacity.

23. (a) Latent heat is independent of configuration. Ordered energy spent in stretching the spring will not contribute to heat which is disordered kinetic energy of molecules of substance.

24. (a) $ms\Delta T = \dfrac{1}{2}\left(\dfrac{1}{2}mv^2\right)$

$$\Delta T = \frac{v^2}{4s} = \frac{(200)^2}{4 \times 125} = \frac{4 \times 10^4}{4 \times 125} = 80^{\circ}C$$

26. (a) Density of water = $10^3\, kg/m^3$

Let the final temperature of the mixture be t

Assuming no heat transfer to or from container.

Heat lost by water at $= 0.1 \times 10^3 \times s_{water} \times (80 - t)$

Heat gained by water at $= 0.3 \times 10^3 \times s_{water} \times (t - 60)$

According to principle of calorimetry

heat lost = heat gain

$0.1 \times 10^3 \times s_{water} \times (80 - t) = 0.3 \times 10^3 \times s_{water} \times (t - 60)$

$\Rightarrow 1 \times (80 - t) = 3 \times (t - 60) \Rightarrow t = 65\,^{\circ}C$

27. (e) $n = 8$ *mole*, $\Delta t = 30^{\circ}C$

$\theta = nc_p \Delta t$

$\theta = 8 \times \dfrac{5}{2} \times 8.31 \times 30 \approx 5000.$

28. (a) Boiling occurs when the vapour pressure of liquid becomes equal to the atmospheric pressure. At the surface of moon, atmospheric pressure is zero, hence boiling point decreases and water begins to boil at 30°C.

29. (d) Thermal capacity $= mc = 40 \times 0.2 = 8\, cal/^{\circ}C$.

30. (c) Heat given for raising the temperature of $W\ g$ of water from $0°C$ to $100°C = W \times 1 \times 100\ cal$

Time taken $= 10 \times 60\ s$

$\therefore$ Heat given per second $= \dfrac{W \times 1 \times 100}{10 \times 60}\ cal$

Heat given out to convert $W\ g$ to steam $= W \times L$

This is the heat supplied in $55 \times 60 s$

$\therefore$ Heat given

$= 100 \times W \times \dfrac{55 \times 60}{10 \times 60} = WL \Rightarrow L = 550\ cal/g$.

32. (a) $\dfrac{C_P}{C_V} = \gamma \Rightarrow C_p = C_V \cdot \gamma$ But $C_P - C_V = R$

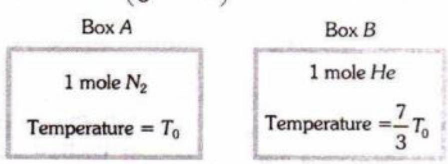
$\Rightarrow C_P = R + C_V$

$\therefore\ \gamma C_V = C_V + R\ \Rightarrow C_V(\gamma - 1) = R\ \Rightarrow\ C_V = \dfrac{R}{\gamma - 1}$.

33. (b) When two gases are mixed together then

Heat lost by the Helium gas = Heat gained by the Nitrogen gas

$$\mu_B \times (C_v)_{He} \times \left(\frac{7}{3}T_0 - T_f\right) = \mu_A \times (C_v)_{N_2} \times (T_f - T_0)$$



$$\Rightarrow 1 \times \frac{3}{2}R \times \left(\frac{7}{3}T_0 - T_f\right) = 1 \times \frac{5}{2}R \times (T_f - T_0)$$

By solving we get $T_f = \dfrac{3}{2}T_0$.

34. (d) We know that when solid carbondioxide is heated, it becomes vapour directly without passing through its liquid phase. Therefore it is called dry ice.

35. (b) $\theta_{mix} = \dfrac{m_1c_1\theta_1 + m_2c_2\theta_2}{m_1c_1 + m_2c_2} = \dfrac{m\,s\,(2t) + 1.5\,(m\,s) \times \frac{t}{3}}{m\,s + 1.5\,(m\,s)} = t$

36. (d) $\theta_{mix} = \dfrac{m_W\theta_W - \dfrac{m_iL_i}{S_W}}{m_i + m_W} = \dfrac{300 \times 25 - \dfrac{100 \times 80}{1}}{100 + 300} = -1.25°C$

Which is not possible. Hence $\theta_{mix} = 0°C$

37. (c) Energy supplied $= 0.93 \times 3600\ joules = 3348\ joules$

Heat required to melt 10 *gms* of ice

$= 10 \times 80 \times 4.18 = 3344\ joules$

Hence block of ice just melts.

38. (b) Suppose person climbs upto height h, then by using

$W = JQ\ \Rightarrow\ mgh = JQ$

$$\Rightarrow 60 \times 9.8 \times h = 4.2 \times \left(10^5 \times \frac{28}{100}\right)\ \Rightarrow h = 200\,m$$

39. (c) We know that thermal capacity of a body expressed in calories is equal to water equivalent of the body expressed in grams.

40. (d) Let final temperature of water be θ

Heat taken = Heat given

$110 \times 1\ (\theta - 10) + 10\ (\theta - 10) = 220 \times 1\ (70 - \theta)$

$\Rightarrow \theta = 48.8°C \approx 50°C$.

41. (b) Suppose $m\ kg$ of ice melts then by using $\underset{(Joules)}{W} = \underset{(Joules)}{H}$

$\Rightarrow\ Mgh = mL\ \Rightarrow\ 3.5 \times 10 \times 2000 = m \times 3.5 \times 10^5$

$\Rightarrow\ m = 0.2\,kg = 200\,gm$

42. (b) $J = \dfrac{W}{Q} = \dfrac{Joule}{cal}$

43. (d) $W = JQ\ \Rightarrow\ (2m)gh = J \times m'c\Delta\theta$

$\Rightarrow\ 2 \times 5 \times 10 \times 10 = 4.2(2 \times 1000 \times \Delta\theta)$

$\Rightarrow\ \Delta\theta = 0.1190°C = 0.12°C$

44. (b) $W = JQ\ \Rightarrow\ \dfrac{1}{2}\left(\dfrac{1}{2}mV^2\right) = J \times mS\Delta\theta\ \Rightarrow\ \Delta\theta = \dfrac{V^2}{4\,JS}$

45. (c) 'J' is a conversion

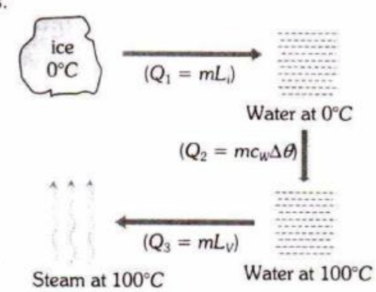
46. (b) $c = \dfrac{Q}{m.\Delta\theta}$; as $\Delta\theta = 0$, hence c becomes ∞.

47. (a) According to energy conservation, change in kinetic energy appears in the form of heat (thermal energy).

$\Rightarrow$ *i.e.*, Thermal energy $= \dfrac{1}{2}m(v_1^2 - v_2^2)\ \left[\because \underset{(Joule)}{W} = \underset{(Joule)}{Q}\right]$

$= \dfrac{1}{2}(100 \times 10^{-3})(10^2 - 5^2) = 3.75\,J$

48. (c) Ice ($0°C$) converts into steam ($100°C$) in following three steps.



Total heat required $Q = Q_1 + Q_2 + Q_3$

$= 5 \times 80 + 5 \times 1 \times (100 - 0) + 5 \times 540 = 3600\,cal$

49. (c) At triple point all the phases co-exist

50. (a) $\Delta\theta = 0.0023\,h = 0.0023 \times 100 = 0.23°C$

51. (c) Since specific heat of lead is given in *Joules*, hence use $W = Q$ instead of $W = JQ$.

$\Rightarrow \dfrac{1}{2} \times \left(\dfrac{1}{2}mv^2\right) = m.c.\Delta\theta \Rightarrow\ \Delta\theta = \dfrac{v^2}{4c} = \dfrac{(300)^2}{4 \times 150} = 150°C$.

52. (d) At boiling point, vapour pressure becomes equal to the external pressure.

53. (c) When pressure increases boiling point also increases.

54. (b) Calorimeters are made by conducting materials.

55. (b) Triple point of water is 273.16 K.

57. (d) $W = JQ \Rightarrow W = 4.2 \times 200 = 840\,J$.

58. (d) Temperature of mixture $\theta = \frac{m_1c_1\theta_1 + m_2c_2\theta_2}{m_1c_1 + m_2c_2}$

$$\Rightarrow 32 = \frac{m_1 \times 0.2 \times 40 + 100 \times 0.5 \times 20}{m_1 \times 0.2 + 100 \times 0.5} \Rightarrow m_1 = 375\,gm$$

59. (d) Suppose m gm ice melted, then heat required for its melting $= mL = m \times 80\,cal$

Heat available with steam for being condensed and then brought to 0°C

$= 1 \times 540 + 1 \times 1 \times (100 - 0) = 640\,cal$

$\Rightarrow$ Heat lost = Heat taken

$\Rightarrow 640 = m \times 80 \Rightarrow m = 8\,gm$

Short trick: You can remember that amount of steam (m') at 100°C required to melt m gm ice at 0°C is $m' = \frac{m}{8}$.

Here, $m = 8 \times m' = 8 \times 1 = 8\,gm$

60. (b) Let the final temperature be T °C.

Total heat supplied by the three liquids in coming down to 0°C = $m_1c_1T_1 + m_2c_2T_2 + m_3c_3T_3$ ..... (i)

Total heat used by three liquids in raising temperature from 0°C to T°C

$= m_1c_1T + m_2c_2T + m_3c_3T$ .....(ii)

By equating (i) and (ii) we get

$(m_1c_1 + m_2c_2 + m_3c_3)T$

$= m_1c_1T_1 + m_2c_2T_2 + m_3c_3T_3$

$$\Rightarrow T = \frac{m_1c_1T_1 + m_2c_2T_2 + m_3c_3T_3}{m_1c_1 + m_2c_2 + m_3c_3}.$$

61. (d) $\theta_{mix} = \dfrac{m_W\theta_W - \dfrac{m_iL_i}{c_W}}{m_i + m_W} = \dfrac{100 \times 50 - 10 \times \dfrac{80}{1}}{10 + 100} \approx 38.2°C$.

62. (a) Water has maximum specific heat.

63. (b) $c = \frac{Q}{m.\Delta\theta} \rightarrow \frac{J}{kg \times °C}$

64. (a) Let L be the latent heat and using principle of calorimetry.

$2L + 2(100 - 54.3) = 40 \times (54.3 - 25.3)$

$\Rightarrow L = 540.3\,cal/g$.

65. (a) $536\,\frac{cal}{gm} = \frac{536 \times 4.2\,J}{10^{-3}\,kg} = 2.25 \times 10^6\,J/kg$

66. (c) Partial pressure of water vapour $P_W = 0.012 \times 10^5\,Pa$,

Vapour pressure of water $P_V = 0.016 \times 10^5\,Pa$

The relative humidity at a given temperature is given by

$= \frac{\text{Partial pressure of water vapour}}{\text{Vapour pressure of water}}$

$= \frac{0.012 \times 10^5}{0.016 \times 10^5} = 0.75 = 75\%$

67. (a) $W = JQ \Rightarrow \frac{1}{2}\left(\frac{1}{2}Mv^2\right) = J(m.c.\Delta\theta)$

$$\Rightarrow \frac{1}{4} \times 1 \times (50)^2 = 4.2[200 \times 0.105 \times \Delta\theta] \Rightarrow \Delta\theta = 7.1°C$$

Critical Thinking Questions

1. (c) Due to volume expansion of both mercury and flask, the change in volume of mercury relative to flask is given by $\Delta V = V_0[\gamma_L - \gamma_g]\Delta\theta = V[\gamma_m - 3\alpha_g]\Delta\theta$

$= 50[180 \times 10^{-6} - 3 \times 9 \times 10^{-6}](38 - 18) = 0.153\,cc$

2. (a) $\gamma_{real} = \gamma_{app.} + \gamma_{vessel}$

So $(\gamma_{app.} + \gamma_{vessel})_{glass} = (\gamma_{app.} + \gamma_{vessel})_{steel}$

$\Rightarrow 153 \times 10^{-6} + (\gamma_{vessel})_{glass} = (144 \times 10^{-6} + \gamma_{vessel})_{steel}$

Further, $(\gamma_{vessel})_{steel} = 3\alpha = 3 \times (12 \times 10^{-6}) = 36 \times 10^{-6}/°C$

$\Rightarrow 153 \times 10^{-6} + (\gamma_{vessel})_{glass} = 144 \times 10^{-6} + 36 \times 10^{-6}$

$\Rightarrow (\gamma_{vessel})_{glass} = 3\alpha = 27 \times 10^{-6}/°C \Rightarrow \alpha = 9 \times 10^{-6}/°C$

4. (c) Heat given by water $Q_1 = 10 \times 10 = 100\,cal$.

Heat taken by ice to melt

$Q_2 = 10 \times 0.5 \times [0 - (-20)] + 10 \times 80 = 900\,cal$

As $Q_1 < Q_2$, so ice will not completely melt and final temperature = 0°C.

As heat given by water in cooling up to 0°C is only just sufficient to increase the temperature of ice from – 20°C to 0°C, hence mixture in equilibrium will consist of 10 g ice and 10 g water at 0°C.

5. (c) $P \times t = mc\Delta\theta$

$$\Rightarrow t = \frac{mc\Delta\theta}{P} = \frac{4200\,m\Delta\theta}{P} = \frac{4200 \times m \times \Delta\theta}{VI}$$

$\left\{\because C_{water} = 4200\,J/kg \times °C\right\}$

$$\Rightarrow t = \frac{4200 \times 1 \times (100 - 20)}{220 \times 4} = 381\,sec \approx 6.3\,min.$$

6. (a) With temperature rise (same 20°C for both), steel scale and copper wire both expand. Hence length of copper wire *w.r.t.* steel scale or apparent length of copper wire after rise in temperature

$L_{app} = L'_{cu} - L'_{steel} = [L_0(1 + \alpha_{Cu}\Delta\theta) - L_0(1 + \alpha_s\Delta\theta)]$

$\Rightarrow L_{app} = L_0(\alpha_{Cu} - \alpha_s)\Delta\theta$

$= 80(17 \times 10^{-6} - 11 \times 10^{-6}) \times 20 = 0.0096\,cm$

$\therefore$ Length of the wire read = 80.0096 cm.

7. (a) Moment of inertia of a rod,

$I = \frac{1}{12}ML^2$ ...(i)

where M is the mass of the rod and L is the length of the rod

$\therefore \Delta I = \frac{1}{12}2ML\Delta L$ ($\because M$ is a constant) ...(ii)

Divide (ii) by (i), we get

$\frac{\Delta I}{I} = 2\frac{\Delta L}{L}$ ...(iii)

As $\Delta L = L\alpha\Delta t$

or $\frac{\Delta L}{L} = \alpha\Delta t$

Substituting the value of $\frac{\Delta L}{L}$ in (iii), we get

$\frac{\Delta I}{I} = 2\alpha\Delta t$.

8. (d) Thermostat is used in electric apparatus like refrigerator, iron *etc* for automatic cut off. Therefore for metallic strips to bend on heating their coefficient of linear expansion should be different.

9. (c) As the coefficient of cubical expansion of metal is less as compared to the coefficient of cubical expansion of liquid, we may neglect the expansion of metal ball. So when the ball is immersed in alcohol at 0°C, it displaces some volume V of alcohol at 0°C and has weight W_1.

$\therefore \quad W_1 = W_0 - V\rho_0 g$

where $\quad W_0$ = weight of ball in air

Similarly, $W_2 = W_0 - V\rho_{59} g$

where $\quad \rho_0$ = density of alcohol at 0°C

and $\quad \rho_{59}$ = density of alcohol at 59°C

As $\rho_{59} < \rho_0$, $\Rightarrow W_2 > W_1$ or $W_1 < W_2$

10. (d) $V = V_0(1 + \gamma\Delta\theta) \Rightarrow$ Change in volume

$V - V_0 = \Delta V = A.\Delta l = V_0\gamma\Delta\theta$

$$\Rightarrow \Delta l = \frac{V_0.\gamma\Delta\theta}{A} = \frac{10^{-6} \times 18 \times 10^{-5} \times (100-0)}{0.004 \times 10^{-4}}$$

$= 45 \times 10^{-3}\, m = 4.5\, cm$

11. (d) $(OR)^2 = (PR)^2 - (PO)^2 = l^2 - \left(\frac{l}{2}\right)^2$

$$= [l(1+\alpha_2 t)]^2 - \left[\frac{l}{2}(1+\alpha_1 t)\right]^2$$

$$l^2 - \frac{l^2}{4} = l^2(1 + \alpha_2^2 t^2 + 2\alpha_2 t) - \frac{l^2}{4}(1 + \alpha_1^2 t^2 + 2\alpha_1 t)$$

Neglecting $\alpha_2^2 t^2$ and $\alpha_1^2 t^2$

$$0 = l^2(2\alpha_2 t) - \frac{l^2}{4}(2\alpha_1 t) \Rightarrow 2\alpha_2 = \frac{2\alpha_1}{4} \Rightarrow \alpha_1 = 4\alpha_2$$

12. (b) Substances are classified into two categories

(i) water like substances which expand on solidification.

(ii) CO_2 like (Wax, Ghee *etc.*) substances which contract on solidification.

Their behaviour regarding solidification is opposite. Melting point of ice decreases with rise of pressure but that of wax etc increases with increase in pressure. Similarly ice starts forming from top to downwards whereas wax starts its formation from bottom to upwards.

13. (b) Heat lost in t sec = mL or heat lost per sec = $\frac{mL}{t}$. This must be the heat supplied for keeping the substance in molten state per sec.

$$\therefore \quad \frac{mL}{t} = P \quad \text{or} \quad L = \frac{Pt}{m}$$

14. (a) Heat is lost by steam in two stages (i) for change of state from steam at 100°C to water at 100°C is $m \times 540$ (ii) to change water at 100°C to water at 80°C is $m \times 1 \times (100 - 80)$, where m is the mass of steam condensed.

Total heat lost by steam is $m \times 540 + m \times 20 = 560\, m$ (*cals*). Heat gained by calorimeter and its contents is $= (1.1 + 0.02) \times (80 - 15) = 1.12 \times 65$ *cals*.

using Principle of calorimetery, Heat gained = heat lost

$\therefore\ 560\, m = 1.12 \times 65$, $m = 0.130\, g$

15. (b) Initially ice will absorb heat to raise it's temperature to 0°C then it's melting takes place

If m_i = Initial mass of ice, m_i' = Mass of ice that melts and m_W = Initial mass of water

By law of mixture, Heat gained by ice = Heat lost by water $\Rightarrow m_i \times c \times (20) + m_i' \times L = m_W c_W [20]$

$\Rightarrow 2 \times 0.5(20) + m_i' \times 80 = 5 \times 1 \times 20 \Rightarrow m_i' = 1 kg$

So final mass of water = Initial mass of water + Mass of ice that melts = 5 + 1 = 6 *kg*.

16. (a) Heat gained by the water = (Heat supplied by the coil) – (Heat dissipated to environment)

$\Rightarrow mc\,\Delta\theta = P_{Coil}\, t - P_{Loss}\, t$

$\Rightarrow 2 \times 4.2 \times 10^3 \times (77 - 27) = 1000\, t - 160\, t$

$$\Rightarrow t = \frac{4.2 \times 10^5}{840} = 500\, s = 8\, min\ 20\, s$$

17. (a) If mass of the bullet is m *gm*,

then total heat required for bullet to just melt down

$Q_1 = m\, c\, \Delta\theta + m\, L = m \times 0.03\,(327 - 27) + m \times 6$

$= 15\, m\, cal = (15m \times 4.2)J$

Now when bullet is stopped by the obstacle, the loss in its mechanical energy $= \frac{1}{2}(m \times 10^{-3})v^2 J$

(As $m\, g = m \times 10^{-3} kg$)

As 25% of this energy is absorbed by the obstacle,

The energy absorbed by the bullet

$$Q_2 = \frac{75}{100} \times \frac{1}{2} mv^2 \times 10^{-3} = \frac{3}{8} mv^2 \times 10^{-3} J$$

Now the bullet will melt if $Q_2 \geq Q_1$

i.e., $\frac{3}{8} mv^2 \times 10^{-3} \geq 15m \times 4.2 \Rightarrow v_{min} = 410\, m/s$

18. (b) We can relate an absorbed energy Q and the resulting temperature increase ΔT with relation $Q = cm\Delta T$. In that equation, m is the mass of the material absorbing the energy and c is the specific heat of that material. An absorbed dose of 3 Gy corresponds to an absorbed energy per unit mass of 3 J/kg. Let us assume that c the specific heat of human body, is the same as that of water, 4180 J/Kg K. Then we find that

$$\Delta T = \frac{Q/m}{c} = \frac{3}{4180} = 7.2 \times 10^{-4} K \approx 700 \mu K$$

Obviously the damage done by ionizing radiation has nothing to do with thermal heating. The harmful effects arise because the radiation damages DNA and thus interferes with the normal functioning of tissues in which it is absorbed.

19. (c) Heat gain = heat lost

$$C_A(16 - 12) = C_B(19 - 16) \Rightarrow \frac{C_A}{C_B} = \frac{3}{4}$$

$$\text{and } C_B(23 - 19) = C_C(28 - 23) \Rightarrow \frac{C_B}{C_C} = \frac{5}{4}$$

$$\Rightarrow \frac{C_A}{C_C} = \frac{15}{16} \quad \text{...(i)}$$

If θ is the temperature when A and C are mixed then,

$$C_A(\theta - 12) = C_C(28 - \theta) \Rightarrow \frac{C_A}{C_C} = \frac{28 - \theta}{\theta - 12} \quad \text{...(ii)}$$

On solving equation (i) and (ii) $\theta = 20.2°C$.

20. (b) Suppose m kg steam is required per hour

Heat is released by steam in following three steps

(i) When 150°C steam $\xrightarrow[Q_1]{}$ 100°C steam

$$Q_1 = mc_{Steam}\,\Delta\theta = m \times 1\ (150 - 100) = 50\ m\ cal$$

(ii) When 100°C steam $\xrightarrow[Q_2]{}$ 100°C water

$$Q_2 = mL_V = m \times 540 = 540\ m\ cal$$

(iii) When 100°C water $\xrightarrow[Q_2]{}$ 90°C water

$$Q_3 = mc_W\,\Delta\theta = m \times 1 \times (100 - 90) = 10\ m\ cal$$

Hence total heat given by the steam $Q = Q_1 + Q_2 + Q_3$ $= 600\ mcal$ ... (i)

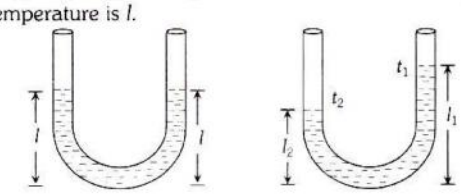
Heat taken by 10 kg water

$$Q' = mc_W\Delta\theta = 10 \times 10^3 \times 1 \times (80 - 20) = 600 \times 10^3\ cal$$

Hence $Q = Q' \Rightarrow 600\ m = 600 \times 10^3$

$\Rightarrow m = 10^3\ gm = 1kg.$

21. (a) Suppose, height of liquid in each arm before rising the temperature is l.



With temperature rise height of liquid in each arm increases i.e. $l_1 > l$ and $l_2 > l$

Also $l = \dfrac{l_1}{1 + \gamma t_1} = \dfrac{l_2}{1 + \gamma t_2}$

$$\Rightarrow l_1 + \gamma l_1 t_2 = l_2 + \gamma l_2 t_1 \ \Rightarrow\ \gamma = \frac{l_1 - l_2}{l_2 t_1 - l_1 t_2}.$$

22. (c) $V = V_0(1 + \gamma\Delta\theta)$

$$L^3 = L_0(1 + \alpha_1\Delta\theta)L_0^2(1 + \alpha_2\Delta\theta)^2 = L_0^3(1 + \alpha_1\Delta\theta)(1 + \alpha_2\Delta\theta)^2$$

Since $L_0^3 = V_0$ and $L^3 = V$

Hence $1 + \gamma\Delta\theta = (1 + \alpha_1\Delta\theta)(1 + \alpha_2\Delta\theta)^2$

$\cong (1 + \alpha_1\Delta\theta)(1 + 2\alpha_2\Delta\theta) \ \cong (1 + \alpha_1\Delta\theta + 2\alpha_2\Delta\theta)$

$\Rightarrow \gamma = \alpha_1 + 2\alpha_2.$

23. (a) $\dfrac{P}{\alpha\Delta\theta} = Y$

$$P = Y\alpha\Delta\theta = 2 \times 10^{11} \times 1.1 \times 10^{-5} \times 100 = 2.2 \times 10^8\ Pa$$

24. (b) Heat gain by water = Heat lost by steam

$20 \times 1 \times (80 - 10) = m \times 540 + m \times 1 \times (100 - 80)$

$\Rightarrow 1400 = 560\ m$

$\Rightarrow m = 2.5\ g$

Total mass of water = 20 + 2.5 = 22.5 g.

Graphical Questions

1. (b) Relation between Celsius and Fahrenheit scale of temperature is $\dfrac{C}{5} = \dfrac{F - 32}{9} \Rightarrow C = \dfrac{5}{9}F - \dfrac{160}{9}$

Equating above equation with standard equation of line $y = mx + c$ we get slope of the line AB is $m = \dfrac{5}{9}$.

2. (c) Since in the region AB temperature is constant therefore at this temperature phase of the material changes from solid to liquid and $(H_2 - H_1)$ heat will be absorb by the material. This heat is known as the heat of melting of the solid.

Similarly in the region CD temperature is constant therefore at this temperature phase of the material changes from liquid to gas and $(H_4 - H_3)$ heat will be absorbed by the material. This heat as known as the heat of vaporisation of the liquid.

3. (a) Initially, on heating temperature rises from –10°C to 0°C. Then ice melts and temperature does not rise. After the whole ice has melted, temperature begins to rise until it reaches 100°C. Then it becomes constant, as at the boiling point will not rise.

4. (a) The volume of matter in portion AB of the curve is almost constant and pressure is decreasing. These are the characteristics of liquid state.

5. (d) Let the quantity of heat supplied per minute be Q. Then quantity of heat supplied in 2 min $= mC(90 - 80)$

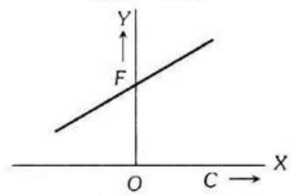
In 4 min, heat supplied $= 2mC(90 - 80)$

$$\therefore\ 2mC(90 - 80) = mL \Rightarrow \frac{L}{C} = 20.$$

6. (b) In the given graph CD represents liquid state.

7. (a) Density of water is maximum at 4°C and is less on either side of this temperature.

8. (a) We know that, $\dfrac{C}{100} = \dfrac{F - 32}{180}$ or $F = \dfrac{9}{5}C + 32$



Equation of straight line is, $y = mx + c$

Hence, $m = (9/5)$, positive and $c = 32$ positive. The graph is shown in figure.

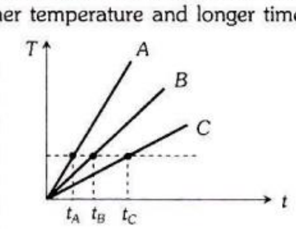
9. (a) $\dfrac{C}{5} = \dfrac{F - 32}{9} \Rightarrow C = \left(\dfrac{5}{9}\right)F - \dfrac{20}{3}$. Hence graph between °C and °F will be a straight line with positive slope and negative intercept.

10. (bc) The horizontal parts of the curve, where the system absorbs heat at constant temperature must depict changes of state. Here the latent heats are proportional to lengths of the horizontal parts. In the sloping parts, specific heat capacity is inversely proportional to the slopes.

11. (a) Initially liquid oxygen will gain the temp. up to its boiling temperature then it change its state to gas. After this again its temperature will increase, so corresponding graph will be.

13. (c) Substances having more specific heat take longer time to get heated to a higher temperature and longer time to get cooled.

If we draw a line parallel to the time axis then it cuts the given graphs at three different points. Corresponding points on the times axis shows that



$$t_C > t_B > t_A \ \Rightarrow\ C_C > C_B > C_A$$

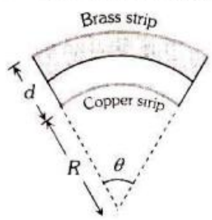
14. (c) From given curve,
Melting point for $A = 60°C$
and melting point for $B = 20°C$
Time taken by A for fusion $= (6-2) = 4$ minute
Time taken by B for fusion $= (6.5-4) = 2.5$ minute
Then $\frac{H_A}{H_B} = \frac{6\times4\times60}{6\times2.5\times60} = \frac{8}{5}$.

15. (a) Anomalous density of water is given by (a). It has maximum density at $4°C$. When ice is formed it floats.

JEE Section

More than one correct answers

1. (bd) Let L_0 be the initial length of each strip before heating.
Length after heating will be



$L_B = L_0(1+\alpha_B\Delta T) = (R+d)\theta$
$L_C = L_0(1+\alpha_C\Delta T) = R\theta$
$\Rightarrow \frac{R+d}{R} = \frac{1+\alpha_B\Delta T}{1+\alpha_C\Delta T}$
$\Rightarrow 1+\frac{d}{R} = 1+(\alpha_B-\alpha_C)\Delta T$
$\Rightarrow R = \frac{d}{(\alpha_B-\alpha_C)\Delta T} \Rightarrow R \propto \frac{1}{\Delta T}$ and $R \propto \frac{1}{(\alpha_B-\alpha_C)}$

Reasoning type questions

3. (c) The correct reason is because under steady state conditions, when temperature constant, the rate of conduction of heat across every lamina is the same.

4. (a) In the absence of atmosphere surrounding the earth, the heat will escape from earth's surface which will make it hospitably cold.

Comprehension type questions

Passage - I

5. (b) Heat lost by water and container
$mC_1(t_2-0)+mC_2(t_2-0)+mL < mC_3(0-t_3)$
$\therefore C_1t_2+C_2t_2+C_3t_3+L<0.$

6. (d) Heat lost $= mC_1(t_2-0)+mC_2(t_2-0)$
Heat gained $= mC_3(0-t_3)+mL$
$\therefore C_1t_2+C_2t_2 > C_3t_3+L$
$\therefore C_1t_2+C_2t_2+C_3t_3-L>0.$

7. (b) $mC_1 = MC_2$
$\therefore M = \frac{mC_1}{C_2}$.

Integer type questions

8. (3) Energy released by water from 25°C to 0°C
$= 2500\times1\times25 = 62500\,cal$
Energy to bring ice to 0°C
$= 2000\times\frac{1}{2}\times15 = 15000\,cal$
Energy used to melt ice of m gram $= m80\ cal$
$\therefore$ Ice melt $m = \left(\frac{62500-15000}{80}\right) = 593.75\,g$
So, mass of water $= (2500+593.75)\,g$
$= 3093.75\,g \simeq 3\,kg.$

Assertion and Reason

1. (a) With rise in pressure melting point of ice decreases. Also ice contracts on melting.

2. (c) Celsius scale was the first temperature scale and Fahrenheit is the smallest unit measuring temperature.

3. (e) Melting is associated with increasing of internal energy without change in temperature. In view of the reason being correct the amount of heat absorbed or given out during change of state is expressed $Q = mL$, where m is the mass of the substance and L is the latent heat of the substance.

4. (a) The temperature of land rises rapidly as compared to sea because of specific heat of land is five times less than that of sea water. Thus, the air above the land becomes hot and light so rises up so pressure drops over land. To compensate the drop of pressure, the cooler air from sea starts blowing towards lands, setting up sea breeze. During night land as well sea radiate heat energy. The temperature of land falls more rapidly as compared to sea water, as sea water consists of higher specific heat capacity. The air above sea water being warm and light rises up and to take its place the cold air from land starts blowing towards sea and set up breeze.

5. (d) The potential energy of water molecules is more. The heat given to melt the ice at $0°C$ is used up in increasing the potential energy of water molecules formed at $0°C$.

6. (c) Water evaporates quickly because of lack of atmospheric pressure, also temperature of moon is much higher during day time but it is very low at night.

7. (c) The relation between F and C scale is, $\frac{C}{5} = \frac{F-32}{9}$. If $F = C \Rightarrow C = -40°C$, *i.e.*, at $-40°$ the Centigrade and Fahrenheit thermometers reads the same.

8. (d) Specific heat of a body is the amount of heat required to raise the temperature of unit mass of the body through unit degree. When mass of a body is less than unity, then its thermal capacity is less than its specific heat and vice-versa.

9. (a) Water has maximum density at $4°C$. On heating above $4°C$ or cooling below $4°C$, density of water decreases and its volume increases. Therefore, water overflows in both the cases.

10. (a) When two bodies at temperature T_1 and T_2 are brought in thermal contact, they do settle to the mean temperature $(T_1+T_2)/2$. They will do so, in case the two bodies were of same mass and material, *i.e.*, same thermal capacities. In other words, the two bodies may be having different thermal capacities, that's why they do not settle to the mean temperature, when brought together.