# THERMAL PROPERTIES OF MATTER

## Important Points:

1. **Heat is a form of energy which has capacity to do the work.**

   **Unit:** SI - Joule

   C. G. S - Calorie

   1 cal = 4.2 J

2. **Temperature is degree of hotness or coldness in a body which determines direction of flow of heat.**

3. $$\frac{F-32}{180}=\frac{C-0}{100}=\frac{K-273}{100}$$

4. **Co-Efficient of linear Expansion:**

   The ratio of increase in length of a metal rod per rise in temperature to its original length is called linear co-efficient of expansion ($\alpha$).

   $$\alpha=\frac{(l_2-l_1)}{l_1(t_2-t_1)}/\,^0\text{C}.$$

5. **Co-Efficient of Areal Expansion:**

   The ratio of increase in area of metal plate per rise in temperature to its original area is called co-efficient of Areal expansion ($\beta$).

   $$\beta=\frac{(a_2-a_1)}{a_1(t_2-t_1)}/\,^0\text{C}.$$

6. **Co-Efficient Volume Expansion:**

   The ratio of increase in volume of metal cube per rise in temperature to its original volume is called co-efficient of volume expansion ($\gamma$).

$$\gamma = \frac{(V_2 - V_1)}{V_1(t_2 - t_1)} / {}^0C.$$

**7. Relation Between** $\alpha.\beta$ *and* $\gamma$

$$\alpha : \beta : \gamma = 1 : 2 : 3$$

**8. Variation of Density of with Temperature**:

As temperature increases, density decreases.

$$d_0 = d_t (1 + \gamma t)$$

$d_0$ and $d_t$ are densities at $0^0$C and $t^0$C respectively.

$\gamma$ Co-efficient of volume expansion

**9**. Platinum is used to seal with glass due to same co-efficient of linear expansion.

**10.** If two rods of different materials have the same difference between their lengths (X) at all temperatures.

$$l_1\alpha_1 = l_2\alpha_2$$

$$l_1 = \frac{X\alpha_2}{\alpha_1 \sim \alpha_2}, \quad l_2 = \frac{X\alpha_1}{\alpha_1 \sim \alpha_2}$$

**11.** Invar steel (steel + nickel) has very low $\alpha$. So it is used in making pendulum clocks, balancing wheels and measuring tapes.

**12.** Linear and a real expansion have no significance for a liquid since shape of liquid depends on shape of vessel.

**13. Anomalous Expansion of Water:**

When water at 0°C is heated, its volume decreases up to 4°C and from 4°C its volume increases with the increase of temperature. This peculiar behavior of water is called anomalous expansion of water.

**14.** Water has maximum density and minimum volume at 4°C (or) 277 K

**15.** Anomalous expansion of water can be demonstrated with Hopes apparatus (or) Dilatometer.

**16. Volume Co-Efficient of a Gas ($\alpha$):**

The ratio of increase in volume of a gas per degree rise of the temperature to the volume at $0^0$C at constant pressure is called Volume Coefficient

$$\alpha = \frac{v_t - v_0}{v_0 t} \text{ Or } \alpha = \frac{v_2 - v_1}{v_1 t_2 - v_2 t_1}$$

**17. Pressure Co-Efficient of a Gas ($\beta$):**

The ratio of increase in pressure of a gas per degree rise of temperature to its pressure at $0^0$C at constant volume is called Pressure Co-Efficient.

$$\beta = \frac{p_t - p_0}{p_0 t} \text{ Or } \beta = \frac{p_2 - p_1}{p_1 t_2 - p_2 t_1}.$$

**18. Relation Between $\alpha$ and $\beta$**

For all gases $\alpha = \beta = \frac{1}{273.15} = 0.00367 /^0 C$

**19. Boyle's Law:**

At constant temperature, the pressure of a given mass of a gas is inversely proportional to its volume.

$$P \propto \frac{1}{V} \text{ or } PV = k \quad \text{(T = constant)}$$

At high temperature and low pressure gases obey Boyle's law.

**20. Charles's -I Law:**

At constant pressure, the volume of a given mass of gas is proportional to absolute temperature.

$$\frac{V}{T} = \text{constant} \Rightarrow \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

**21. Charles's -II Law:**

At constant volume, the pressure of a given mass of a gas is directly proportional to its absolute temperature.

$$\frac{P}{T} = \text{constant} \ (or) \ \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

**22. Real Gas:**

The gas which obeys gas laws at high temperature and low pressure is called a Real Gas.

**23. Ideal gas Equations:**

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

Where P is the pressure, V is the volume of 1gram mole of a gas, T is the absolute temperature and R is the universal gas constant.

R = 8.31 Joule /gm/K = 2 cal/gm/mole/K

**24.** From gas equation $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

**25. Boltzmann's Constant:**

K = 1.38 x $10^{-23}$ J/K and K = $K = \frac{R}{N}$

Where N = 6.02 x $10^{23}$ molecules per mole. N is the Avogadro's number.

**26. Absolute Zero:**

It is the temperature at which the volume of a gas becomes zero at constant pressure (or) pressure becomes zero at constant volume.

**27. Specific Heat:**

The quantity of heat required to rise the temperature of unit mass of a substance through $1^0C$ is called Specific Heat 'c'

$$c = \frac{1}{m} . \frac{dQ}{dt}$$

**Units:** S.**I.:** $J/_{kg\,K}$

C. G. S**:** $Cal/_{gm}\,{}^0C$

Dimensional formula: $L^2T^{-2}K^{-1}$

**28. Latent Heat:**

The amount of heat required by unit mass of a substance to change its state at constant temperature is called Latent Heat (L)

$Q = mL$

**Units** **:** S.I.: J/kg

C. G. **S** **:** cal/ gm

Dimensional formula $\therefore L^2T^{-2}$

**29. Latent heat of fusion of Ice:**

The quantity of heat required to change the state of 1gram of ice into water at is called Latent Heat of Fusion of Ice.

$L_{ice} = 80 cal / gm$

$L_{ice} = 0.336 \times 10^6 J / kg$

**30. Latent heat of Steam:**

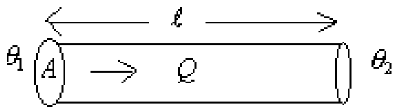
The quantity of heat required to change the state of 1gram of water into steam at $100^0 C$ is called Latent Heat of Steam.

$L_{steam} = 540 cal / gm$

$L_{steam} = 2.268 \times 10^6 J / kg$

**31. Co-Efficient of Thermal Conductivity:**

a) At steady state the quantity of heat Q flowing through a metal rod of $l$ length and cross-section A in a time **t** when its ends are at temperature $\theta_1$ and $\theta_2$ $(\theta_1 > \theta_2)$ is given by




$$Q = \frac{KA(\theta_1 - \theta_2)}{l} t$$

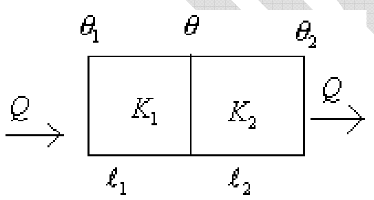
Where K is coefficient of thermal conductivity

b) K depends on the nature of the metal.

c) It is defined as the rate of flow of heat per unit area and per unit temperature gradient in steady state.

d) **Junction Temperature:**

In steady state,




$$\theta = \frac{(K_1\theta_1 + K_2\theta_2)}{(K_1 + K_2)}$$

**32. Thermal Resistance:**

Thermal resistance R of a conductor of length, cross-section A and conductivity K is given by

$$R = \frac{l}{KA}$$

**33. Radiation:**

The process of transfer of heat that takes place without the help of the intervening medium is called Radiation.

**Ex.** Heat received by the earth from the sun.

**34. Black Body:**

A body completely absorbing the radiation of all wavelengths falling on it is called a black body.

**35. Emissive Power:**

a) The amount of energy emitted per second per unit surface area of a body at a given temperature for a given wavelength range is called emissive power.

b) At a given temperature if the radiations emitted have a wave length difference, then the emissive power is equal to $e_\lambda d\lambda$.

c) **Unit** -$Wm^{-2}$

**D.F**. - $MT^{-3}$

**36. Emissivity (e):**

a) The ratio of radiant energy emitted by a surface to radiant energy emitted by a black body under same conditions is called Emissivity.

b) For a perfect black body emissivity e = 1.

**37. Absorptive Power** $(a_\lambda)$ **:**

a) At a given temperature, for a given wavelength range, the ratio of energy absorbed to the energy incident on the body is absorptive power.

$$a_\lambda = \frac{Amount\ of\ radiant\ energy\ absorbed}{Amount\ of\ radiant\ energy\ incident}$$

b) For a perfect black body, the absorptive power, $a_\lambda = 1$.

**38. Prevost theory of heat Exchange:**

a) Every object emits and absorbs radiant energy at all temperatures except at absolute zero.

b) The rate of emission increases with the increase in the temperature of the body.

c) If the body emits more radiant energy. Than absorbed, its temperature decreases.

d) If the body absorbs more radiant energy than it emits, its temperature increases.

**39. Kirchhoff's Laws:**

a) At a given temperature, for a given wave length range, the ratio of emissive power to absorptive power of a substance is constant.

b) This constant is equal to the emissive power of a perfect black body at the given temperature and wavelength.

i.e. $\frac{e_\lambda}{a_\lambda} = const = E_\lambda$,

Where '$E_\lambda$'is the emissive power of perfect black body. '$e_\lambda$' And '$a_\lambda$' are emissive and absorptive powers of a given substance respectively.

c) Good absorbers are good emitters.

**40. Stefan's Law:**

The amount of heat radiated by a black body per second per unit area is directly proportional to the fourth power of its absolute temperature.

$E \propto T^4 \Rightarrow E = \sigma T^4$.

Where

$\sigma$ = Stefan's constant

$= 5.67 \times 10^{-8} Wm^{-2} K^{-4}$

**41. Stefan - Boltzmann's Law:**

a) If a black body at absolute temperature T is surrounded by an enclosure at absolute temperature $T_o$, then the rate of loss of heat energy by radiation per unit area is given by.

$$E = \sigma(T^4 - T_0^4)$$

b) For any hot body, $E = \sigma Ae(T^4 - T_0^4)$

Where 'e' is the emissive power and 'A' is the area of cross-section of the hot body

**42. Newton's Law of Cooling:**

The rate of cooling of a hot body is directly proportional to the excess mean of temperature of the body above the surroundings, when the difference in temperature of the body and that of surroundings is small.

$$\frac{d\theta}{dt} \alpha \left(\frac{\theta_1 + \theta_2}{2} - \theta_0\right)$$

$\theta_1, \theta_2$ are the initial and final temperatures of the body respectively. $\theta_0$ is temperature of surroundings .

## Very Short Answer Questions

**1. Distinguish between heat and temperature?**

A.

| Heat | Temperature |
|---|---|
| 1) Heat is a form of energy. | 1) It is the degree of hotness or coldness contained in a body. |
| 2) Heat is the source. | 2) Temperature is the effect |
| 3) Unit of heat energy is Joule | 3) Unit of temperature is centigrade. |

**2. What are the lower and upper fixed points of Celsius and Fahrenheit scale?**

A. **Celsius Scale:**

Lower fixed point: $0^0C$

Upper fixed point: $100^0C$

**Fahrenheit scale:**

Lower fixed point: $32^0F$

Upper fixed point: $212^0F$

**3. Do the values of coefficients of expansion differ, when the temperatures are measured on Centigrade scale or on Fahrenheit scale?**

A. Yes. $\frac{C}{5}=\frac{F-32}{9}$

**4. Can a substance contract on heating? Give an example?**

A. Yes, Lead, cast iron, pure water when heated from, rubber etc. contract on heating.

**5. Why gap are left between rails on a railway track?**

**A.** A gap should be left between two successive rails to allow for linear expansion of the rails in summer.

**6. Why do liquids have no linear and areal Expansions?**

**A.** Liquids do not have a specific size or shape. The shape of a liquid depends on the shape of the container. Hence the liquids do not have linear and areal expansions.

**7. What is latent of heat of fusion?**

A. **Latent of heat of Fusion:**

At constant temperature, the quantity of heat required to change unit mass of substance from solid state to liquid state is called latent heat of fusion.

**8. What is latent heat of Vaporization?**

**A. Latent heat of Vaporization:**

The amount of heat required to change unit mass of liquid into vapor at constant temperature is called latent heat of vaporization.

**9. What is specific gas constant? Is it same for all Gases?**

**A.** i) For 1 gm of a gas $\frac{PV}{T} = r$. For m grams of the gas $\frac{PV}{T} = mr$ 'r' is the specific gas constant. ii) The specific gas constant is different for different gases.

**10. What are the units and dimensions of specific gas constant?**

**A. Units:** $J\ Kg^{-1}\ K^{-1}$

**Dimensions**: $M^0\ L^2 T^{-2} K^{-1}$

**11. Why utensils are coated black? Why the bottoms of the utensils are made of Copper?**

A. i) Black surface is a good absorber and good emitter. Hence utensils are coated black.

ii) Copper is a good conductor of heat .Hence copper is used at the bottom of cooking utensils.

**12. State wein's displacement Law.**

**A.** The wavelength $\lambda_m$ corresponding to maximum energy emitted by a black body is inversely proportional to its absolute temperature.

$\lambda_m T$=constant.

The value of constant is 2.9x$10^{-3}$ mK.This is called wein's displacement law.

**13. Ventilators provided in rooms just below the roof. Why?**

A. Ventilators are placed below the roof in rooms to allow hot air to escape.

**14. Does a body radiate heat at 0 K? Does it radiate heat at $0^0$C?**

**A.** i) A body does not radiate heat at 0 K.

ii) A body can radiate heat at $0^0$C.

**15. State the different modes of transmission of heat. Which of these modes require medium?**

**A.** Heat is transferred or propagated by three distinct processes namely conduction, convection and radiation.

Conduction and convection require medium.

**16. Define coefficient of thermal conductivity and temperature gradient?**

**A. Thermal Conductivity:**

It is the quantity of heat flowing normally per unit time through unit area of the substance per unit temperature gradient.

$$K = \frac{Q d}{A(\theta_2 - \theta_1)t}$$

If A = 1m$^2$, $\frac{\theta_2 - \theta_1}{d}$ =$1^0$ c/m and t = 1s, then K = Q

**Temperature Gradient:**

Temperature difference per unit length is called temperature gradient.

Temperature gradient = $\frac{\theta_2 - \theta_1}{d}$ $0$ c / m

**17. What is thermal resistance of a conductor? On factors does it depend?**

A. **Thermal resistance (*R*):**

The thermal resistance of a body is a measure of its opposition to the flow of heat through it. It is defined as the ratio of temperature difference to the heat current.

$$R = \frac{l}{KA}$$

Thermal resistance of a body depends on length and area of cross-section of the conductor.

**18. State the units and dimensions of Coefficient of Convection?**

A. **Units** : $Wm^{-2} K^{-1}$

**Dimensions** : $\left[MT^{-3}K^{-1}\right]$

**19. Define emissive power and emissivity.**

A. **Emissive power ($e_\lambda$):**

i) The amount of energy emitted per second per unit surface area of a body at a given Temperature for a given wavelength range ($\lambda$ and $\lambda + d\lambda$) is called emissive power.

ii) At a given temperature if the radiations emitted have a wavelength difference $d\lambda$, then the Emissive power is equal to $e_\lambda \, d\lambda$.

iii) S.I unit of emissive power is $Wm^{-2}$ and its dimensional formula is $MT^{-3}$.

**Emissivity (e):** The ratio of radiant energy emitted by a surface to radiant energy emitted by a black body under same conditions is called emissivity.

i) For a perfect black body emissivity e=1.

**20. What is Green House Effect? Explain Global Warming?**

A. The surface of the earth and atmosphere gets heated up due to absorption of radiation from sun by green house gases, namely Carbon dioxide, Methane, Nitrous oxide, etc. This is known as green house effect.

Hence the earth becomes warmer and the average temperature of the earth increases. This is known as global warming. This global warming may cause problem for human life, plants and animals. Because of global warming, ice caps are melting faster, sea level is rising and weather pattern is changing.

**21. Define absorptive power of a body. What is the absorptive power of a perfect black body?**

A. **Absorptive Power ($a_\lambda$):**

i) At a given temperature, for a given wavelength range, the ratio of energy absorbed to the energy incident on the body is absorptive power.

ii) For a perfect black body, the absorptive power, $a_\lambda = 1$.

**22. State Newton's Law of Cooling?**

**A. Newton's Law of Cooling:**

The rate of fall of temperature of a body is proportional to the excess mean temperature of the body over the surroundings.

If a body cools from a temperature $\theta_1$ to the temperature $\theta_2$ in the surroundings at a $\theta_0$ temperature, then

$$\frac{d\theta}{dt} \alpha \left( \frac{\theta_1 + \theta_2}{2} - \theta_0 \right)$$

**23. State the conditions under which Newton's law of cooling is applicable?**

**A. Conditions:** Newton's law of cooling is applicable when

(i) Heat lost by the body is mainly by convection.

(ii) The hot body is cooled in uniformly stream lined flow of air or forced convection.

(iii) The temperature of every part of the body is same.

**24. The roof buildings are often painted white during summer. Why?**

**A.** The roof buildings are often painted white during summer, because white is a poor absorber.

## Short Answer Questions

**1. Explain Celsius and Fahrenheit scales of temperature. Obtain the relation between Celsius and Fahrenheit scales of temperature.**

A. **Celsius scale of temperature:**

In the centigrade scale, the lower fixed point (ice point) is $0^0$C and the upper fixed point (steam point) is $100^0$C. The difference between two fixed point values is $100^0$C. The interval between these two points is divided into 100 equal parts and each corresponds to $1^0$C on the scale.

**Fahrenheit scales of Temperature:**

In the Fahrenheit scale, the lower fixed point is $32^0$F and upper fixed point is taken as $212^0$F . The difference between two fixed point values is $180^0$F. The interval between these two points is divided into 180 equal parts then each part corresponds to $1^0$F on the scale.

**Relation between Celsius and Fahrenheit scales:**

The temperature difference between the ice and stream points should be the same on Celsius and Fahrenheit scales.

In the centigrade scale, the lower fixed point (ice point) is $0^0$C and the upper fixed point (steam point) is $100^0$C.

In the Fahrenheit scale, the lower fixed point is $32^0$F and upper fixed point is taken as $212^0$F . The difference between two fixed point values is $180^0$F.

Let the temperature of a body on Celsius and Fahrenheit scales be C and F respectively.

Then, $\frac{C-0}{100}=\frac{F-32}{180} \Rightarrow \frac{C}{5}=\frac{F-32}{9}$

**2. Two identical rectangular strips one of copper and the other of steel are riveted together to form a bimetallic strip. What will happen on heating?**

A. **Bimetallic Strip:**

A bimetallic strip consists of strips made of two different metals of different coefficients of expansion, riveted together. When heated, it bends such that the strip with more expansion (copper) lies on the convex side.

**Uses:**

A bimetallic strip is used

(i) For continuous recording temperature

(ii) As a thermostat to control the temperature of a body

(iii) As a fire alarm.

**3. Pendulum clocks generally go fast in winter and slow in summer. Why?**

**A.** $T = 2\pi\sqrt{\frac{l}{g}}$ or $T \alpha \sqrt{l}$

Time period of a pendulum clock is directly proportional to square root of the length of the Pendulum.

i) In winter the length of the pendulum decreases and its time period decreases. So clock goes fast.

ii) In summer the length of the Pendulum increases and its time period increases. So the clock goes slow.

**4. In what way is the anomalous behavior of water advantageous to aquatic animals?**

**A.** In cold countries, at nights as temperature decreases, the upper layers of the lake contract and sink to the bottom. This process goes on until the temperature of water becomes $4^0$C. When the top layer cools further it does not sink to the bottom. With further cooling the top layers gradually form ice at the top. This results in water at the bottom at $4^0$C, so that aquatic life can live in a pond.

**5. Explain conduction, convection and radiation with Examples?**

**A. Conduction:**

The process of transfer of heat that takes place without the movement of the particles of the medium is called conduction.

**Ex.** Heating up of a metal rod

**Convection:**

The process of transfer of heat with the bodily movement of the particles of the medium is called convection.

**Ex.** Heating up of a liquid

**Radiation:**

The process of transfer of heat that takes place without the help of the intervening medium is called radiation.

**Ex.** Heat received by the earth from the sun.

## Long Answer Questions

**1. State Boyle's law and Charles' law. Hence derive ideal gas equation. Which of the two laws is better for the purpose of thermometry and why?**

A. **Boyle's Law:**

At constant temperature, the pressure (P) of a given mass of a gas is inversely proportional to its volume (V). $P \alpha \frac{1}{V}$ Or PV = constant

**Charles' Law at Constant Pressure:**

At constant Pressure, the volume (V) of given mass of gas is directly proportional to its absolute temperature (T). $V \propto T$ Or V / T = constant

**Charles Law at Constant Volume:**

At constant volume, the pressure (P) of a given mass of a gas is directly proportional to its absolute temperature (T). $P \alpha T$ *Or* $\frac{P}{T} =$ Constant

**Ideal Gas Equation:**

Consider a gas of volume; pressure and temperature are $V_1$, $P_1$ and $T_1$ respectively. Let these values are changed to $V_2$, $P_2$ and $T_2$ in two different stages $P_1V_1 = P_2V$ .

i) Keeping the temperature $T_1$ constant, the pressure of the gas is changed from $P_1$ to $P_2$. Then let its volume changes from $V_1$ to V.

From Boyles law,

$$\therefore V = \frac{P_1V_1}{P_2} \quad \text{.........................} (1)$$

ii) Now Keeping pressure $P_2$ constant, the temperature of the gas is changed from $T_1$ to $T_2$.Then let its volume changes from $V_1$ to $V_2$.

From Charles law $\frac{V}{T_1} = \frac{V_2}{T_2}$,

$$\therefore V = \frac{V_2 T_1}{T_2} \text{ ............................ (2)}$$

From equations (1) and (2)

Or $\frac{P_1V_1}{P_2} = \frac{V_2T_1}{T_2} \Rightarrow \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow \frac{PV}{T} = r$

The constant 'r' is called specific gas constant which is different for different gases. For one mole of gas,

PV = RT    this is called ideal gas equation.

Here R is called universal gas constant. R = 8.314 J $mole^{-1}$ $k^{-1}$

For 'n' moles of gas,    PV = nRT

**Gas Thermometers:**

Charles' law is better for the purpose of measurement of temperature because in Boyle's law temperature is constant.

**2. Explain thermal conductivity and coefficient of thermal conductivity.**
**A copper bar of thermal conductivity 401W/(mK) has one end at $104^0$ C and the other at $24^0$ C. The length of the bar is 0.10m and the cross sectional area is $1.0 \times 10^{-6} m^2$. What is the rate of heat conduction along the bar?**

**A. Thermal Conductivity:**

**Definition**:

The ability of a solid to conduct heat is called thermal conductivity.

**Explanation:**

When one end of a metal rod is heated, the amplitude of vibration of the atoms at that end increases. These atoms collide with the adjacent atoms by sharing their energy with them. Thus heat energy flows from higher temperature end to lower temperature end of the rod.

**Coefficient of Thermal Conductivity (K):**

The amount of heat (Q) flowing through a rod is directly proportional to

i. The area of cross section (A) of the rod

ii. Temperature difference ( $\theta_2 - \theta_1$ ) between the ends of the rod

iii. The time (t) of flow the heat through the rod and

iv. is inversely proportional to the length ($l$) of the rod.

Where K is called the co-efficient of thermal conductivity of the rod

**Definition of K:**

$$K = \frac{Q/t}{A(\theta_1 - \theta_2)/l}$$

If A = 1 and $\frac{(\theta_1 - \theta_2)}{l} = 1$, then $K = \frac{Q}{t}$

It is defined as the quantity of heat flowing normally per second through unit area of cross-section of the rod per unit temperature gradient.

**Problem:**

K = 401 w/mk ; L = 0.1 m ; A = 1 × $10^{-6}$ $m^2$ ; $\theta_2 - \theta_1$ = 104 - 24 = 80°C

Rate of heat conduction (P) $= \left(\frac{Q}{t}\right) = \frac{\Delta\theta}{R}$

Where R = thermal resistance of Cu = $\frac{L}{K_{cu}A} = \frac{0.1}{401x10^{-6}} = 249.3$

$$P = \frac{\Delta\theta}{R} = \frac{80}{249.3} = 0.32\ W$$

**3. State and explain Newton's Law of cooling. State the conditions under which Newton's Law of cooling is applicable.**

**A body cools down from 60°C to 50°C in 5 minutes and to 40°C in another 8 minutes. Find the temperature of the surroundings.**

**A. Newton's Law of Cooling:**

The rate of fall of temperature of a body is proportional to the difference between the mean temperature of the body and the temperature of the surroundings

**Explanation:**

Let a body cools from a temperature $\theta_2$ to $\theta_0$ the temperature .Let be the temperature of the surroundings. Then the rate of fall of temperature of the body $\frac{d\theta}{dt}$ is given by

$$\frac{d\theta}{dt}\alpha\left(\frac{\theta_1+\theta_2}{2}-\theta_0\right)$$

Or $\frac{d\theta}{dt}=K\left(\frac{\theta_1+\theta_2}{2}-\theta_0\right)$

Where K is a positive constant that depends on area and the nature of the surface of the body

The amount of heat lot is given by $Q=ms\theta \Rightarrow \frac{dQ}{dt}=ms\frac{d\theta}{dt}$

Or $\frac{d\theta}{dt}=\frac{1}{ms}\frac{d\theta}{dt}(or)\frac{d\theta}{dt}=\frac{1}{ms}\sigma A\left(T^4-T_0^4\right)$

**Conditions:**

Newton's law of cooling is applicable when (i) the heat lost by conduction is negligible and heat lost by the body is mainly by convection (ii) the hot body is cooled in uniformly stream lined flow of air or forced convection (iii) the temperature of every part of the body is same.

**Problem:**

From Newton's law of cooling,

$\frac{(60-50)}{5}\alpha\left(\frac{60+50}{2}-\theta\right)$ and $\left(\frac{50-40}{8}\right)\alpha\left(\frac{50+40}{2}-\theta\right)$

Dividing, $\theta = 28.34°C$

## Problems

1. **What is the temperature for which the readings on Kelvin and Fahrenheit scales are same?**

A: $$\frac{K-273.15}{100}=\frac{F-32}{180}$$

Here K = F

$$\frac{F-273.15}{100}=\frac{F-32}{180}$$

$$\therefore\ F=574.6^0 C$$

2. **Find the increase in temperature of aluminum rod if its length is to be increased by 1 %.($\alpha$ for aluminum=$25\times10^{-6}/^0C$).**

A: $$\alpha=\frac{l_2-l_1}{l_1(t_2-t_1)}\Rightarrow(t_2-t_1)=\frac{l_2-l_1}{l_1\alpha}$$

$\therefore$ Percentage increase in length = $25\times10^{-6}\times1\times100$

$$1=25\times10^{-6}(t_2-t_1)\times100$$

$$(t_2-t_1)=\frac{1}{25\times10^{-6}}\times\frac{1}{100}=400^oC.$$

3. **The mass of a litre of a gas is 1.562g at $0^oC$ under a pressure of 76cm of Mercury. The temperature is increased to $250^oC$ and the pressure to 78cm of mercury. What is the mass of one litre of the gas under new conditions?**

A: $P_1=76cm$ of mercury; $P_2=76cm$ of mercury; $T_1=273K$;

$T_2=273+250=523K$; $\rho_1=1.562g/litre$

$$\frac{P_1}{\rho_1T_1}=\frac{P_2}{\rho_2T_2}$$

$$\rho_2 = \frac{P_2 T_1 \rho_1}{P_1 T_2} = \frac{78\times 273\times 1.562}{76\times 523} = 0.8366g$$

**4. The volume of a mass of gas at 37°C and a pressure of 75cm of mercury is 620 c.c. Find the volume at N.T.P**

A: At NTP, $P_1 = 76cm$ ; $T_1 = 273K$

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

Or $\frac{75\times 620}{310} = \frac{76\times V}{273} \Rightarrow V = 538.8\ C.C$

**5. How much steam at $100^0C$ is to be passed into water of mass 100g at $20^0C$ to raise its temperature by $5^0C$? (Latent heat of steam is 540 cal/g and specific heat of water is $1cal/g^0C$)**

**A:** $t_2 = 100^0C$, $m_1 = 100g$, $t_1 = 20^0C$, $t_3 = t_1 + 5 = 20 + 5 = 25^0C$

L = 540 cal/gm, $S = 1cal/g^0C$

Heat gained by cold body = heat lost by hot body

If m is the mass of vapour to be added $m_1 s(t_3 - t_1) = m(L + s\times t_2 - t_3)$

$100\times 1\times (25-20) = m(540 + 1\times (100-25))$

500 = m (615)

$$m = \frac{500}{615} = 0.813gm$$

**6. 2kg of air is heated at constant volume. The temperature of air is increased from 293K to 313K. If the specific heat of air at constant volume is 0.718kJ/kg K, find the amount of heat absorbed in kJ and kcal. (J = 4.2 kJ/kcal)**

**A:** m = 2kg, $T_1 = 273K, T_2 = 313K$

$C_v = 0.719\,KJ/Kg\,K$, $J = 4.2\,KJ/Kcal$

$Q = mC_v(T_2 - T_1) = 2\times 0.718\times(313-273) = 28.72kJ$

$= \frac{28.72}{4.2} = 6.838K\,cal$

7. **A clock, with a brass pendulum, keeps correct time at 20$^0$C, but loses 8.212 s per day, when the temperature rises to 30$^0$C. Calculate the coefficient of linear expansion of brass?**

A: Loss of time for one day $= \frac{1}{2}\times\alpha(t_2 - t_1)\times 86400 \Rightarrow 8.212 = \frac{1}{2}\times\alpha\times 10\times 86400$

$\alpha = 19\times 10^{-6}\,/^0\,C$

8. **If the volume of nitrogen of mass 14kg is $0.4m^3$ at $30^0C$. Calculate the pressure?**

**A:** Mass of the gas = m = 14kg = 14 x $10^3 gm$

Molecular weight of nitrogen (M) = 28

$V = 0.4m^3$, T = 30 + 273 = 303K

$PV = nRT \Rightarrow PV = \frac{m}{M}RT$

$P = \frac{mRT}{MV} = \frac{14\times 10^3\times 8.317\times 303}{28\times 0.4} = 31.5\times 10^5\,N/m^2$

9. **A body cools from 60°C to 40°C in 7 minutes and what will be its temperature after next 7 minutes, if the temperature of its surroundings is 10°C?**

**A.** From Newton's law of cooling,

$$\frac{(60-40)}{7}\alpha\left(\frac{60+40}{2}-10\right) and \left(\frac{40-\theta}{7}\right)\alpha\left(\frac{40+\theta}{2}-10\right)$$

Dividing and solving, $\theta$ = 28 °C

**10. If the maximum intensity of radiation for a black body is found at 2.65 $\mu$ m, what is the temperature of the radiating body?**

**(Wien's constant** = $2.90 \times 10^{-3}$ mK**)**

**A.** $\lambda_{max} = 2.65\ \mu m = 2.65 \times 10^{-6}$ m.

But, $\lambda_{max} T$ = constant = $2.90 \times 10^{-3}$ mK.

$$T = \frac{2.90 \times 10^{-3}}{\lambda_{max}} = \frac{2.90 \times 10^{-3}}{2.65 \times 10^{-6}} = 1094 \text{ K}$$