Chapter 12

Thermodynamics

1 Marks Questions

1.If a air is a cylinder is suddenly compressed by a piston. What happens to the pressure of air?

Ans. Since the sudden compression causes heating and rise in temperature and if the piston is maintained at same Position then the pressure falls as temperature decreases.

2. What is the ratio of find volume to initial volume if the gas is compressed adiabatically till its temperature is doubled?

Ans. Since for an adiabatic Process,

PV^{Y}= constant

Since PV = RT

$$P = \frac{RT}{V}$$

$$\text{So, } \frac{RT\ VY}{V} = \text{constant}$$

Or TV y - 1 = constant T_1, V_1 = Initial temperature and Initial Volume

∴ T_1 V_1 y - 1 = T_2 V_2 y - 1 T_2, V_2 = Final temperature and Final volume.

$$\frac{V_2}{V_1} = \left(\frac{T_1}{T_2}\right)^{\frac{1}{\gamma-1}}$$

Since T_2 = 2 T_1(Given)

$$\frac{T_1}{T_2} = \frac{1}{2}$$

So, $\frac{V_2}{V_1} = \left(\frac{1}{2}\right)^{\frac{1}{Y-1}}$

Since $\frac{4}{Y} > 1$, $\frac{V_2}{V_1}$ is less than $\frac{1}{2}$.

3.What is the ratio of slopes of P-V graphs of adiabatic and isothermal process?

Ans. The slope of P-V graph is $\frac{dP}{dV}$

For an isothermal process, (PV = constant)

So, $\frac{dP}{dV} = \frac{P}{V} \rightarrow (1)$

For an adiabatic process (PV^Y = constant)

$$\frac{dP}{dV} = \frac{YP}{V} \rightarrow (2)$$

Divide 2) by 1)

So, the ratio of adiabatic slope to isothermal slope is Y.

4.What is the foundation of Thermodynamics?

Ans. The foundation of thermodynamics is the law of conservation of energy and the fact the heat flows from a hot body to a cold body.

5.Differentiate between isothermal and adiabatic process?

Ans.

	Isothermal process		Adiabatic process
1)	In this, temperature remains constant	1)	In this, no heat is added or removed.
2)	It occurs slowly	2)	It occurs suddenly.
3)	Here, system is thermally conducting to surroundings	3)	Here, system is thermally insulated from surroundings.
4)	State equation :→ PV = constant	4)	State equation : → PV^{Y} = constant.

6.A Carnot engine develops 100 H.P. and operates between 27^0C and 227^0C. Find 1) thermal efficiency; 2) heat supplied3) heat rejected?

Ans. Here, energy = W = 100 H. P.

= 100 × 746 W (1 H.P. = 746W)

$$= \frac{(100\times 746)}{4.2} cal|s \quad \left(1W = \frac{cal|s}{4.2}\right)$$

High temperature, $T_H = 227^0C = 227 + 273 = 500K$

Low temperature, $T_h = 27^0C = 27 + 273 = 300K$

1) Thermal efficiency, $\eta = 1 - \frac{T_L}{T_H}$

$$\eta = 1 - \frac{300}{500}$$

$$\eta = \frac{200}{500} = 0.4 \ or \ 40\%$$

2) The heat supplied Q_H is given by:-

$$Q_H = \frac{W}{\eta} = \frac{100 \times 746}{4.2 \times 0.4} = 4.44 \times 10^4 cal | s$$

3) The heat rejected Q_L is given by:-

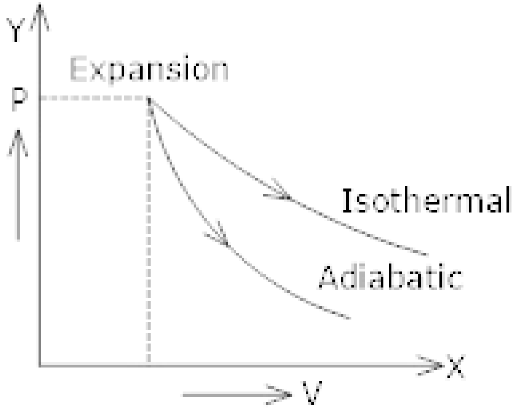
$$Q_L = Q_H \frac{T_L}{T_H} \text{ or } \frac{Q_L}{Q_H} = \frac{T_L}{T_H}$$

$$Q_L = 4.44 \times 10^4 \times \frac{300}{500}$$

$$Q_L = 2.66 \times 10^4 cal | \Delta$$

7.Draw a p – v diagram for isothermal and adiabatic expansion?

Ans.



8.State zeroth law of thermodynamics?

Ans. Acc. to this, when the thermodynamic system A and B are separately in thermal equilibrium with a third thermodynamic system C, then the system A and B are in thermal equilibrium with each other also.

9.Can a gas be liquefied at any temperature by increase of pressure alone?

Ans. No, a gas can be liquefied by pressure alone, only when temperature of gas is below its critical temperature.

10.Can you design heat energy of 100% efficiency?

Ans. Since efficiency of heat engine = $1-\frac{T_2}{T_1}$, so, efficiency will be 100% or 1 if T_2 = OK or T_1 = α. Since both these conditions cannot be practically attained, so heat engine cannot have 100% efficiency.

11.If air is a bad conductor of heat, why do we not feel warm without clothes?

Ans. This is because when we are without clothes air carries away heat from our body due to convection and we feel cold.

12.A body with large reflectivity is a poor emitter why?

Ans. This is because a body with large reflectivity is a poor absorber of heat and poor absorbers are poor emitters.

13.Animals curl into a ball, when they feel very cold?

Ans. When animals curl, they decrease their surface area and since energy radiated varies directly to surface area hence loss of heat due to radiation is also reduced.

14.Why is the energy of thermal radiation less than that of visible light?

Ans. The energy of an electromagnetic ware is given by :- E = hf

h = Planck's constant; f = frequency of wave. Since the frequency of thermal radiation is less than that of visible light, the energy associated with thermal radiation is less than associated with visible light.

15.Two rods A and B are of equal length. Each rod has its ends at temperature T_1 and T_2 ($T_1 > T_2$). What is the condition that will ensure equal rates of flow through the rods A and B?

Ans. Heat flow, $Q=\frac{KA(T_1-T_2)}{d}$

K = Thermal conductivity

A = Area

T_1 = Temperature of hot body

T_2 = Temperature of cold body

d = distance between hot and cold body.

Q = heat flow

When the rods have the same rate of conduction,

$Q_1 = Q_2$

$$\frac{K_1A_1(T_1-T_2)}{d}=\frac{K_2A_2(T_1-T_2)}{d}$$

$K_1, K_2 \rightarrow$ Thermal conductivity of first and second region

$A_1, A_2 \rightarrow$ Area of first and second region

or, $K_1 A_1 = K_2 A_2$

or

$$\frac{A_1}{A_2}=\frac{K_2}{K_1}$$

16.A Sphere is at a temperature of 600 k. Its cooling rate is R in an external environment of 200k. If temperature falls to 400k. What is the cooling rate R_1 in terms of R?

Ans. Acc. to Stefan's law;

E = constant T^4

Also, R_1 = constant $(T_2^4 - T_1^4)$

R = constant $(T_3^4 - T_1^4)$

T_2 = heat of hot junction = 400K

T_1 = heat of cold junction = 200K

T_3 = heat of hot junction = 600K

R_1 = constant $\left[(400)^4 - (200)^4\right] \rightarrow (1)$

R_1 = constant $\left[(600)^4 - (200)^4\right] \rightarrow (2)$

Divide eq^4 1) & 2)

$$\frac{R_1}{R} = \frac{\left[(400)^4 - (200)^4\right]}{\left[(600)^4 - (200)^4\right]}$$

$$\frac{R_1}{R} = \frac{256\times10^8 - 16\times10^8}{1296\times10^8 - 16\times10^8} = \frac{240\times10^8}{1280\times10^8}$$

$$\frac{R_1}{R} = \frac{24}{128}$$

$$\frac{R_1}{R} = \frac{3}{16}$$

Therefore, $R_1 = \left(\frac{3}{16}\right)R$

17.If the temperature of the sun is doubled, the rate of energy received on each will

increases by what factor?

Ans. By Stefan's law : →

Rate of energy radiated α T^4

T = Temperature

E_1 = constant T_1^4

E_2 = constant T_2^4

T_1 = Initial temperature

T_2 = Final temperature

$T_2 = 2T_1$

$T_2^4 = (2)^4 T_1^4$

$T_2^4 = 16T_1^4$

E_2 = constant $(16 T_1^4)$

E_2 = 16 (constant T_1^4)

$E_2 = 16 E_1$

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18. On a winter night, you feel warmer when clouds cover the sky than when sky is clear. Why?

Ans. We know that earth absorbs heat in day and radiates at night. When sky is covered, with clouds, the heat radiated by earth is reflected back and earth becomes warmer. But if sky is clear the heat radiated by earth escapes into space.

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19. If a body is heated from 27^0 C to 927^0C then what will be the ratio of energies of radiation emitted?

Ans. Since, By Stefan's law:→

E = Energy radiated

T = Temperature.

E_1, T_1 $\Rightarrow$ Initial energy and temperature

E_2, T_2 $\Rightarrow$ Final energy and temperature.

$T_1 = 27^0C = 27+273 = 300K$

$T_2 = 927^0C = 927+273K = 1200K.$

E = constant T^4

So, E_1 = constant ${T_1}^4$

$$\frac{E_1}{T_1^4} = \text{constant} \rightarrow (1)$$

$$\text{Also, } \frac{E_2}{T_2^4} = \text{constant} \rightarrow (2)$$

Equating equation 1) &2)

$$\frac{E_1}{T_1^4} = \frac{E_2}{E_2^4}$$

$$or \ \frac{E_1}{E_2} = \left(\frac{T_1}{T_2}\right)^4$$

$$\frac{E_1}{E_2} = \left(\frac{\cancel{300}^1}{\cancel{1200}_4} \right)^4$$

$$\frac{E_1}{E_2} = \left(\frac{1}{4} \right)^4$$

$$\frac{E_1}{E_2} = \frac{1}{256}$$

or $E_1 : E_2 = 1 : 256$

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20. Which has a higher specific heat ; water or sand?

Ans. Water has higher specific heat than sand as

$\Delta T = \frac{Q}{mc}$, where T = Temperature, Q = Heat, m = Mass,

C = Specific heat; Since for water temperature increases less slowly than sand hence the result.

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21. Why is latent heat of vaporization of a material greater than that of latent heat of fusion?

Ans . When a liquid changes into a gas, there is large increase in the volume and a large amount of work has to be done against the surrounding atmosphere and heat associated with change from solid to gas is latent heat of vaporization and hence the answer.

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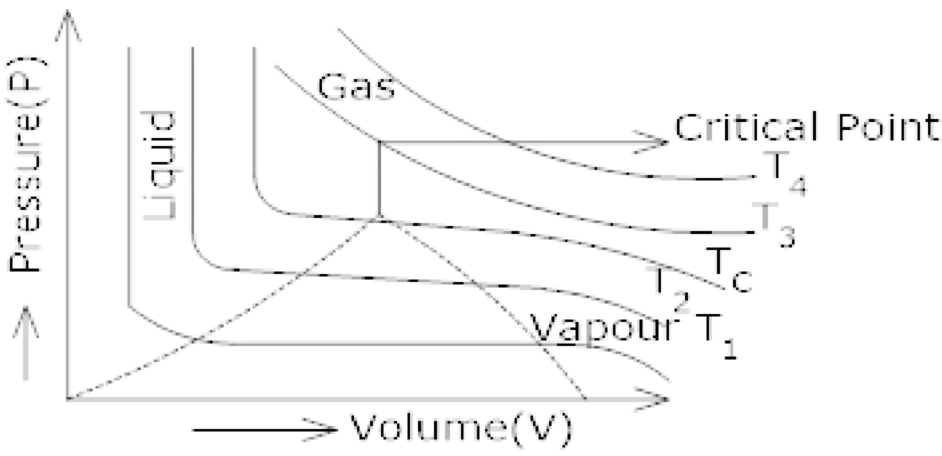
22. Draw a P – V diagram for Liquid and gas at various temperatures showing critical point?

Ans.



23. Why is temperature gradient required for flow of heat from one body to another?

Ans. Heat flows from higher temperature to lower temperature. Therefore, temperature gradient (i.e. temperature difference) is required for the heat to flow one part of solid to another.

24. Why are Calorimeters made up of metal only?

Ans. Calorimeters are made up of metal only because they are good conductor of heat and hence the heat exchange is quick which the basic requirement for the working of calorimeter.

25. If a body has infinite heat capacity? What does it signify?

Ans. Infinite heat capacity means that there will be no change in temperature whether heat is taken out or given to the substance.

26. Define triple point of water?

Ans. Triple point of water represents the values of pressure and temperature at which water co-exists in equilibrium in all the three states of matter.

27. State Dulong and petit law?

Ans. Acc. to this law, the specific heat of all the solids is constant at room temperature and is equal to 3R.

28. Why the clock pendulums are made of invar, a material of low value of coefficient of linear expansion?

Ans. The clock pendulums are made of Inver because it has low value of α (co-efficient of linear expansion) i.e. for a small change in temperature, the length of pendulum will not change much.

29. Why does the density of solid | liquid decreases with rise in temperature?

Ans. Let P = Density of solid | liquid at temperature T

P^1 = Density of solid | liquid at Temperature T+ΔT

Since Density = $\frac{Mass}{Volume}$

So, P = $\frac{M}{V}$ →(1) P^1 = $\frac{M}{v^1}$ →(2)

V^1 = Volume of solid at temperature T + ΔT

V = Volume of solid at temperature T

Since on increasing the temperature, solids | liquids expand that is their volumes increases, so by equation

i) & 2) Density is inversely proportional to volumes, so if volume increases on increasing the temperature, Density will decrease.

30. Two bodies at different temperatures T_1, and T_2 are brought in thermal contact do not necessarily settle down to the mean temperature of T_1 and T_2?

Ans. Two bodies at diff temperatures T_1 and T_2 when in thermal contact do not settle always at their mean temperature because the thermal capacities of two bodies may not be always equal.

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31. The resistance of certain platinum resistance thermometer is found to be 2.56 Ω at 0^0c and 3.56 Ω at 100^0c. When the thermometer is immersed in a given liquid, its resistance is observed to 5.06 Ω. Determine the temperature of liquid?

Ans.R_o = Resistance at0^0c = 2.56Ω

R_t = Resistance at temperature T = 100^0c = 3.56Ω 100

R_t = Resistance at unknown temperature t ;

R_t = 5.06Ω

Since,

$$t = \frac{R_t - R_o}{R_{100} - R_o} \times 100$$

$$= \frac{(5.06 - 2.56)}{(3.56 - 2.56)} \times 100$$

$$= \frac{2.5 \times 100}{1}$$

$$= \frac{25}{10} \times 100$$

t = 250^0c

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32. Calculate C_p for air, given that C_v =0.162 cal g^{-1} k^{-1} and density air at N.T. P is 0.001293 g | cm^3?

Ans. Specific heat at constant pressure = C_p= ?

Specific heat at constant volume = C_V = 0.162 Cal g^{-1} k^{-1}

Now, Cp – Cv = $\frac{r}{J} = \frac{PV}{TJ}$ $(\because PV = nRT)$

Or CP – Cv = $\frac{P \times 1}{s \times TJ}$ $(s = Density)$

Cp – Cv = $\frac{1.01\times10^{6}}{273\times4.2\times10^{7}\times1.293\times10^{-3}}$

= $\frac{1.01\times10^{6+3-7}}{273\times4.2\times1.293}$

= $\frac{1.01\times10^{2}}{1482.5}$

= $6.8\times10^{-4+2}$

Cp – Cv = 0.068

Cp = 0.162+0.068

Cp = 0.23 Cal g^{-1} k^{-1}

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33. Develop a relation between the co-efficient of linear expansion, co-efficient superficial expansion and coefficient of cubical expansion of a solid?

Ans. Since, co-efficient of linear expansion = α = $\frac{\Delta L}{L\Delta T}$

ΔL = change in length

L = length

ΔT = change in temperature

Similarly, co-efficient of superficial expansion = β = $\frac{\Delta S}{S\Delta T}$

ΔS = change in area

S = original area

ΔT = change in temperature

Co-efficient of cubical expansion, = Y = $\frac{\Delta V}{V\Delta T}$

ΔV = change in volume

V = original volume

ΔT = change in temperature.

Now, ΔL=αL ΔT

L + ΔL = L + αL ΔT

L + ΔL = L (1+αΔT) → (1)

Similarly V+ ΔV = V (1+YΔT) →(2)

And S+ΔS=S (1+βΔT) → (3)

Also, $(V+\Delta V) = (L+\Delta L)^3$

V+ΔV = $\left[L\left(1+\alpha\Delta T\right)\right]^3$

V+ΔV = $L^3 \left(1+3\alpha\Delta T+3\alpha^2\Delta T^2+\alpha^3 T^3\right)$

Since α^2, α^3 are negligible, so,

V+γ VΔT= V(1+3αΔT) [as L^3=V]

So, V+γVΔT = V+V3αΔT

$\gamma V\Delta T = 3\alpha\Delta T$

$Y = 3\alpha$

Similarly, $\beta = 2\alpha$ [using $L^2 = S$ (Area)]

So, $\alpha = \frac{\beta}{2} = \frac{\gamma}{3}$

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34. Calculate the amount of heat required to convert 1.00kg of ice at – 10^0c into steam at 100^0c at normal pressure. Specific heat of ice = 2100J|kg|k. Latent heat of fusion of ice = $3.36\text{x}10^5$J|kg, specific heat of water = 4200J|kg|k. Latent heat of vaporization of water = 2.25 $\text{x}10^6$J|kg?

Ans.(1) Here, heat is required to raise the temperature of ice from – 10^0c to 0^0c.

So, change in temperature = $\Delta T = T_2 - T_1 = 0-(-10) = 10^0$c

So, $\Delta Q_1 = cm\Delta T$

C = specific heat of ice

M = Mass of ice

$\Delta T = 10^0$c

$\Delta Q_1 = 2100\times1\times10 = 21000$J

(2) Heat required to melt the ice to 0^0c water:-

$\Delta Q_2 = mL$

L = Latent heat of fusion of ice = 3.36×10^5J/kg

m = Mass of ice

$\Delta Q_2 = 1 \times 3.36 \times 10^5 J/kg$

$\Delta Q_2 = 3.36 \times 10^5 J$

$\Delta Q_2 = 336000J$

(3) Heat required to raise the temperature of water from 0^0c to 100^0c:-

$\Delta T = T2 - T1 = 100 - 0 = 100^0c$

$\Delta Q_3 = cm\Delta T$ c = specific heat of water

$= 4200 \times 1 \times 100$

$= 420,000J$

(4) Heat required to convert 100^0c water to steam at 100^0c

$\Delta Q_4 = mL$ L = Latent heat of vapourisation $= 2.25 \times 10^6 J/kg$

$\Delta Q_4 = 1 \times 2.25 \times 10^6 J|kg$

$\Delta Q_4 = 2250000J$

$\therefore$ Total Heat required $= \Delta Q_1 + \Delta Q_2 + \Delta Q_3 + \Delta Q_4$

ΔQ total $= 21000+336000+420000+2250000$

ΔQ total $= 3027000J$

ΔQ total $= 3.027 x 10^6 J$

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35. Why is mercury used in making thermometers?

Ans. Mercury is used in making thermometers because it has wide and useful temperature range and has a uniform rate of expansion.

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36. How would a thermometer be different if glass expanded more with increasing temperature than mercury?

Ans. If glass expanded more with increasing temperature than mercury, the scale of the thermometer would be upside down.

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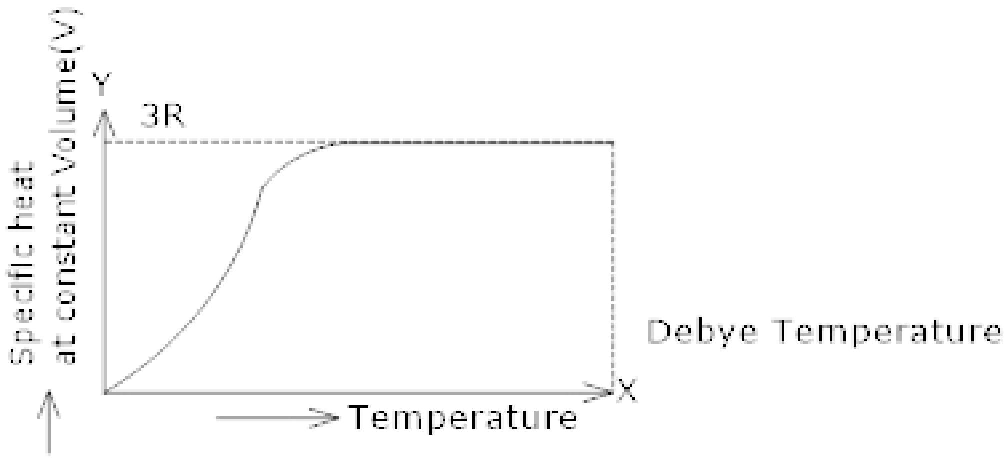
37. Show the variation of specific heat at constant pressure with temperature?

Ans.



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38. Two thermometers are constructed in the same way except that one has a spherical bulb and the other an elongated cylindrical bulb. Which one will response quickly to temperature change?

Ans. The thermometer with cylindrical bulb will respond quickly to temperature changes because the surface area of cylindrical bulb is greater than the of spherical bulb.

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39. State Carnot's Theorem?

Ans. According to Carnot's Theorem, no engine working between two temperatures can be more efficient than a Carnot's reversible engine working between the same temperatures.

2 Marks Questions Part 1

1.A motor car tyre has a Pressure of four atmosphere at a room temperature of 27^0C. If the tyre suddenly bursts, calculate the temperature of escaping gas?

Ans. Since the tyre suddenly bursts, the change taking place is adiabatic, for adiabatic change:-

$$\frac{P_1^{Y-1}}{T_1^4} = \frac{P_2^{Y-1}}{T_2^4}$$

Or

$$T_2^4 = T_1^4\left(\frac{P_2}{P_1}\right)^{Y-1} \rightarrow (1)$$

Hence, T_1 = 273 + 27 = 300K

P_1 = Initial Pressure; P_2 = final Pressure

So, $\frac{P_1}{P_2} = 4,\ 4=1.4$

So, Putting the above values in eq^4 i)

$$T_2^{14} = (300)^{14} \times \left(\frac{1}{4}\right)^{1.4-1}$$

$$(T_2)^{14} = (300)^{1.4} \times \left(\frac{1}{4}\right)^{0.4}$$

Taking 1.4 Power

$$T_2 = (300)^{\frac{1.4}{1.4}} \times \left(\frac{1}{4}\right)^{\frac{0.4}{1.4}}$$

W_1=-150J→ (1)

Work done by the gas in the process B → C is : →

$$W_2 = -[area \text{ under the curve BC}]$$

$$W_2 = -[(area \text{ of } \Delta \text{ B C D}) + area \text{ of rectangle C B D E F}]$$

$$= -\left(\left[\frac{1}{2} \times Base \times \text{Height}\right] + [Length \times \text{Breadth}]\right)$$

$$\left(\left[\frac{1}{2} \times \text{ CD} \times \text{BD}\right] + [CD \times \text{EF}]\right)$$

$$= -\left(\left[\frac{1}{2} \times (3 \times 10^5) \times 200 \times 10^{-6}\right] + [2 \times 10^5 \times 200 \times 10^{-6}]\right)$$

$$W_2 = -70J \rightarrow (2)$$

Adding equation i) & 2)

Net work done by the gas in the whole process is W = $W_1 + W_2$

$$T_2 = 300 \times \left(\frac{1}{4}\right)^{\frac{0.4}{1.4}}$$

W = 150 – 70 = - 22 OJ

$$T_2 = 300 \times \left(\frac{1}{4}\right)^{\frac{4^2}{14_7}}$$

T_2 = 201.8 K

∴ T_2 = 201.8 – 273 = - 71.2^{0}C

2.How does Carnot cycle operates?

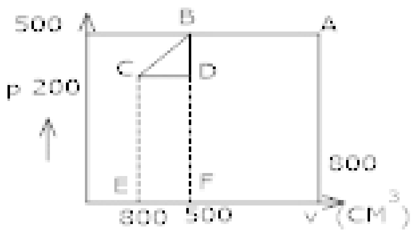
Ans. A Carnot cycle operates a follows:-

1) It receives thermal energy isothermally from some hot reservoir maintained at a constant high temperature T_H.

2) It rejects thermal energy isothermally to a constant low–temperature reservoir (T_2).

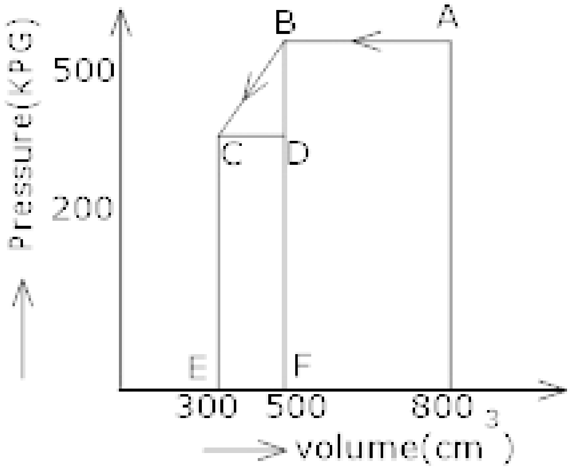
3) The change in temperature is reversible adiabatic process.

Such a cycle, which consist of two isothermal processes bounded by two adiabatic processes, is called Carnot cycle.



3.Calculate the work done by the gas in going from the P-V graph of the thermodynamic behavior of a gas from point A to point B to point C?

Ans.Work done by the gas in the process A → B is



W_1 = - (area under curve A B)

$= -\left[(P_{AB})\times(V_2 - V_1)\right]$

$= -\left[5\times10^5\times(800-500)\times10^{-6}\right]$

P_{AB} = 500 Pa

$= 5\times10^5$ N|m^2

$(V_2 - V_1) = (300)$ cm^3 or 300×10^{-6}m^3

4.Why does absolute zero not correspond to zero energy?

Ans. The total energy of a gas is the sum of kinetic and potential energy of its molecules. Since the kinetic energy is a function of the temperature of the gas. Hence at absolute zero, the kinetic energy of the molecules ceases but potential energy is not zero. So, absolute zero temperature is not the temperature of zero energy.

5.State the Second law of thermodynamics and write 2 applications of it?

Ans. According to second law of thermodynamics, when a cold body and a hot body are brought into contact with each other, heat always from hot Body to the cold body. Also, that no heat engine that works in cycle completely converts heat into work.

Second law of thermodynamics is used in working of heat engine and of refrigerator.

6.At 0^0C and normal atmospheric pressure, the volume of 1g of water increases from $1cm^3$ to $1.091\ cm^3$ on free zing. What will be the change in its internal energy? Normal atmospheric pressure is $1.013x10^5\ N|m^2$ and the latent heat of melting of ice is 80 cal/g?

Ans. Since, heat is given out by 1 g of water in freezing is

m = Mass of water = 1 g

Q = - (mLf) Lf = Latent heat of melting of ice = 80 cal|g

[Negative sign is assigned to Q because it is given out by water]

During freezing, the water expands against atmospheric pressure. Hence, external work done (W) by water is :- W = P × Δ V

$P = 1.013 \times 10^5\ N|m^2$; $\Delta V = 1.091 - 1 = 0.091\ cm^3 = o.o91 \times 10^{-6}\ m^3$

$\Delta V = V_2 - V_1$; V_2 = final volume = $1.91\ cm^3$

V_1 = Initial volume = $1\ cm^3$

So, W = $\left(1.013\times10^{5}\right)\times\left(0.091\times10^{-6}\right)$

W = 0.0092 J

Since, 1 cal = 4.2J so,

W = $\frac{0.0092}{4.2} = 0.0022 \text{ cal} \rightarrow 2)$

Since the work has been done by ice, it will be taken positive.

Acc. to first law of thermodynamics,

Q = ΔU + W ΔU = change in internal energy

So, ΔU = Q – W

= $\left(-80\right)-\left(-0.0022\right)$ (Using 1) & 2))

ΔU = - 80.0022 cal

Negative sign indicates that internal energy of water decreases on freezing.

7.Two different adiabatic paths for the same gas intersect two thermals at T_1 and T_2 as shown in P-V diagram. How does $\frac{VA}{VD}$ Compare with $\frac{VB}{VC}$?

Ans. Now, A B and C D are isothermals at temperature T_1 and T_2 respectively and BC and AD are adiabatic.

Since points A and D lie on the same adiabatic.

$\therefore T_A V_A^{Y-1} = T_D V_D^{Y-1}$

$T_1 V_A$ Y-1 = $T_2 V_D$Y-1

$\frac{T_1}{T_2} = \left(\frac{V_D}{V_A}\right)^{Y-1}$

Also, points B and C lie on the same adiabatic,

$\backslash T_B V_B^{Y-1} = T_C V_C^{Y-1}$

or $T_1 V_B Y\text{-}1 = T_2 V_C Y\text{-}1$

$$\therefore \frac{T_1}{T_2} = \left(\frac{V_C}{V_B}\right)^{Y-1}$$

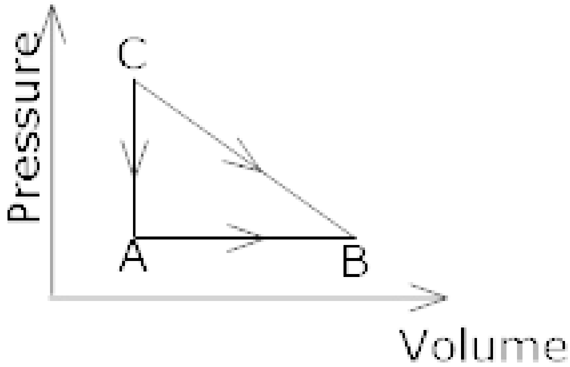
From equation 1) & 2)

$$\left(\frac{VD}{VA}\right)^{Y-1} = \left(\frac{VC}{VB}\right)^{Y-1}$$

$$\frac{VD}{VA} = \frac{VC}{VB}$$

$$\frac{VA}{VD} = \frac{VB}{VC}$$

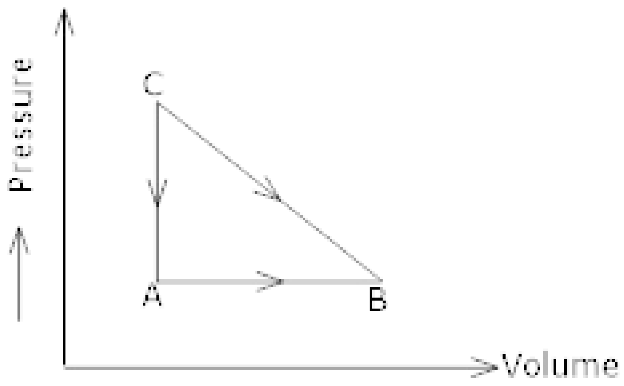
$$\therefore \frac{(VA/VD)}{(VB/VC)} = 1$$



8.The internal energy of a compressed gas is less than that of the rarified gas at the same temperature. Why?

Ans. The internal energy of a compressed gas is less than that of rarified gas at the same temperature because in compressed gas, the mutual attraction between the molecules increases as the molecules comes close. Therefore, potential energy is added to internal energy and since potential energy is negative, total internal energy decreases.

9.Consider the cyclic process A B C A on a sample 2 mol of an ideal gas as shown. The temperature of the gas at A and B are300 K and 500K respected. Total of 1200 J of heat is with drawn from the sample. Find the work done by the gas in part BC?



Ans. The change in internal energy during the cyclic process is zero. Therefore, heat supplied to the gas is equal to work done by it,

$\therefore W_{AB} + W_{BC} + W_{CA} = -1200J \rightarrow(1)$

(- ve because the cyclic process is traced anticlockwise the net work done by the system is negative)

The work done during the process AB is

$W_{AB} = P_A (V_B - V_A) = nR(T_B - T_A)$ $\left(QP_V = nRT\right)$

WAB = 2×8.3(500-300) = 3320J →2)

R = Universal gas constant

N = No. of volume

Since in this process, the volume increases, the work done by the gas is positive.

Now, WCA = O ($\because$ volume of gas remains constant)

$\therefore$ 3320 + WBC + O = - 1200 (Using equation 1) & 2)

WBC = - 1200 – 3320

$W_{BC} = -4520J$

10.A refrigerator placed in a room at 300 K has inside temperature 264K. How many calories of heat shall be delivered to the room for each 1 K cal of energy consumed by

the refrigerator, ideally?

Ans. High temperature, T_H = 300K

Low temperature, T_h = 264K

Energy = 1K cal.

Co - efficient of performance, is given by:-

$$COP = \frac{T_H}{T_H - T_L} = \frac{264}{300-264} = \frac{22}{3}$$

Now, COP = $\frac{Q_L}{W}$

Q_L = heat rejected

Q_L = COP × W

Q_L = $\frac{22}{3} \times 1 = \frac{22}{3} Kal$

The mechanical work done by the compressor of the refrigerator is:-

W = $Q_H - Q_L$

Q_H = W + Q_L

Q_H = $\frac{22}{3} + 1$

$$Q_H = \frac{25}{3} Kal$$

Q_H = 8.33 K cal

11.If the door of a refrigerator is kept open in a room, will it make the room warm or

cool?

Ans. Since a refrigerator is a heat engine that operates in the reverse direction i.e. it extracts heat from a cold body and transforms it to hot body. Since it exhaust more heat into room than it extracts from it. Therefore, the net effect is an increase in temperature of the room.

12.The following figure shows a process A B C A per formed on an ideal gas, find the net heat given to the system during the process?

Ans . Since the process is cyclic, the change in internal energy is zero. Therefore, the heat given to the system is equal to work done by it. The net work done by the gas in the process ABCA is:-

$W = W_{AB} + W_{BC} + W_{CA}$

Now $W_{AB} = O$ $\left(\because \text{Volume remains constant}\right)$

During the path BC, temperature remains constant. So it is an isothermal process. So, W_{BC} = nRT_2 Loge $\frac{V_2}{V_1}$

During the CA, $V \alpha T$ so that $\frac{V}{T}$ is constant.

$$P = \frac{nRT}{V} = cons\tan t$$

∴ Work done by the gas during the part CA is :-

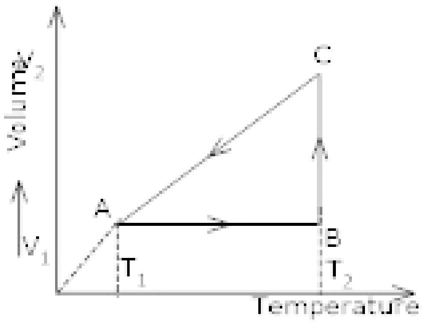
$W_{CA} = P (V_1 - V_2)$

$= nR (T_1 - T_2)$

$= - nR (T_2 - T_1)$ → Using equation 1)

$W = O + nR\, T_2$ Loge $\frac{V_2}{V_1}$ $- nR (T_2 - T_1)$

$$W = nR\left[T_2 Loge\frac{V_2}{V_1} - (T_2 - T_1)\right]$$



13.A certain gas at atmospheric pressure is compressed adiabatically so that its volume becomes half of its original volume. Calculate the resulting pressure?

Ans. Let the original volume, V_1=V

∴ final volume $V_2 = \frac{V}{2}$ (∴volume become half)

Initial pressure P_1 = o.76m of Hg column

Final pressure P_2 after compression =?

As the change is adiabatic, so

$P_1V_1^{\gamma} = P_2V_2^{\gamma}$ Y = $\frac{CP}{cv}$ = 1.4 for air

$P_2 = P_1\left(\frac{V_1}{V_2}\right)^4$

$= 0.76 \times \left(\frac{V}{V/2}\right)^{1.4}$

$P_2 = 0.76 \times (2)^{1.4}$

P_2 = 2m of Hg column

P_2 = h sg

$P_2 = 2.672 \times 10^5$ N|m^2

$P_2 = 2\times (13.6\text{x}10^3)\times 9.8$

h = height of Hg column

s = Density of air

g = Acceleration due to gravity

14.Why is conversion of heat into work not possible without a sink at lower temperature?

Ans. For converting heat energy in to work continuously a part of heat energy absorbed from the source has to be rejected. The heat energy can be rejected only to a body at lower temperature which is sink, so we require a sink to convert heat into work

---

15.Write the sign conventions for the heat and work done during a thermodynamic process?

Ans. 1) When heat is supplied to a system d Q is taken positive but when heat is supplied by a system, d Q is taken negative.

2) When a gas expands, d w is taken as positive but when a gas compresses, work done is taken as negative.

16.Does the working of an electric refrigerator defy second law of thermodynamics?

Ans. No, it is not against the second law; this is because external work is done by the compressor or for this transfer of heat.

17.A Carnot engine absorb 6×10^5 cal at 227^0c calculate work done per cycle by the engine if it sink is at 127^0c?

Ans. Here, heat abs or bed = $Q_1 = 6 \times 10^5$ cal.

Initial temperature = $T_1 = 227^0c = 227+273 = 500K$

Final temperature = $T_2 = 127^0c = 127 + 273 = 400K$

As, for Carnot engine;

$$\frac{Q_2}{Q_1} = \frac{T_2}{T_1}$$

$$Q_2 = Q_1 \frac{T_2}{T_1}$$

$$Q_2 = \frac{400}{500} \times 6 \times 10^5$$

$Q_2 = 4.8 \times 10^5$ cal

Q_2 = Final heat emitted

As $w = Q_1 - Q_2 = 6 \times 10^5 - 4.8 \times 10^5$

$= 1.2 \times 10^5$ cal

Work = $w = 1.2 \times 10^5 \times 4.2$ J

Dore = 5.04×10^5 J

18.How does second law of thermodynamics explain expansion of gas?

Ans. Since from second law,.

$dS \geq O$ dS = change in entropy

During the expansion of gas, the thermodynamic probability of gas is larger and hence its entropy is also very large. Since form second law, entropy cannot decrease ∴ following the second law, gas molecules move from one partition to another.

19.Why is it hotter at the same distance over the top of the fire than in front of it?

Ans. At a point in front of fire, heat is received due to the process of radiation only, while at a point above the fire, heat reaches both due to radiation and convection. Hence the result.

---

20. A metal rod of length 20cm and diameter 2cm is covered with a non-conducting substance. One of it ends is maintained at 100^0c while the other is at 0^0c. It is found that 25g of ice melts in 5 min calculate coefficient of thermal conductivity of metal?

Ans. Length of rod = Δx = 20cm = 2×10^{-3}m

Diameter = 2cm

$R = 10^{-2}$m

Area of cross-section = πr^2

$= \pi (10^{-2})^2$

$= 10^{-4} \pi$ sq. m

$\Delta T = T_2 - T_1 = 100 - 0 = 100^0$c

Mass of ice melted = m = 25g

Latent heat office = 80 cal/g

Heat conducted, $\Delta Q = mL$

$= 25 \times 80$

= 2000 cal

= 2000 × 4.2J

Δ t = 5 min = 300s

So,

$$\frac{\Delta Q}{\Delta t} = KA\frac{\Delta T}{\Delta x}$$

$$K = \frac{\Delta Q / \Delta t}{A\Delta T / \Delta x} = \frac{\Delta Q \Delta x}{\Delta t A \Delta T}$$

$$= \frac{2000 \times 4.2 \times 20 \times 10^{-2}}{300 \times 10^{-4} \pi \times 100}$$

K = 1.78J |s|m|^{0}c

K = coefficient of thermal conductivity

21.Calculate the temperature in Kelvin at which a perfectly black body radiates at the rate of 5.67 w/cm^2?

Ans. E = 5.67w|cm^2 ; E = energy radiated

= 5.67 x 10^7 erg | s | cm^2

σ = Stefan's constant = 5.67 × 10^{-5} ergs |s | cm^2| K^4, from Stefan's law

E = σ T^4

$$T = \left(\frac{E}{\sigma}\right)^{\frac{1}{4}}$$

$$T = \left(\frac{5.67 \times 10^{7}}{5.67 \times 10-^{5}}\right)^{\frac{1}{4}}$$

$T = \left(10^{12}\right)^{\frac{1}{4}} = 10^3 = 1000K$

22.How do you explain the emission of long - wavelength by the object at low temperature?

Ans. Since by Wein's law: →

$$\lambda m \ \alpha \ \frac{1}{T}$$

$$\lambda m = \text{constant } T$$

i.e temperature is inversely proportional to the wavelength so, if temperature is less, then wavelength will be long. If temperature is high, then wavelength will be short.

23.If the radiation from the moon gives maxima at λ = 4700 A^0 and λ = 14x10^{-6}m. What conclusion can be drawn from the above information?

Ans. Acc. to wien's displacement law, $\lambda m \ T = b$

Now, according to the question, λ m = 4700 A^0 = 4700×10^{-10}m

T_1 = Temperature of moon,

$$T_1 = \frac{b}{\lambda m}$$

b = 2.9 ×10^{-3} mK

$$T_1 = \frac{2.9\times10^{-3}}{4700\times10^{-10}}$$

$$= \frac{29\times10^{-4}\times10^{10}}{4700}$$

$$T_1 = 6170K$$

Let the temperature corresponding to $\lambda m = 14\times10^{-6} m = T_2$

So, $T_2 = \frac{b}{\lambda m}$

$$T_2 = \frac{2.9\times10^{-3} mK}{14^{-}\times10^{-6} m} = \frac{29\times10^{-4+6}}{14} K = 207K$$

24.Differentiate between conduction, convection and radiation?

Ans.

	Properties	Conduction	Convection	Radiation
1.	Material Medium	Essential	Essential	Not Essential
2.	Molecules	Do not leave their mean position	More bodily from one place to another.	Medium does not play any part
3.	Transfer of heat	Can be in any direction along any part	Only vertically upward	In all direction in straight lines
4.	Speed of transfer of heat	Slow	Rapid	Fastest with the speed of light.

25.The tile floor feels colder than the wooden floor even though both floor materials are at same temperature. Why?

Ans. This happens because the tile is better heat conductor than wood. The heat conducted from our foot to the wood is not conducted away rapidly. So, the wood quickly heats up on its surface to the temperature of our foot. But the tile conducts the heat away rapidly and thus can take more heat from our foot, so its surface temperature drops.

2 Marks Questions Part 2

26.A room has a 4m x 4m x10cm concrete roof (K_1 = 1.26w|m|^{0}C). At some instant, the temperature outside is 46^{0}c and radius 32^{0}c.

1) Calculate amount of heat flowing per second into the room through the roof.

2) If bricks (K_2 – 0.56w |m|^{0}c) of thickness 7.5cm are laid down on roof, calculate the new rate of heat flow under the same temperature conditions?

Ans. 1) Area of roof = 4 × 4 = 16 m^2

Thickness of roof, x_1 = 10 cm = 0.1m,

Thermal resistance of the roof is given by :-

$$R_1 = \frac{x_1}{K_1A_1} = \frac{0.1}{1.26\times16} = 4.96\times10^{-3}\ {}^0c/w$$

∴ Rate of heat flow through the roof is:-

$$H_1 = \frac{\theta}{t} = \frac{\theta_1 - \theta_2}{R} = \frac{46-32}{4.96\times10^{-3}}$$

$$H_1 = \frac{14\times10^3}{4.96}$$

$$H_1 = 2822w$$

2) The thermal resistance of the brick is given by:-

$$R_2 = \frac{x_2}{K_2A_2} = \frac{7.5\times10^{-2}}{0.65\times16} = 7.2\times10^{-3}\ {}^0C/W$$

The equivalent thermal resistance of the roof now is :→

$$R = R_1 + R_2 = (4.96+7.2) \times 10^{-3} = 1.216\times10^{-2} oC/W$$

∴ Rate of heat through the roof is :→

$$H_2 = \frac{\theta}{t} = \frac{\theta1-\theta2}{R} = \frac{46-32}{1.216\times10^{-2}} = 1152W$$

27.A bar o copper of length 75cm and a bar of length 125cm are joined end to end. Both are of circular cross – section with diameters 2cm. The free ends of copper and steel are maintained at 100^0c and 0^0c respectively. The surfaces of the bars are thermally insulated. What is the temperature of copper – steel junction? Thermal conductivity of copper = $9.2\text{x}10^{-2}$k cal |m|^{0}c|s and that of steel is $1.1\text{x}10^{-2}$ k cal|m|^{0}c|s?

Ans. l_1 = lengths of copper bars AB

l_2 = length of steel bars BC.

Θ_1 = temperature of free ends A

Θ_2 = temperature of free ends C.

Θ = temperature of copper – steel.

In steady state, the heat flowing per second through two bars is the same i.e

$H_1 = H_2$

$$\frac{K_1A(\theta_1-\theta_2)}{l_1} = \frac{K_2A(\theta-\theta_2)}{l_2}$$

$$\frac{K_1\theta_1}{l_1} - \frac{K_1\theta_2}{l_1} = \frac{K_2\theta}{l_2} - \frac{K_2\theta_2}{l_2}$$

$$or\ \frac{K_1\theta_1}{l_1} + \frac{K_2\theta_2}{l_2} = \frac{K_2\theta}{l_2} + \frac{K_1\theta}{l_1}$$

$$\frac{K_1}{l_1}\theta_1 + \frac{K_2}{l_2}\theta_2 = O\left(\frac{K_1}{l_1} + \frac{K_2}{l_2}\right)$$

∴ Temperature of junction = θ :→

28.Two rods A and B are of equal length. Each rod has its ends at temperatures T_1 and T_2. What is the condition that will ensure equal rates of flow of heat through the rods A and B?

Ans. Since θ = $\frac{KA(\theta_1 - \theta_2)t}{x}$

Θ = heat flow

K = co – efficient of thermal conductivity

A = Cross – Sectional Area

Θ1 = Temperature of hot body

Θ2 = Temperature of cold body

X = distance between hot and cold faces

t = time

For rod A :

$$\frac{\theta_A}{t} = \frac{K_A(T_1 - T_2)A_A}{x}$$

$$\text{And } \frac{\theta_A}{t} = \frac{K_A(T_1 - T_2)A_B}{x}$$

For equal rates of flow, $\frac{\theta_A}{t} = \frac{\theta_B}{t}$ $K_A A_A = K_B A_B$

29.A layer of ice 10cm thick is formed on a pond. The temperature of air is – 10^0C. Calculate how long it will take for the thickness of ice to increase by 1mm. Density of ice = 1g|cm^3; Thermal conductivity of ice = 0.005Cal|s|cm|^{0}C; Latent heat of ice = 80Cal|g?

Ans. Let t = time required to increase the thickness of ice by 1mm (=0.1cm)

Mass of ice required to be formed is :-

m = Volume x Density

Let A = Area of upper surface

Volume = Area x Thickness

= A × 0.1

m = (A × 0.1) × 1

m = 0.1 A gram →1)

Now, heat must flow from lower surface to the upper surface of ice and finally into atmosphere.

Θ = heat that flows out of pond into atmosphere.

λ = Latent heat of ice

m = Mass of ice

k = co – efficient of thermal conductivity

A = Cross – sectional Area

t = time

x = Distance between hot and cold surface

θ_1 = temperature of hot surface

θ_2 = temperature of cold surface

∴ θ = m L ;

Θ = 0.1×A×80 (Using equation 1)

Θ = 8 A Cal → 2)

But $\theta = \frac{KA(\theta_1 - \theta_2)t}{x}$

Usinge quation 2)

$$8A = \frac{KA(\theta_1 - \theta_2)t}{x}$$

$$t = \frac{8x}{K(\theta_1 - \theta_2)}$$

Now, x = 10cm,

K = 0.005 cal|cm|Δ|^{0}C

$\Theta_1 - \theta_2 = 0 - (-10) = 10^0C$

$$t = \frac{8 \times 10}{0.005 \times 10} = 1600 \text{ Sec}$$

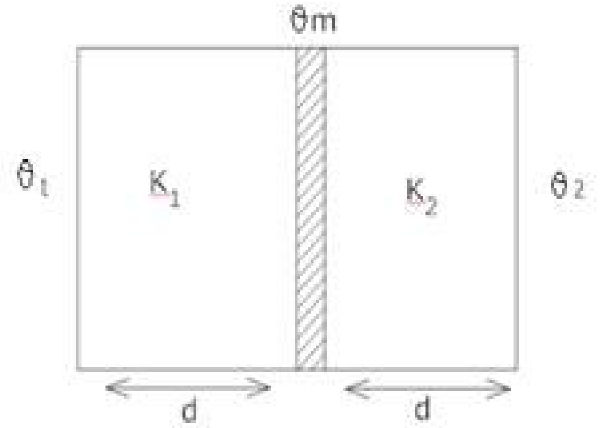
30.Two conducting slabs of thermal conductivities K_1 and K_2 are joined as shown in the figure. The temperature of the ends of slab are θ_1 and θ_2 ($\theta_1 > \theta_2$). Find the final temperature of (θm)?

Ans. Let θ_1 = temperature of hot slab

Θ_2 = temperature of cold slab

K_1 = Co – efficient of thermal conductivity of hot slab

K_2 = Co – efficient of thermal conductivity of cold slab



Θ_m = final temperature

d = Distance b/w hot and cold surface

A = Area of cross – section

t = time

Now, since is steady state, the rate of heat transfer in both the slabs is same i. e

$$\frac{\theta_1}{t} = \frac{\theta_2}{t}$$

$$\text{or } \frac{K_1 \cancel{A}(\theta_1 - \theta_m)}{\cancel{d}} = \frac{K_2 \cancel{A}(\theta_m - \theta_2)}{\cancel{d}}$$

$$K_1(\theta_1 - \theta_m) = K_2(\theta_m - \theta_2)$$

$\Theta_1 - \theta_m$ = because first heat flows from θ_1 to the junction

$\Theta_2 - \theta_m$ = then heat flows from junction to second surface

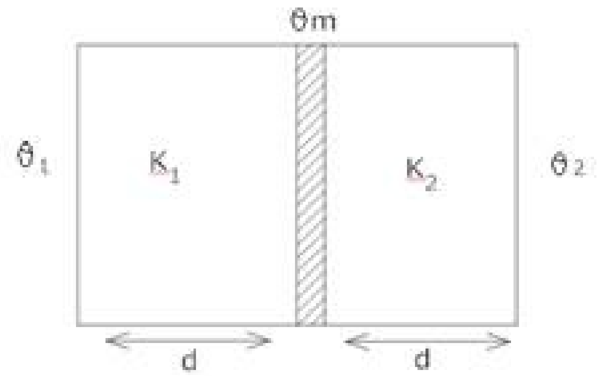
So, $K_1(\theta_1 - \theta_m) = K_2(\theta_m - \theta_2)$

$$K_1\theta_1 - K_1\theta_m = K_2\theta_m - K_2\theta_2$$

$$K_1\theta_1 + K_2\theta_2 = K_2\theta_2 + K_1\theta_m$$

$$K_1\theta_1 + K_2\theta_2 = \theta_m(K_1 + K_2)$$

So, $\theta_m = \dfrac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$



31.The ends of the two rods of different materials with their thermal conductivities, radii of cross – section and length in the ratio 1:2 are maintained at the same temperature difference. If the rate of flow of heat through the larger rod is 4 cal |s, what is the rate of flow through the shorter rod?

Ans.K_1 = thermal conductivity of first region

K_2 = thermal conductivity of second region

r_1 = radius of cross section of first region

r_2 = radius of cross – section of second region

l_1 – length of first region

l_2 = length of second region

Θ_1 = heat flow of first region

Θ_2 = heat flow of second region

Now, $\frac{K_1}{K_2} = \frac{1}{2}$

Also, $\frac{r_1}{r_2} = \frac{1}{2}$ and $\frac{l_1}{l_2} = \frac{1}{2} (Given)$

and $\frac{\theta_2}{t}$ = rate of flow of heat from second region

$\frac{\theta_2}{t}$ =4cal/sec

$\theta_1 - \theta_2$ =Same.

Now, we know, $\frac{\theta}{t} = \frac{KA(\theta_1 - \theta_2)}{x}$

$\frac{\theta}{t} = \frac{K\pi r^2 (\theta_1 - \theta_2)}{}$

So, Let

$\theta_1 = T_1$
$\theta_2 = T_2$

$\frac{\theta_1}{t_1} = \frac{K_1 \pi r_2^2 (T_1 - T_2)}{l_1}$

$\frac{\theta_2}{t_2} = \frac{K_2 \pi r_2^2 (T_1 - T_2)}{l_2}$

Now, Divide eq^4 1) & 2)

$$\frac{\theta_1}{t_1} X \frac{t_2}{\theta_2} = \frac{K_1(\pi r_1^2)(\theta_1 - \theta_2)}{K_2(\pi r_2^2)(\theta_1 - \theta_2)} X \frac{l_2}{l_1}$$

Since

$$\frac{\theta_2}{t_2} = 4, \frac{t_2}{\theta_2} = \frac{1}{4}; \frac{r_1}{r_2} = \frac{1}{2}\left(\frac{r_1}{r_2}\right)^2 = \frac{1}{4}$$

$$\frac{l_1}{l_2} = \frac{1}{2}; \frac{l_2}{l_1} = \frac{2}{1}$$

$$\frac{\theta_1}{t_1} \times \frac{1}{4} = \frac{1}{2} \times \left(\frac{1}{2}\right)^2 \times \left(\frac{1}{2}\right)$$

$$\frac{\theta_1}{t_1} \times \frac{\cancel{1}}{\cancel{4}} = \frac{\cancel{1}}{\cancel{2}} \times \frac{\cancel{1}}{\cancel{4}} \times \cancel{2}$$

$$\frac{\theta_1}{t_1} = 1 \text{cal/sec}$$

32.What are thermal radiation? Write its properties of thermal radiation?

Ans. The radiant energy emitted be a body solely on account of its temperature is called thermal radiation.

Properties of thermal Radiation:-

1) They travel through vacuum

2) They obey laws of refraction

3) They can be refracted

4) They travel with the speed of light

5) They do not heat the medium through which they passes.

6) They exhibit phenomena of interference, diffraction and polarization.

33.An indirectly heated filament is radiating maximum energy of wavelength 2.16x 10^{-7}m. Find the net amount of heat energy lost per second per unit area, the temperature of surrounding air is 13^0C. Given b = 2.88x10^{-3} mk, σ = 5.77x10^{-8} J|s|m^2|k^4?

Ans. By Wien's Law:-

The product of wavelength (λm) at which maximum energy is emitted and the absolute temperature (T) of the black body is always constant.

i.e λm T = constant = b →(1)

b = Wien's constant = 2.9×10^{-3} mK

Now, $\lambda m = 2.16 \times 10^{-7} m$

T=Temperature of filament

$$\text{So, } T = \frac{b}{\lambda m} \text{ (by equation 1)}$$

$$T = \frac{2.9 \times 10^{-3}}{2.16 \times 10^{-7}}$$

$$T = \frac{2.9 \times 10^{-3+7}}{2.16}$$

$$T = \frac{29 \times 10^{5}}{216}$$

T = 13333.3K

Now, Temperature of surrounding, To = 13 + 273 = 286K.

Net amount of heat energy lost per second per unit area:-

$E = \sigma\left(T^4 - To^4\right) \Rightarrow$ By stefan's law: $\rightarrow$

$$E = 5.77 \times 10^{-8}\left[(13333.3)^4 - (286)^4\right]$$

E = 1.824 × 10^8 J/s/m^2

---

34. Animals in the forest find shelter from cold in holes in the snow. Why?

Ans. Animals in the forest find shelter from cold in holes in the snow because snow has trapped air (as in ice there is no air) so, it acts as a heat insulator. Therefore, the snow prevents the transmission of heat from the body of the animal to the outside.

35.A brass boiler has a base area of 0.15m^2 and thickness 1.0cm. It boils water at the rate of 6kg| min when placed on a gas stove, Estimate the temperature of the part of flame in contact with the boiler. Thermal conductivity of brass = 109J|s|m|^{0}C, heat of vaporization of water = 2256J|g?

Ans. Rate of boiling of water is = 6.0Kg / min

$$= \frac{6 \times 10^3\, g}{60\ \text{sec}}$$

= 100 g/s

∴ Rate at which heat is supplied by the flame to water is :-

m = Rate of boiling of water

L = heat of vaporization of water

θ = m L

$$= \frac{100g}{s} \times \frac{2256J}{g}$$

Θ = 225 600J/s

Now, T_2 = Temperature of cold junction = 100^0C

$$\theta = \frac{KA(T_1 - T_2)x}{t}$$

$\theta = heatflow$

$A = Area\ of\ cross - section$

T_1 = Temperature of hot junction

T_2 = Temperature of cold junction

t = time

x = Distance b/w hot and cold junction

$$225600 = \frac{KA(T_1 - T_2)x}{t}$$

$$(T_1 - T_2) = \frac{225600 \times x}{KAt}$$

Now, x = 1.0 cm = 1.0 X 10^{-2}m

K = 109 J|s|m|^0C

A = 0.15 m^2

t = 1 s

$$T_1 - T_2 = \frac{225600 \times 1.0 \times 10^{-2}}{109 \times 0.15 \times 1}$$

$$T_1 - T_2 = 137.98^0C$$

$$T_1 = 137.98^0C + T_2$$

$T_1 = 137.98 + 100$

$T_1 = 237.98^0C$

---

36. How do you explain heating of rooms based on principle of convection?

Ans. Convection is the process by which heat is transmitted from one point to another due to the movement of heated particles of the substance.

During heating of the room by a heater, the air molecules in immediate contact with heater are heated up, they acquire sufficient energy and rise upward. The cool air particles near to the roof are dense and more down and in turn it is heated and the moves upwards. Hence by the movement of heated air particles, the entire room heats up.

---

37. If for a gas, $\frac{R}{C_V}$ = 0.67 then which gas is this:- monatomic, diatomic and tri atomic?

Ans. Since for an ideal gas, $C_P - C_V = R \rightarrow 1)$

C_P = Specific heat at constant pressure

C_V = Specific heat at constant volume

R = Universal Gas Constant

And given $\frac{R}{C_V} = 0.67$

or $\frac{C_P - C_V}{C_V} = 0.67 \quad (\because \text{ Using equation 1)})$

$\frac{C_P}{C_V} - 1 = 0.67$

$\frac{C_P}{C_V} = 1 + 0.67$

$$\frac{C_P}{C_V} = 1.67$$

And we know, that $\frac{C_P}{C_V}$ = 1.67 is for monatomic gas ; So the gas is monatomic in question.

38.A 50g lead bullet, specific heat 0.02 cal |g | ^{0}C is initially at 30^{0}C. It is fixed vertically upward with a speed of 840m |s and on returning to the starting level strikes a cake of ice at 0^{0}C. How much ice is melted? Assume that all energy is spent in melting ice only?

Ans. Speed of bullet hitting the ice = V = 840 m | s

Heat produced due to kinetic energy of the bullet:- = $\frac{1}{2}mV^2$

Now, m = Mass of bullet = $50g = \left(50\times10^{-3}\right)Kg$

Hence $\Rightarrow \frac{1}{2}mV^2 = \frac{1}{2}\times\left(50\times10^{-3}\right)\times(840)^2$

$$= \frac{1}{2}\times 50\times10^{-3}\times 705600$$

$$= 17640J$$

$$= \frac{17640}{4.2}Cal \ \left[\because \text{ To convert J } \rightarrow \text{ Cal we divide by 4.2}\right]$$

$$\frac{1}{2}mV^2 = 4200 \text{ Cal } \rightarrow 1)$$

Now, heat given by bullet due to temperature difference = m c $\left(Q_2 - Q_1\right)$

$$= 50\times 0.02(30-0)$$

$$= 30 \ Cal \ \rightarrow 2)$$

From 1) & 2)

m = Mass of bullet

c = Specific heat of bullet

Q_2 = Initial Temperature

Q_1 = Final Temperature

Total heat given by bullet = 4200 + 30 = 4230 Cal.

Now, entire heat of bullet is used in melting the ice only, Let M = Mass of Ice that melted

L = Latent heat of ice

Hence $m \times L = 4230$

$$m = \frac{4230}{L} = \frac{4230}{80}$$

$$m = 52.88g$$

39.A gas mixture consists of 2 moles of oxygen and 4 moles of argon at temperature T. If we neglect all vibration modes, find the total energy of the system?

Ans. Let N_A = Avogadro's Number

No. of degrees of freedom of O_2 molecule (diatomic) = 5

No. of degrees of freedom of 2 moles of oxygen = 2 N_A × 5 = 10 N_A

No. of degrees of freedom of 4 moles of argon (monatomic) = 4 N_A × 3

= 12 N_A (∵ 3 = degrees of freedom)

Total degrees of freedom of mixture = 10 N_A + 12 N_A = 22 N_A →1)

Energy associated with each degree of freedom | molecule = $\frac{1}{2}KT$

Total energy of mixture = 22 N_A × $\frac{1}{2}KT$ (∵ Using equation1)

$= 11K\ N_A\ T$

$= 11RT\ \left(KN_A = R\right)$

---

40. Show that C_P - C_V = R Where [C_P = specific heat at constant pressure ; C_V = specific heat at constant volume and R = Universal Gas constant] for an ideal gas?

Ans. Now, Let first heat the gas at constant volume and temperature increases by ΔT, So,
$\Delta Q = C_V \Delta T \rightarrow 1)$

Since volume remains the same, hence no work is heating the gas then according to law of conservation of energy, the entire heat supplied goes into raising the internal energy and hence the temperature of the gas.

Now, $CV\Delta T = \Delta U$

∴ ΔU = increase in the internal energy of the gas Let heat the gas at constant pressure and if the temperature of the gas increases by ΔT but here external work is done to expand the gas hence

$\Delta Q^1 = \Delta U + \Delta W$

$C_P \Delta T = C_V \Delta T + \Delta W$ (Q from equation 1))

But $\Delta W = P\Delta V$, so

$C_P \Delta T = C_V \Delta T + P\Delta V \rightarrow 2)$

Now, form ideal gas equation :→

$PV = RT \rightarrow 3)$ or $P\left(V + \Delta V\right) = R\left(T + \Delta T\right) \rightarrow 4)$

Subtracting equation 3) from equation 4)

$P\Delta V = R\Delta T$

Put $P\Delta V = R\Delta T$ in equation 2)

$C_P\Delta T = C_V\Delta T + P\Delta V$

$C_P\Delta T = C_V\Delta T + R\Delta T$

$C_P = C_V + R$

or $C_P - C_V = R$

---

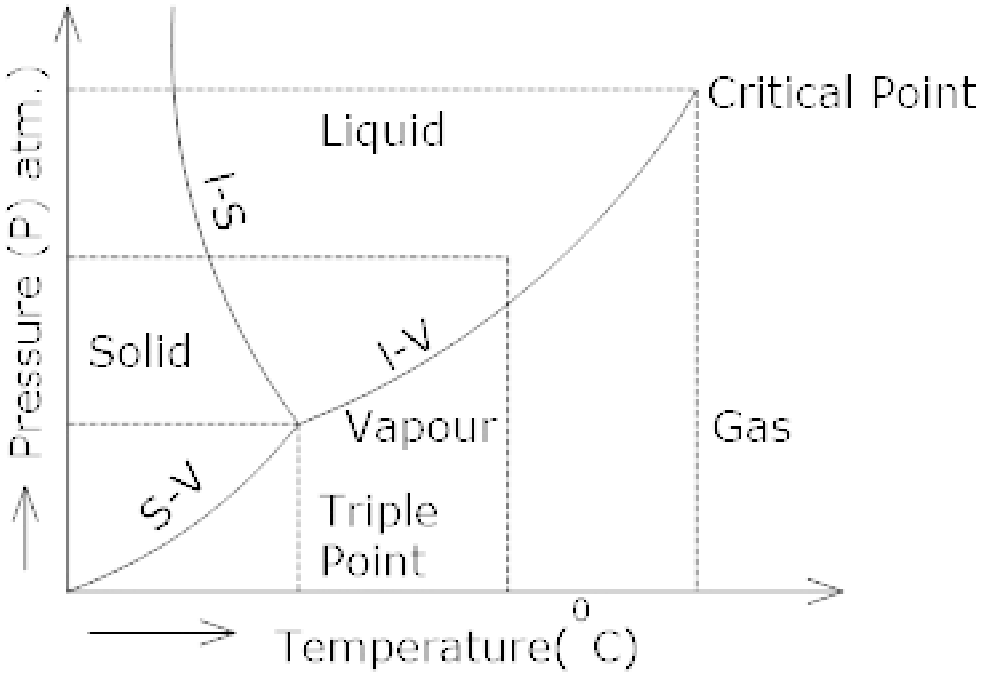
41. How do you justify that when a body is being heated at melting point, the temperature remains Constant?

Ans. When a body is being heated below the malting point, the heat supplied increases the potential as well as the kinetic energy of the molecules. Due to the increase in the kinetic energy of the mole clues, the temperature increases. But at melting point, heat goes, to increase only the potential energy of molecules and hence the temperature remains the same.

---

42. Draw and explain a P – T diagram for water showing different phases?

Ans.



1) The l - V curve represent those points where the liquid and vapour phases are in equilibrium.

2) The s – l curve represent the points where the solid and liquid phases exist in equilibrium.

3) The s – v is the sublimation curve where a solid changes into vapour phase without passing through the liquid stage

4) Triple point → Intersection of three curves is the triple point. It represents a unique temperature and pressure and it is only at this point that the three phases can exist together in equilibrium.

---

43. From what height should a piece of ice fall so that it completely melts? Only one – quarter of heat produced is absorbed by the ice. Given latent heat of ice is 3.4×10^5 J | Kg and acceleration due to gravity, g = 10m | s^2?

Ans. Let m = Mass of piece of ice

h = height from which it falls.

∴ Loss of Potential energy = m g h

The Potential energy of ice is converted into heat.

Since the ice absorbs only one – quarter of this,

∴ Heat absorbed by ice, $Q = \frac{1}{4} mgh \rightarrow 1)$

If L Joules | Kg is the latent heat of ice, them

$Q = mL \rightarrow 2)$

Equating 1) & 2) for Q

$\frac{1}{4} \cancel{m} gh = \cancel{m} 2$

$h = \frac{4L}{g}$

$h = \frac{4 \times \left(3.4 \times 10^5\right)}{10}$

$h = 136 \times 10^3 m$

$h = 136 Km$

---

44. A gas can have any value of specific heat depending upon how heating is carried out. Explain?

Ans. If m = Mass of gas

Q = heat supplied

ΔT = Change in temperature

then specific heat of gas, $C = \frac{Q}{m\Delta T}$

1) Let gas is compressed suddenly, So no heat is supplied from outside (i.e. Q = 0) but the temperature of the gas in the gas increases due to compression,

$$C = \frac{Q}{m\Delta T} = 0$$

2) Let the gas is heated in a way that the temperature is constant (ΔT = O) then,

$$C = \frac{Q}{m\Delta T} = \frac{Q}{mXo} = \alpha$$

Hence, depending upon conditions of heating. The value of C will be different.

---

45. A 0.20 Kg aluminum block at 80^0C is dropped in a copper calorimeter of mass 0.05 Kg containing 200 cm^3 of ethyl alcohol at 20^0C. What is the final temperature of the mixture? Given Density of ethyl alcohol = 0.81 g | cm^3 ; specific heat of ethyl alcohol = 0.6 cal | g | ^{0}C ; specific heat of copper = 0.094 cal | g | ^{0}C, specific heat of Al = 0.22 cal | g | ^{0}C?

Ans. Let θ^0C = final temperature of the mixture.

Mass of ethyl alcohol = volume ×Density

= 200 × 0.81

= 162 g

Heat lost by Aluminum block = Mass X specific heat X fall in temperature

$$= \left(0.20 \times 10^3\right) \times 0.22 \times (80 - \theta)$$

$$= 20 \times 22 \times 10^{-4} \times 10^3 (80 - \theta)$$

$$= 440 \times 10^{-1} (80 - \theta)$$

$$= 44 (80 - \theta) \rightarrow 1)$$

Heat gained by the ethyl alcohol and calorimeter = (Mass of ethyl alcohol × specific heat × change in Temperature) + Mass of copper calorimeter × specific heat X change in

Temperature

$$=\left[162\times0.6\times(\theta-20)\right]+\left[0.05\times10^{3}\times0.094\times(\theta-20)\right]$$

$$=101.9(\theta-20)\quad\rightarrow2)$$

But, Heat gained = Heat Lost

So, from equation 1) & 2)

$$44(80-\theta)=101.9(\theta-20)$$

$$\Rightarrow3520-44\theta=101.9\theta-2038$$

$$3520+2038=101.9\theta+44\theta$$

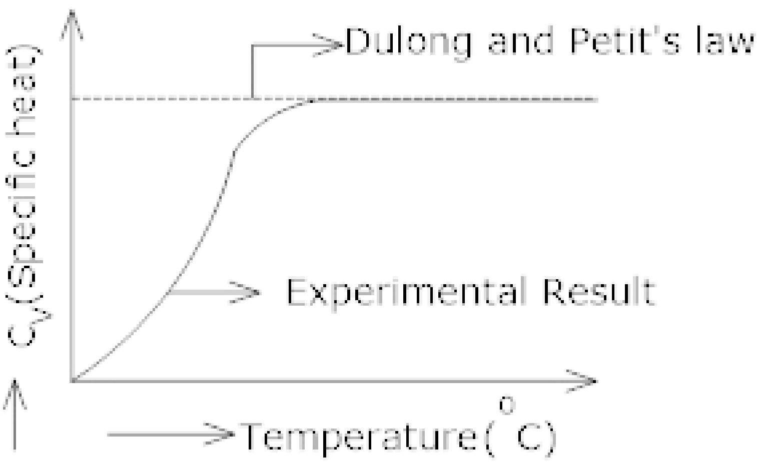
$$5558=145.9\theta$$

$$\theta=\frac{5558}{145.9}$$

$$\theta=38.1^{0}C$$

---

46. Why is there a difference in the specific heat curve as given by Delong's petit law and the experimental result at low temperatures?



Ans. Now, from Dulong & Petit law, the specific heat is independent of temperature but it is experimentally seen that specific heat at lower temperatures is directly proportional to the cube of temperatures. The above dependence is because of the fact that the particles in the crystal oscillate as if they are coupled Quantum Harmonic Oscillator.

---

47. Specific heat of Argon at constant Pressure is o.125 cal | g | K and at constant volume is 0.075 cal | g | K. Calculate the density of argon at N.T.P. Given that J = 4.2J | cal?

Ans. Specific heat at constant and Pressure, C_P = 0.125 cal | g | K

C_P = 0.125 × 4.2 × 1000 J | Kg | K

C_P = 525 J | Kg | K →1)

Specific heat at constant volume, C_V = 0.075 cal | g | K

$$C_V = 0.075 \times 4.2 \times 1000$$

$$C_V = 315 J | Kg | K$$

The gas constant, r for I kg of gas is given by:-

$$r = C_P - C_V = 525 - 315 = 210 J | Kg | K$$

Normal pressure = P = h P g = 0.76 ×13600 × 9.8 = 101292.8N | m^2

Normal Temperature = T = 273K.

Suppose V = Volume of argon in m^3 at N. T. P.

$$PV = n\,r\,T$$

for n = 1 mole

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

$$V = \frac{rT}{P} = \frac{210 X 273}{101292.8} = 0.566 m^3$$

∴ Density of Argon, $P = \frac{Mass}{Volume} = \frac{1}{0.566} = 1.8 Kg | m^3$.

48. How is heat loss reduced in Calorimeter?

Ans.1) Heat loss due to radiation is reduced by polishing inner and outer surfaces of the Calorimeter.

2) Heat loss due to conduction is reduced by filling the space between the calorimeter and insulating jacket with poor conductor of heat.

3) Heat loss due to convection is done by using a insulating lid.

49. What is critical temperature? How will you differentiate between a gas and a vapour depending on critical temperature?

Ans. The temperature above which a gas connot be liquefied, no matter how great the pressure is called critical temperature. If the substance lies above the critical temperature then it falls in the gaseous region. If the substance lies below the critical temperature than it falls in the vapour stage.

50. If for hydrogen CP – CV = a and for oxygen CP – CV = b where CP & CV refer to specific heat at constant pressure and volume then what is the relation between a and b?

Ans. For H_2, $C_P - C_V = a$

C_P = Specific heat at constant pressure

C_V = Specific heat at constant Volume

For $O_2 = C_P - C_V = b$

And r = $\frac{R}{MJ}$

M = Molecular weight

I = Mechanic cal equivalent of heat

Now, we know that, $C_P - C_V = r$

$$C_P - C_V = \frac{R}{MJ}$$

So, for $H_2 \Rightarrow C_P - C_V = a = \frac{R}{2J}$

$$M_{H2} = 2 \Big| C_P - C_V = a = \frac{R}{2J} \rightarrow 1)$$

$$For\ O_2 \Rightarrow C_P - C_V = b = \frac{R}{32J} \rightarrow 2)$$

from equation 1)

2a = $\frac{R}{J}$

from equation 2)

32b = $\frac{R}{J}$

Equating above equations for $\frac{R}{J} :\rightarrow$

2a = 32 b

a = 16 b

---

51. A ball is dropped on a floor from a height of 2cm. After the collision, it rises up to a height of 1.5m. Assuming that 40% of mechanical energy lost goes to thermal energy into the ball. Calculate the rise in temperature of the ball in the collision. Specific heat

capacity of the ball is 800J/k. Take g = 10m/s^2

Ans. Initial height = h_1=2m

Final height = h_2=1.5m

Since potential energy = mechanical energy for a body at rest as K.E =0

Mechanical energy lost = $|mg(h_1 - h_2)|$

= $|1 \times 10(105 - 2)|$

= $|10 \times (.5)|$

= 5 J

Now (mechanical energy lost) × 40% = heat gained by ball

$$\frac{40}{100} \times 5 = cm\Delta T \quad \text{C = specific heat of ball}$$

$$\frac{40}{100} \times 5 = 800 \times 1 \times \Delta T \quad \text{m = Mass of ball =1kg}$$

$$\Delta T = \frac{\cancel{40}^{\cancel{2}\,1} \times \cancel{5}^{1}}{\cancel{100}_{\cancel{5}} \times \cancel{800}_{400}} = \frac{1}{400}$$

$$\frac{1}{400} = \Delta T$$ ΔT = 2.5×10^{-3} ^{0}C

2 Marks Questions Part 3

52.A thermometer has wrong calibration. It reads the melting point of ice as – 10^0C. It reads 60^0C in place of 50^0C. What is the temperature of boiling point of water on the scale?

Ans. Lower fixed point on the wrong scale = -10^0C.

Let 'n' = no. divisions between upper and lower fixed points on this scale. If Q = reading on this scale, then $\frac{C-O}{100}=\frac{Q-(-10)}{n}$

Now, C = Incorrect Reading = 60^0C

Q = Correct Reading = 50^0C

So, $\frac{50-0}{100}=\frac{60-(-10)}{n}$

$$\frac{50}{100}=\frac{70}{n}$$

$$n=70\times\frac{100}{50}$$

n = 140

Now, $\frac{C-O}{100}=\frac{Q-(-10)}{140}$

On, the Celsius scale, Boiling point of water is 100^0C

So, $\frac{100-0}{100}=\frac{Q+10}{140}$

$$Q=140-10$$

Q = 130^0C

53. Write the advantages and disadvantages of platinum resistance thermometer?

Ans. Advantages of Platinum Resistance thermometer:-

1) High accuracy of measurement

2) Measurements of temperature can be made over a wide range of temperature i.e. from –260^0C to 1200^0C.

→ Disadvantages of Platinum Resistance thermometer:-

1) High Cost

2) Requires additional equipment such as bridge circuit, Power supply etc.

54.If the volume of block of metal changes by 0.12% when it is heated through 200C. What is the co-efficient of linear expansion of the metal?

Ans. The co-efficient of cubical expansion y of the metal is given by:-

$$Y = \frac{1}{V} \times \frac{\Delta V}{\Delta T}$$

$$Y = \frac{\Delta V}{V} \times \frac{1}{\Delta T}$$

Here, $\frac{\Delta V}{V} = \frac{0.12}{100}$

$$\Delta T = 20^0 C$$

$$Y = \frac{0.12}{100} \times \frac{1}{20}$$

$$Y = 6 \times 10^{-5} |^0 C$$

∴ Co-efficient of linear expansion of the metal is :-

$$\alpha = \frac{Y}{3} = \frac{6.0 \times 10^{-5}}{3}$$

$$\alpha = 2.0 \times 10^{-5} |^0 C$$

---

55. The density of a solid at0^0C and 500^0C is in the ratio 1.027 : 1. Find the co-efficient of linear expansion of the solid?

Ans . Density at 0^0C = S_O

Density at 500^0C = S_{500}

Now, $S_O = S_{500}$ $\left(1 + Y\Delta T\right)$

Where, Y = Co-efficient of volume expansion

ΔT = Change in temperature

$$\because \frac{SO}{S_{500}} = \frac{1.027}{1}$$

ΔT = Change in temperature

ΔT = Final Temperature – Initial temperature

ΔT = 500 - 0^0C

ΔT = 500^0C

Or $1.027 = 1 \times \left(1 + Y\Delta T\right)$

$$1.027 = 1 + Y\Delta T$$

$$1.027 - 1 = Y\Delta T$$

$$0.027 = Y\Delta T$$

$$\frac{0.027}{500} = Y$$

$$Y = 54 \times 10^{-6} |^0 C$$

Now, Co-efficient of linear expansion (α) is related to co-efficient of volume expansion (Y) as :-

$$\alpha = \frac{Y}{3}$$

$$\alpha = \frac{54 \times 10^{-6}}{3}$$

$$\alpha = 18 \times 10^{-6} |^0 C$$

---

56. If one Mole of a monatomic gas is mixed with 3 moles of a diatomic gas. What is the molecular specific heat of the mixture at constant volume?

Ans. For, a monatomic gas, Specific heat at consent volume = $C_{V1} = \frac{3}{2}R$; R = Universal Gas Constant

No. of moles of monatomic gas = n_1 = 1 mole

No. of moles of diatomic gas = n_2 = 3 moles.

For, diatomic gas, specific heat at constant volume $C_{V2} = \frac{5}{2}R$.

Applying, conservation of energy.

Let C_V = Specific heat of the mixture;

$$C_V = \frac{n_1 Cv_1 + n_2 Cv_2}{n_1 + n_2}$$

$$C_V = \frac{1 \times \frac{3}{2}R + 3 \times \frac{5}{2}R}{1+3}$$

$$C_V = \frac{\frac{3}{2}R + \frac{15}{2}R}{4}$$

R = Universal Gas constant

$$C_V = \frac{18R}{2 \times 4}$$

$$C_V = \frac{9R}{4}$$

$$C_V = \frac{9}{4} \times 8.31$$

$$C_V = 18.7J \mid mol \mid^0 K$$

---

57. Calculate the difference between two principal specific heats of 1g of helium gas at N. T. P. Given Molecular weight of Helium = 4 and J = 4.186 J/cal and Universal Gas constant, R = 8.314J / mole / K?

Ans. Molecular weight of Helium = M = 4

Universal Gas Constant, R = 8.31J | mole | K

C_P = specific heat at constant Pressure

C_V = specific heat at constant Volume

Now, $C_P - C_V = \frac{r}{J}$ for 1 mole of gas.

$$C_P - C_V = \frac{R}{MJ}$$

Where R = Universal Gas Constant = 8.31J | mole | K

J = 4.186 J | cal

M = Molecular weight of Helium = 4

$$C_P - C_V = \frac{8.31}{4 \times 4.186}$$

$$C_P - C_V = 0.496\ cal\,|\,g\,|\,K$$

---

58. Why does heat flow from a body at higher temperature to a body at lower temperature?

Ans. When a body at higher temperature is in contact with a body at lower temperature, molecule with more kinetic energy that are in contact with less energetic molecules give up some of their kinetic energy to the less energetic ones.

---

59. A one liter flask contains some mercury. IT is found that at different temperatures, then volume of air inside the flask remains the same. What is the volume of mercury in the flask? Given the co-efficient of linear expansion of glass = 9×10^{-6} / ^{0}C and co-efficient of volume expansion of mercury = 1.8×10^{-4} /
^{0}C

Ans. It is given that volume of air in the flask remains the same at different temperature. This is possible only when the expansion of glass is exactly equal to the expansion of mercury,

Co-efficient of cubical expansion of glass is :-

$$\gamma_g = 3\alpha_g = 3 \times 9 \times 10^{-6}$$

$=27\times10^{-6}|^{0}C$

Co-efficient of cubical expansion of mercury is :→

$\gamma_m = 1.8\times10^{-4}|^{0}\ C(Given)$

Volume of flask, V = 1 liter = 1000 cm^3.

Let V_m Cm^3 be the volume of mercury in the flask.

Expansion of flask = Expansion of Mercury

$CX\gamma_g \times t = V_m X\gamma_m \times t$

∴ Volume of Mercury, $V_m = \dfrac{V\times\gamma g}{\gamma_m}$

$$V_m = \frac{1000\times27\times10^{-6}}{1.8\times10^{-4}} = 150cm^3$$

---

60. A refrigerator is to maintain eatables kept inside at 9°C. If room temperature is 36° C, calculate the coefficient of performance.

Ans. Temperature inside the refrigerator, T_1 = 9°C = 282 K

Room temperature, T_2 = 36°C = 309 K

Coefficient of performance = $\dfrac{T_1}{T_2 - T_1}$

$$= \frac{282}{309-282}$$

= 10.44

Therefore, the coefficient of performance of the given refrigerator is 10.44.

---

61. A steam engine delivers 5.4×10^8 J of work per minute and services 3.6×10^9 J of heat per minute from its boiler. What is the efficiency of the engine? How much heat is wasted per minute?

Ans. Work done by the steam engine per minute, W = 5.4×10^8 J

Heat supplied from the boiler, H = 3.6×10^9 J

Efficiency of the engine = $\frac{Output\ energy}{Input\ energy}$

$$\therefore \eta = \frac{W}{H} = \frac{5.4 \times 10^8}{3.6 \times 10^9} = 0.15$$

Hence, the percentage efficiency of the engine is 15 %.

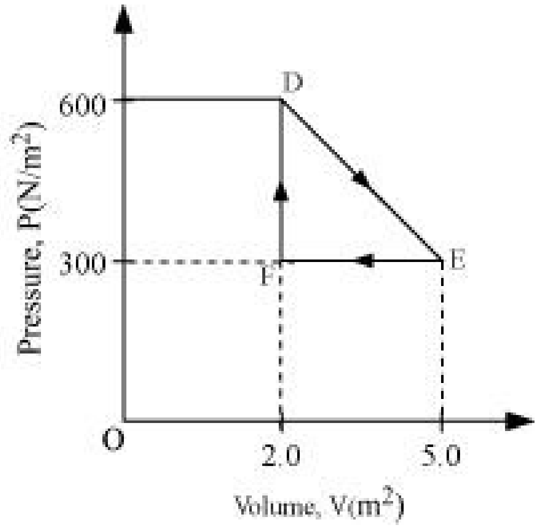
Amount of heat wasted = $3.6 \times 10^9 - 5.4 \times 10^8$

= 30.6×10^8 = 3.6×10^9 J

Therefore, the amount of heat wasted per minute is 3.6×10^9 J.

---

62. A thermodynamic system is taken from an original state to an intermediate state by the linear process shown in Fig. (12.13)



Its volume is then reduced to the original value from E to F by an isobaric process. Calculate the total work done by the gas from D to E to F

Ans. Total work done by the gas from D to E to F = Area of ΔDEF

Area of ΔDEF = $\frac{1}{2} DE \times EF$

Where,

DF = Change in pressure

= $600\ N/m^2 - 300\ N/m^2$

= 300 N/ m^2

FE = Change in volume

= $5.0\ m^3 - 2.0\ m^3$ = 3.0 m3

Area of ΔDEF = $\frac{1}{2} \times 300 \times 3$ = 450 J

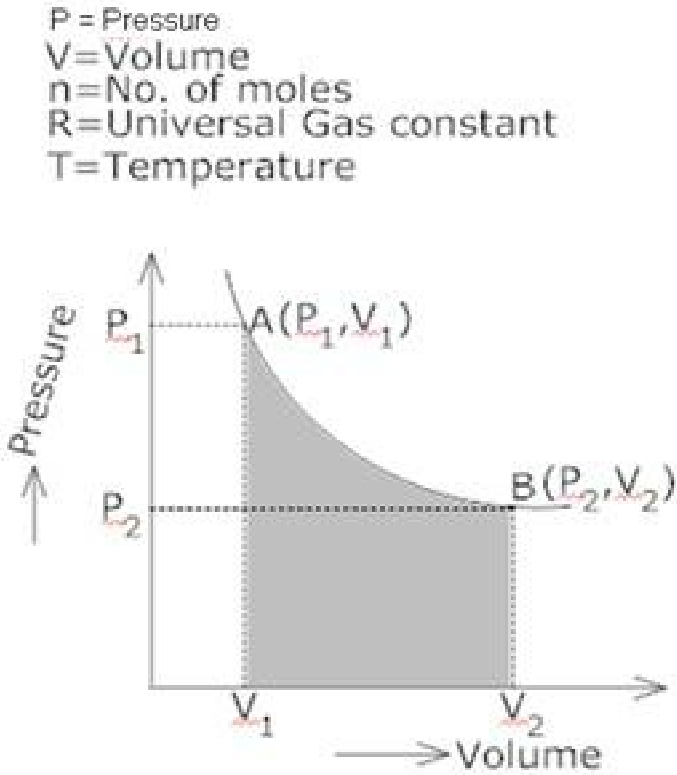
Therefore, the total work done by the gas from D to E to F is 450 J.

3 Marks Questions

1.Calculate the work done during the isothermal Process?

Ans. Let an ideal gas is allowed to expand very slowly at constant temperature. Let the expands from state A (P_1, V_1) to state B (P_2, V_2)

The work by the gas in expanding from state A to B is



$$W = +\int_{V_1}^{V_2} PdV \rightarrow (1)$$

For ideal gas, PV = N R T

or $P = \frac{nRT}{V} \rightarrow (2)$

Use 2) in i)

$$W = \int_{V_1}^{V_2} \frac{nRT}{V} dV$$

Since n, R and T are constant so,

W = $nRT\int_{V_1}^{V_2}\frac{dV}{V}$ $\left(\because \int\frac{dn}{n} = Logem\right)$

W isothermal = nRT Loge V $\Big|_{V_1}^{V_2}$

W isothermal = $nRT\left[LogeV_2 - LogeV_1\right]$ $\left(\because Logm - Logn = Log\frac{m}{n}\right)$

W isothermal – nRT Loge $\frac{V_2}{V_1}$

W isothermal = 2.303 nRT Log 10 $\frac{V_2}{V_1}$ $(Loge = 2.303Log10)$

If M = Molecular Mass of gas then for 1 gram of ideal gas,

W isothermal = 2.303 $\frac{RT}{M}Log10\frac{V_2}{V_1}$

W isothermal 2.303 r T Log 10 $\frac{V_2}{V_1}$

r = Gas constant for 1 gm of an ideal gas,

Since $P_1 V_1 = P_2 V_2 \Rightarrow \frac{V_2}{V_1} = \frac{P_1}{P_2}$

So W isothermal = 2.303 r T log 10 $\frac{P_1}{P_2}$

2.Five moles of an ideal gas are taken in a Carnot engine working between 100^0C and 30^0C. The useful work done in 1 cycle is 420J. Calculate the ratio of the volume of the gas at the end and beginning of the isothermal expansion?

Ans. High temperature, $T_H = 100^0C = 100 + 273 = 373K$

Low temperature, $T_L = 30^0C, = 30 + 273 = 303K$

Amount of the gas, n = 5 moles

Useful work done per cycle, $W = Q_H - Q_L$

Now, W = 420 J

So, $Q_H - Q_L = 420J \rightarrow 1)$

Now, $\frac{Q_H}{Q_L} = \frac{T_H}{T_L}$

$$\frac{Q_H}{Q_L} = \frac{373}{303}$$

Or $Q_H = \frac{373}{303} Q_L$ in equation 1)

$$\frac{373}{303} Q_L - Q_L = 420J$$

$$\frac{373Q_L - 303Q_L}{303} = 420J$$

$$\frac{70\ Q_L}{303} = 420$$

$$Q_L = \frac{420 X 303}{70}$$

Q_L = 1818J

or, Q_H-Q_L = 420J

Q_H – 1818 = 420J

Q_H = 420 + 1818 = 2238J

When the gas is carried through Carnot cycle, the heat absorbed Q_H during isothermal expansion is equal to the work done by gas.

V_1 – Initial Volume

V_2 = Final Volume,

In isothermal expansion,

Q_H = 2.303 nRT_H Log 10 $\frac{V_2}{V_1}$

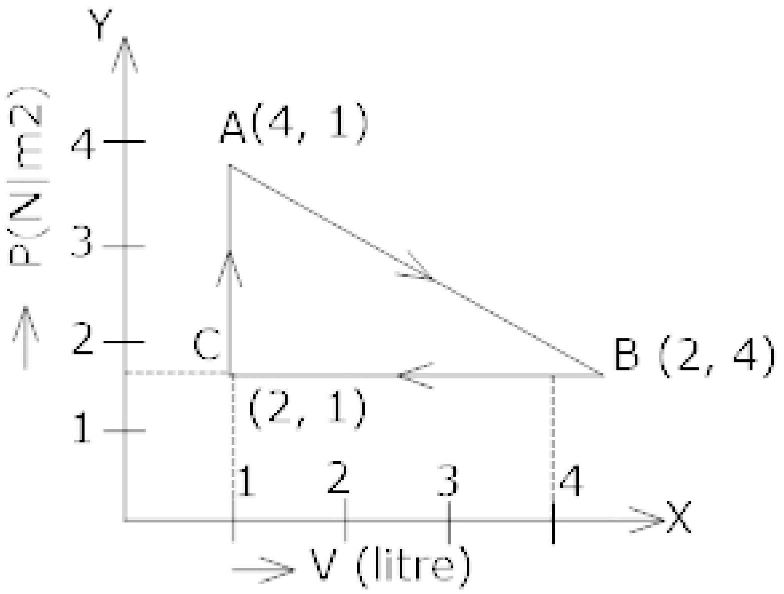
22 38 = 2.303 × 5 × 8.4 × 373 Log 10 $\frac{V_2}{V_1}$

$$\text{Log } 10\ \frac{V_2}{V_1} = \frac{2238}{2.303 \times 5 \times 8.4 \times 373}$$

$$\text{Log } 10\ \frac{V_2}{V_1} = 0.0620$$

$$\frac{V_2}{V_1} = 1.153$$

3.Deduce the work done in the following complete cycle?



Ans.1) Work done during the process from A to B = W_{AB}

W_{AB} = area ABKLA (∴ because area under p-v curve gives work done)

= area of Δ ABC + area of rectangle

$$= \left(\frac{1}{2}\times BC\times AC\right)+\left(KL\times LC\right)$$

BC = KL = 4-1 = 3l = $3x10^{-3}m^3$

AC = 4-2 = 2N|m^2

LC = 2-0 = 2N|m^2

$$W_{AB} = \left(\frac{1}{2}\times 3\times 10^{-3}\times 2\right)+\left(3\times 10^{-3}\times 2\right)$$

$= 3\times10^{-3}+6\times10^{-3}$

$W_{AB} = 9\times10^{-3}J$

Since gas expands during this process, hence $W_{AB} = 9\times10^{-3}J$

2) Work done during the process from B to C(compression) is W_{BC} = -area BCLK

(- ve because gas compresses during BC)

= - KL × LC

$W_{BC} = -3\times10^{-3}\times2$

$= -6\times10^{-3}J$

3) Work done during the process from C to A :-

As there is no change in volume of gas in this process, W_{CA} = O

So, net work done during the complete cycle = $W_{AB} + W_{BC} + W_{CA}$

$= 9\times10^{-3}-6\times10^{-3}+0$

Net work done = $3\times10^{-3}J$

4.One kilogram molecule of a gas at 400k expands isothermally until its volume is doubled. Find the amount of work done and heat produced?

Ans. Initial volume, V_1= V

Final volume, V_2= 2V

Initial temperature T = 400k

Find temperature = 400k (∴ process is isothermal)

Gas constant, R = 8. 3kJ |mole |k=$8.3\text{x}10^{-3}$J|mole|k

Work done during is thermal process=w=2.3026RT Log 10 $\left(\frac{V_2}{V_1}\right)$

$W = 2.3026 \times 8.3 \times 10^{-3} \times 400 \times \log 10 \left(\frac{2V}{V}\right)$

$W = 2.3026 \times 8.3 \times 10^{-3} \times 400 \times \text{Log } 10\ (2)$

W = 2.3016J

If H is the amount of heat produced than,

$$H = \frac{W}{J} = \frac{2.3016}{4.2} = 0.548 \text{ cal}$$

5.Calculate difference in efficiency of a Carnot energy working between:-

1) 400K and 350K

2) 350K and 300K

Ans. Efficiency of heat engine = n = 1 - $\frac{T_2}{T_1}$

T_2 = final temperature

T_1 = Initial temperature

1) 400K and 350K,

$T_2 = 350$, $T_1 = 400$

$n = 1 - \frac{350}{400}$

$= \frac{50}{400}$

$n_1 = \frac{1}{8}$ or $\frac{100\%}{8} = 12.5\%$

2) 350K and 300K

$T_2 = 300K; T_1 = 350K$

$n_1 = 1 - \frac{T_2}{T_1}$

$= 1 - \frac{300}{350}$

$= \frac{50}{350}$

$n_1 = \frac{1}{7} = \frac{100\%}{7} = 14.3\%$

Change in efficiency = $n_2 - n_1$ = 14.3% - 12.5% = 1.8%

6.How do you derive Newton's law of cooling from Stefan's law?

Ans. Acc. to Newton's law of cooling, the rate of loss of heat of a liquid is directly proportional to the difference in temperature of the liquid and the surrounding, provided the difference in temperature is very small.

$E \alpha (T - To)$

Let a body be maintained at T K. Let T_o be the temperature of the surroundings. Let T ≫ To. There will be loss of heat be the body

Acc. to Stefan's law, amount of heat energy lost per second per unit area of the body is

$E = \epsilon \, \sigma \left(T^4 - To^4\right)$

σ = Stefan's constant

ε = Emissivity of the body and surroundings

E = $\varepsilon\sigma\left(T^2 - To^2\right)\left(T^2 + To^2\right)$

$\left(\because \left(a^4 - b^4\right) = \left(a^2 - b^2\right)\left(a^2 + b^2\right)\right)$

Incase of Newton's cooling, T ≈ To

E = ε σ $\left(T - To\right)\left(To + T\right)\left(To^2 + To^2\right)$

E = ε σ $\left(\text{T-To}\right)4T_o^3$

$E = K\left(T - T_o\right)$

$K = 4\varepsilon\sigma To^3$

Hence, → Hence the Newton's law of cooling

E α $\left(T - T_o\right)$

7.Define the terms reflectance, absorptance and transmittance. How are they related?

Ans.1) Reflectance – Ratio of amount of thermal radiations reflected by the body in a given time to total amount of thermal radiations incident on body It is represented by r, 2) Absorptance – is the ratio of the amount of thermal to the total amount of thermal radiations incident on it. It is represented by a

3) Transmittance – It is the ratio of the amount of thermal radiations transmitted by body in a given time to the total amount of thermal radiations incident on the body in a given time. It is represented by t.

Let Q = Amount of the radiations incident by the body in a given time

Q_1 = Amount of thermal radiations reflected by the body in a given time.

Q_2 = Amount of thermal radiations absorbed by the body in a given time.

Q_3 = Amount of thermal radiations transmitted by the body in a given time,

∴ By definition,

$$r = \frac{Q_1}{Q}$$

$$a = \frac{Q_2}{Q}$$

$$t = \frac{Q_3}{Q}$$

New, r + a + t = $\frac{Q_1}{Q} + \frac{Q_2}{Q} + \frac{Q_3}{Q}$

R + a + t = $\frac{Q_1 + Q_2 + Q_3}{Q}$

R + a + t = 1

$$\left(\because Q^1 + Q_2 + Q_3 = Q\right)$$

If t = 0

A = 1 – r

that is good reflectors are bad absorbers

---

8. If half mole of helium is contained in a container at S. T. P. How much heat energy is needed to double the pressure of the gas, keeping the volume of the gas constant? Given specific heat of gas = 3J | g |K.

Ans. Number of moles of Helium gas = $n = \frac{1}{2}$.

Specific heat of Helium gas = $C_V = 3J | g | K$

Molecular weight = M = 4

Temperature, T_1 = 273 K.

∴ Molar specific heat at constant volume = $C_V = M_{CV}$

$C_V = 4 \times 3$

C_V = 12 J | mol | K

Since, Volume is constant, Pα T or $\frac{P}{T}$ = Constant

$$\therefore \frac{P_2}{T_2} = \frac{P_1}{T_1} \qquad P = \text{Pressure; } T = \text{Temperature}$$

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

P_2 = Final Pressure = 2 P

P_1 = Initial Pressure = P

$$\frac{2P}{P} = \frac{T_2}{T_1}$$

$$\frac{T_2}{T_1} = 2$$

$$T_2 = 2T_1$$

$$T_2 = 2X273$$

$$T_2 = 546K$$

$$\Delta T = T_2 - T_1 = 546 - 273 = 273K$$

Now, Heat required, $= Q = nC_V\Delta T$

$$= \frac{1}{2} \times 12 \times 273$$

Heat required = 1638 J

---

9. Calculate the amount of heat necessary to raise the temperature of 2 moles of HE gas from 20^0C to 50^0C using:-

1) Constant – Volume Process   2) Constant Pressure Process

Here for, He; C_V = 1.5 R and C_P = 2.49R

Ans .1) The amount of heat required for constant – volume process is :- $Q_V = nC_V\Delta T$

Here, n = 2 moles, C_V = 1.5 R = 1.5 X 8.314 J | mol | ^{0}C

T_2 = final Temperature

T_1 = Initial Temperature

$$\Delta T = T_2 - T_1$$

$$= 50 - 20$$

$$= 30^0C$$

$$Q_V = 2 \times 1.5 \times 8.314 \times 30$$

$$Q_V = 748J$$

2) The amount of heat required for constant – Pressure process is :-

$$Q_p = nC_p\Delta T$$

Here, n = 2 moles, $C_p = 2.49R = 2.49 \times 8.314$

$\Delta T = 30$

$Q_P = 2 \times 2.49 \times 8.314 \times 30$ $Q_P = 1242J$

Since the temperature rise is same in both the cases, the change in internal energy is the same i.e. 748J. However, in constant – pressure Process excess heat is supplied which is used in the expansion of gas.

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10. An electric heater supplies heat to a system at a rate of 100W. If system performs work at a rate of 75 Joules per second. At what rate is the internal energy increasing?

Ans. Heat is supplied to the system at a rate of 100 W.

∴Heat supplied, Q = 100 J/s

The system performs at a rate of 75 J/s.

∴Work done, W = 75 J/s

From the first law of thermodynamics, we have:

$Q = U + W$

Where,

U = Internal energy

∴U = Q–W

= 100 –75

= 25 J/s

= 25 W

Therefore, the internal energy of the given electric heater increases at a rate of 25 W.

4 Marks Questions

1. A geyser heats water flowing at the rate of 3.0 litres per minute from 27 °C to 77 °C. If the geyser operates on a gas burner, what is the rate of consumption of the fuel if its heat of combustion is 4.0×10^4 J/g?

Ans. Water is flowing at a rate of 3.0 litre/min.

The geyser heats the water, raising the temperature from 27°C to 77°C.

Initial temperature, T_1 = 27°C

Final temperature, T_2 = 77°C

∴Rise in temperature, ΔT = $T_2 - T_1$

= 77–27= 50°C

Heat of combustion = $4\times10^4\ J/g$

Specific heat of water, c = 4.2 $J\ g^{-1}\ {}^{\circ}C^{-1}$

Mass of flowing water, m = 3.0 litre/min = 3000 g/min

Total heat used, $\Delta Q = mc\,\Delta T$

= $3000\times4.2\times50$

= $6.3\times10^5\ J/min$

∴ Rate of consumption = $\dfrac{6.3\times10^5}{4\times10^4}$ = 15.75 g/min

2. What amount of heat must be supplied to 2.0×10^{-2} kg of nitrogen (at room temperature) to raise its temperature by 45 °C at constant pressure? (Molecular mass of $N_2 = 28$; $R = 8.3\ J\ mol^{-1}\ K^{-1}$.)

Ans. Mass of nitrogen, $m = 2.0\times10^{-2}\ kg = 20\ g$

Rise in temperature, ΔT = 45°C

Molecular mass of N_2, M = 28

Universal gas constant, R = $8.3 \text{ J mol}^{-1} \text{ K}^{-1}$

Number of moles, $n = \frac{m}{M}$

$$= \frac{2.0 \times 10^{-2} \times 10^{3}}{28} = 0.714$$

Molar specific heat at constant pressure for nitrogen, $C_P = \frac{7}{2}R$

$$= \frac{7}{2} \times 8.3$$

$$= 29.05 J\, mol^{-1} K^{-1}$$

The total amount of heat to be supplied is given by the relation:

$$\Delta Q = nC_P \Delta T$$

$$= 0.714 \times 29.05 \times 45$$

= 933.38 J

Therefore, the amount of heat to be supplied is 933.38 J.

---

3. Explain why

(a) Two bodies at different temperatures T_1 and T_2 if brought in thermal contact do not necessarily settle to the mean temperature $(T_1 + T_2)/2$.

(b) The coolant in a chemical or a nuclear plant (i.e., the liquid used to prevent the different parts of a plant from getting too hot) should have high specific heat.

(c) Air pressure in a car tyre increases during driving.

(d) The climate of a harbour town is more temperate than that of a town in a desert at the same latitude.

Ans.(a) When two bodies at different temperatures T_1 and T_2 are brought in thermal contact, heat flows from the body at the higher temperature to the body at the lower temperature till equilibrium is achieved, i.e., the temperatures of both the bodies become equal. The equilibrium temperature is equal to the mean temperature $(T_1 + T_2)/2$ only when the thermal capacities of both the bodies are equal.

(b) The coolant in a chemical or nuclear plant should have a high specific heat. This is because higher the specific heat of the coolant, higher is its heat-absorbing capacity and vice versa. Hence, a liquid having a high specific heat is the best coolant to be used in a nuclear or chemical plant. This would prevent different parts of the plant from getting too hot.

(c) When a car is in motion, the air temperature inside the car increases because of the motion of the air molecules. According to Charles' law, temperature is directly proportional to pressure. Hence, if the temperature inside a tyre increases, then the air pressure in it will also increase.

(d) A harbour town has a more temperate climate (i.e., without the extremes of heat or cold) than a town located in a desert at the same latitude. This is because the relative humidity in a harbour town is more than it is in a desert town.

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4. A cylinder with a movable piston contains 3 moles of hydrogen at standard temperature and pressure. The walls of the cylinder are made of a heat insulator, and the piston is insulated by having a pile of sand on it. By what factor does the pressure of the gas increase if the gas is compressed to half its original volume?

Ans. The cylinder is completely insulated from its surroundings. As a result, no heat is exchanged between the system (cylinder) and its surroundings. Thus, the process is adiabatic.

Initial pressure inside the cylinder = P_1

Final pressure inside the cylinder = P_2

Initial volume inside the cylinder = V_1

Final volume inside the cylinder = V_2

Ratio of specific heats, Y = 1.4

For an adiabatic process, we have:

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$

The final volume is compressed to half of its initial volume.

$$\therefore V_2 = \frac{V_1}{2}$$

$$P_1 (V_1)^{\gamma} = P_2 \left(\frac{V_1}{2}\right)^{\gamma}$$

$$\frac{P_2}{P_1} = \frac{(V_1)^{\gamma}}{\left(\frac{V_1}{2}\right)^{\gamma}} = (2)^{\gamma} = (2)^{1.4} = 2.639$$

Hence, the pressure increases by a factor of 2.639.

---

5. In changing the state of a gas adiabatically from an equilibrium state *A* to another equilibrium state *B*, an amount of work equal to 22.3 J is done on the system. If the gas is taken from state *A* to *B* via a process in which the net heat absorbed by the system is 9.35 cal, how much is the net work done by the system in the latter case? (Take 1 cal = 4.19 J)

Ans.The work done (W) on the system while the gas changes from state A to state B is 22.3 J.

This is an adiabatic process. Hence, change in heat is zero.

$\therefore \Delta Q = 0$

$\Delta W = -22.3$ J (Since the work is done on the system)

From the first law of thermodynamics, we have:

$\Delta Q = \Delta U + \Delta W$

Where,

ΔU = Change in the internal energy of the gas

$\therefore \Delta U = \Delta Q - \Delta W = -(-22.3 \text{ J})$

$\Delta U = +\ 22.3$ J

When the gas goes from state A to state B via a process, the net heat absorbed by the system is:

$\Delta Q = 9.35 \text{ cal} = 9.35 \times 4.19 = 39.1765$ J

Heat absorbed, $\Delta Q = \Delta U + \Delta Q$

$\therefore \Delta W = \Delta Q - \Delta U$

$= 39.1765 - 22.3$

$= 16.8765$ J

Therefore, 16.88 J of work is done by the system.

---

6. Two cylinders *A* and *B* of equal capacity are connected to each other via a stopcock. *A* contains a gas at standard temperature and pressure. *B* is completely evacuated. The entire system is thermally insulated. The stopcock is suddenly opened. Answer the following:

(a) What is the final pressure of the gas in *A* and *B*?

(b) What is the change in internal energy of the gas?

(c) What is the change in the temperature of the gas?

(d) Do the intermediate states of the system (before settling to the final equilibrium state) lie on its *P-V-T* surface?

Ans.(a) 0.5 atm

(b) Zero

(c) Zero

(d) No

Explanation:

(a) The volume available to the gas is doubled as soon as the stopcock between cylinders *A* and *B* is opened. Since volume is inversely proportional to pressure, the pressure will decrease to one-half of the original value. Since the initial pressure of the gas is 1 atm, the pressure in each cylinder will be 0.5 atm.

(b) The internal energy of the gas can change only when work is done by or on the gas. Since in this case no work is done by or on the gas, the internal energy of the gas will not change.

(c) Since no work is being done by the gas during the expansion of the gas, the temperature of the gas will not change at all.

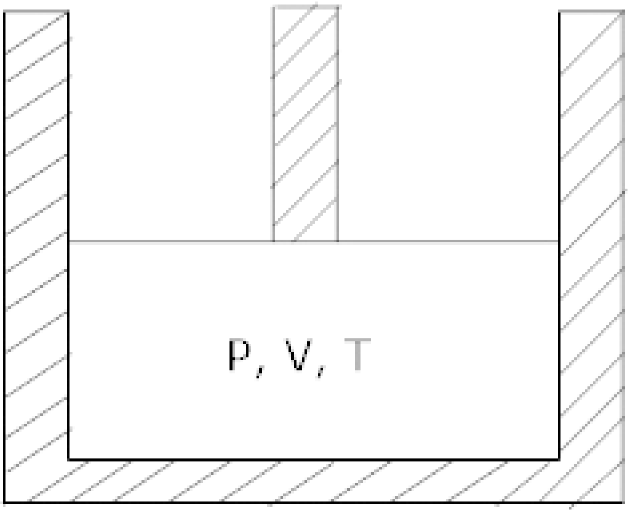
(d) The given process is a case of free expansion. It is rapid and cannot be controlled. The intermediate states do not satisfy the gas equation and since they are in non-equilibrium states, they do not lie on the *P-V-T* surface of the system.

5 Marks Questions

1.Derive the equation of state for adiabatic change?

Ans. Let P = pressure, V = volume and T = Temperature of the gas in a cylinder fitted with a perfectly

frictionless piston.



Suppose a small amount of heat d Q is given to the system. The heat is spent in two ways:-

1) In increasing the temperature of the gas by la small range d T, at constant volume

2) In expansion of gas by a small volume d v

So, $dQ = C_V\, dT + P\, dV$

In adiabatic change, no heat is supplied from outside

So, $dQ = O$

$C_V\, dt + P\, dV = O \rightarrow (1)$

Acc. to standard gas equation

$PV = RT$

Diff both sides

P d V + V d P = R d R

R d T = P d V +V d P (d R=O as R is a constant)

$$d\,T = \frac{PdV + VdP}{R}$$

Using this in equation i)

$$C\,v\left(\frac{PdV + VdP}{R}\right) + \text{PdV} = \text{O}$$

C_V P d V + C_V V d P + R P d V = O

(C_V + R) P d V + C_V V d P = O →2)

As, $C_P - C_V = R$

or $C_P = R + C_V$

So equation 2) becomes

C_P P d V + C_V V d P = O

Dividing above equation by C_V P_V

$$\frac{C_P PdV}{C_V PV} + \frac{C_V VdP}{C_V PV} = O\left(\because \frac{C_P}{C_V} = 4\right)$$

$$\gamma\frac{dV}{V} + \frac{dP}{P} = O$$

Integrating both sides

$$\gamma\int\frac{dV}{V}+\int\frac{dP}{P}=\int O$$

γ Loge V + Loge P = constant

Loge V^{γ} + Loge P = constant $\left(\because a\ \text{Log}\ b=\text{Log}(b)^{a}\right)$

Loge P V^{γ} = constant $\left(\because Loga+Logb=Log\ a\ b\right)$

PV^{γ} = antilog (constant)

$$PV^{\gamma}=K$$

K = another constant

2.Derive an expression for the work done during isothermal expansion?

Ans. Consider one gram mole of ideal gas initially with pressure, volume and temperature as P, V, T, Let the gas expand to a volume V_2, when pressure reduces to P_2 and at the same temperature T

If A = Area of cross – section of piston

Force = Pressure × Area

F = P x A

If we assume that piston moves a displacement d x,

the work done : → d w = F d x

d w = P × A × d x

d w = P × d v

Total work done in increasing the volume from V_1 to V_2

$$W = \int_{V_1}^{V_2} PdV$$

Since, PV = RT (from ideal gas equation)

$$P = \frac{RT}{V}$$

$$W = \int_{V_1}^{V_2} \frac{RT}{V} dV$$

$$W = RT \int_{V_1}^{V_2} \frac{dV}{V}$$

$$\left(\because \int \frac{dx}{x} = Loge\, x \right)$$

$$W = R\,T\, Loge\, V \Big|_{V_1}^{V_2}$$

$$W = R\,T \left[Loge V_2 - Loge V_1 \right]$$

$$W = R\,T\, Loge \frac{V_2}{V_1}$$

$$W = 2.3026\, R\,T\, Log\, 10 \left(\frac{V_2}{V_1} \right)$$

$$\left(\because Log\, m - Log\, n = Log\, \frac{m}{n} \right)$$

As $P_1 V_1 = P_2 V_2$

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

So W = 2.3026 R T Log 10 $\left(\frac{P_1}{P_2}\right)$

3.Briefly describe a Carnot cycle and derive an expression for the efficiency of Carnot cycle?

Ans. The construction of a heat engine following Carnot cycle is :-

1) Source of heat :- It is maintained at higher temperature T_1

2) Sink of heat – It is maintained at lower temperature T_2

3) Working base :- A perfect ideal gas is the working substance.

Theory :- Carnot cycle consist of four stages:-

1) I so thermal expansion

2) Adiabatic expansion

3) I so thermal compression

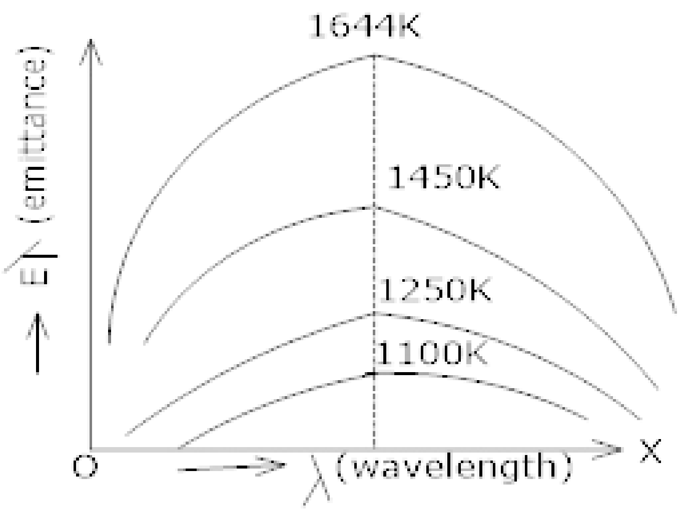
4) Adiabatic compression.

---

4. Discuss briefly energy distribution of a black body radiation. Hence deduce wien's displacement law?

Ans. For a black body, the monochromatic emittance $(E\pi)$ of the black body and the wavelength (λ) of the radiation emitted.

So, at a given temperature of black body :→



a) The energy emitted is not distributed uniformly amongst all wavelengths.

b) The energy emitted in maximum corresponding to a certain wavelength (λm) and its falls on either side of it.

As temperature of black body is increased.

a) The total energy emitted rapidly increases for any given wavelength.

b) The wavelength corresponding to which energy emitted is maximum is shifted towards shorter wavelength side i. e, λ m decreases with rise in temperature i.e $\lambda m \propto \frac{1}{T}$

or λ m T = constant

$\Rightarrow$ Thus is the wein's displacement law.