Kinetic Theory of gas

→ Collision is elastic
→ No intermolecular force of attraction due to negligible
→ $K.E \propto T$

Pressure exerted by molecules of gas on the containing vessel

Change in momentum = $2mv$



Pressure exerted on the walls of containing vessel:-

$$P = \frac{1}{3} \rho \bar{c}^2$$

$$P = \frac{1}{3} \frac{M}{V} \bar{c}^2$$

$$P = \frac{1}{3} \frac{mn}{V} \bar{c}^2$$

→ Mean square speed ($\bar{c}^2$)

$$\bar{c}^2 = \frac{c_1^2 + c_2^2 + \dots + c_n^2}{N}$$

$$P = \frac{1}{3} \rho \bar{c}^2$$

$$\bar{c}^2 = \frac{3P}{\rho} = \frac{3PV}{m} = \frac{3RT}{M}$$

$\bar{c}^2 \propto T$

* Root mean square speed (c_{rms})

$$c_{rms} = \sqrt{\bar{c}^2}$$

$$c_{rms} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3PV}{m}} = \sqrt{\frac{3KT}{M}}$$

$c_{rms} \propto \sqrt{T}$

$c_{rms} \propto \frac{1}{\sqrt{m}}$

c_{rms} does not depend on pressure.

Hydrogen and Nitrogen have equal rms speed.

Q. The hydrogen has rms speed at temp 27°C is equal to the rms speed of oxygen at temp - - ?

→ $(C_{rms})_{O_2} = (C_{rms})_{H_2}$

$$\sqrt{\frac{T}{M_{O_2}}} = \sqrt{\frac{300}{M_{H_2}}}$$

$$\frac{T}{32} = \frac{300}{2}$$

$$\therefore \boxed{T = 4800\,K.}$$

* Average speed (C_{av}):-

$$\boxed{C_{av} = \frac{C_1 + C_2 + \dots + C_2}{N}}$$

$$C_{av} = \sqrt{\frac{8P}{\pi\rho}} = \sqrt{\frac{8PV}{\pi M}} = \sqrt{\frac{8RT}{\pi M}}$$

$$\boxed{C_{av} \propto T}$$

* Most probable speed (C_{mp}):- speed possesed by large no. of molecules.
→ most repeated speed.

$$C_{mp} = \sqrt{\frac{2P}{\rho}} = \sqrt{\frac{2PV}{M}} = \sqrt{\frac{2RT}{M}}$$

→ $\frac{C_{rms}}{\sqrt{3}} > \frac{C_{av}}{\sqrt{8/\pi}} > \frac{C_{mp}}{\sqrt{2}}$ @RAM.

Q. If large no. of molecules in a closed vessel are in uniform motion. Which is correct?

(a) $C_{rms} > C_{av} > C_{mp}$ (b) $C_{rms} = C_{av} = C_{mp}$

(c) $C_{rms} = C_{av} > C_{mp}$ (d) $C_{rms} < C_{av} < C_{mp}$

2 m/s, 2 m/s, 2 m/s, 2 m/s

$C_{rms} = \sqrt{\frac{2^2+2^2+2^2+2^2}{4}} = 2$ m/s.

$C_{av} = \frac{2+2+2+2}{4} = 2$ m/s.

$C_{mp} = 2$ m/s.

Q. If a single molecule in a closed vessel is in ... m...
Which is correct →

→ $C_{rms} = C_{av} = C_{mp}$.

$C_{rms} = \sqrt{\frac{2^2}{1}} = 2$.

$C_{av} = \frac{2}{1} = 2$.

$C_{mp} = 2$.

Velocity of sound in air

$$V = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma PV}{M}} = \sqrt{\frac{\gamma RT}{M}}$$

Q. Rms speed of gas molecule is c & velocity of sound in ... is v. What is the relation between c & v?

→ $C = \sqrt{\frac{3P}{\rho}}$

$V = \sqrt{\frac{\gamma P}{\rho}}$

$c = \sqrt{\frac{3}{\gamma} \cdot \frac{\gamma P}{\rho}}$

$$c = \left(\frac{3}{\gamma}\right)^{1/2}$$

→ Kinetic energy of gas per mole = $\frac{f}{2} RT$.

→ K.E of gas per molecule = $\frac{f}{2} KT$. (f — degree of freedom.)

∴ K.E of ~~gas~~ monoatomic gas per mole = $3/2\, RT$.

" " " " per molecule = $3/2\, KT$.

∴ Translational K.E of monoatomic gas per mole = $3/2\, RT$.

" " " " per molecule = $3/2\, KT$.

∴ Rotational K.E of monoatomic gas per mole = 0.

$\Rightarrow P = \frac{1}{3}\frac{M}{V}\bar{c}^2$

$3PV = M\bar{c}^2$

$\frac{3}{2}PV = \frac{1}{2}M\bar{c}^2$ K.E.

$\therefore E = \frac{3}{2}PV$

Transfer of Heat

(1) Conduction :-



→ Transfer of heat from one point to another point without the actual movement of ~~heat~~ molecules.
→ Mass, momentum ~~remain cons~~ does not move but energy transfer.
→ Slowest process.
→ Medium is necessary.
→ Generally in solid.

(2) Convection :-



→ Transfer of heat from one point to another point with the actual movement of molecule.
→ mass, energy & momentum all transfer.
→ Faster than conduction but slower than radiation.
→ Medium is necessary.
→ Generally in liquid and gas.

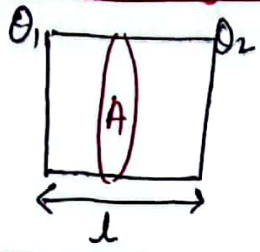
Convection → Natural convection → against gravity.
Convection → Forced convection → Along the direction of applied force.

(3) Radiation :-

→ Transfer of heat from one point to another itself.
→ No need of medium.
→ Fastest process.
→ Every body above 0K emits radiation.
→ Radiation cannot be stopped but can be minimized.
e.g. Heat from sun to earth.

* Cooking utensils → high conductivity & low sp. heat capacity

Rate of transfer of Heat



If $\theta_1 > \theta_2$,

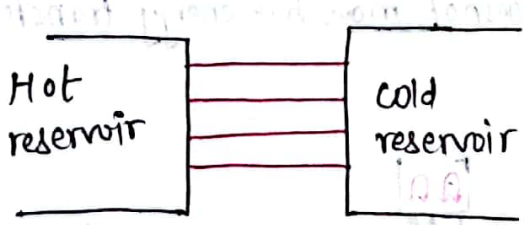
$$\boxed{Q = \frac{KA\Delta\theta}{l}}$$

$Q \rightarrow$ rate of transfer of heat $(= Q/T)$

- Unit of K → depends upon material.

$$\frac{J/s\,m}{m^2 K} = J s^{-1} m^{-1} K^{-1} = W m^{-1} K^{-1}.$$

Concept



Connected by 4 different conductors, the rate of transfer of heat or conduction will be more from:—

(a) $l = 1m$, $r = 2m = r/l = 2$. (b) $l = 2m$ & $r = 1m = r/l = 0.5$

(c) $l = 0.5$, $r = 2m = r/l = 4$. (d) $l = 0.5m$, $r = 1m = r/l = 2$.

$Q \propto \frac{A}{l}$ (r/l) Factor जुन को धेरै आउछ त्यस बाट Transfer more हुन्छ।

⇒ ~~Rods in series~~ Thermal conductivity बढी हुनेको electrical conductivity बढी हुन्छ। e.g. Silver – high. (T.C & E.C).

Proceilin → low. (T.C & E.C).

K → Thermal conductivity

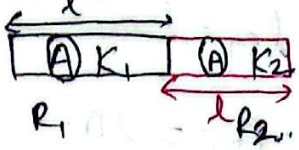
σ → electrical conductivity.

$$\rho = \frac{1}{\sigma}$$

$$R = \frac{\rho l}{A} = \frac{l}{\sigma A}$$

∴ Thermal resistance $(R) = \frac{l}{KA}$

Rods in series



$l_{eq} = 2l.$

$A_{eq} = A.$

$R_{eq} = R_1 + R_2$

$$\frac{l_{eq}}{K_{eq} A_{eq}} = \frac{l}{K_1 A} + \frac{l}{K_2 A}$$

$$\frac{2l}{K_{eq} A} = \frac{l}{K_1 A} + \frac{l}{K_2 A}.$$

$$\therefore \frac{2}{K_{eq}} = \frac{1}{K_1} + \frac{1}{K_2}$$

Thermal conductivity.

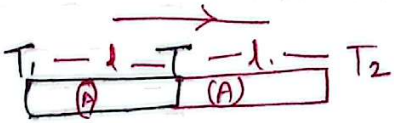
$$\therefore \boxed{K_{eq} = \frac{2K_1K_2}{K_1+K_2}} \rightarrow (H.M).$$

$$\boxed{\sigma_{eq} = \frac{2\sigma_1\sigma_2}{\sigma_1+\sigma_2}} \text{ - electrical conductivity.}$$

$$\boxed{K_{eq} = \frac{2K_1K_2}{K_1+K_2}}$$

die. con.

Temperature of junction



At steady state,

└ The rate of transfer of heat through any section is constant

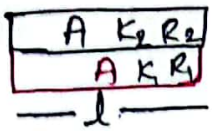
$$\left(\frac{Q}{t}\right)_1 = \left(\frac{Q}{t}\right)_2$$

$$\frac{K_1 A(T_1 - T)}{l} = \frac{K_2 A(T - T_2)}{l}$$

$$K_1T_1 - K_1T = K_2T - K_2T_2$$

Temp^r of junction $\boxed{(T) = \frac{K_1T_1 + K_2T_2}{K_1+K_2}}$

Rods in parallel



$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

$$l_{eq} = l.$$

$$A_{eq} = 2A.$$

$$\frac{l_{eq}}{K_{eq} A_{eq}} = \frac{\frac{l}{K_1 A} \cdot \frac{l}{K_2 A}}{\frac{l}{K_1 A} + \frac{l}{K_2 A}}$$

$$\frac{l}{K_{eq} 2A} = \frac{\frac{l}{K_1 A} \cdot \frac{l}{K_2 A}}{\frac{l}{K_1 A} + \frac{l}{K_2 A}}.$$

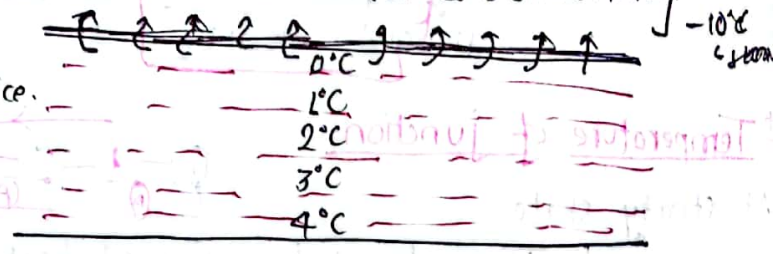
$$\therefore \boxed{K_{eq} = \frac{K_1 + K_2}{2}} \rightarrow A.M$$

⇒ Formation of ice on a lake

→ Temp of surrounding must be negative.

→ The rate of formation of ice is directly proportional to the temp difference between the surface water & surrounding.

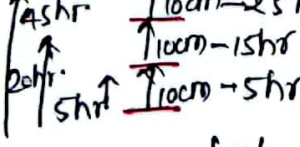
→ More the -ve temp more will be rate of formation of ice.



- Rate of formation of ice is inversely proportional to the instantaneous thickness.

→ Ratio of time to grow the sucessive equal thickness ⇒





1 : 3 : 5 : - - - - - -

but From starting, Ratio of time to grow the sucessive equal thick

$= 1^2 : 2^2 : 3^2 : - - - -$

Q. Ice forms on a pond if the temp. of surrounding is -10°C. The time taken to grow 10cm thickness of ice is 5hr. What is the time to grow the thickness from 10cm to 20cm?

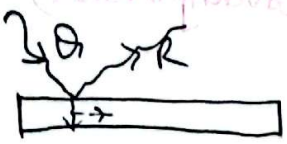
→ 10cm – 5hr.

10 – 20cm ⇒ 5×3 = 15hr.

but; 0 – 10cm ⇒ 5hr.

0 – 20cm → 20hr.

0 – 30cm → 45hr.

⇒ 

$\theta = A + R + T$

θ = heat fall

R → radiation reflection

T → Transmitted radiation

A → absorbed radiation

$1 = \frac{A}{\theta} + \frac{R}{\theta} + \frac{T}{\theta}$

$1 = a + r + t$

$a = \frac{A}{\theta}$ – Fraction of absorbed heat.

$r = R/\theta$ → " " reflected "

$t = T/\theta$ → " " transmitted "

→ If t = 0, no transmission

$a + r = 1$

$a = 1 - r$ – bad reflector

Good absorber

- Good absorber are bad reflector.
  e.g. black rough source.

$r = 1 - a$

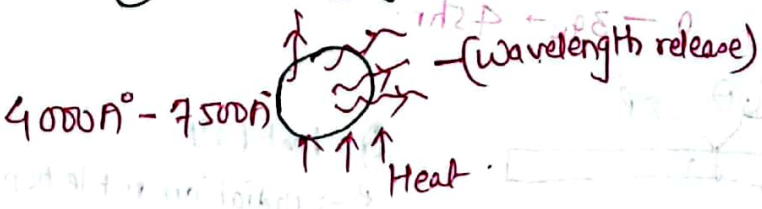
- Good reflector are bad absorber.
  e.g. polished smooth white surface.

- Good absorber are good emitter. (जुनले छेरै absorb गर्छ त्यो नै धेरै emit गर्छ).
  ↓
  Kirchoff's law.

If r=0, t=0
a=1 → The body which absorbs the radiation of almo all possible wavelength. but none are reflec
↓
perfect black body.

When perfect body is heated, it appears:-

(a) black (b) white (c) Red (d) Yellow.



→ Black body emits continuous spectrum.
↳ white spectrum.

Emissive Power:- Total radiation emitted by unit area of a body in unit time.

$$E = \frac{Q}{At}$$

Emissivity (e):- The ratio of ~~any~~ emissive power of any body at the particular temp to the perfectly black body at same temp.

~~e =~~ ~~any body~~

$$e = \frac{\text{Emissive power of any body at a particular temp}}{\text{emissive power of perfect black body at same temp}}$$

For any body, $e < 1$.

For perfect black body, $e = 1$.

Stefan's law:- used to measure temp of sun.

$E \propto T^4$.

$E = \sigma T^4$

$\frac{Q}{At} = \sigma T^4$

$\therefore P = \sigma A T^4$ ↳ for P.B.B

σ = Stefan's constant
↳ 5.6×10^{-8}
↳ unit ⇒ W/m^2K^4

T → absolute temp.

E ⇒ emissive power.

If the body is not perfect black body:-

then, $E = e\sigma T^4$

$P = eA\sigma T^4$

→ placed in an enclosure having temp^r (T_0)

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

$P = eA\sigma(T^4 - T_0^4)$

} → stefan's boltzmann law.

$\frac{dQ}{dt} = eA\sigma(T^4 - T_0^4)$

$\frac{msdT}{dt} = eA\sigma(T^4 - T_0^4)$

$\boxed{\frac{dT}{dt} = \frac{eA\sigma}{ms}(T^4 - T_0^4)}$

↳ rate of cooling by radiation

(i) $\frac{dT}{dt} \propto e$

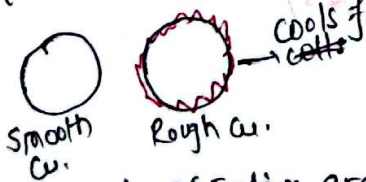
⇒ Cooling will be faster for perfect black body.

e.g. Temp^r ← white painted / black painted kept in surrounding then, → reading will be faster for the black painted thermometer.

but final reading will be same for both.

(ii) $\frac{dT}{dt} \propto A$

⇒



↳ effective area more for rough surface.

Concept - same mass, same material is used to form a circular disc, a cube & a sphere. All are heated to same temp^r & left in surrounding. Which one cools faster.

(a) disc (b) cube (c) sphere (d) same for all.

minimum area → sphere.

max. area → disc — $dT/dt \propto A$.

@ Cir Cu S.

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iii) $\frac{dT}{dt} \propto \frac{1}{m}$ (solid) (Hollow) cools fast.

iv) $\frac{dT}{dt} \propto \frac{1}{\text{Sp. heat capacity}}$

(v) $\frac{dT}{dt} \rightarrow$ ↑es if temp of body ↑es.

(vi) $\frac{dT}{dt} \Rightarrow$ ↑es if temp of surrounding ↑es.

Newton's law of cooling

- For small temp difference.
- based on stefan's law.
- Graph → Rectangular hyperbolic
  - exponential. (Not priority).

$$\boxed{\frac{dT}{dt} = -\frac{K}{ms}(T - T_0)}$$

(60°C 50°C)

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

Q. Liquid cools from 60°C to 50°C in 5 min. What is the time required to cool from 50°C to 40°C if the temp of surrounding is 25°C?

$T = \frac{60+50}{2} = 55°C.$

$$\frac{60-50}{5} = \frac{-K}{ms}(55-25)$$

$$\frac{50-40}{t} = \frac{-K}{ms}(45-25)$$

$$\frac{t}{5} = \frac{30}{20}$$

$$t = 7.5 \text{ min}$$

Q. Substance cools from 60°C to 50°C in 10min. What will be the tempr after next 10min? (Tempr of surrounding is 25°C) $\frac{60+50}{2} = 55$ (ULC)

(6) → $\frac{60-50}{10} = \frac{-K}{ms}(60-25)$ — 60 ≤ 50 के Lish → 60°C

50 ≤ x के Lh - (50)

$$\frac{50-x}{10} = \frac{-K}{ms}(50-25)$$

$$\frac{10}{50-x} = \frac{\cancel{35}\,7}{\cancel{25}\,5}$$

$\therefore 50 = 350 - 7x$

$$\boxed{x = \frac{300}{7} = 42°C}$$

Wein's law:-

$\lambda T = b$

$\boxed{\lambda \propto \frac{1}{T}}$

$$\boxed{\frac{T_1}{T_2} = \frac{\lambda_2}{\lambda_1}}$$

wein's constant = b.
↓
dimension →

- color of star determines tempr.
- Yellow, blue & red.
  - Yellow → max Intensi.
  - blue → star is hotter than sun
  - red → star is colder than sun.

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