Ch-10 - Thermal Properties Of Matter

* **Temperature :-**

→ Measurement of coldness or hotness is known as temperature.

- Device used to measure temperature :-

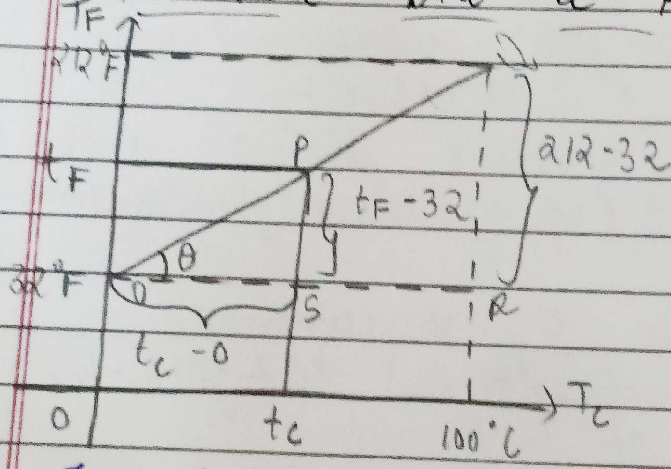
→ Thermometer.

- Unit :- SI = Kelvin

Other units ⇒ Celsius, Fahrenheit.

* **Relation b/w a temp. scale :-**

→



When we draw graph b/w temperature in celsius & Fahrenheit then it is straight line as a diagram.

→ For ΔOPS

$$\tan\theta = \frac{PS}{SO}$$

$$\tan\theta = \frac{t_f - 32}{t_c - 0} \quad ①$$

For ΔOQR

$$\tan\theta = \frac{QR}{RO}$$

$$\tan\theta = \frac{212 - 32}{100 - 0} \quad ②$$

from ① & ②

$$\frac{t_f - 32}{t_c} = \frac{180}{100}$$

$$t_f - 32 = \frac{9}{5} t_c$$

$$\boxed{t_f = \frac{9}{5} t_c + 32}$$

⇒ Let $t_F = t_C = x$

$x = \frac{9}{5}x + 32$

$\frac{9}{5}x - x = -32$

$\frac{4x}{5} = -32$

⇒ $x = \frac{-32 \times 5}{4}$ ⇒ $\boxed{x = -40}$

* Ideal Gas eqⁿ & Absolute Temperature :-

- **Boyle's law :-**

$P \propto \frac{1}{V}$ ⇒ $P = \frac{const.}{V}$ ⇒ $\boxed{PV = const.}$ — ①

- **Charle's law :-**

$V \propto T$ ← absolute temp.

$V = const. \times T$

$\boxed{\frac{V}{T} = const.}$ — ②

⇒ From ① & ②,

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

where, const. = μR

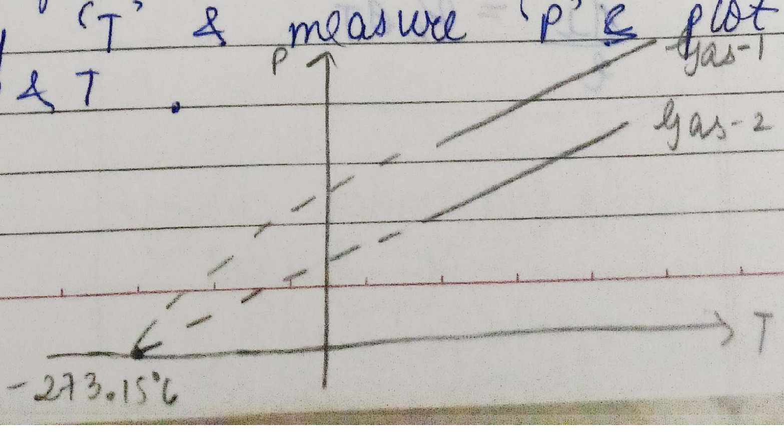
So, $\frac{PV}{T} = \mu R$

$\boxed{PV = \mu R T}$

no. of moles
absolute temp.
universal gas const.
volume
Pressure

⇒ Let for certain gas V take const.

→ And we vary 'T' & measure 'P' & plot graph b/w P & T.



→ At high temp., we get straight line graph according to $P \propto T$ as per ideal gas eqⁿ.

→ We draw graph upto low temp. where $P=0$ & that temp $= -273.15°C$

→ This temp. is same for all gases.

→ This temperature is known as absolute 0 K temp.

So, $-273.15°C = 0K$

→ Relation b/w celsius scale & Kelvin scale

$$t_c = t_K - 273.15$$

* Thermal expansion :-

→ Due to rise in temp. of any body its dimensions get increased, that's called thermal expansion.

(i) Linear expansion
(ii) Area expansion
(iii) Volume expansion

(i) Linear expansion :-

→ Let us consider a wire of length 'l' if we increase temp. of the wire by ΔT, then its length is changed by Δl

→ It is practically seen that relation b/w l, ΔT & Δl

$$\Delta l \propto l \Delta T$$

$$\Delta l = l \alpha_l \Delta T$$, where α_l = linear expansion co-efficient.

→ depends on temperature & material

→ Unit $= K^{-1}$ or $°C^{-1}$

$$\boxed{\frac{\Delta l}{l} = \alpha_l \Delta T}$$

→ fractional change in length

(ii) Area expansion :-

⇒ Let consider a surface of area 'A', if we increase its temp. by ΔT, then change in its area is 'ΔA', then

$$\Delta A \propto A \Delta T$$

$$\Delta A = \alpha_A A \Delta T$$

α_A → area expansion co-efficient
→ depends on temp. & material
→ unit = K^{-1} or $°C^{-1}$

(iii) Volume expansion :-

⇒ Let us consider an object of volume V. If we increase its temp. Δt then its volume increases by ΔV.

then, $\Delta V \propto V \Delta T$

$$\Delta V = \alpha_V V \Delta T$$

$$\frac{\Delta V}{V} = \alpha_V \Delta T$$

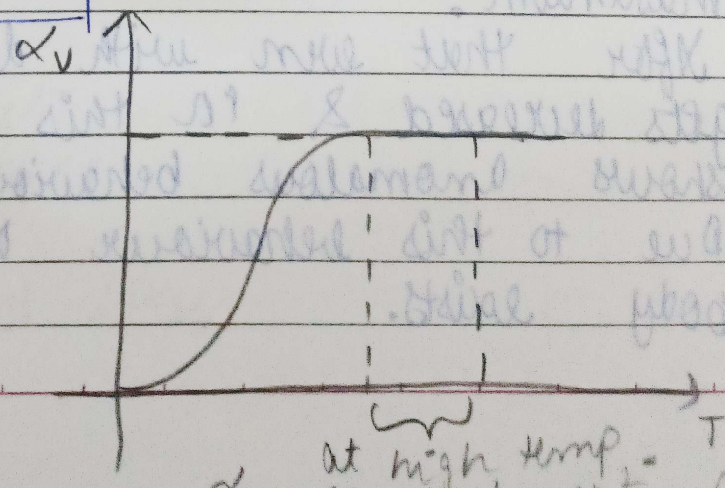
fractional change in volume → $\frac{\Delta V}{V}$

α_V → volume expansion co-efficient
→ depends on temp. & material
→ unit = K^{-1} or $°C^{-1}$

* Variation of volume expansion co-efficient with temp.

⇒ $\alpha_V = \frac{1}{\Delta T} \frac{\Delta V}{V}$

graph of $\alpha_V \propto T$ for copper is :



at high temp α_V is almost const.

* extra :-

$$\frac{\Delta l}{l_0} = \alpha_l \Delta T$$

$$\frac{l - l_0}{l_0} = \alpha_l (T - T_0)$$

l = length at T temp.
l_0 = length at T_0 temp.

$$\Rightarrow \quad l - l_0 = \alpha_l \, l_0 (T - T_0)$$

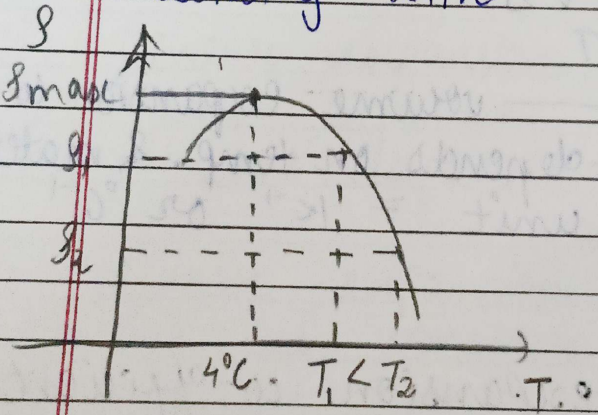
$$l = l_0 + \alpha_l \, l_0 (T - T_0)$$

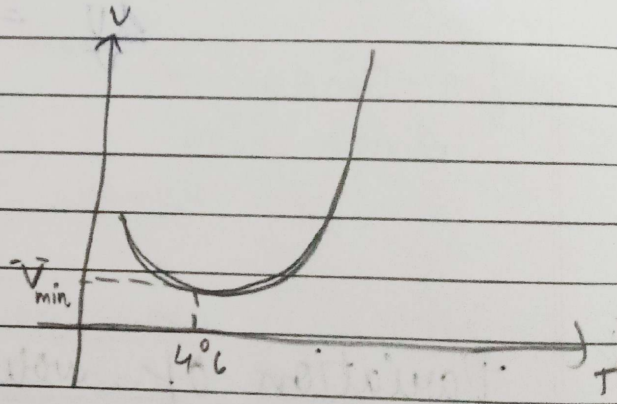
~~$A = A_0$~~

$$\boxed{\begin{aligned} l &= l_0 [1 + \alpha_l (T - T_0)] \\ A &= A_0 [1 + \alpha_A (T - T_0)] \\ V &= V_0 [1 + \alpha_V (T - T_0)] \end{aligned}}$$

* Anomalous behaviour of water :-

⇒ Here, below graph shows variation of density with temprature.





⇒ In water, if its temp. decreases then its density get increased upto 4°c temp, where it becomes maximum.

→ After that even with decreasing temp. density gets decreased & in this way density variation shows anomalous behaviour of water.

→ Due to this behaviour of water, living body exists.

* Volume expansion co-efficient of ideal gas

→ From ideal gas eqⁿ,

$$PV = \mu RT \quad \} \quad V = \frac{\mu RT}{P}$$

→ If temp. varies ΔT at const. pressure,

$$\frac{P\Delta V}{\Delta T} = \mu R \frac{\Delta T}{\Delta T}$$

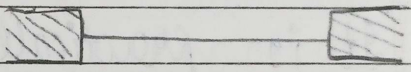
So, $\Delta V = \frac{\mu R \Delta T}{P}$

Now, $\alpha_V = \frac{\Delta V}{V} \times \frac{1}{\Delta T}$

$$= \frac{\mu R \Delta T}{P \times \frac{\mu RT}{P}} \times \frac{1}{\Delta T}$$

So, $\boxed{\alpha_V = \frac{1}{T}}$

* Thermal Stress :-

→ Let us consider a wire  of length 'l' tied between two rigid support with little tension, so it can't be slake.

→ Let we decrease temp. by ΔT, so expected change in length will be Δl which is not occured due to rigid support.

→ So, strain developed in wire is $\frac{\Delta l}{l} = \alpha_l \Delta T$

We know $Y = \frac{F}{A \Delta l / l}$

So, $Y = \frac{F}{A \times \alpha_l \Delta T}$

$$\underbrace{\boxed{\frac{F}{A}}}_{\text{thermal stress}} = Y \alpha_l \Delta T$$

* Relation b/w α_l & α_v (extra)

We know, $\alpha_v = \frac{dV}{dT}\frac{1}{V}$

$$\alpha_l = \frac{dl}{dT}\frac{1}{l}$$

for any cube. $V = l^3$

$$\frac{dV}{dT} = 3l^2\frac{dl}{dT}\times\frac{l}{l}$$

$$\frac{dV}{dT} = \frac{3l^3}{l}\frac{dl}{dT}$$

$$\frac{dV}{dT}\times\frac{1}{l^3} = \frac{dl}{dT}\times\frac{1}{l}\times 3$$

$$\frac{dV}{dT}\times\frac{1}{V} = \frac{dl}{dT}\times\frac{1}{l}\times 3$$

$$\boxed{\alpha_v = 3\alpha_l}$$

* Heat Capacity :-

- It is practically seen that required heat to rise temp. is directly proportional to rise of temp.
- If required heat to rise temp. ΔT is Q then, $\Delta Q \propto \Delta T$

$$\Delta Q = S\Delta T$$

$$S = \frac{\Delta Q}{\Delta T}$$ } heat required to rise unit temp.

Heat capacity

unit = J/K

- It depends on mass.
- Here, $S = ms$.

$$s = \frac{S}{m}$$ } heat capacity of unit mass is called specific heat capacity.

Specific heat capacity

unit = $\frac{J}{kg\,K}$

∴ $\boxed{\Delta Q = ms\Delta T}$

Here, $s = \mu c$

$c = \frac{s}{\mu}$ } heat capacity per unit mole is molar specific heat capacity

→ unit of c is $\frac{J}{mol.K}$

So, $\boxed{\Delta Q = \mu s \Delta T}$

→ Here c = molar specific heat capacity can be defined at const. volume or const. pressure

C_p = molar specific heat capacity at const. pressure.

C_v = molar specific heat capacity at const. volume

* Calorimetry :-

→ Measurement of heat is known as calorimetry.

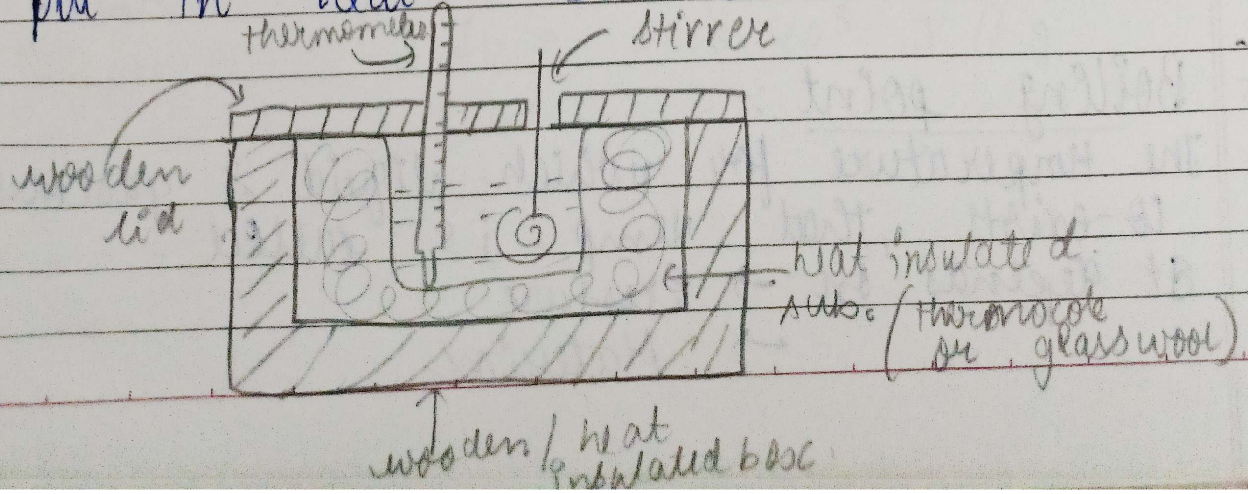
→ Device used to measure heat is known as calorimeter.

- **Principle :-**

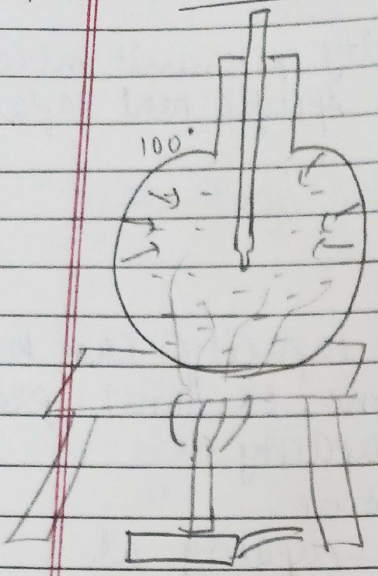
→ calorimeter works on the principle of cons. law of energy.

- **Construction :-**

→ It consists of copper vessel, stirrer & thermometer put in heat insulated box.



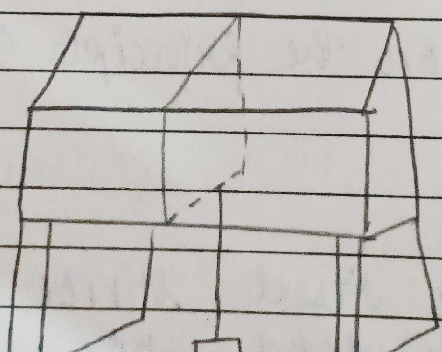
* Change of state :-



- → During the phase change, there is no change in temperature.
- → That means heat given is used to change the phase.

Freezing
* Boiling point or Melting point :-

- → The temp. for that solid & liquid state co-exists, that temp. is called . . .
- → It depends on → Pressure
  → material
- → For water at atmospheric pressure melting point of ice is 0°C.



For H_2O

Pressure increase → Melting point decrease

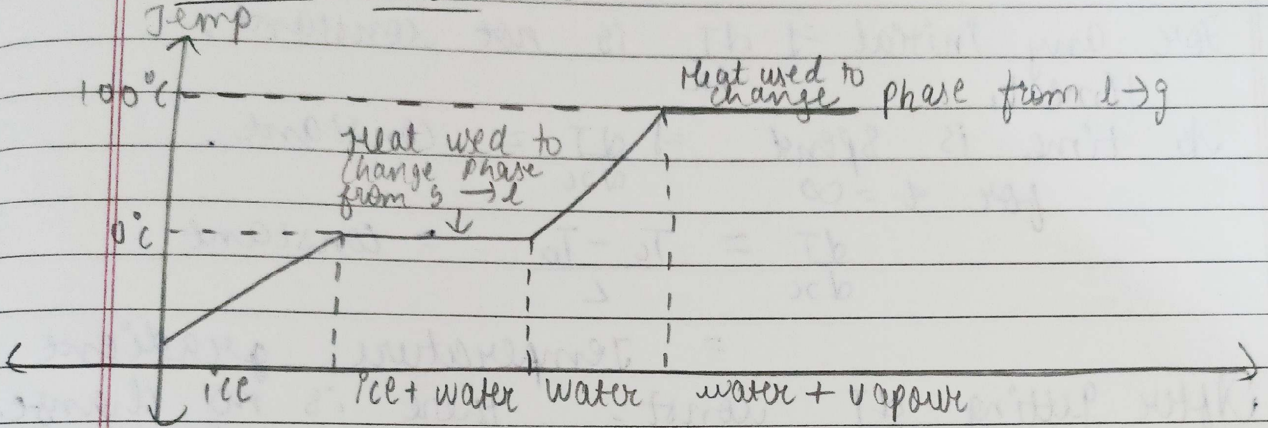
* Boiling point :-

- → The temperature for which liquid & gaseous state co-exists, that temp. is called . . .
- → It depends on → Pressure
  → Material

→ For water at atm. pressure boiling point of water is 100°C.

⇒ For water :- If pressure ↑ Boiling point ↑
If pressure ↓ ~~Boiling~~ Melting point ↓

* Latent Heat :-



⇒ Latent heat :- heat required to change phase of 1 kg substance is called latent heat.

So, latent heat = $\frac{\text{Heat to change phase}}{\text{mass}}$

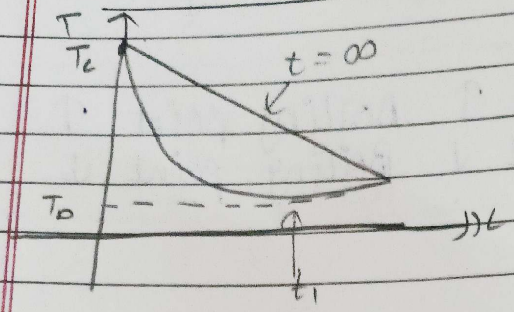
$L = \frac{Q}{m}$ So, $\boxed{Q = mL}$

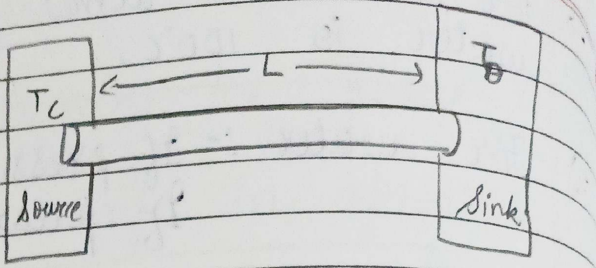
⇒ If solid ↔ liquid ⇒ $Q = mL_f$
↳ Latent heat of fusion

⇒ If liquid ↔ gas ⇒ $Q = mL_v$
↳ Latent heat of vapourisation.

o
emember { For H_2O ↱ $L_f = 3.33 \times 10^5$ J/kg
↳ $L_v = 22.6 \times 10^5$ J/kg

* Conduction :-





Here $T_c > T_0$

⇒ For any initial time t_1 ⇒ $\frac{dT}{dx}$ is not constant.

⇒ As time is spend ⇒ $\frac{dT}{dx}$ = constant.
for $t = \infty$

$$\frac{dT}{dx} = \frac{T_c - T_0}{L} = \text{constant}$$

= Temperature gradient

⇒ After getting $\frac{dT}{dx}$ const., there is no change in temp. of each point of rod.

→ This is steady state condition of heat conduction.

→ In steady state condition of heat conduction heat flow rate is always constant.

→ $\frac{dQ}{dt} = \frac{Q}{t} = H$ = heat current.

⇒ Heat flow rate ∝ cross-sectional area of rod × temp. gradient.

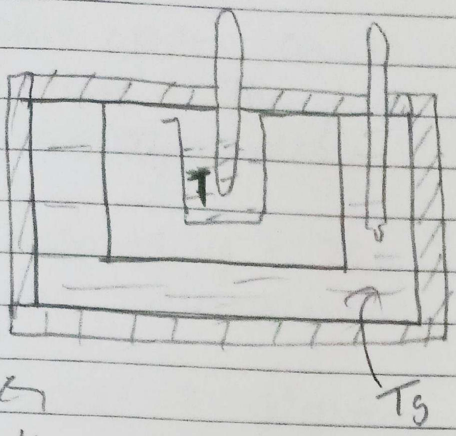
$$\frac{Q}{t} = H \propto A\left(\frac{T_c - T_0}{L}\right)$$

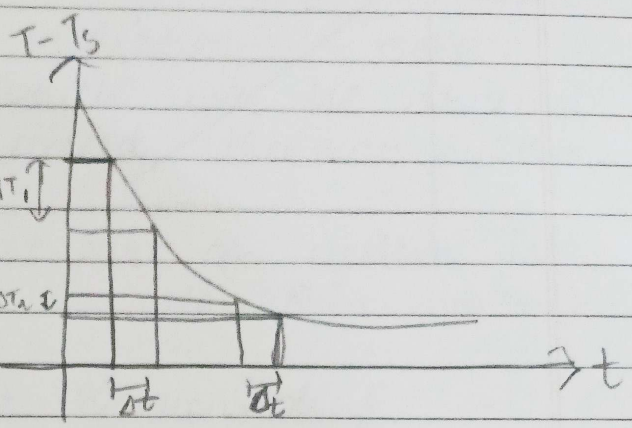
$$H = \frac{KA(T_c - T_0)}{L}$$

where K = conductivity

⇒ $\boxed{\text{unit} = \frac{W}{mK}}$

* Newton's cooling law :-





T − Ts

temp. of body (system) temp. of surrounding.

⇒ According to newton's law heat flow rate from obj./system to surrounding is directly proportional to temp. difference of system & surrounding.

$\boxed{\frac{dQ}{dt} \propto T - T_s}$ $\boxed{\frac{dQ}{dt} \propto T - T_s}$ -ve sign indi. system is losing heat.

⇒ $\frac{-dQ}{dt} \propto T - T_s$ ⇒ $-\frac{dQ}{dt} = K(T - T_s)$

⇒ Here, system is losing heat so, its temp gets decreased by dT.

So, $dQ = msdT$

$$-\frac{msdT}{dt} = K(T - T_s)$$

for numerics

$$-\frac{msdT}{dt} = K(T - T_s)$$

$$-ms\frac{\Delta T}{\Delta t} = K(T - T_s).$$

$$\int \frac{dT}{T - T_s} = \int \frac{-K}{ms} dt$$

⇒ $\boxed{\ln(T - T_s) = \frac{-K}{ms} t + C}$ → Compare with

$y = mx + c$

$y = \ln(T - T_s)$

$m = \frac{-K}{ms}$

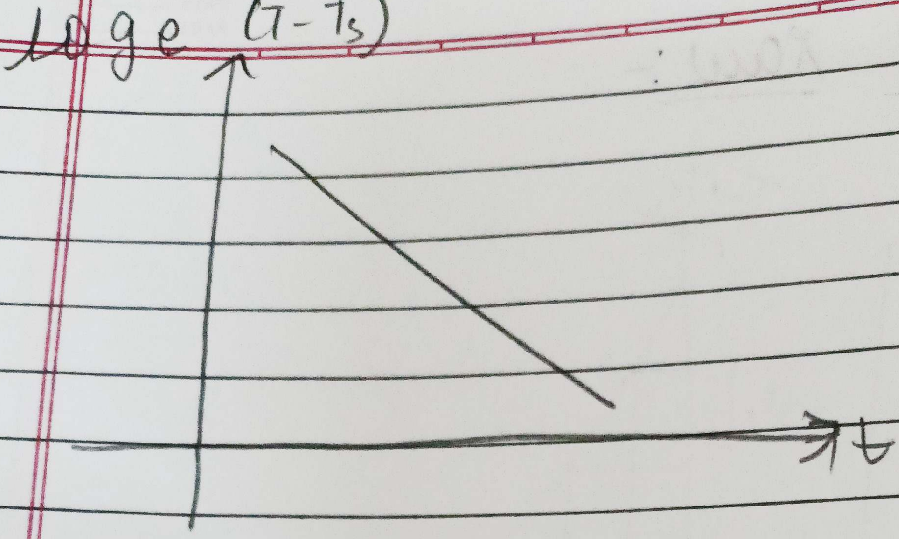
$x = t.$

$$T - T_s = e^{(-K/ms\, t + c)}.$$

$$= e^{(-K/ms\, t)} \times e^c$$

Let $\frac{-K}{ms} = \alpha$ & $e^c = \beta$

So, $\boxed{T - T_s = \beta e^{-\alpha t}}$


$\log_e (T-T_s)$
t