

Three Theorems:

Th. 1.

$$dz = Mdx + Ndy$$

this equation will be exact differential only when

$$\left(\frac{\partial M}{\partial y}\right)_x = \left(\frac{\partial N}{\partial x}\right)_y$$

Th. 2.

If ~~f~~ $f = \phi(x, y, z)$

$$\left(\frac{\partial x}{\partial y}\right)_f \cdot \left(\frac{\partial y}{\partial z}\right)_f \cdot \left(\frac{\partial z}{\partial x}\right)_f = 1$$

Th. 3.

If $z = \phi(x, y)$

$$\left(\frac{\partial x}{\partial y}\right)_z \cdot \left(\frac{\partial y}{\partial z}\right)_x \cdot \left(\frac{\partial z}{\partial x}\right)_y = -1$$

Maxwell Equation:

$$T \cdot ds = dU + Pdv \quad (\text{Anythings})$$

$$dU = T \cdot ds - Pdv$$

$$dz = Mdx + Ndy$$

$$\begin{matrix} M = T & N = -P \\ x = s & y = v \end{matrix}$$

$$\left(\frac{\partial T}{\partial v}\right)_s = \left(\frac{\partial (-P)}{\partial s}\right)_v$$

$$\boxed{\left(\frac{\partial T}{\partial v}\right)_s = -\left(\frac{\partial P}{\partial s}\right)_v} \quad \text{--- (i)}$$

$$T \cdot ds = dH - v dp$$

$$dH = T ds + v dp$$

$$\boxed{\left(\frac{\partial T}{\partial p}\right)_s = \left(\frac{\partial v}{\partial s}\right)_p} \quad \text{--- (ii)}$$

~~dh~~ $h = H - TS$

$$dh = dH - T \cdot ds - s \cdot dT$$

$$dh = v dp - s dT$$

$$\boxed{\left(\frac{\partial v}{\partial T}\right)_p = -\left(\frac{\partial s}{\partial p}\right)_T} \quad \text{--- (iii)}$$

$$F = U - TS$$

$$dF = dU - T \cdot ds - S \cdot dT$$

$$dF = -pdv - SdT$$

$$\left[\frac{\partial(-P)}{\partial T} \right]_V = \left[\frac{\partial(-S)}{\partial V} \right]_T$$

$$\boxed{\left[\frac{\partial P}{\partial T} \right]_V = \left[\frac{\partial S}{\partial V} \right]_T} \quad - (1V)$$

T ds Equations

$$S = \phi(T, V)$$

$$ds = \left(\frac{\partial s}{\partial T} \right)_V \cdot dT + \left(\frac{\partial s}{\partial V} \right)_T \cdot dV$$

$$T \cdot ds = T \cdot \left(\frac{\partial s}{\partial T} \right)_V \cdot dT + T \left(\frac{\partial s}{\partial V} \right)_T \cdot dV$$

$$\frac{dT}{ds} = \left(\frac{T}{C_V} \right)$$

$$\textcircled{1} \left(\frac{ds}{dT} \right) = \left(\frac{C_V}{T} \right)$$

$$\textcircled{2} T \left(\frac{ds}{dT} \right) = C_V$$

from maxwell relation:

$$\left(\frac{\partial s}{\partial V} \right)_T = \left(\frac{\partial P}{\partial T} \right)_V$$

$$\boxed{T \cdot ds = C_V dT + T \left(\frac{\partial P}{\partial T} \right)_V dV}$$

↳ 1st T.ds equation.

Applicable for ANY gas

$$S = \phi(T, P)$$

$$ds = \left(\frac{\partial s}{\partial T} \right)_P \cdot dT + \left(\frac{\partial s}{\partial P} \right)_T \cdot dP$$

$$T \cdot ds = T \left(\frac{\partial s}{\partial T} \right)_P \cdot dT + T \left(\frac{\partial s}{\partial P} \right)_T \cdot dP$$

$$\frac{dT}{ds} = \left(\frac{T}{C_P} \right) \textcircled{1} \left(\frac{ds}{dT} \right) = \left(\frac{C_P}{T} \right)$$

$$T \left(\frac{ds}{dT} \right)_P = C_P$$

$$\left(\frac{\partial s}{\partial P} \right)_T = - \left(\frac{\partial V}{\partial T} \right)_P$$

$$\boxed{T \cdot ds = C_P dT - T \left(\frac{\partial V}{\partial T} \right)_P dP}$$

↳ 2nd T.ds equation.

Applicable for any gas

$$c_p dT - T \left(\frac{\partial v}{\partial T} \right)_p dp = c_v dT + T \left(\frac{\partial p}{\partial T} \right)_v dv$$

$$\Rightarrow (c_p - c_v) dT = T \left(\frac{\partial p}{\partial T} \right)_v dv + T \left(\frac{\partial v}{\partial T} \right)_p dp$$

$$\Rightarrow dT = \left(\frac{T}{c_p - c_v} \right) \left(\frac{\partial p}{\partial T} \right)_v dv + \left(\frac{T}{c_p - c_v} \right) \left(\frac{\partial v}{\partial T} \right)_p dp$$

$$T = \phi(p, v)$$

$$dT = \left(\frac{\partial T}{\partial p} \right)_v dp + \left(\frac{\partial T}{\partial v} \right)_p dv$$

$$\left(\frac{\partial T}{\partial p} \right)_v = \left(\frac{T}{c_p - c_v} \right) \cdot \left(\frac{\partial p}{\partial T} \right)_v$$

$$\boxed{c_p - c_v = T \left(\frac{\partial v}{\partial T} \right)_p \left(\frac{\partial p}{\partial T} \right)_v} \quad \text{--- (1)}$$

$$z = \phi(x, y)$$

$$T = \phi(p, v)$$

~~$$\left(\frac{\partial T}{\partial p} \right)_v \left(\frac{\partial p}{\partial v} \right)_T \left(\frac{\partial v}{\partial T} \right)_p = -1$$~~

$$\left(\frac{\partial p}{\partial v} \right)_T \left(\frac{\partial v}{\partial T} \right)_p \left(\frac{\partial T}{\partial p} \right)_v = -1$$

$$-\left(\frac{\partial p}{\partial v} \right)_T \left(\frac{\partial v}{\partial T} \right)_p = \left(\frac{\partial p}{\partial T} \right)_v \quad \text{--- (2)}$$

$$c_p - c_v = T \left(\frac{\partial v}{\partial T} \right)_p \left[-\left(\frac{\partial p}{\partial v} \right)_T \left(\frac{\partial v}{\partial T} \right)_p \right]$$

$$c_p - c_v = -T \left(\frac{\partial v}{\partial T} \right)_p^2 \left(\frac{\partial p}{\partial v} \right)_T \quad \rightarrow \text{valid for any gas}$$

$$\begin{array}{ccc} \downarrow & \downarrow & \downarrow \\ +ve & +ve & -ve \end{array}$$

$$c_p - c_v = +ve.$$

* c_p and c_v will be equal at OK (Absolute zero)

$$\gamma = \frac{c_p}{c_v}$$

On \rightarrow when will be $\gamma = 1$.

Ans: $T = OK$.

* Coefficient of volume expansivity (β)

$$\beta = \frac{1}{V} \left(\frac{\partial V}{\partial T} \right)_P$$

* Isothermal compressibility (K_T)

$$K_T = -\frac{1}{V} \left(\frac{\partial V}{\partial P} \right)_T$$

$$C_p - C_v = -T \left(\frac{\partial P}{\partial V} \right)_T \left(\frac{\partial V}{\partial T} \right)_P^2$$

$$\left(\frac{\partial V}{\partial T} \right)_P = (\beta V)$$

$$\left(\frac{\partial P}{\partial V} \right)_T = -\left(\frac{1}{V K_T} \right)$$

$$C_p - C_v = -T \left[-\frac{1}{V K_T} \right] [\beta^2 V^2]$$

$$C_p - C_v = \frac{T V \beta^2}{K_T}$$

Mayer's eqn
Valid for any gas.

* Energy Equation:

$$T ds = du + p dv$$

$$du = T ds - p dv$$

$$T \cdot ds = C_v dT + T \left(\frac{\partial P}{\partial T} \right)_V dv \rightarrow 1^{st} T ds eqn$$

$$du = C_v dT + \left[T \left(\frac{\partial P}{\partial T} \right)_V - p \right] dv$$

$$du = C_v dT + \left[T \left(\frac{\partial P}{\partial T} \right)_V - p \right] dv$$

valid for
ANY GAS

(A)

Let ANY gas undergo constant volume process
 $v = c, dv = 0$

$$\boxed{dU = C_v dT} \rightarrow \text{Any gas if it undergoes const volume process.}$$

Ideal Gas:

$$PV = nRT$$

$$P = \left(\frac{nR}{V}\right) \cdot T$$

$$\left(\frac{\partial P}{\partial T}\right)_V = \left(\frac{nR}{V}\right) = \left(\frac{P}{T}\right)$$

$$\left(\frac{\partial U}{\partial V}\right)_T = T \left(\frac{\partial P}{\partial T}\right)_V - P = 0$$

The eqⁿ $dU = C_v dT$ is valid for Ideal Gas undergoing any process.

$$U = f(T, V)$$

$$dU = \left(\frac{\partial U}{\partial T}\right)_V \cdot dT + \left(\frac{\partial U}{\partial V}\right)_T \cdot dV \quad \text{--- (B)}$$

Comparing eqⁿ (A) & (B)

$$\left(\frac{\partial U}{\partial T}\right)_V = C_v$$

$$\left(\frac{\partial U}{\partial V}\right)_T = [T \left(\frac{\partial P}{\partial T}\right)_V - P]$$

For an Ideal Gas, internal energy is independent of volume.

$$T = \phi(U, P, V)$$

$$\left(\frac{\partial U}{\partial P}\right)_T \left(\frac{\partial P}{\partial V}\right)_T \left(\frac{\partial V}{\partial U}\right)_T = 1$$

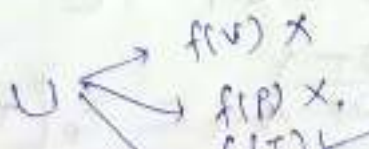
$$\left(\frac{\partial U}{\partial P}\right)_T \left(\frac{\partial P}{\partial V}\right)_T = \left(\frac{\partial U}{\partial V}\right)_T$$

$$\left(\frac{\partial P}{\partial V}\right)_T = \left(\frac{P}{V}\right)$$

for an ideal gas.

It means it does not equal to zero, (for ideal gas).

$$\textcircled{5} \left(\frac{\partial U}{\partial P}\right)_T = 0 \quad \text{for an ideal gas.}$$



Joule Thomson Coefficient

$$\mu = \left(\frac{\partial T}{\partial P} \right)_h$$

$$T ds = dh - v dp$$

$$dh = T ds + v dp$$

$$T ds = c_p dT - \left[T \left(\frac{\partial v}{\partial T} \right)_p dp \right]$$

$$dH = c_p dT + \left[v - T \left(\frac{\partial v}{\partial T} \right)_p \right] dp$$

$$dH = c_p dT - \left[T \left(\frac{\partial v}{\partial T} \right)_p - v \right] dp \quad \text{Any gas.}$$

Let any gas undergo constant pressure. $[dp = 0]$

$$\boxed{dH = c_p dT} \quad \text{valid for any gas undergoing } p = c.$$

Let us take an ideal gas

$$pV = mRT$$

$$\left(\frac{\partial v}{\partial T} \right)_p = \left(\frac{mR}{p} \right)$$

$$= \left(\frac{v}{T} \right)$$

$$T \left(\frac{\partial v}{\partial T} \right)_p - v = T \times \frac{v}{T} - v = 0$$

$$dH = c_p dT \quad \text{valid for ideal gas for any process.}$$

$$dH = c_p dT - \left[T \left(\frac{\partial v}{\partial T} \right)_p - v \right] dp$$

Let it undergo throttling.

$$c_p dT = \left[T \left(\frac{\partial v}{\partial T} \right)_p - v \right] dp$$

$$\left(\frac{dT}{dp} \right)_{h=c} = \frac{1}{c_p} \left[T \left(\frac{\partial v}{\partial T} \right)_p - v \right]$$

$$\left(\frac{\partial T}{\partial P} \right)_{h=c} = \frac{1}{c_p} \left[T \left(\frac{\partial v}{\partial T} \right)_p - v \right]$$

$$u = \frac{1}{c_p} \left[T \left(\frac{\partial v}{\partial T} \right)_p - v \right]$$

for an ideal gas

$$T \left(\frac{\partial v}{\partial T} \right)_p - v = 0$$

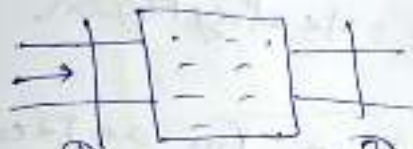
$$\mu_j = 0$$

Joule Thomson coefficient for an ideal gas is zero.

$$\mu_j = \left(\frac{\partial T}{\partial p} \right)_h = 0$$

$$h = \text{const}$$

$$\partial T = 0 \quad \text{or} \quad T = c$$

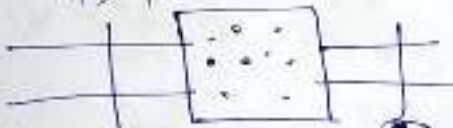


Porous Plug (Throttling).

$$\textcircled{1} \quad p_1, v_1, h_1, T_1$$

$\textcircled{2}$

$$p_2, v_2, h_2, T_2 \quad (h_2 = h_1)$$



$$h_1 \quad \textcircled{1}$$

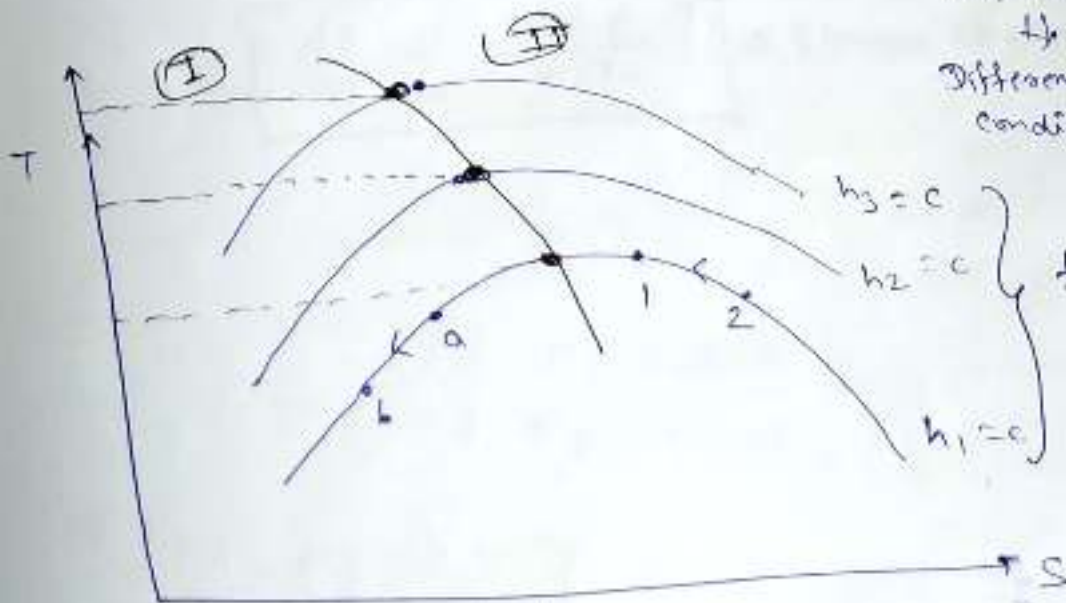
$\textcircled{2}$

$$h_1 \quad (\text{or } T_3)$$

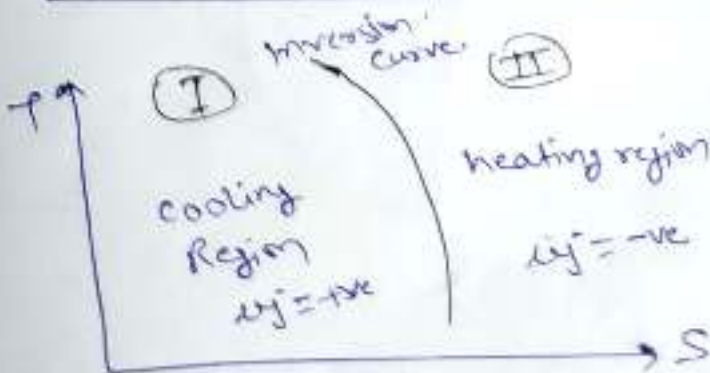
(changing no. of porous.)

friction act ~~diff~~ different.

different outlet conditions.



for different inlet to porous plug



Throttling always in $p \downarrow$ dir.

Because irreversible

$a \rightarrow b$
 $2 \rightarrow 1$

In Region (I):

$$\alpha = \left(\frac{\partial T}{\partial P} \right) = \frac{T_b - T_a}{P_b - P_a} = \left(\frac{-ve}{-ve} \right)$$

$$\Delta T = (+ve)$$

$T \downarrow =$ cooling Region

In region (II):

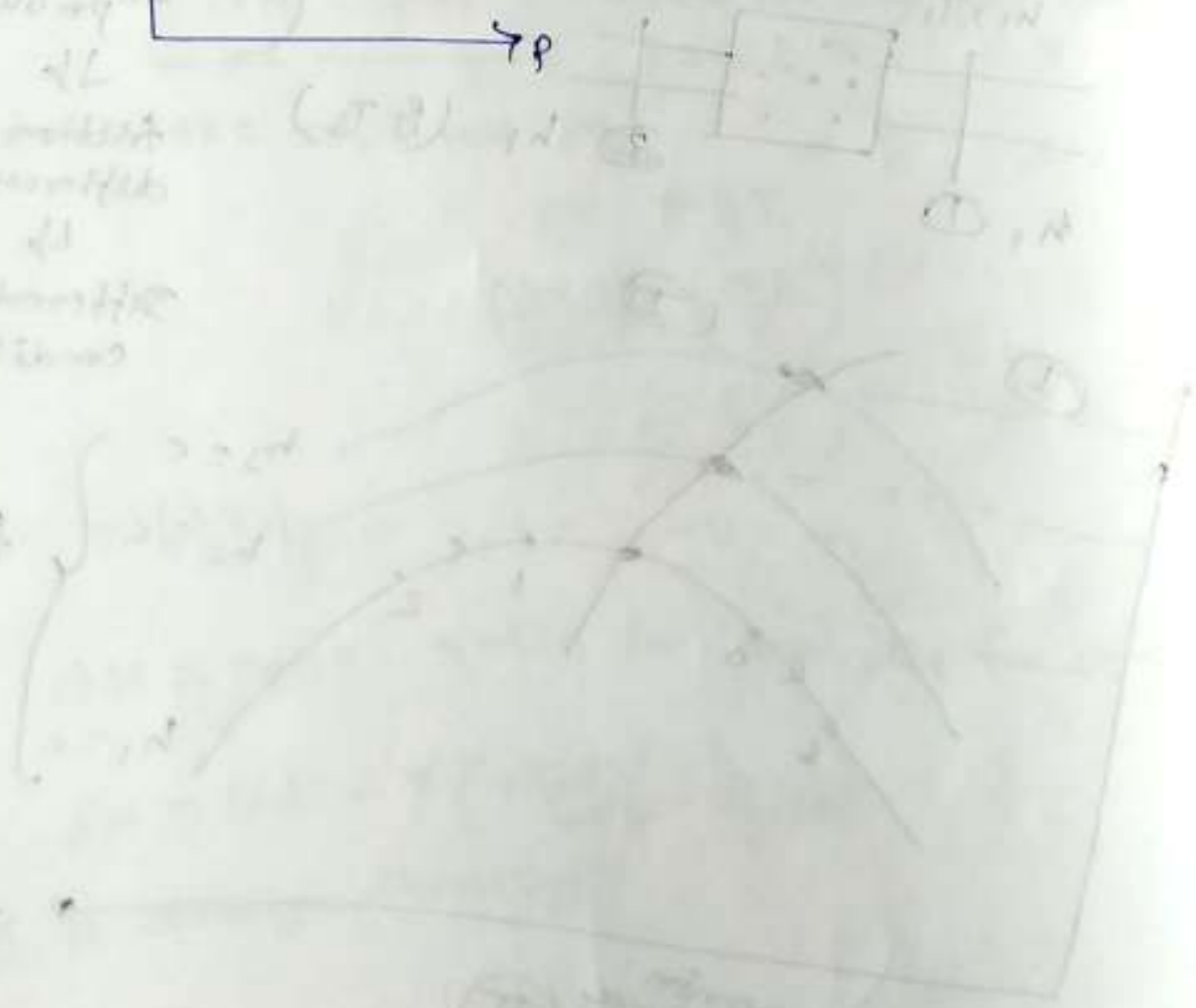
$$\alpha = \left(\frac{\partial T}{\partial P} \right) = \left(\frac{+ve}{-ve} \right) = (-ve)$$

$$\Delta T = -ve$$

$T \uparrow =$ Heating Region.



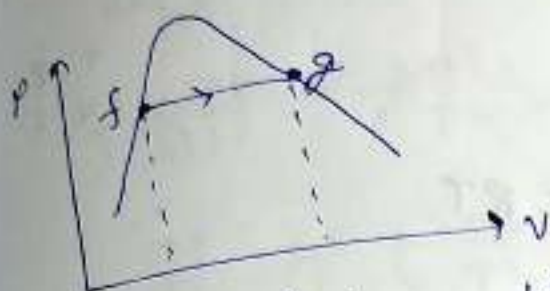
$\left(\frac{\partial T}{\partial P} \right) = 0$ for an ideal gas.



Clausius Clapeyron Equation:

Maxwell Equation

$$\left(\frac{\partial P}{\partial T}\right)_V = \left(\frac{\partial S}{\partial V}\right)_T$$



Let us take phase change.

During phase change P & T are independent of volume.

$$\left(\frac{dP}{dT}\right) = \frac{S_g - S_f}{V_g - V_f}$$

$$\boxed{\left(\frac{dP}{dT}\right) = \frac{LH}{T(V_g - V_f)}} \rightarrow \text{Clapeyron Equation}$$

f → liquid
g → vapour $V_g \gg V_f$

$$\frac{dP}{dT} = \frac{LH}{TV_g}$$

$V_g \rightarrow$ ideal gas

$$PV = nRT$$

$$\frac{V}{n} = v = \left(\frac{RT}{P}\right)$$

$$\left(\frac{dP}{dT}\right) = \frac{LH}{T \left(\frac{RT}{P}\right)}$$

$$\boxed{\frac{dP}{dT} = \frac{(LH) \cdot P}{RT^2}} \rightarrow \text{Clausius Clapeyron Eqn.}$$

Sol) For a gas obeying van der Waals eqn of state $\left(\frac{\partial S}{\partial T}\right)_V$ is

(a) $\frac{R}{V-b}$ (b) $\frac{R}{(V-b)^2}$ (c) $\frac{RV^2}{V-b}$ (d) $\frac{R}{(V-b)^2}$

$$\left(\frac{\partial S}{\partial T}\right)_V = \left(\frac{\partial P}{\partial T}\right)_V$$

$$\left(P + \frac{a}{V^2}\right)(V-b) = RT$$

$$P = \frac{RT}{V-b} - \left(\frac{a}{V^2}\right)$$

$$\left(\frac{\partial P}{\partial T}\right)_V = \left(\frac{R}{V-b}\right) \cdot 1$$

Ans) The saturated pressure of liquid ammonia (in atm) in the vicinity of the triple point can be expressed as $\ln p + \frac{3063}{T} = 15.16$ where T is in K. In a similar manner, the saturated pressure of solid NH_3 can

be measured expressed as $\ln p + \frac{3754}{T} = 18.7$

Take $M_{NH_3} = 17 \text{ kg/kmol}$.

(i) The temp (K) and pressure (atm) of NH_3 at triple point.

(ii) the LH of vaporisation is — kJ/kg

$$\ln p + \frac{3063}{T} = 15.16 \quad (\text{liq } NH_3) \quad \text{--- (i)}$$

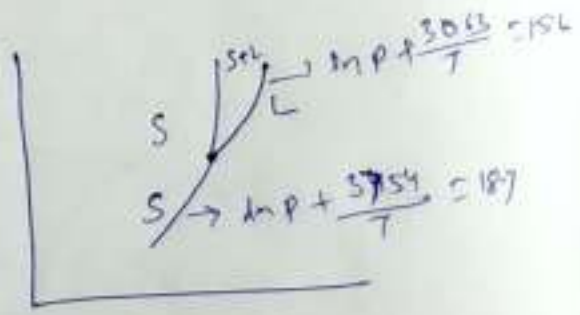
$$\ln p + \frac{3754}{T} = 18.7 \quad (\text{solid } NH_3) \quad \text{--- (ii)}$$

$$\frac{(ii) - (i)}{\frac{3754}{T} - \frac{3063}{T}} = \frac{18.7 - 15.16}{1}$$

$$\frac{691}{T} = 3.54$$

$$T = \frac{691}{3.54}$$

$$T = 195.199 \text{ K}$$



from (i) $p = 0.587 \text{ atm}$

$$\frac{dp}{dT} = \frac{P(LH)}{RT^2}$$

$\ln p + \frac{3063}{T} = 15.16$ (vaporisation will be take place across liquid/vaporisation curve)

$$\frac{1}{p} \left(\frac{dp}{dT} \right) - \frac{3063}{T^2} = 0$$

$$\frac{dp}{dT} = \left(\frac{3063p}{T^2} \right)$$

$$\frac{3063p}{T^2} = \frac{p \cdot LH}{RT^2}$$

$$R = \frac{R_u}{M} = \left(\frac{8.314}{17} \right)$$

$$LH = 3063 \times R$$

$$LH = 1498 \text{ kJ/kg}$$

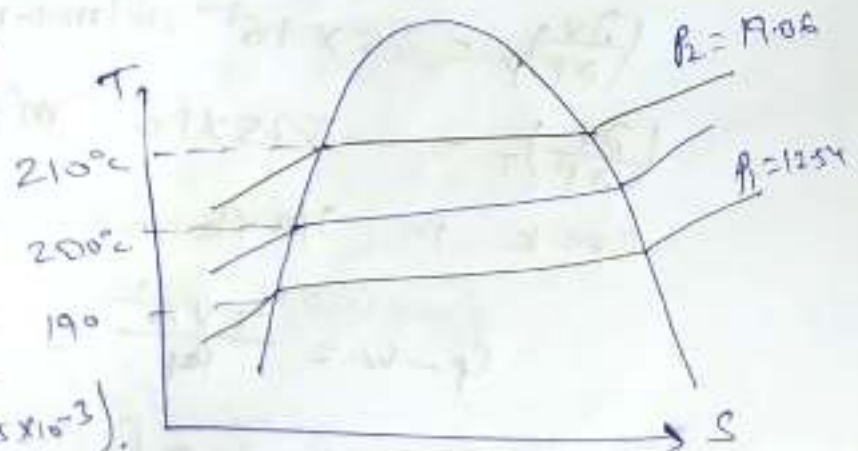
Q2) Given for water at 19°C, sat. pres = 12.54 bar.

at 21°C, $P_{sat} = 19.06 \text{ bar}$.

at 20°C specific volume of ~~liquid~~ sat liquid = $1.1565 \times 10^{-3} \text{ m}^3/\text{kg}$

@ 20°C, saturation volume of sat vapour = $0.1274 \text{ m}^3/\text{kg}$

Using clausius clapeyron eqn find LH of vaporisation of water at 20°C.



$$\frac{dp}{dT} = \frac{LH}{T(v_g - v_f)}$$

$$\frac{19.06 - 12.54}{20} = \frac{LH}{473 (0.1274 - 1.1565 \times 10^{-3})}$$

$$LH = 1946.6 \text{ kJ/kg}$$

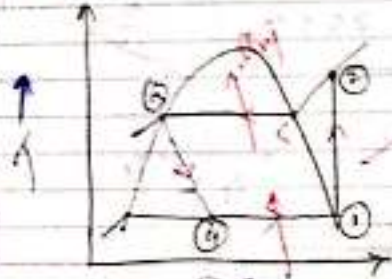
Refrigeration cycle

1 Vapour compression cycle (V/C)

Applications

- 1) Domestic fridge
- 2) Air conditioning
- 3) Cold storage

Two constant pressure +
one isobaric process +
one throttling

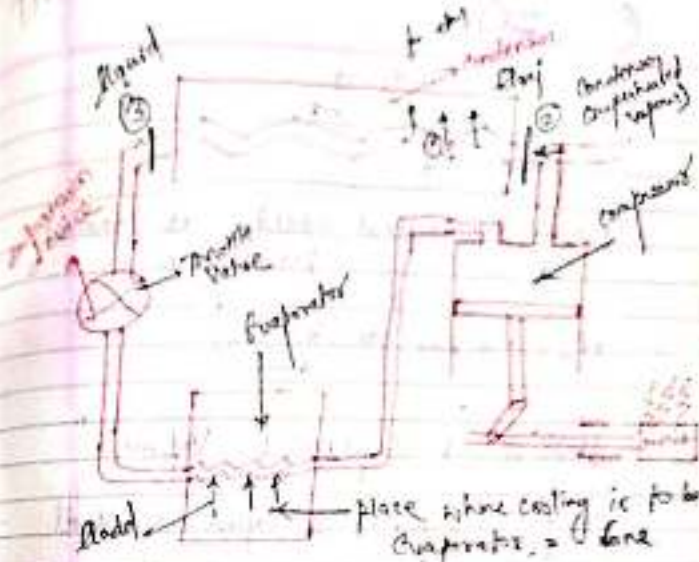


subcooled liquid
superheated vapor
mixture

for throttling
 $Q_{add} = 0$
 $W_{pump} = 0$
 $Q_{out} = 0$
 $W_{ref} = 0$
 $Q_{12} = 0$

$$COP_{ref} = \frac{Q_{add}}{W_{net}} = \frac{Q_{add}}{Q_{add} - Q_{out}}$$

Disc



Capillary tube is used as throttling device in domestic A.C. & small refs.

Let m kg/sec is refrigerant flow rate.

1-2 \rightarrow isentropic compression (S.F.C.)

$$W_{12} = m(h_1 - h_2)$$

$$Q_{23} = m(h_3 - h_2)$$

$$Q_{ref} = Q_{cond} = m(h_3 - h_4)$$

3-4 → Throttling

$$h_3 = h_4$$

Process 4-1 → Heat added at constant pressure.

$$Q_{4-1} = Q_{\text{add}} = m(h_1 - h_4)$$

State ① is superheated vapour.

Assuming superheated vapour as ideal gas.

$$s_1 = \text{given}, \quad s_5 = \text{given}$$

$$s_2 = s_5 + c_{pv} \ln \frac{T_2}{T_5} \quad s_1 = s_2$$

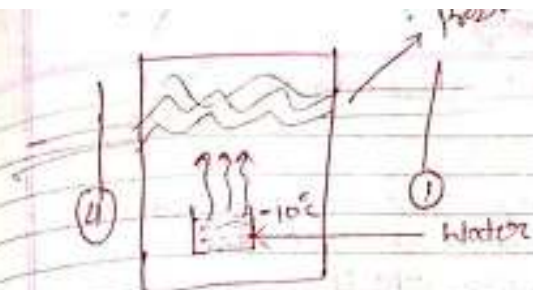
$T_5 = T_{\text{sat}}$ at condenser pressure.

$$s_1 = s_5 + c_{pv} \ln \frac{T_2}{T_5}$$

find → T_2

$$h_2 = h_5 + c_{pv}(T_2 - T_5)$$

$T_2 - T_5 = \text{Degree of superheat}$



$$T_1 = T_4 = T_{\text{sat}} \text{ at evaporator pressure}$$

$$T_4 < -10^\circ\text{C}$$

More heat added in the refrigerant, more amount of cooling in the water.

$$T_2 > T_{\text{atm}} \quad \left. \begin{array}{l} T_{\text{atm}} > T_{\text{sat}} \\ T_1 < T_{\text{sat}} \end{array} \right\} \text{Refrigeration is possible.}$$

Definitions → (1) "TON" (of refrigeration) → Represents cooling capacity in terms of heat transfer.

$$1 \text{ TON} \rightarrow 3.5167 \text{ kJ/sec} \rightarrow 3.5167 \text{ kW}$$

Cooling Capacity is also sharing evaporator capacity = Evaporator load.

→ Q_{add} in (kJ/sec)

$$\text{e.g.} \rightarrow \text{ton capacity of ref.} = 0.2 \times 3.5167 \text{ kW}$$

220 liter = Evaporator (refrigerant volume)

(ii) Refrigeration effect (R.E.) = Q_{add} is heat absorbed in evaporator, i.e. cooling capacity in capacity of refrigeration.

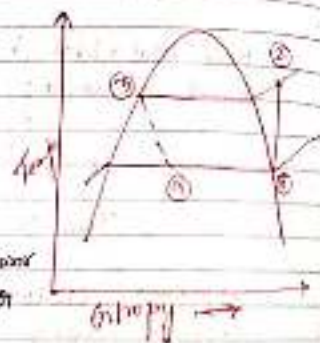
Calculation of COP & other parameters



m kg/sec is refrigerant flow rate.

(ii) Process 1-2, isentropic compression cycle

$$W_{1-2} = m(h_2 - h_1) = \text{compressor power}$$



$$W_{input} = m(h_2 - h_1)$$

$Q_{4-1} = m(h_1 - h_4) = Q_{add} = Q_{absorb} = R.E. = \text{cooling capacity} = \text{capacity of cycle} = \text{Evaporator load}$

$$COP = \frac{Q_{add}}{W_{input}} = \frac{m(h_1 - h_4)}{m(h_2 - h_1)} = \frac{R.E.}{\text{Compressor work}} = \frac{\text{Cooling Cap.}}{\text{Comp. work}}$$

An ice plant using R-12 is having an evaporator saturation temp of -25°C and condenser saturation temp of 35°C . The vapour is having the comp. at 65°C . Find COP of system (12% the capacity of plant is 5 kW) then find the refrigerant flow rate and power consumption. Also find heat rejected and the quality of vapour entering the evaporator.

Properties of refrigerant —

Temp	Press. kPa	h_f kJ/kg	h_g kJ/kg
-25	123.1	13.5	176.5
35	850	69.8	201.5

Enthalpy of superheated refrigerant at 850 kPa and $46^\circ\text{C} = 205.5 \text{ kJ/kg}$

5% $T_1 = -25^\circ\text{C}, T_2 = 65^\circ\text{C}, T_3 = 35^\circ\text{C}$

$$T_1 = -25^\circ\text{C} = T_4$$

$$Q_{add} = m(h_1 - h_4) = 100 \text{ kg} \times (176.5 - 13.5) = 106.9 \text{ kJ/kg} \quad \underline{\underline{A}}$$

$$W_{input} = m(h_2 - h_1) = 100 \text{ kg} \times (205.5 - 176.5) = 29 \text{ kJ/kg} \quad \underline{\underline{B}}$$

$$COP = \frac{106.9}{29} = 3.686 \quad \underline{\underline{A}}$$

$59.5 = \alpha \times 176.5 + (1-\alpha) \times 13.3$
 $69.6 = 176.5 \alpha + 13.3 - 13.3 \alpha$
 $69.6 - 13.3 = 176.5 \alpha - 13.3 \alpha$
 $56.3 = 163.2 \alpha$
 $\alpha = 0.345$

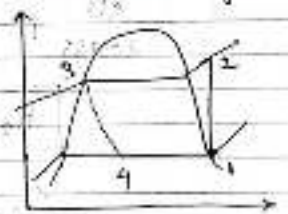
Power consumption: max loop work
 $0.046 \times 48.5 = 2.209 \text{ kW}$

Amount of flashing = Degree of saturation:
 quality of vapour = 31.5%

A refrigerator operating on a simple (simple or basic) vapour cycle has COP = 6.5 and is driven by 30 kW compressor. The enthalpy of saturated vapour in & saturated vapour at condensing temp of 30°C are 69.55 and 201.46 kJ/kg resp. The saturated vapour leaving the evaporator has enthalpy of 187.53 kJ/kg. Find the refrigerant temp at subcooled discharge. Assume Cp, vapour = 0.615 kJ/kgK. Also find capacity in ton of heat ref.

Soln

$h_1 = 187.53 \text{ kJ/kg}$
 $h_3 = 69.55 \text{ kJ/kg}$
 $h_4 = 69.55 \text{ kJ/kg}$
 $h_2 =$



$6.5 = \frac{Q_{add}}{W} \Rightarrow Q_{add} = 325 \text{ kW}$
 $Q_{ref} = 325 + 30 = 355 \text{ kW}$

$$975 = h_1 - h_2$$

$$375 = h_2 -$$

$$225 = m(187.5 - 69.55)$$

$$m = 2.755 \text{ kg/sec}$$

$$50 = (h_2 - h_1)h$$

$$\frac{50}{2.755} + 187.53 = h_2$$

$$h_2 = 205.68$$

$$205.68 = 273.15 + 0.6155 \times (T_2 - 273.15) + h_f$$

$$\frac{205.68 - 201.45}{2.755 \times 0.6155} = (273.15)$$

$$T_2 = 314.87 \text{ Kelvin}$$

$$\text{Load} = \frac{325}{2.15} = 151.17 \text{ Ton}$$

$$\text{Req} = 375 \text{ kW}$$

- A refrigerator works on comp cycle. It works between temp limits of -20°C & 40°C . The refrigerant enters the condenser as saturated vapor at 40°C and leaves as saturated liquid at 40°C .
- (a) If refrigerant circulated is 0.025 kg/sec , find refrigeration effect in kW.
- (b) find COP of ref.
- (c) If it operates like H.P., find its COP.

Sol Property Table:

$T^\circ\text{C}$	h_f	h_g	s_f	s_g
-20	20	180	0.07	0.7366
40	80	200	0.3	0.97

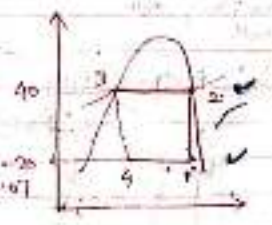
$$T_1 = T_4 = 40^\circ\text{C} = 313.15 \text{ K}$$

$$T_2 = T_3 = 40^\circ\text{C}$$

$$0.97 = x \times 0.7366 + (1-x) \times 0.07$$

$$\frac{0.97 - 0.07}{0.7366 - 0.07} = x \Rightarrow x = 0.30$$

$$h_1 = 0.30 \times 180 + (1 - 0.30) \times 20 = 104 \text{ kJ/kg}$$





L = Stroke length

D = Diameter (Bore) of cylinder or piston

$V_{swept} = V_{stroke} = V_s$ = stroke volume.

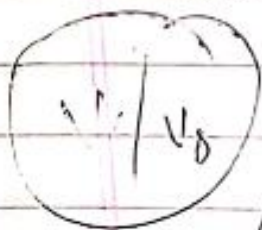
$P_s = P_1$ = Suction pressure (inlet or entry press).

$P_d = P_2 = P_3$ = Discharge (delivery pressure) exit press.

V_c = clearance volume = V_3

$\frac{V_c}{V_s}$ = Clearance factor or clearance ratio.

Volumetric eff of comp = $\frac{V_{act}}{V_{stroke}} = \frac{V_{act}}{V_{theo}}$



$$\eta_v = \frac{V_1 - V_3}{V_1 - V_3}$$

$$\frac{V_{act}}{V_c} = \delta$$

$$\eta_v = 1 + c - c \left(\frac{P_d}{P_s} \right)^{1/n_c}$$

$\frac{V_s}{V_c} = N$ = rpm of Crank or crank shaft

$$\left[\eta_v \times \frac{\pi D^2 L N}{4 \times 60} \right] P_1 = \text{mass flow rate}$$