

02/07/17

Thermodynamics Part-1

It is study of Transfer of Energy with respect to heat and work.

- * Thermodynamics is a macroscopic property
- * Thermodynamics are used to find possibility feasibility of a process

Some definition Related to Thermodynamics:

1. System: Part of universe on which Study of Thermodynamics being done called System

Types of system:

← Transfer

	Energy	mass.	Example
<u>Close</u>			
1) Open System	✓	✓	Hot water filled in a open container.
2) Close system	✓	X	Hot water filled in a closed container.
3) Isolated System	X	X	Thermos flask, universe

SBG STUDY

* Boundary: Boundary separate system from surrounding.

* Different types of Boundary:

(1) adiabatic or diathermic boundary.

⇒ Heat flow not possible

⇒ Heat flow is possible.

(2) Rigid or non

⇓

⇒ change in vol. is not possible

(3) non Rigid Boundary.

⇓

change in vol. is possible

(3) permeable and non permeable boundary.

⇒ flow of mass is possible

flow of mass is not possible.

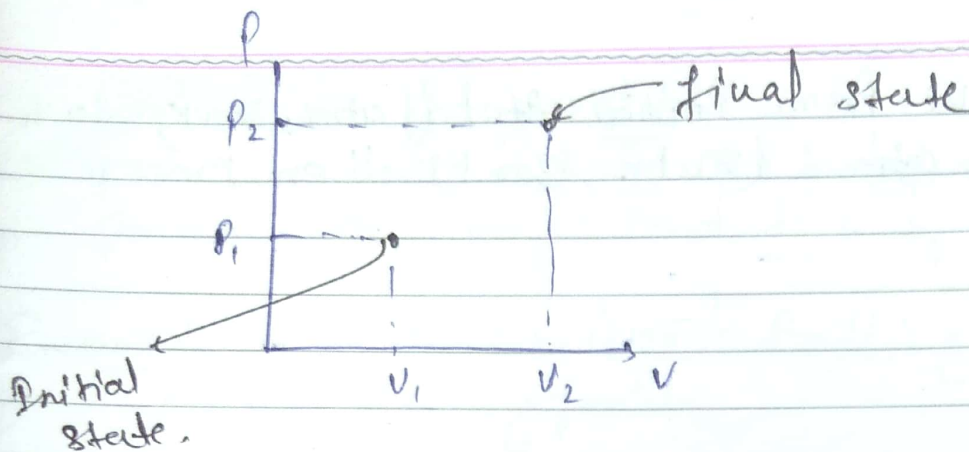
(3) * Surrounding: Remaining part of universe

except system and boundary called surrounding.

* Process in thermodynamics:

Path by which we move from initial to final state called process. there can be infinite no. of process in thermodynamics.

q = change in Heat.



There can be some specific types of process like.

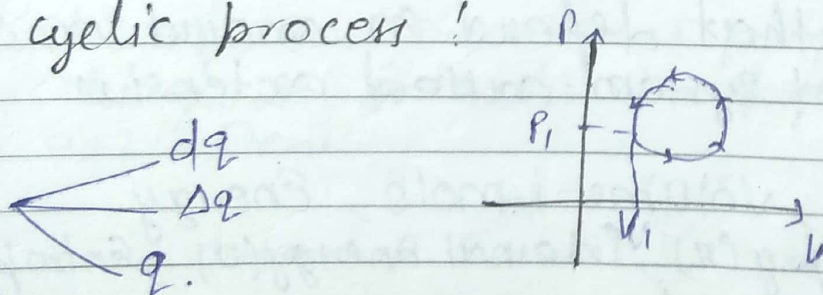
(1) Isothermal process: $T = \text{constant}$ $dt = 0$

(2) Isobaric process: $P = \text{constant}$

(3) Isochoric process: $v = \text{const.}$ (i)

(4) adiabatic process: $dq = 0$

(5) cyclic process:



All three will represent change in heat

* Initial and final state will be same in cyclic process.

Q. A system move from initial state (1 atm, 300 K) to final state ~~to atm~~ (2 atm, 300 K) then process must be a

- a) Iso-thermal
- b) adiabatic
- c) cyclic
- ~~d) none of these.~~

* Only by analysing the state path of system can not be determine.

* Extensive and Intensive Properties in thermodynamics!

* Extensive properties!

Properties that depend on amount or shape or size of system called extensive properties

For ex! mass, volume, mole, Energy, Enthalpy (H), Internal energy (U), Entropy (S), Gibbs free energy (G).

* Extensive properties are additive in nature.

$$\begin{array}{|c|c|} \hline \eta & \\ \hline \eta_1 & \eta_2 \\ \hline \end{array} \quad \eta = \eta_1 + \eta_2.$$

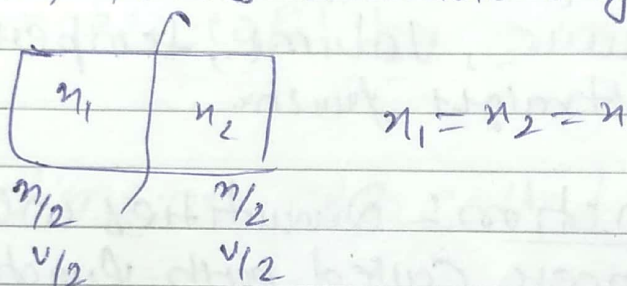
* Generally Quantity of Physics like refractive index, viscosity constant etc will be intensive properties

* Intensive properties:

These properties are independent from amount or shape and size of system

Example: Temperature, Boiling point, melting point, freezing point.

* All Concentration terms like molarity, % w/w, etc.



* Intensive properties are non-additive in nature

* Ratio of two extensive properties will be always an intensive property.
for ex: Density.

$$\text{intensive} \leftarrow d = \frac{m \rightarrow E}{V \rightarrow E}$$

Pressure of ideal gas = $P = \frac{n}{V} RT$

intensive \leftarrow $\frac{n}{V}$ \rightarrow intensive

* If a extensive property is defined for unit mole or unit mass then it becomes intensive properties.

for ex: molar volume $\Rightarrow (V_m) = \frac{V}{n}$ Quantity defined for unit mol

Specific volume $\Rightarrow (V_s) = \frac{V}{m}$ Quantity defined for unit mass

State.

* Straight function and path function in Thermodynamics

State.

* Straight function: Quantities that can be defined at a certain state called state functions.

State

* A straight function will have a definite value at a definite state.

For ex: Pressure, Volume, temperature. (H, U, S, C)
all will be straight functions. Energy.

* Path function: Quantities which depends on path or process called path function.

For ex: Work, heat capacity,

* Impor-tant point!

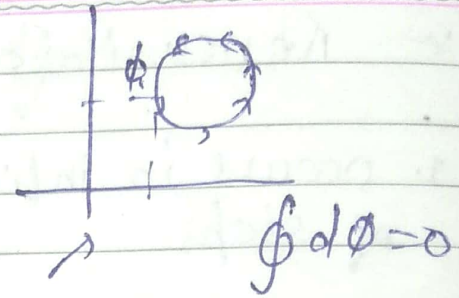
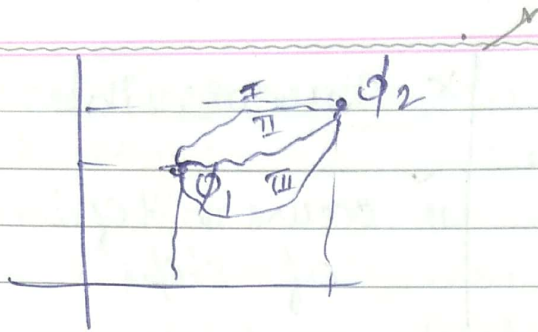
* change in a state function like $\Delta p, \Delta v, \Delta T$ etc. neither will be a state function nor will be a path function.

Every Quantity can not be categorised as a path function or state function.

Change in a state function b/w two definite states remain constant. It will not depend on own path by which we are moving from initial state to final state.

R.A \Rightarrow
ch. eq

0-2 = 1 to 5
0-1 \Rightarrow 1 to 10



$$\Delta\phi_I = \Delta\phi_{II} = \Delta\phi_{III} = \phi_2 - \phi_1$$

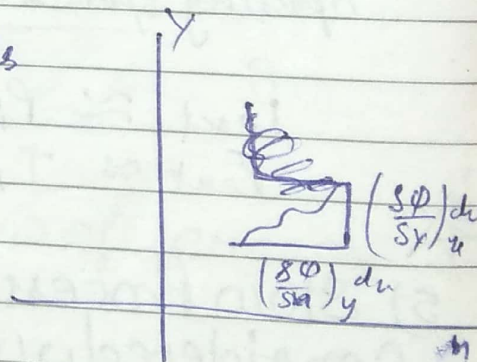
* change in a state function during a cyclic process will be equal to zero.

* State functions are also called Thermodynamic Quantities.

gram-atom = mol of atom
gram molecules = mol of molecules

$$\phi = f(n, y)$$

$$d\phi = \left(\frac{\partial\phi}{\partial n} \right)_y dn + \left(\frac{\partial\phi}{\partial y} \right)_n dy$$



change in ϕ corresponding to n keeping y constant

change in ϕ corresponding to y keeping n constant

* reversible & irreversible process

* Reversible

1. occurs in infinite no. of steps.
2. Ideal reversible process is impossible
- 3) System remains in eqb at each and every step of process.
- 4) Driving force will be approximately equal to opposing force.

$$P_{ext} \approx P_{int}$$
$$T_{ext} \approx T_{int}$$

- ★
- 5) Slow process are considered reversible process

* Irreversible

- 1) occurs in definite no. of steps
- 2) Every process in nature is a irreversible process
- 3) System remains in eqb at initially and final state only
- 4) There will be a significant difference b/w driving force and opposing force

- ★
- 5) Fast process are considered irreversible process.

* If term against a 'constant external pressure' given in question then it can be considered ~~not~~ ~~irreversible~~ ~~process~~ and irreversible process.

* Sign Convention in Thermodynamic in Chemistry:

- * Heat given to system : +ve
- * Heat released by system: -ve
- * Work done on system: +ve (Compression)
- * Work done by system: -ve (Expansion)

* Zeroth law of Thermodynamics:

If two bodies B and C are in thermal eq^s with a third body A separately then B and C will be also in Thermal eq^s with each other.

* First Law of thermodynamics:

$$q + w = \Delta U$$

* First law of T.D. is basically law of energy conservation.

* First law of T.D. is not applicable for open system.

* Work in Thermodynamics:

physics

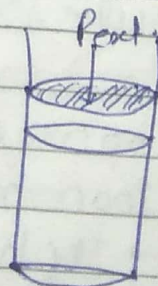
$$w = f \cdot dn$$

$$w = P_{ext} \cdot A \cdot dn$$

$$w = P_{ext} \cdot dx$$

By sign conversion of T.H
in Chemistry

$$w = - P_{ext} \cdot du$$



$$W = - \int_{v_1}^{v_2} P_{ext} dv$$

$\begin{matrix} \text{men} & & \text{kur} \\ & \wedge & / \\ & v_1 & v_2 \end{matrix}$
 $P_{ext} \approx P_{int} (\text{gas})$

$$W = - \int_{v_1}^{v_2} P_{gas} dv$$

$$W = - P_{ext} \int_{v_1}^{v_2} dv$$

$$W = - P_{ext} (v_2 - v_1)$$

Units

* $P \Rightarrow \text{Atm}$
 $V \Rightarrow \text{litre}$
 $R = 0.0821 \frac{\text{atm} \cdot \text{litre}}{\text{mol} \cdot \text{K}}$
 $W = \text{litre-atm}$

$P = \text{bar}$
 $V = \text{litre}$
 $R = 0.083 \frac{\text{bar} \cdot \text{litre}}{\text{mol} \cdot \text{K}}$
 $W = \text{bar} \cdot \text{litre}$

S.I

$P = \text{Pascal}$
 $V = \text{m}^3$
 $R = 8.3 \frac{\text{Pa} \cdot \text{m}^3}{\text{mol} \cdot \text{K}}$
 $= 8.3 \frac{\text{Joule}}{\text{mol} \cdot \text{K}}$
 $W = \text{Joule}$

$1 \text{ atm} = 1.01325 \times 10^5 \text{ Pascal}$
 $1 \text{ bar} = 10^5 \text{ Pascal}$
 $1 \text{ atm} = 1.01325 \text{ bar}$
 $760 \text{ mmHg} = 760 \text{ torr} = 1 \text{ atm}$

$1 \text{ m}^3 = 1000 \text{ litre}$

$1 \text{ litre} = 1000 \text{ ml} = 1000 \text{ cm}^3 = 1000 \text{ c.c}$

$1 \text{ dm}^3 = 1 \text{ litre}$

$$1 \text{ atm} \cdot \text{litre} = 101.3 \text{ Joule}$$

$$1 \text{ bar} \cdot \text{litre} = 100 \text{ Joule}$$

$$1 \text{ Calorie} = 4.18 \text{ J.}$$

$$R = \frac{2 \text{ Cal}}{\text{mol K}}$$

Ques: A gas is compressed from 10 litre to 5 litre. against a const external pressure of 1 bar. if in this process 1 kJ Heat is supplied to the system then calculate change in internal energy of system in kJ.

Ans

$$W = -P\Delta V$$

$$= -1(5-10)$$

$$= -1 \times -5$$

$$= +5 \text{ bar litre}$$

$$W = \frac{5 \times 100}{1000} = 0.5 \text{ kJ.}$$

$$Q + W = \Delta U$$

$$1 + 0.5 = \Delta U$$

$$\Delta U = 1.5 \text{ kJ.}$$

Q. A real gas follows the equation $P = \frac{25}{V^2}$. Here P is in bar and V is in litre. if 10 kJ is extracted from gas then pressure of gas change from 25 bar to 1 bar. if this process is slow process and initial value of internal energy is 50 kJ. then find out value of internal energy at final state.

(C.O.E) H.W. is not complete.
 (R.A) = 0.2 \Rightarrow 6 to 8.

Ans RE $\frac{25}{v^2}$

10 ps
~~25 bar~~ - 1 bar.

$$W = - \int_{v_1}^{v_2} P dv = - \int \frac{25}{v^2} dv$$

$$W = + \left[\frac{25}{v} \right]_1^5 = 5 - 25$$

$$25 = \frac{25}{v_1^2}$$

$$v_1 = 1$$

$$1 = \frac{25}{v_2^2}$$

$$v_2 = 5$$

$$W = -20 \text{ bar.litre.}$$

$$W = \frac{-20 \times 100}{1000} = -2 \text{ kJ}$$

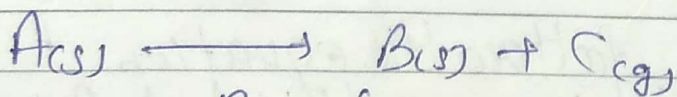
$$q + w = \Delta U$$

$$+10 - 2 = U_2 - 50$$

$$U_2 = 50 - 12 = 38 \text{ kJ}$$

Ques: 20ml of A (solid) on providing 2 kJ of heat dissociate in 10ml of B (solid) and 10 litre C (gas) against a const. External pressure of pressure is 1 atm. then calculate change in internal process energy in process.

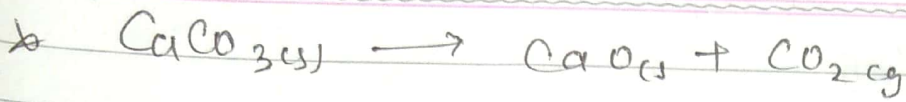
Ans:



$$W = -P_{\text{ext}} (v_2 - v_1)$$

$$= -1 \left(10 + \frac{10}{1000} - \frac{20}{1000} \right) \text{ atm litre.}$$

$$= -10 \text{ atm.litre.}$$



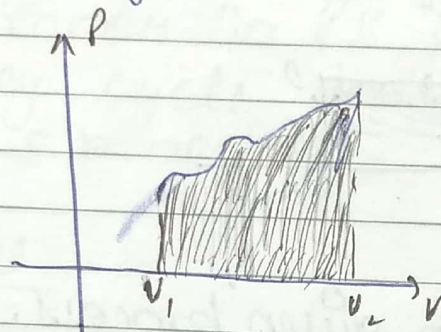
$V_{\text{gas}} \gg \gg \gg V_{\text{liquid}} > V_{\text{solid}}$

Questions of work based on PV graph.

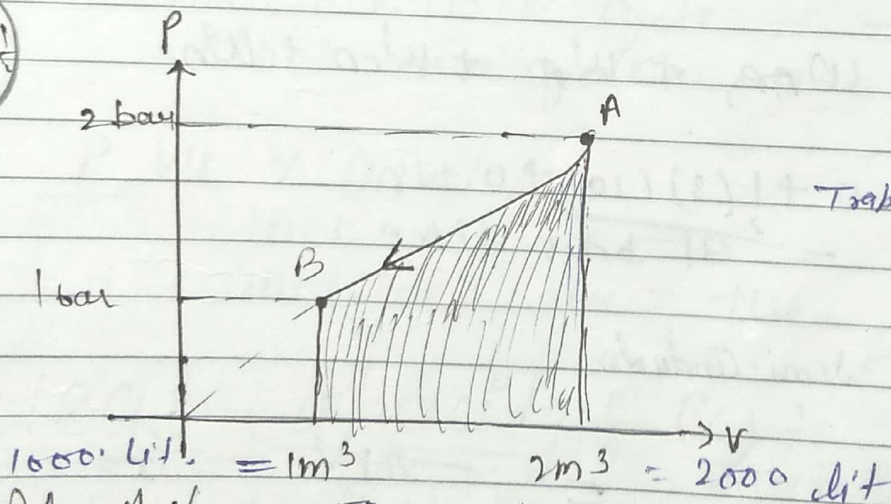
Area under the PV curve denote magnitude of work in the process

$w = - \int_{v_1}^{v_2} P dv$

Area = |w|



(Ques)



$T_{\text{gas}} = \text{rel.}$

If $\Delta V_{BA} = 50 \text{ kJ}$ then calculate changing in process ΔH and work.

$w_{AB} = \frac{1}{2} (3) (1000)$

$w = -P_{\text{ext}}(v_2 - v_1)$

$= 1500 \text{ bar litre}$

$= \frac{1500 \times 100}{1000} = 150 \text{ kJ}$

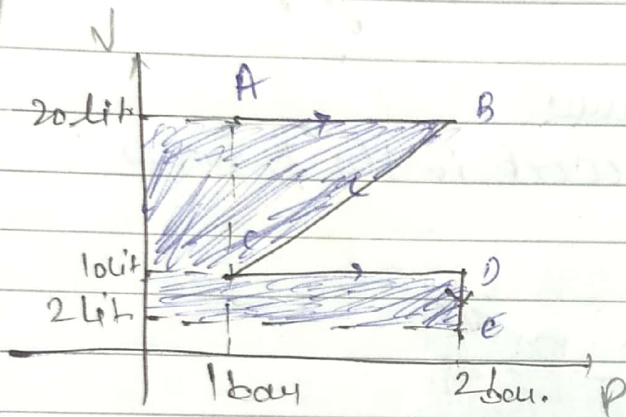
$\frac{1}{2}$ sum of πr^2 & dist. from
mid:

$$Q_{AB} + W_{AB} = \Delta U_{AB}$$

$$Q_{AB} + 150 = -50$$

$$Q_{AB} = -200 \text{ kJ}$$

Ques:



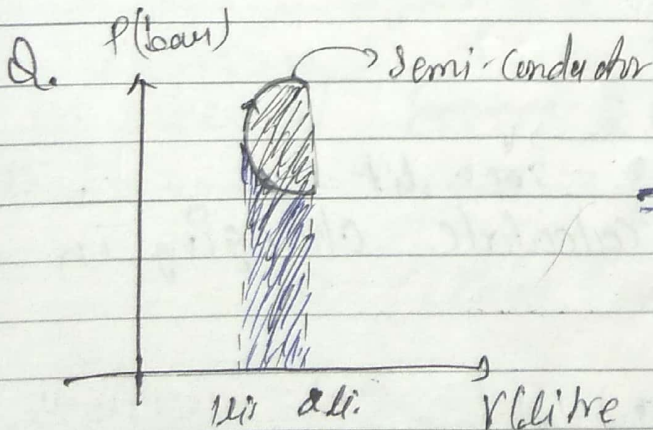
$$A B = 0$$

Calculate work in given process.

$$W = W_{AB} + W_{BC} + W_{CD} + W_{DE}$$

$$= 0 + 1(3)(10) + 0 + 16$$

$$= \frac{2}{31} \text{ bar litre}$$

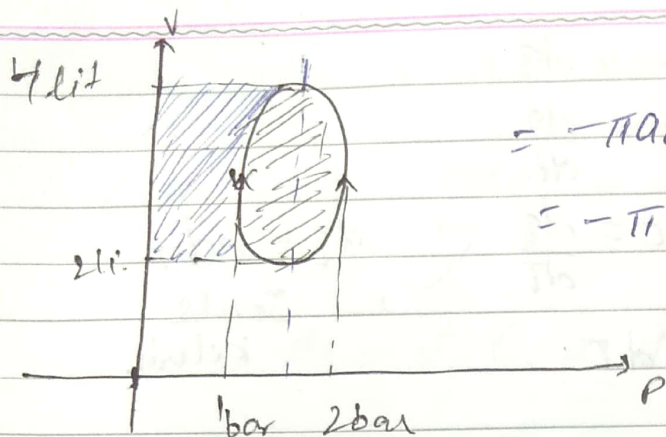


$$= \frac{\pi r^2}{2}$$

$$r = 1$$

$$= \frac{\pi}{2}$$

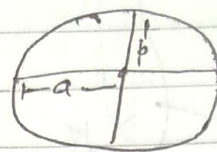
ellips area = πab



= $-\pi ab$

= $-\pi (1) (\frac{1}{2})$

= $-\frac{\pi}{2}$



* In a cyclic process in PV graph area enclosed by cycle denote magnitude of work in cyclic process

* In V/P Curve

anticlockwise cycle = -ve
clockwise cycle = +ve

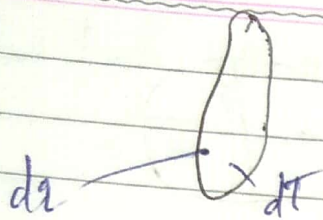
* In P vs V Curve!

clockwise = -ve
anticlockwise = +ve

* Heat Capacity (C):

Heat Required to increase temp. by one degree Celsius 1°C and 1°K . Called Heat capacity

Let for increasing heat temp. required heat is dq the increasing temp by 1°C required heat will be $\frac{dq}{dt}$



$$dT \rightarrow dq$$

$$1 \rightarrow \frac{dq}{dT}$$

$$c = \frac{dq}{dT}$$

$$dq = c dT$$

Joule
kelvin

$$\Delta q = \int_{T_1}^{T_2} c dT$$

if c is constant

$$\Delta q = c \Delta T$$

Molar Heat Capacity! (C_m)

$$C_m = \frac{c}{n} = \frac{\text{Joule}}{\text{mol} \cdot \text{K}}$$

$$c = n C_m$$

$$dq = n C_m dT$$

$$\Delta q = \int_{T_1}^{T_2} n C_m dT$$

if C_m constant

$$\Delta q = n C_m \Delta T$$

Specific Heat Capacity! (C_s / ρ)

$$C_s = \frac{c}{m} = \frac{\text{Joule}}{\text{g} \cdot \text{K}}$$

$$c = m C_s$$

$$dq = m C_s dT$$

$$\Delta q = \int_{T_1}^{T_2} m C_s dT$$

if C_s is constant

$$\Delta q = m C_s \Delta T$$

Volume atomic heat capacity

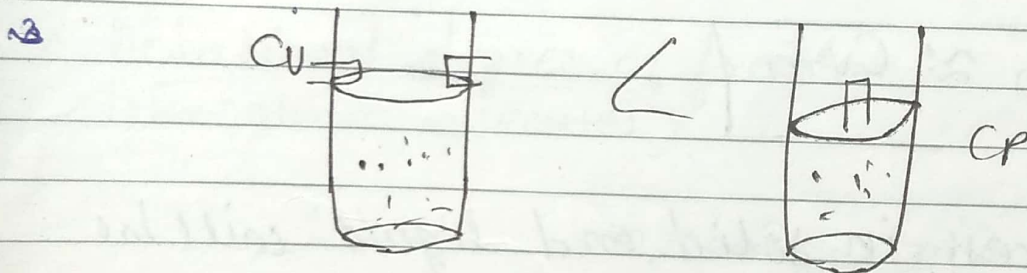
$$C_{v.m.c} = \frac{c}{V} \frac{\text{Joule}}{\text{mol} \cdot \text{K}}$$

$$dq = \sqrt{C_{v.m.c}} dt$$

* Important point Regarding Heat Capacity!

1) Every type of heat capacity is a path function

2) Isothermal $\rightarrow \infty$ $C_p > C_v > C_{\text{adiabatic}} \rightarrow 0$



3)* heat capacity is an extensive property but molar heat capacity and specific heat capacity are intensive property. $\frac{c}{n}$

4) for any substance $C_{p,m} - C_{v,m}$

$$C_{p,m} - C_{v,m} = \frac{T}{n} \left(\frac{\partial p}{\partial T} \right)_V \left(\frac{\partial T}{\partial T} \right)_P$$

for ideal gas $PV = nRT$

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

$$C_{pm} - C_{vm} = \frac{1}{n} \left(\frac{nR}{V} \right) \left(\frac{nR}{P} \right)$$

$$C_{pm} - C_{vm} = nR^2 T$$

$$\boxed{C_{pm} - C_{vm} = R}$$

* for solid & liquid:

In any process Vol. of solid & liquid almost remain constant.

$$\left(\frac{\Delta V}{\Delta T} \right)_P = 0$$

$$\boxed{C_{pm} \approx C_{vm}}$$

* every process in solid and liquid will be almost a isochoric process

(5) For every substance heat capacity depend upon temp. on increasing temp. value of heat capacity always increase for every substance (except for ideal gas).

Because on increasing temp vibrational degree of freedom activate within molecules.

Not Dmk.

$$\frac{NR^2}{PV} \quad \frac{NR^2}{RT} \quad R/T$$

Ratio $\approx 0.2 \rightarrow 8$ to 11

0-1 \rightarrow (thermodynamics)
1 to 6
8-1 \rightarrow thermo
1 to 6

* Degree of freedom =

$$f_{\text{Total}} = 3N$$

Here N is atomicity of molecules

For ex: $\text{CH}_4 \rightarrow N=5$

* As a unified body of particles system can do three types of motions.

* Translational degree of freedom =

$$f_{\text{trans}} = 3 \quad \text{for any type of molecules}$$

* Rotational degree of freedom!
(Monoatomic molecules)

$$f_{\text{rot}} = 0 \quad \text{[monoatomic molecules]} \\ \text{Ex: He}$$

$$f_{\text{rot}} = 2 \quad \text{[diatomic molecules or linear polyatomic molecules]} \\ \text{Ex: } \text{O}=\text{O} \\ \text{O}=\text{C}=\text{O}$$

$$f_{\text{rot}} = 3 \quad \text{[non-linear polyatomic molecules]}$$

$$f_{\text{rot}} = 3 \quad \text{[non-linear polyatomic molecules]} \\ \text{Ex: } \begin{array}{c} \text{H}-\text{N}-\text{H} \\ | \\ \text{H} \end{array}$$

* Vibrational degree of freedom!

$$f_{\text{vibrational}} = 3N - (f_{\text{trans}} + f_{\text{rot}})$$

for an Ideal gas $C_{vm} = \frac{f}{2} R$

Here $f = f_{trans} + f_{rot} + 2f_{vib}$

because vibration motion contain kinetic as well as potential energy.

Vibrational degree of freedom activate only at higher temp. So, at normal temp. $f_{vib} = 0$

$f = f_{trans} + f_{rot}$

⇒ Position relation: (γ)

$\gamma = \frac{C_{pm}}{C_{vm}}$

for Ideal gas

$C_{pm} - C_{vm} = R$

$\gamma = \frac{C_{vm} + R}{C_{vm}}$

$\gamma = 1 + \frac{R}{C_{vm}}$

$\gamma - 1 = \frac{R}{C_{vm}}$

$\gamma - 1 = \frac{R}{C_{vm}}$

$C_p - C_v = nR$

$C_{vm} = \frac{R}{\gamma - 1}$

$\gamma = \frac{C_{pm}}{C_{vm}}$

$C_{pm} = \gamma C_{vm}$

$C_{pm} = \frac{\gamma R}{\gamma - 1}$

without considering
vib motion

considering vib
motion

types of molecules	f_{trans}	f_{rot}	f_{vib}	$C_{v,m} = \frac{f}{2}R$	$C_{p,m}$	γ	$C_{v,m}$	$C_{p,m}$	γ
1. mono atomic Ex: He	3	0	0	$\frac{3}{2}R$	$\frac{5}{2}R$	$\frac{5}{3}$ 1.66	$\frac{3}{2}R$	$\frac{5}{2}R$	$\frac{5}{3}$
2. Diatomic Ex: O ₂	3	2	1	$\frac{5}{2}R$	$\frac{7}{2}R$	$\frac{7}{5}$ 1.4	$\frac{5}{2}R$	$\frac{7}{2}R$	$\frac{7}{5}$
3. Linear Poly = CO ₂ atomic Ex: O=C=O	3	2	4	$\frac{5}{2}R$	$\frac{7}{2}R$	$\frac{7}{5}$ 1.4	$\frac{13}{2}R$	$\frac{15}{2}R$	$\frac{15}{13}$
4. non linear Poly atomic Ex: $\begin{matrix} H-N-H \\ \\ H \end{matrix}$	3	3	6	$3R$	$4R$	$\frac{4}{3}$ 1.33	$9R$	$10R$	$\frac{10}{9}$

$\gamma \downarrow$ atomicity \uparrow

Ques: In an Isochoric process heat capacity of a real gas is $1 + 0.02T$ joule/mol.K. In this isochoric process temp. of gas increased from 27°C to 127°C then calculate change in molar internal energy of gas.

Ans:

$$q + w = \Delta U$$

$$T_2 = 400$$

$$n = 1 \text{ mol}$$

$$q = \int n C_{v,m} dT$$

$$T_1 = 300$$

$$Q = \int_{300}^{400} (1 + 0.02T) dt$$

$$Q = [T + 0.01T^2]_{300}^{400} = 800 \text{ Joule.}$$

* Internal Energy^o (U)

This is total energy of system due to all internal factors

Energy due to external factors will not be considered in internal energy. Like
 Ex: 1) Kinetic Energy due to external motion.
 2) Potential Energy due to external field

Ex: Gravitational field

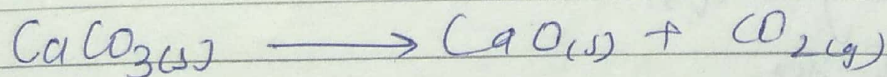
$$U = U_{KE} + U_{PE}$$

Internal Internal

* Exact value of internal energy can not be calculated

From 1st law of thermodynamic change in internal energy can be calculated

$$U_{\text{gas}} \gg \gg U_{\text{liquid}} > U_{\text{solid}}$$



$\Delta U = +ve$

* At constant volume change in internal energy will be equal to heat change in the process.

$$q_v = \Delta U$$

$$q_v = \Delta U$$

* For any substance internal energy will function of
of $U = f(n, P, V, T)$.

For a fixed amount of substance

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

From eq of state one of the term from P, V, T can be expressed in form of other two term.

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

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

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

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

Imp.

* Internal energy of non-reacting ideal gas will be function of Temperature only.

$$U = f(T)$$

Explanation! Let us change volume when keeping its temp const. as temp is constant kinetic energy of gas will not change and potential energy of ideal gas will also not change because there are no attraction and

~~Dmp~~

Repulsion force exist b/w Ideal gas molecules.

→ For a non reacting gas in an Isothermal process change in internal energy $\neq 0$. True

→ For a chemical or phase change reaction occur at const. temp. change in internal energy $= 0 =$ false

During the reaction inter atomic bond dissociate and formed so, value of potential energy will change.

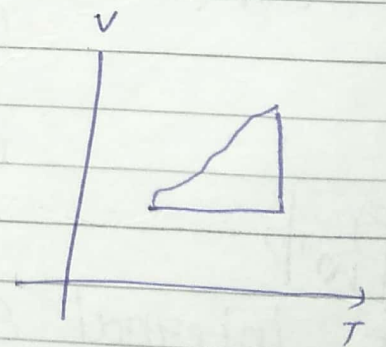
$$T = \text{Const.}$$

$$\Delta U \neq 0.$$

* For internal energy $U = f(V, T)$

$$dU = \left(\frac{\partial U}{\partial V} \right)_T dV + \left(\frac{\partial U}{\partial T} \right)_V dT.$$

$$dU = \left(\frac{\partial U}{\partial V} \right)_T dV + n C_{v,m} dT.$$



* for an Ideal gas

$$U = f(T)$$

$$\Rightarrow \left(\frac{\partial U}{\partial V} \right)_T = 0$$

$$dU = n C_{v,m} dT$$

Valid for non-reacting ideal gas in every process.

~~Ans~~

(ii) For Real gas:

$$du = \left(\frac{du}{dv} \right)_T dv + n c_{vm} dT$$

(iii) For ideal gas in isochoric process

$$du = n c_{vm} dT$$

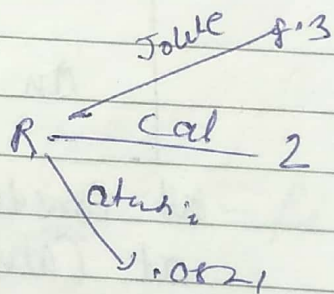
Ques! In a irreversible isochoric process temp. of diatomic gas increase from 27°C to 127°C . Calculate change in molar internal energy for this diatomic gas.

$$= du = n c_{vm} dT$$

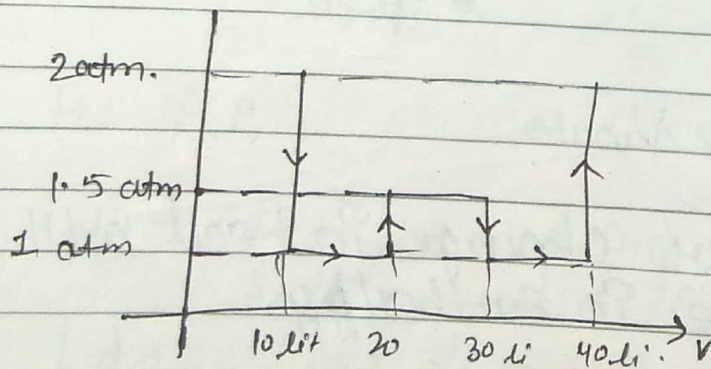
$$\Delta U = n c_{vm} \Delta T$$

$$\Delta U = 1 \left(\frac{5}{2} R \right) (100)$$

$$\Delta U = 250 R$$



For an ideal gas $\gamma = \frac{4}{3}$ calculate change in internal energy in given process (in KJ).



$$c_{vm} = \frac{R}{\gamma - 1}$$

$$\gamma = \frac{4}{3} = \frac{c_{pm} - c_{vm} + R}{c_{vm} - c_{vm}}$$

$$4 c_{vm} = 3 c_{vm} + 3R$$

$$\Delta U = n c_{vm} \Delta T = 3 n R \Delta T$$

$$= 3 (P_2 V_2 - P_1 V_1)$$

$$= 3 (180 - 20) = 180 \text{ atm} \cdot \text{lit}.$$

$$P_1 V_1 = nRT_1$$

$$P_2 V_2 = nRT_2$$

$$P_2 V_2 - P_1 V_1 = nR\Delta T$$

$$\Delta pV = nR\Delta T$$

* Enthalpy :

$$H = U + pV$$

- * Exact value of Enthalpy can not be calculated.
- * But change in Enthalpy can be calculated.

$$\Delta H = \Delta U + \Delta pV$$

or

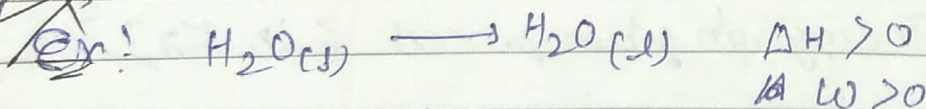
$$\Delta H = \Delta U + P_2 V_2 - P_1 V_1$$

at Const. Pressure = $\Delta H = \Delta U + p\Delta V$

at Const. vol. = $\Delta H = \Delta U + V\Delta P$

$H_{\text{gas}} \gg \gg \gg H_{\text{liq.}} > H_{\text{solid}}$

~~Ex:~~



$V_{\text{ice}} > V_{\text{water}}$

*

At constant pressure change in heat will be equal to change in enthalpy.

$$dq + w = du$$

$$dq - PdV = du$$

$$dq = PdV + du$$

$$\boxed{dq_p = dH}$$

* for any substance $H = f(n, P, V, T)$

If amount of substance is constant

$$H = f(P, V, T)$$

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

$$H = f(P, V)$$

$$H = f(P, T)$$

* for non reacting ideal gas: $H = f(T)$.

Explanation:

$$H = U + PV$$

$f(T)$

$$\left(\frac{\partial H}{\partial P} \right)_T = 0$$

$$H = U + nRT$$

$f(T)$

$$\left(\frac{\partial H}{\partial V} \right)_T = 0$$

$$H = f(P, T)$$

$$dH = \left(\frac{\partial H}{\partial P} \right)_T dP + \left(\frac{\partial H}{\partial T} \right)_P dT$$

$$\boxed{dH = \left(\frac{\partial H}{\partial P} \right)_T dP + nC_p dT}$$

* For a non-reacting ideal gas:

$$\boxed{dH = n c_{p,m} dT}$$

→ valid for non-reacting ideal gas in every process

* For a real gas:

$$dH = \left(\frac{\partial H}{\partial P} \right)_T dP + n c_{p,m} dT$$

* For a real gas in a isobaric process:

$$\boxed{dH = n c_{p,m} dT}$$

* Relation b/w ΔH and ΔU for a real gas Reaction:

$$H = U + PV$$

Temp: Const.

$$\Delta H = \Delta U + \Delta PV$$

$$\boxed{\Delta H = \Delta U + \Delta n g R T}$$

non-reacting ideal gas $\Delta H = \Delta U + \Delta PV$ reacting ideal gas

$$\leftarrow \Delta H = \Delta U + n R \Delta T$$

$$\Delta H = n C_{v,m} \Delta T + n R \Delta T$$

$$\Delta H = n (C_{v,m} + R) \Delta T$$

$$\boxed{\Delta H = \Delta U + \Delta n g R T}$$

$$\boxed{\Delta T = n c_{p,m} \Delta T}$$