First week:

Physical Chemistry

Chapter One . (Gaseous State)

There are two types of gases

1-IdeaL gases

2- Non – IdeaL or real gases

1-IdeaL gases : ideal gases are obeys gas laws such as BoyLes law and Charles law at all temperatures and pressure .

2- Areal gases : areal gases obeys these law only at law pressure and high temperature .

Equation state :

The state of a fluid depends on the volume , pressure ,and temperature if the effect of the gravitational and external electric and magnetic fields are neglected .
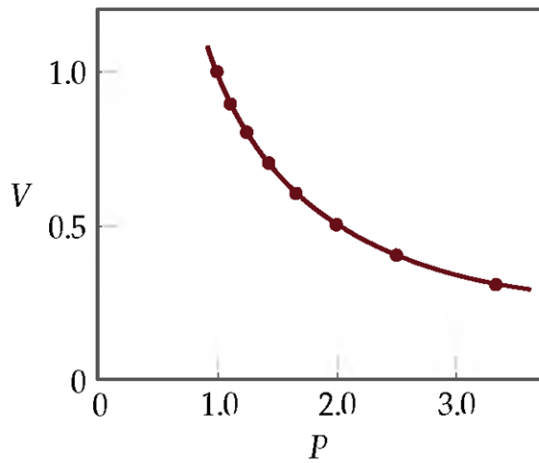
P= f (V,T)   equation of state

Boyles Law : this law given by Robert Boyle in 1662 at constant temperature , the volume of a given quantity of a gas varies inversely as pressure on the gas .
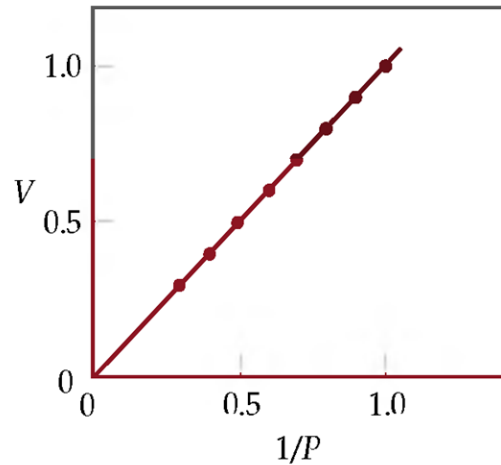
v α 1/ p

At constant Temperature .

PV = cons . = K

(a)

(b)

- At constant temperature and a quantity of gas :
- $P_1 V_1 = P_2 V_2 = K$

Charles or Gay- Lussaces Law :

Charles observed at 1787 that :

1- At constant pressure the volume of any gas expanded by the same fraction of its initial volume at 0 °C for every one degree centigrade rise in temperature .

$v \alpha$ T $\qquad \frac{V}{T} = \text{cons}$.

Gay –Lussac in1802 found that for each degree rise in temperature, the volume of the gas increased by approximately 1/ 273 of the volume of gas at0 °C.

2- Constant volume , the pressure of any quantity of any gas is proportionl with temperature .

P αT

P / T = cons.

- At constant pressure

- $\dfrac{V2}{V1} = \dfrac{T2}{T1}$

At contant volume

- $\dfrac{P2}{P1} = \dfrac{T2}{T1}$

- Or $\dfrac{P1V1}{T1} = \dfrac{P2V2}{T2}$

-

General gas Law:

For any definite quantity of gas obeying Boyles and Charles :

PV α T

pV_m α T pV_m / T = cons . V_m = molar volume

PV =n RT

H.W / Prove the general (ideal) gas law .

H.W / Prove that the R = 0.082 L.atm .mol^{-1} .K^{-1} .

$$= 8.3 \text{ J. } mol^{-1} .K^{-1} .$$

$$= 1.982 \text{ cal . mol}^{-1}.\text{K}^{-1}.$$

<u>Dalton Law and Partial Pressures of gases :</u>

- For A gas , n_A moles in V volume , according for ideal gas equation :
- $P_A = n_A \ (RT/ V)$
- $P_B = n_B \ (RT/V)$
- $P_t = P_A + P_B = (n_A + n_B) \ (RT/V)$
- $P_j = n_j \ (RT / V)$ …………(1)
- $n_t = n_A + n_B + …..$
- $X_j = n_j / n$

The equation (1) become .

$P_j = n_j \ (RT /V) = X_j \ (n \ RT /V) = X_j \ P .$

H.W / Prove that the $\quad P_j = X_j \ P.$

<u>Grahames Law of Diffusion</u> .

At constant pressure and temperature , the rate of diffusion of any gas is inversely proportional to the square of the density or the molecular weight of the gas .

$$\frac{r_1}{r_2} = \frac{\sqrt{d_2}}{\sqrt{d_1}} \qquad \textbf{or} \qquad \frac{r_1}{r_2} = \frac{\sqrt{M_2}}{\sqrt{M_1}}$$

EX: A system of gases enclosed in asteel cylinder it contains (125g) of O_2 , (52g) of nitrogen and (0.002)kg of H_2 at standard condition . Calcutate :

a) The volume of the cylinder .

b) Partial pressure of each gas .

a) $n_{O_2} = \dfrac{126}{32} = 3.93 \text{mole}$

b) $n_{H_2} = \dfrac{2}{2} = 1 \text{mole}$

c) $n_{N_2} = \dfrac{52}{28} = 1.85 \text{ mole}$

PV =n RT , $V = \dfrac{nRT}{P} = \dfrac{6.7 * 0.082 * 273}{1} = 151.93 \text{ L}$

b) $x_{O_2} = \dfrac{3.93}{6.78} = 0.579$

$x_{N_2} = \dfrac{1.85}{6.78} = 0.272$

$p_{O_2} = x_{O_2}\, p_t = 0.579 * 1 = 0.579 \text{ atm}$

$p_{N_2} = x_{N_2}\, p_t = 0.272 * 1 = 0.272 \text{ atm}$

$p_{H_2} = x_{H_2}\, p_t = 0.147 * 1 = 0.147 \text{ atm}$

EX : what is the relative rate of diffusion for H_2 molcules compared to those of O_2 at the same temperature .

$$\frac{r_{H2}}{r_{o2}} = \frac{\sqrt{M_{H2}}}{\sqrt{M_{o2}}}$$

$$\frac{r_{H2}}{r_{o2}} = \frac{\sqrt{32}}{\sqrt{2}} \qquad =4$$

اذن جزئيات الهيدروجين تنتشرا اسرع باربعة مرات من جزئيات الاوكسجين .

second week :

The kinetic of ideal Gases :

The kinetic theory of gases , first proposed by Bernoulli (1738) and subsequently developed by Claudius , Clark , Maxwell , Boltzmann Vander Waals and others .

-The essential postulates of kinetic theory of ideal gases are :

1. Every gas consists of a very large number of ting solid particles called molecules .
2. The molecules of gas within a container are in a state of constant rapid motion in all possible directions . They trail in straight lines until on collision with another molecule or with the walls of the container the direction of motion is changed .

3. The pressure of a gas on any surface is the result of continuous bombardment on the surface by its molecules . Pressure increase and volume decrease at constant temperature , Pressure increase and temperature decrease at constant volume .

4. The collisions of the molecules with each other and the walls of the container are perfectly elastic and there is no loss of kinetic energy resulting from their collisions .

5. The absolute temperature of a gas is measure of the average kinetic energy of all the molecules present in it and is directly proportional to it .

6. There is no effect of gravity on the motion of the molecules of a gas.

7. The molecules are very small as compared to the distances between them.

Consider a cubical vessel each side (L) with perfectly elastic wall containing a very large number of molecules (n´), (m) the mass of each molecule ,(u) is the velocity . (the velocity taken here is known as the mean square velocity).

$$U^2 = U^2_x + U^2_Y + U^2_Z$$

The molecules strikes the face (A)with velocity (U_X) and momentum (mu_x) .

After striking , velocity $(-U_X)$ and momentum $(-m\ U_X)$ in the back direction .

Change in momentum is :

$\Delta S = m\ U_X - (-\ m\ U_X) = 2mU_X$

The time taken by the molecules to go to the other side and the to come back
= $2L / U_X$.

The number of impacts with the wall A per second is :

= $U_X / 2L$

The force f = change in momentum x number of impacts

$f_x = (2mU_X)(U_X / 2L) = mU^2_X / L$ to the face A and

$f_x = mU^2_X / L$ to the face A′

The $f_x = 2mU^2_X / L$ for X - direction

The $f_Y = 2mU^2_Y / L$ for Y - direction

The $f_x = 2mU^2_Z / L$ for Z - direction

The total force $f = 2mU^2_X / L + 2mU^2_Y / L + 2mU^2_Z / L$

$$= 2m / L \ (U^2_X + U^2_Y + U^2_Z)$$

$$= 2m \ U^2 / L$$

For n′ molecules :

$f = 2mn′ \ U^2 / L$

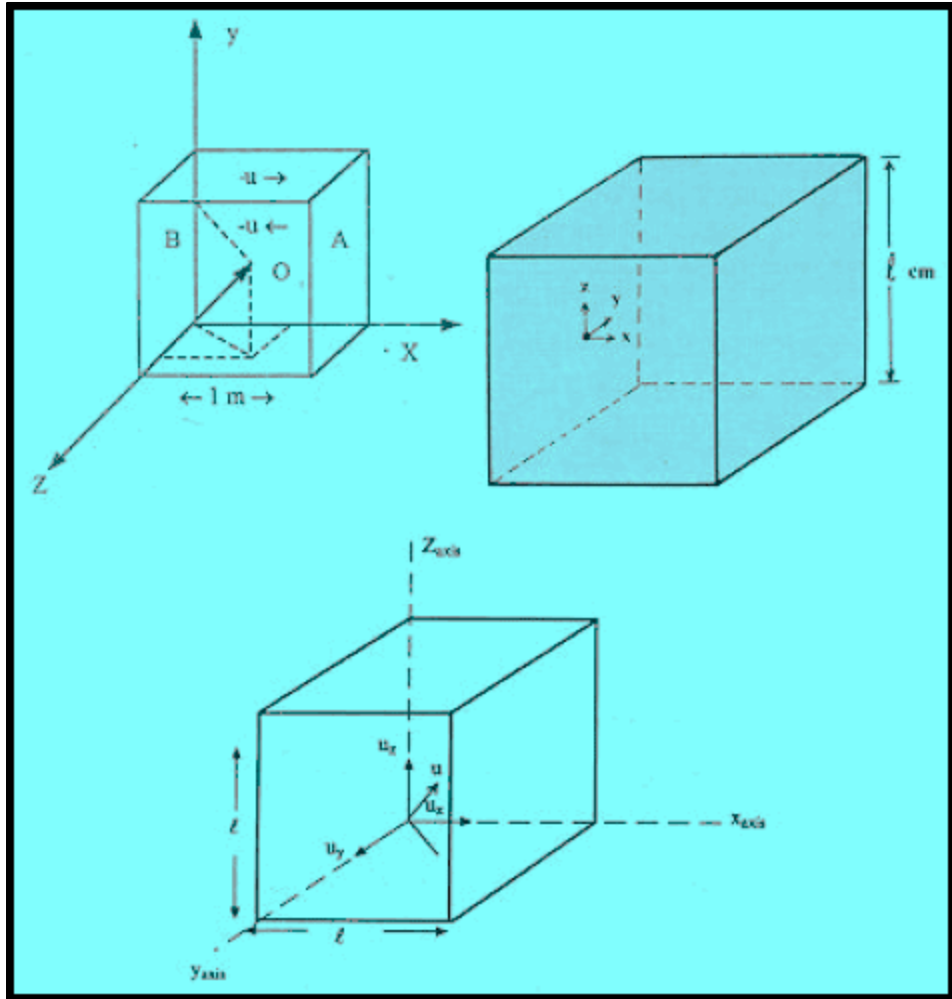$P = f / A$

$= 2mn′ \ U^2 / LA$

The total area the wall = $6 L^2$

$$P = m \, n' \, U^2 / 3L^3$$

The volume of the cube $= L^3$

$$P = m \, n' \, U^2 / 3V$$

or $PV = m \, n' \, U^2 / 3$ for cubic vessel .

Third week :

Deduction Of Gas Laws From Kinetic Theory :

1- Boyles Law :

According to postulate (5) the kinetic energy for (n´) molecules $(\frac{1}{2} m n´ u^2)$ is directly proportional to the absolute temperature

$$(\frac{1}{2} m n´ u^2 \; \alpha \; T)$$

$$(\frac{1}{2} m n´ u^2 = K T) \qquad K = constant$$

$$\frac{3}{2} (1/3 \; m n´ u^2 = K T)$$

$$\frac{1}{3} (m n´ u^2 = 2/3 \; K T)$$

$$PV = \frac{2}{3} \; KT \qquad = constant \qquad if \quad T \; constant$$

2- Charles Law :

From above $PV = \frac{2}{3} \; KT$

or $V = \frac{2}{3} \; (K / P)T$

$V \; \alpha \; T$ if p constant .

3- Avogadro's Law :

Equal volume of two gases under similar condition s of temperature and pressure condition equal number of molecule

$$P_1 V_1 = \frac{1}{3} \; m_1 n_1´u_1^2 \qquad and \qquad P_2 V_2 = \frac{1}{3} \; m_2 n_2´u_2^2$$

if P and V of two gases are equal

$$P_1 V_1 = P_2 V_2$$

$$\frac{1}{3} \, m_1 \, n_1' \, u_1^2 \quad = \quad \frac{1}{3} \, m_2 \, n_2' \, u_2^2 \quad \text{------------(1)}$$

The two gases are at the same temperature

$$\frac{1}{2} \, m_1 \, u_1^2 \quad = \quad \frac{1}{2} \, m_2 u_2^2 \quad \text{----------(2)}$$

$$K = \frac{1}{2} \, m_1 \, U_1^2 \quad \text{kinetic energy} .$$

From equation (1) and (2)

$$n_1 \quad = \quad n_2$$

4 - Grahams Law of Diffusion .

$$PV \; = \frac{1}{3} \, m_1 \, n' \, u^2$$

$$u^2 \; = \; \frac{3 \, PV}{m \, n'}$$

$$d = \frac{m \, n'}{V'}$$

$$u^2 = \frac{3 \, P}{d} \qquad \text{or} \qquad u = \sqrt{\frac{3 \, P}{d}}$$

$$u \; \alpha \; \sqrt{\frac{1}{d}} \qquad \text{if pressure is constant}$$

For two gases at constant volume and pressure

$$\frac{1}{3} \, m_1 \, n_1' \, u_1^2 \quad = \quad \frac{1}{3} \, m_2 \, n_2' \, u_2^2$$

$$u_1^2 \; / \; u_2^2 \; = m_2 \, n_2' \; / \; m_1 \, n_1'$$

$$u_1 \; / \; u_2 \; = \sqrt{(\, m_2 \, n_2' \; / \; m_1 \, n_1' \;)} \; = \; \sqrt{(M_2 \; / \; M_1)}$$

$$n_2' = n_1' \; = N \quad \text{(Avogadro number)}$$

at constant temperature and pressure , the two gases will have the same molar volume

$$u_1 / u_2 = \sqrt{(d_2 / d_1)}.$$

5- Daltons Law of Partial pressure :

$$PV = \frac{1}{3} m_1 n' u^2$$

$$P_1 = \frac{1}{3V} m_1 n_1 ' u_1^2$$

$$P_2 = \frac{1}{3V} m_2 n_2 ' u_2^2$$

$$P_3 = \frac{1}{3V} m_3 n_3 ' u_3^2$$

If there gases are forced together in another flask of the same volume and the same temperature , the total pressure (p) is give by .

$$P = \frac{1}{3V} m_1 n_1 ' u_1^2 + \frac{1}{3V} m_2 n_2 ' u_2^2 + \frac{1}{3V} m_3 n_3 ' u_3^2$$

$$P = P_{1+} P_{2+} P_3 \qquad \text{Daltons Law}$$

$$PV = \frac{1}{3} m n' u^2 = n RT$$

$$n' = n N$$

$$PV = \frac{1}{3} n(m N) u^2 \ n RT$$
Where N = Avogadro s number

$$PV = n M u^2 / 3 = n RT$$
Where M = Nm.

H.W Prove that the $u = \sqrt{\frac{3pv}{M}}$, $u = \sqrt{\frac{3p}{d}}$, $u = \sqrt{\frac{3RT}{M}}$

By using kinetic theory of gases where u = velocity of molecules .

Fourth week:

Real Gases :

Deviation from ideal behaviors .
A gas is said to be an ideal gas if it obeys the various gas law ,
expressed in the form of equation (PV = n RT) . Actual behaviors of
various gases , it is found that very few gases obey the ideal gas
equation only at law pressures and high temperature . however , at
high pressures and low temperature marked deviation from the ideal
behaviour have been observed .

- To illustrate how much a gas deviates ideal gas behaiour ,
  consider (PV = n RT)
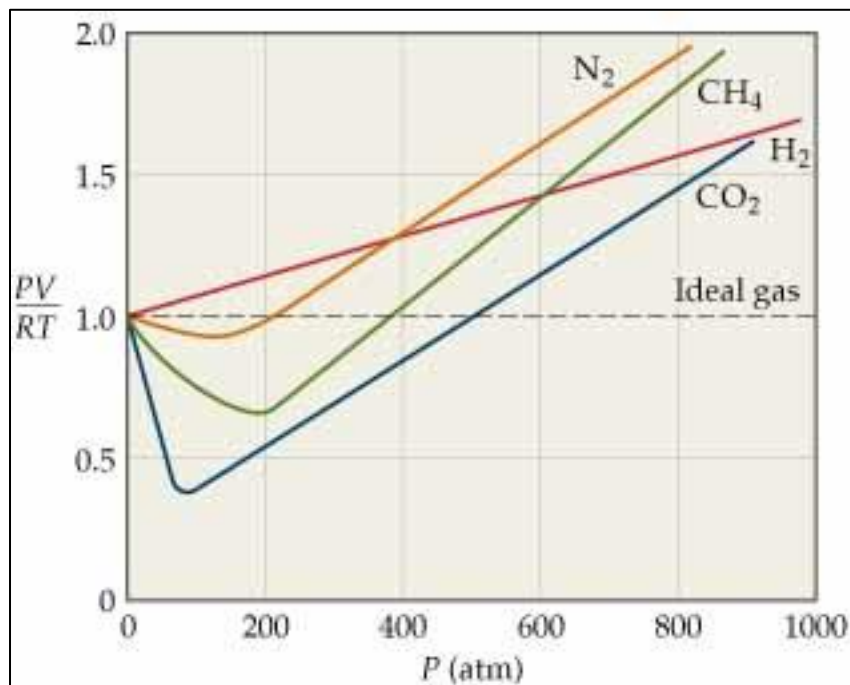
Type One / The curve from the value of PV and value PV increases continually with increases pressure . this type of curve is obtained for various gases having smaller molecules , H_2, H_e .

Type two / The curve from the value of PV and value PV decreases in the beginning ,passes through a minimum and then begins to increase with increasing pressure . this type of curve is generally obtained for gases having Larger molecules , O_2 CO_2.

مقدار الانحرافات عن المثالية فيقاس بواسطة عامل الانضغاطية (compression facter)

$Z = P V / RT$

For ideal gas z =1 and is independent of pressure and temperature .

For real gas Z is a function of both temperature and pressure and its s value varies

Modification of the Ideal Gas Equation :

1 - the attraction face between the molecules give to touch them near and this the measured pressure less than the ideal pressure .

2 – the v that occupied by a gas is b and the volume for n molecules is (nb) , and the volume in the ideal equation be (v –nb).

If (v) is the volume occupied by (n) moles of the gas then both these two factors and hence the correction term (p´) is directly proportional to (n^2 / v^2) .

$p´ \alpha n^2 / v^2$

$p' = a\,n^2 / v^2$

$p_j = p + a\,n^2 / v^2$

where a = constant characteristic of each gas .

p_j = ideal pressure

if $(p + a\,n^2 / v^2)\,(v - nb) = n\,RT$ Vander – Waals eq .

$(p + a / v^2)\,(v - b) = n\,RT$, for one mole of a gas .

Specific Heat of Gases :

The amount of heat in calories required to rise the temperature of one gram of the substance through 1°c for one mole .

Molar heat capacity = Molecular weiht * specific heat

The T↑ at constant volume → ↑ enternal energy of the gas which is due to the kinetic energy of the motion of the molecules and no work will be done . cv

If the gas heated at constant pressure , the energy supplied not only ↑ the internal energy of the gas molecules but also some work in the expansion of the gas against the constant external pressure . cp

For solid and liquids , the difference between the two heat capacities is very small and negligible because the effect of heat on volume is very small . but in case of gases ,effect of heat on volume is very high .

The translational energy ($E_k = 3/2\ RT$)

E_k = internal rnergy of the gas at temperature T.

If the temperature raised by 1 ℃ from (T) to (T + 1) .

 The internal energy = 3/2 R (T+ 1)

$\Delta E = 3/2\ R(T + 1) - 3/2\ RT$

$\Delta E = 3/2\ R = C_v$

لان الحرارة المسلطة للغاز لمول واحد بثبوت الحجم سوف يزيد الطاقة الحركية بمقدار 1 درجة مئوية من انجاز الشغل .

Suppose one of the gas is heated at constant pressure in acy linder the heat increase E_k, but will also do external work through the expansion .

 $W= P\ \Delta V$

$C_P = C_V + W$

$C_P = C_V + P\ \Delta V$

For one mole of an ideal gas .

$P\ \Delta V = R\Delta T$

$\Delta T = 1$

$P\ \Delta V = R$

$C_P = C_V + R$

$C_V = 3/2\ R$

$C_P = 5/2\ R$

$\gamma = C_P\ /\ C_V$

fifth week :

Phase Equilibria :

The phase rule is a generalization which seems to explain the equilibrium existing between the heterogeneous system and was theoretically deduced by Willard Gibbs in 1876 .

$F + P = C + 2$

F = number of degree of freedom

P =   number of phases

C = number of components

Phase : is defined as any homogeneous and physically distinct part of a system which is separated from other parts of the system by definite boundary surfaces .

 Ex:

1) Liq.H_2O + vap. H_2O.
2) Mohr´s salt $FeSO(NH_4)\ SO_4 . 6\ H_2O$.
3) 2 imiscible Liq. are one phase .
4) 2 immiscible Liq. are two phase (benzene + H_2O)

Component :
The number of components of a system at eq. is the smallest number of independently variable constituents by means of which the composition of

each phase can be expressed either directly in the from of chemical equation
.

Ex:

1) Water sys. Three phases (ice , Liq , vap) the composition .
   Of each is $H_2O \rightarrow$ 0ne component system .
2) Sulphur sys. Four phases (rhombic , monoclinic , Liq . , vap)
3) Acetic acid .
   Ex/
   $Ca\ CO_3\ (s) \leftrightarrow Ca\ O + CO_2\ (g)$

- Three phases .
- Two components . $(Ca\ CO_3 + Ca\ O\ ,\ Ca\ CO_3 + CO_2\ )$
- The composition of (3) phases expressed by :

- $Ca\ CO_3 + Ca\ O\ ,$

- $Ca\ CO_3 + CO_2$

- Ex /
- $CuSO_4 . 5H_2O \leftrightarrow CuSO_4 . 3H_2O\ (s)\ + H_2\ (g)\ .$

- Three phases

- Two comonents . ($CuSO_4 . + H_2O$)

- Ex /

- $Fe\ (s)\ + H_2O\ (g) \leftrightarrow Fe\ O(s)\ +\ H_2(g).$

- Four phases .

- Three components . $(Fe + H_2O\ + H_2\ ,\ Fe\ O + H_2O +\ H_2)$

Degree of freedom (variance).:

- the number of degree of freedom or variance of asystem is the number of variable factors such temp. , pressure , or conc.

Which must be specified in order to define the system completely .

Ex :

-H_2O gas (one phases sys. →to define (temp . + pressure)the system has (2) degree of freedom (bivariant)

-ice + Liq H_2O(2 phase sys.) . →to define (temp . + pressure)the system has (2) the system has (1) degree of freedom (univariant)

- ice + Liq H_2O+ vap. H_2O (3 phase sys.) . →to define (no degree of freedom) .

 Because the three phases can co – exist in eq. only at particular tem . and pressure which are automatically fixed . (invariant).

Determination of degrees of freedom without phase rule :

Ex: gas system (one phase , one component) .

$F + P = C + 2$ or $F + P = C + 2 - P$

$F = 1+2-1 = 2$

$f (P ,T .C)= 0$ $F = V – E$

V = variables

E= equation s

$F = 3-1 = 2$

Ex : H_2O+ vap. H_2O (two phases , one component)

 $F = C+2-P$

$F = 1+2-2 = 1$

$f_L (P,T.C_l)= 0$

$f_v (P,T.C_v)= 0$

for each phase $F = 2$

$M^L_{H2O} (P,T.C_v)= M^V_{H2O} (P,T.C_v)$ $M =$ Chemical potential

$F= V -E$

$F= 4-3$ $= 1$

Ex:

- ice + Liq H_2O+ vap. H_2O (3 phase, one component)

$F = C+ 2 - P$

$F = 1+2- 3= 0$

$f (P,T.C_i)= 0$

$f (P,T.C_l)= 0$

$f (P,T.C_v)= 0$

$M^i_{H2O} = M^L_{H2O}$, $M^L_{H2O} = M^v_{H2O}$

$F = V -E$

  $= 5-5 = 0$

EX : Homogeneous solution of sugar in . H_2O

$F = C+ 2 - P$

  $= 2+ 2-1 =3$

$f (T,P.C_{H2O}, C_{sug.})= 0$

$F= V-E$

  $= 4-1 =3$

Sixth week :

Free energy function :

Entropy is a measure of unavaiable energy . when entropy is multiplied by a bsolute temperture the product (TS) is equal to the amount of heat (energy) which is not free to be used for useful work . then the total heat absorbed by a system the amountless by (TS) must be the available amount of heat which can be put for useful work . thus free energy (x) can be expressed as :

$X = q - TS$

Then the (q) may be repllaced either by (E) or (H)

The free energy would be equal to (E- TS) or (H- TS).

$A = E - TS$ A = Helmholtz free energy

$G = H - TS$ G = Gibbs free energy

$\Delta A = nR \, Ln \; \dfrac{v_1}{v_2}$

$\Delta A = nR \, Ln \; \dfrac{P_2}{P_1}$

$\Delta G = nR \, Ln \; \dfrac{v_1}{v_2}$

$\Delta G = nR \, Ln \; \dfrac{P_2}{P_1}$

$\Delta G = \Delta H - T \Delta S$ for isothermal and isobaric change

Solution :

Type of solution .

1) G- G   (mixture of gases , air)
2) G- L   (NH_3 in H_2O , aerated water)
3) G- S   (H_2 in pd)
4) L – G   (vaporization of a liquid into a gas)
5) L-L   (H_2O in ethanol)
6) L-S   (liquid benzene in solid into a gas)
7) S – G   (sublimation of a solid into a gas)
8) S – L   (sugar in H_2O)
9) S – S   (pb in Ag , Cu in Ni)

Modes of expressing composition (concentration) of solution s:

Ex :

B → A

   1) Weight per cent   %B = $\frac{WB}{WA+WB}$ *100

   2) Weight ratio   = $\frac{WB}{WA}$

   3) Volume percent   %B(volume) = $\frac{vB}{v}$ *100

   4) Molarity (M)   M = $\frac{Wt}{M.Wt}$ *100/ v(mL)

   5) Normality (N)   M = $\frac{Wt}{eq.Wt}$ *100/ v(mL)

   6) Formality (F)   M = $\frac{Wt}{F.Wt}$ *100/ v(mL)

7) Molarliy (L) $\qquad$ $L = \dfrac{no.moles}{solv.(kg)}$

8) Mole fraction (x) $\qquad$ $X_A = \dfrac{nA}{nA+nB}$

$$X_B = \dfrac{nB}{nA+nB}$$
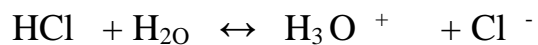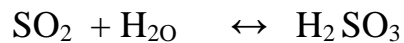
$X_A + X_B = 1$

Solution of gases in Liquids :

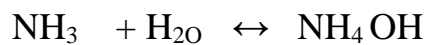Most of gases are easily soluble in (H_2O) forming true solution .(O_2 in H_2O)

Gas in aliquid is an two component system :

$F + P = C+2$

$F + 2 = 2+2$

$F = 2$

$NH_3 + H_2O \leftrightarrow NH_4 OH$

$CO_2 + H_2O \leftrightarrow H_2 CO_3$

$SO_2 + H_2O \leftrightarrow H_2 SO_3$

$HCl + H_2O \leftrightarrow H_3 O^+ + Cl^-$

seventh week :

The gases can be easily Liquified are fairly soluble in solvent

The gases cannot be easily Liquified are least soluble in solvent

Effect of (T) on solubility :

According to Le- Chatelier principle , solubility of a gas in a liquid will decrease with rise of temperature

(except of H_2, O_2 and the inert gases

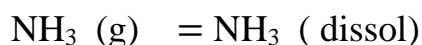Effect of (p) on solubility . (Henry´s law)

(Henry´s law) At constant temperature the mass of a gas dissolved in a unit volume of a liquid is directly proportional to the pressure of the gas above the liquid at eq.
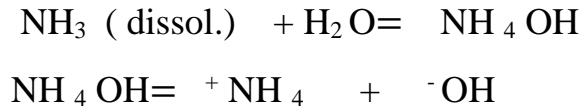
m α p

m= k p   k= Henrys constant

It has been abserved that for the (strict applicability of Henrys law)

1) (T) should be high
2) (p) should be low
3) No chemical reaction should taken

$HCL (g) = HCL (dissol)$

$HCL (dissol) + H_2O = H_3O^+ + CL^-$

$NH_3 (g) = NH_3 (dissol)$

NH_3 (dissol.) $+ H_2O=$ NH_4OH

$NH_4OH=$ $^+NH_4$ $+$ ^-OH

Henry´s law and Raoult´s law:

$m = kp$-------- (1)

$m = w_2/w_1$ $w_2/w_1 = k'p_2$ -------- (2)

p = eq . pressure

p_2 = vapor pressure of avolatil solute

w_2 = weight of gas

w_1 = weight of solvent

$$\frac{\frac{w_2}{M_2}}{\frac{w_1}{M_1}} = k'p_2 \quad \text{-------- (3)}$$

$$\frac{n_2}{n_1} = k'p_2 \quad \text{-------- (4)}$$

If the gas has very little solubility :

$$\frac{n_2}{n_1} == \frac{n_2}{n_1+n_2} \quad \text{-------- (5)}$$

$$\frac{n_2}{n_1+n_2} = x_2 = k''p_2$$

In dilute solution , the $p_2 \alpha x_1$

If $p°_2$ is the pressure of the pure solute


$1 = k'p_2$ if $x_2 = 1$

eitghth week :

Therodynamics :

System / a thermodynamics . sys. is the part of the physical universe to which we direct our attrention for the purpose of experimental or theoretical investigation .

Surroundings / the surrounding are the remainder of the universe which can in any way effect or can be effect by the system .

**Boundary** / the space separating the system from the sourrunding
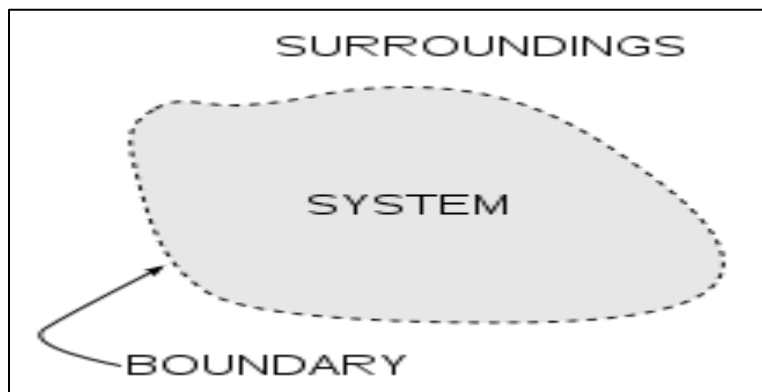
System :

Aclosed sys. : It is a sys . enclosed by impermeable walls in this sys. the mass ermains constant but the energy may change $(dM = 0$, $d E \neq 0)$.

Anopen sys. : It is a sys . enclosed by impermeable walls that can exchange both the energy and the matter with the surrounding across the boundary (dM ≠ 0 , d E≠ 0) .

Anisolated sys. : It is a sys . enclosed by rigid , adiabatic walls and not acted up on by any external force field . (dM= 0 , d E= 0)
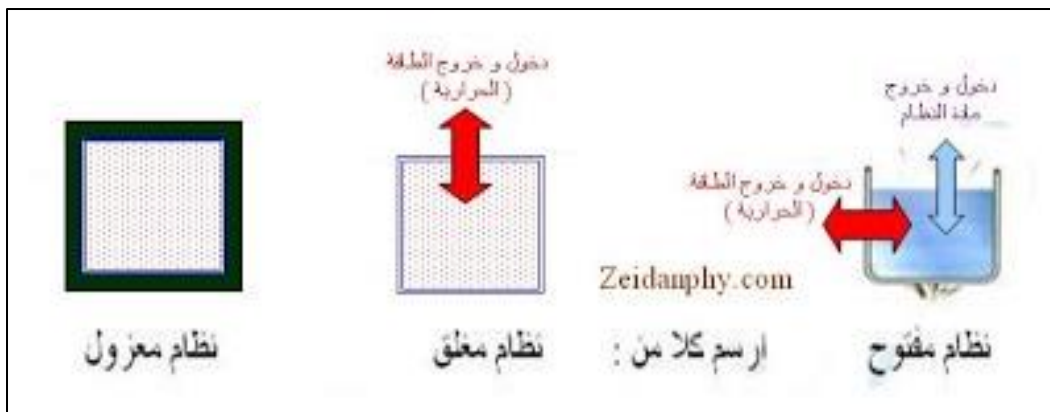
Process:

Isothermal process : when the temp. of the system is kept constant during various operation then the process said to be isothermal .

Adiabatic process: there is no exchange of heat between the system and sourrounding and (Q) is zero . thus in Adiabatic process there is always a change in temp.

Isobaric process : when the pressure of the system . remains constant during the period of the change .

Cylic process : If a sysytem having undergone a change returns to initaial state then procss is called cyclic process.

Reversible process: when the process acc urs in such away that the properties of the system . at every instant process is one which porcessds through a succession of eq. Step, each of which is an eq. state

Irreversible process : If the change is produced rapidly and the sysytem . doesnot have to a change to attion eq. then the process called irreversible all natural process are irreversible and hence spontaneous.

ninth week :

First Law of thermodynamics :

Matter cantain energy . the first law is based on the observation that energy can neither be created nor destroyed , the total energy of system is conserved .

- The change in internal energy (ΔE) in any sysytem is the difference between the heat entering the sysytem . (q) and the work done by sysytem (W). the internal energy of an isolated sysytem is constant and $q = w = 0$

$d E = d q - dw$

Reversible and Irreversible process(work):

1) $P_{int} > P_{ext}$ (expansion work against P_{ext})

2) $P_{int} < P_{ext}$ (expansion work against P_{int})

3) $P_{int} = P_{ext}$ (equ. Reversible work of expan)

d w= F d h = $(P_{ext}$ dv) $(P_{int}$ - d p) dv $\cong$ P_{int} d v

because dp dv is very small .

Reversible work : Reversible process are of great importance because they yeild maximum amount of work which may be obtained from a given net change .

d w = (p –dp) d v

dw = pdv – dpdv

dw = pdv

$\int dw = \int_{v_1}^{v_2} pdv$

$W_{rev} = \int_{v_1}^{v_2} pdv$

PV= nRT

$W_{rev} = \int_{v_1}^{v_2} \frac{nRT}{V} dv$

$W_{rev} = \int_{v_1}^{v_2} \frac{nRT}{V} dv$

$W_{rev} = nRT \ Ln \frac{V_2}{V_1}$ isothermal revrsible

$\frac{V_2}{V_1} = \frac{p_2}{p_1}$ or $p_1 \ v_1 = p_2 v_2$

$W_{rev} = nRT \ Ln \ \frac{p_1}{p_2}$

 Heat contents (Enthalpy)   **. Heat change at constant p).**

H = E + PV

$\Delta H = \Delta E + \Delta(PV)$

$\Delta H = \Delta E + P\Delta V + V\Delta P$

$\Delta H = \Delta E + P\Delta V$ because $\Delta p = 0$ (p is constant) from first Law of thermodynamic

$\Delta H = q_p$

Heat change at constant V.

$\Delta E = q - w$ (from first Law)

$q = \Delta E + w$

$q = \Delta E + p\Delta v$

$q_{(v)} = \Delta E$ because $\Delta V = 0$

Heat capacity of ideal gases .

Heat capacity / is a heat required to raise the temp. of the sysytem by one degree .

$C = \frac{\partial q}{\partial T}$

$C_V = (\frac{\partial q}{\partial T})_V$

$q = \Delta E + p\Delta v$

$q_V = \Delta E$ where $v = 0$ (constant)

$C_V = (\frac{\partial E}{\partial T})_V$

$C_V = (\frac{\partial E}{\partial T})_V$ for ideal gases

$C_p = (\frac{\partial q}{\partial T})_p$

$\Delta H = q_p$

$C_p = (\frac{\partial H}{\partial T})_p$

$C_p = (\frac{\partial H}{\partial T})$ for ideal gases

$C_P - C_V = (\frac{\partial H}{\partial T})_p - (\frac{\partial E}{\partial T})_V$ ---------(1)

H = E – PV

$$\left(\frac{\partial H}{\partial T}\right)_p = \left(\frac{\partial E}{\partial T}\right)_P + P\left(\frac{\partial V}{\partial T}\right)_p \quad ---------(2)$$

Sub . (2) in (1)

$$C_P - C_V = \left(\frac{\partial E}{\partial T}\right)_p + P\left(\frac{\partial V}{\partial T}\right)_P - P\left(\frac{\partial E}{\partial T}\right)_V$$

ربط الحد الاول والاخير بعلاقة رياضية تقوم : E= f (T,V)

$$E = \left(\frac{\partial E}{\partial T}\right)_V dT - P\left(\frac{\partial E}{\partial V}\right)_{dv} \quad --------(4)\text{ نقسم معادلة (4 على}dT\text{ بثبوت الضغط}$$

$$\left(\frac{\partial E}{\partial T}\right)_p = \left(\frac{\partial E}{\partial V}\right)_T \left(\frac{\partial V}{\partial T}\right)_p + \left(\frac{\partial E}{\partial T}\right)_V \quad ---------- (5)$$

وبتعويض 5 في 3 يعطي :

$$C_P - C_V = \left(\frac{\partial E}{\partial V}\right)_T \left(\frac{\partial V}{\partial T}\right)_P + P\left(\frac{\partial V}{\partial T}\right)_P \quad ------- (6)$$

وبنفس الطريقة اعتمادا على

H= f (T, P)

نكتب H= f (T, V) مثل

$$C_P - C_V = \left(\frac{\partial P}{\partial V}\right)_V \left[\left(\frac{\partial H}{\partial T}\right)_{T-V}\right] \quad ---------(8)$$

)الغرام مول واحد من غاز مثالي يكون

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

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

One mole of ideal gas has   PV = n RT

اشتقاق ر هذه المعادلة نسبة الى درجة الحرارة بثبوت الضغط يكون: $\quad \frac{V}{T} = \frac{R}{P}$

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

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

$$C_P - C_V = R$$

tenth week :

Irreversible work :

$$w = \int_{v_1}^{v_2} p \, dv$$
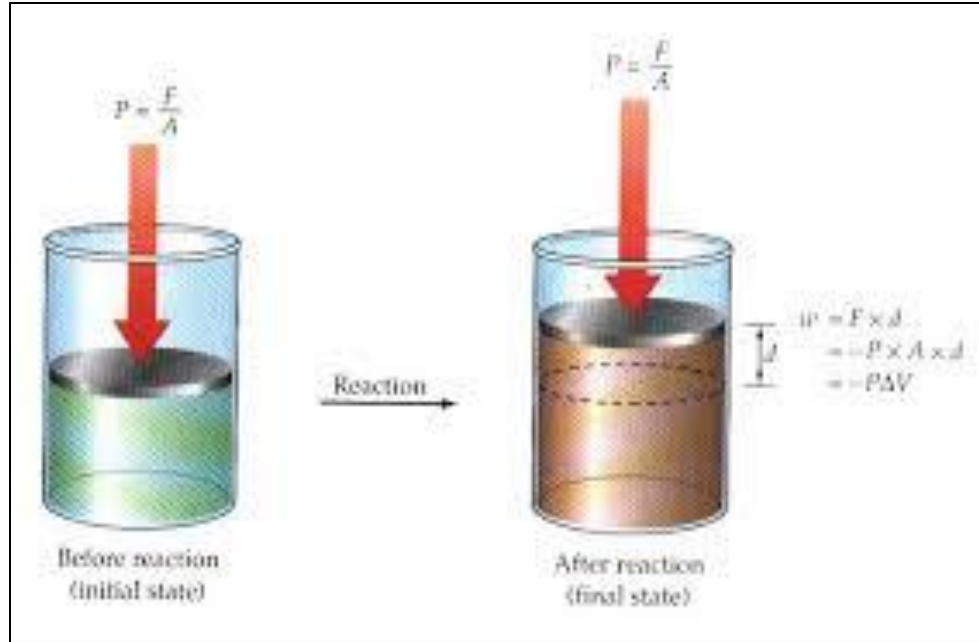
$$w = \int_{v_1}^{v_2} p_2 \, dv$$

$$w = p_2 \int_{v_1}^{v_2} dv$$

$$w = p_2 (v_2 - v_1) \qquad = p_2 \Delta v$$

$$w = p_2 \left[\frac{nRT}{p_2} - \frac{nRT}{p_1} \right]$$

$$w_{irr} = nRT \left[1 - \frac{p_2}{p_1} \right]$$

Comparison of W_{rev} and W_{irr} :

$W_{rev} = nRT \left[\ 1 - \dfrac{p_1}{p_2}\ \right]$

من اضافة وطرح واحد يعطي :

$W_{rev} = nRT \left[\ 1 - 1 + \dfrac{p_1}{p_2}\ \right]$

$W_{rev} = nRT \left[\ 1 - \left(1 - \dfrac{p_1}{p_2}\right)\ \right]$

$\{Ln\ (1-x) = -x - 1/2\ x^2 \cong\ -x$

$W_{rev} = - nRT \left[\ \left(1 - \dfrac{p_1}{p_2}\right)\ \right]$

$W_{rev} = nRT \ [\ (\ \frac{p_1}{p_2} - 1) \ ]$

$W_{irr} = nRT \ [\ (1 - \frac{p_2}{p_1}) \ ]$

$W_{rev} - W_{irr} = nRT \ [\ (\ \frac{p_1}{p_2} - 1) \ ] \ - nRT \ [\ (1 - \frac{p_2}{p_1}) \ ]$

$W_{rev} - W_{irr} = nRT \ [\ (\ \frac{p_1}{p_2} - 2 + \frac{p_2}{p_1}) \ ]$

$W_{rev} - W_{irr} = nRT \ [\ (\ \frac{p1^2 \ -2p1p2 \ +p2^2}{p1p2} \ ) \ ]$

$W_{rev} - W_{irr} = nRT \ /p_1p_2 \ \ (p_1p_2)^2$

Adiabatic expansion :

In Adiabatic   q= 0

$\Delta E = q - w$ (from first Law)

$\Delta E = - w$

$w = - \Delta E \ \ , \frac{T_2}{T_1} = (\frac{V_1}{V_2})^{\gamma - 1} \ \ , \frac{P_2}{P_1} = (\frac{V_1}{V_2})^{\gamma} \ \ , \frac{P_2}{P_1} = (\frac{T_1}{T_2})^{\gamma}/_{\gamma - 1}$

Adiabatic reversible expansion:

$d E = n \, C_V \, d T$

$\int_{E1}^{E_2} dE = n \int_{T1}^{T_2} C_V \ d T$

$\Delta E = \ E_2 - E_1 \ \ = n \, C_V (\ T_2 - T_1)$

$\Delta E = n \, C_V (\ T_2 - T_1) \ \ = -w$

$$W_{ad} = - n\, C_V(\ T_2 - T_1) \quad , \quad W_{ad} = C_V\, T_1\, [\ (\tfrac{p_2}{p_1})^{\gamma-1}/\gamma\ ]$$

$$W_{ad} = R(\ T_2 - T_1)\ /\ 1 - \gamma$$

Enthalpy change (ΔH):

$$\Delta H = H_2 - H_1\ =(\ E_2 + p_2 v_2) - (\ E_1 + p_1 v_1)$$

$$\Delta H = (E_2 - E_1) + (p_2 v_2 - p_1 v_1)$$

$$\Delta H = \Delta E + n\, R(\ T_2 - T_1)$$

$$\Delta H = n\, C_V(\ T_2 - T_1) + n\, R(\ T_2 - T_1)$$

$$\Delta H = n\ (\ T_2 - T_1) + (C_V + R)$$

$$\Delta H = n C_p\ (\ T_2 - T_1)$$

a) Rrlation between (T) and (V):

$$d E = n\, C_V\, d T$$

$$dw = pdv$$

for adiabatic q= 0

$$d E = -pdv = n\, C_V\, d T$$

$$n\, C_V\, d T = \frac{-nRT}{V}\, dv \qquad\qquad P = \frac{nRT}{V}$$

$$\frac{C_v}{R}\frac{dT}{T} = \frac{-dV}{V}$$

$$\frac{C_v}{R}\int_{T_1}^{T_2}\frac{dT}{T} = -\int_{V_1}^{V_2}\frac{dV}{V}$$

$$\frac{C_v}{R} Ln\frac{T_2}{T_1} = -Ln\frac{v_2}{v_1}$$

$$\frac{C_v}{R} Ln\frac{T_2}{T_1} = Ln\frac{v_1}{v_2}$$

$$Ln(\frac{T_2}{T_1})^{cv/R} = (Ln\frac{v_1}{v_2})$$

$$Ln(\frac{T_2}{T_1}) = (Ln\frac{v_1}{v_2})^{cv/R}$$

$$C_p - C_v = R$$

$$Ln\frac{T_2}{T_1} = (Ln\frac{v_1}{v_2})^{C_p - C_v/C_V}$$

$$Ln\frac{T_2}{T_1} = (Ln\frac{v_1}{v_2}) (C_p/C_V) - 1$$

$$Ln\frac{T_2}{T_1} = (Ln\frac{v_1}{v_2})^{\gamma - 1} \qquad \frac{C_p}{C_v} = \gamma$$

$$\frac{T_2}{T_1} = (\frac{v_1}{v_2})^{\gamma - 1}$$

eleventh week :

b) Relation between (p) and (v):

$$\frac{T_2}{T_1} = (\frac{v_1}{v_2})^{\gamma - 1}$$

$$T_2 v_2^{\gamma - 1} = T_1 v_1^{\gamma - 1}$$

$$p_2 v_2 /R \ v_2^{\gamma - 1} = p_1 v_1 /R \ v_1^{\gamma - 1}$$

$$P_2 v_2^{\gamma} = P_1 v_1^{\gamma}$$

$$\frac{P_2}{P_1} = (\frac{v_1}{v_2})^{\gamma}$$

C) Relation between (P) and (T):

$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2} \right)^{\gamma - 1}$$

$$Ln\frac{T_2}{T_1} = Ln\left(\frac{v_1}{v_2} \right)^{\gamma - 1}$$

$$1/\gamma\text{-}1 \;\; Ln\frac{T_2}{T_1} = Ln\left(\frac{v_1}{v_2} \right)$$

$$\frac{P_2}{P_1} = \left(\frac{v_1}{v_2} \right)^{\gamma}$$

$$Ln\frac{P_2}{P_1} = Ln\left(\frac{v_1}{v_2} \right)^{\gamma}$$

$$1/\gamma \;\; Ln\frac{P_2}{P_1} = Ln\left(\frac{v_1}{v_2} \right)$$

$$1/\gamma \;\; Ln\frac{P_2}{P_1} = 1/\gamma\text{-}1 \;\; Ln\frac{T_2}{T_1}$$

$$Ln\frac{P_2}{P_1} = \gamma/\gamma\text{-}1 \;\; Ln\frac{T_2}{T_1}$$

$$Ln\frac{P_2}{P_1} = Ln\left(\frac{T_2}{T_1} \right)^{\gamma/\gamma - 1}$$

$$Ln\frac{P_2}{P_1} = Ln\left(\frac{T_2}{T_1} \right)^{cp/R}$$

$$\frac{P_2}{P_1} = \left(\frac{T_2}{T_1} \right)^{cp/R}$$

$$\gamma/\gamma - 1 = \frac{\frac{c_p}{c_v}}{\frac{c_p}{c_v} - 1}$$

$$= \frac{\frac{C_p}{C_v}}{\frac{C_p - C_V}{C_v}}$$

$$= \frac{C_p}{R}$$

Adiabatic irreversible expansion (Free expansion):

$q = 0$

the gas expands into vacuum where there is no pressure therefore the work $=$ zero

$\Delta E = q - w \qquad 0\text{-}0 = 0$

$\Delta E = n\, C_V(\ T_2 - T_1)\ = 0$

$T_2 = T_1$

$\Delta H = C_P(\ T_2 - T_1)\ = 0$

W , q , ΔE, ΔH are zero for free expansion .

Adiabatic irreversible expansion:

$W_{irr} = \int_{v_1}^{v_2} p_2\, dv$

$\qquad = p_2(\ v_2 - v_1)$

Real gases . (Non ideal gases)

$(p + a\, n^2\ /\ v^2\ )\ (v - nb) = n\, RT$

Twelevth week:

Reversible isothermal expansion :

dw = pdv

$$= \int_{v_1}^{v_2} pdv$$

$$P = \frac{nRT}{V-nb} - \frac{an^2}{v^2}$$

$$P = \int_{v_1}^{v_2} \frac{nRT}{V-nb} \, dv \quad - \int_{v_1}^{v_2} \frac{an^2}{v^2} \, dv$$

$$W = nRT \, Ln \, \left(\frac{v_2 - nb}{v_1 - nb}\right) + an^2 \left(\frac{1}{v_2} - \frac{1}{v_1}\right)$$

$$d \, E = \frac{an^2}{v_2} \, dv$$

$$\int_{E_1}^{E_2} dE = \int_{V_1}^{V_2} \frac{an^2}{v_2} \, dv$$

$$E_2 - E_1 = \Delta E = - an^2 \left(\frac{1}{v_2} - \frac{1}{v_1}\right)$$

$$\Delta E = - an^2 \left(\frac{1}{v_2} - \frac{1}{v_1}\right)$$

$$\Delta H = H_2 - H_1$$

$$= (E_2 + p_2 v_2) - (E_1 + p_1 v_1)$$

$$\Delta H = (E_2 - E_1) + (p_2 v_2 - p_1 v_1)$$

$$\Delta H = \Delta E + (p_2 v_2 - p_1 v_1)$$

$$P = \frac{nRT}{V-nb} - \frac{an^2}{v^2}$$

$$\Delta H = \Delta E + n\,RT \left(\frac{v_2}{v_2-nb} - \frac{v_1}{v_1-nb}\right) + an^2\left(\frac{1}{v_2} - \frac{1}{v_1}\right)$$

$$\frac{v_2}{v_2-nb} - \frac{v_1}{v_1-nb} = \frac{v_2(v_2-nb)-v_1(v_1-nb)}{(v_2-nb)(v_1-nb)}$$

$$= \frac{nb(v_1-v_2)}{(v_2-nb)(v_1-nb)}$$

$$\Delta H = \Delta E + n\,RT \left(\frac{nb}{v_2-nb} - \frac{nb}{v_1-nb}\right) + an^2\left(\frac{1}{v_2} - \frac{1}{v_1}\right)$$

$$\Delta E = -an^2\left(\frac{1}{v_2} - \frac{1}{v_1}\right) + n\,RT\left(\frac{nb}{v_2-nb} - \frac{nb}{v_1-nb}\right) + an^2\left(\frac{1}{v_2} - \frac{1}{v_1}\right)$$

$$\Delta H = nb^2\,RT\left(\frac{nb}{v_2-nb} - \frac{nb}{v_1-nb}\right) + 2an^2\left(\frac{1}{v_2} - \frac{1}{v_1}\right)$$

$$q = \Delta E + w$$

$$q = -an^2\left(\frac{1}{v_2} - \frac{1}{v_1}\right) + n\,RT\left(\frac{nb}{v_2-nb} - \frac{nb}{v_1-nb}\right) + an^2\left(\frac{1}{v_2} - \frac{1}{v_1}\right)$$

$$q = n\,RT\,Ln\left(\frac{v_2-nb}{v_1-nb}\right)$$

Adiabatic reversible expansion :

$$q = 0$$

$\Delta E = -w$

$E = E\ (T, V)$

$E = (\frac{\partial E}{\partial T})_V\ dT\ -\ P\ (\frac{\partial E}{\partial V})_{dv}$

$(\frac{\partial E}{\partial T})_V\ = n\ C_V\ ,\ \ (\frac{\partial E}{\partial T})_V = \frac{an^2}{v^2}$

$d\ E = n\ C_V\ d\ T + \frac{an^2}{v^2}\ d\ v$

$\int_{E_1}^{E_2} dE\ = n\ C_V\ \int_{T_1}^{T_2} dT + an^2\ \int_{V_1}^{V_2} \frac{dv}{v^2}\ dv$

$\Delta H = (E_2 - E_1)\ = \Delta E\ = n\ C_V(\ T_2 - T_1)\ -\ an^2(\frac{1}{v_2}\ -\ \frac{1}{v_1}\ )$

$W\ = - n\ C_V(\ T_2 - T_1)\ +\ an^2(\frac{1}{v_2}\ -\ \frac{1}{v_1}\ )$

Thirteen weak :

step (1):

the gas cylinder is placed in a constant temperature bath maintained at temperature (T_2) and the gas is expanded isothermally at a temperature (T_2) from an initial volume (v_1) to a volume (v_2) the gas will absorb heat (q_2) and perfrom work on its surrounding

$\Delta E = 0$

$q_2 = w_1 = RT_2 Ln\ \frac{v_2}{v_1}$

step (2):

the cylinder is then insulated the gas allowed to expand reversibly and adiabatically to volume (v_2) since no heat is transferred (q= 0) the temperature of the gas will fall from T_2 to T_1

$$W = - \Delta E = - n \, C_V(T_2 - T_1) = C_V(T_2 - T_1)$$

step (3):

the gas cylinder is now placed in a constant temperature bath maintained at temperature (T_1) and the gas is compressed isothermally and reversibly at a temperature (T_1) from volume (v_3) to a volume (v_4) the gas will absorb heat (q_1) is given out to the cold reservoir . since the gas ideal and the temperature is constant

$$q_1 = w_3 = n \, RT_1 \text{Ln} \frac{v_4}{v_3}$$

v_4 less than v_3

$\text{Ln} \frac{v_4}{v_3}$ is negative

q_1 , w_3 are negative and correso=pond to the heat being given off from the gas and the work the being done the gas

step (4):

the gas finally compressed reversibly and adiabatically from volume (v_4) to a volume (v_1) the gas performs amount of work (w4) and temperature of the system rises from (T_1) to(T_2) and returns to its original state .

$$q = 0$$

$$W_4 = - \Delta E_4 = - n \, C_V(T_2 - T_1)$$

$W = q_2 - q_1$

$W = w_1 + w_2 + w_3 + w_4$

$W = n\,RT_1\mathrm{Ln}\ \frac{v_2}{v_1} + n\,C_V(\ T_2 - T_1) - n\,RT_1\mathrm{Ln}\ \frac{v_3}{v_4} - n\,C_V(\ T_2 - T_1)$

$W = n\,RT_1\mathrm{Ln}\ \frac{v_2}{v_1} - n\,RT_1\mathrm{Ln}\ \frac{v_3}{v_4}$

$\frac{v_2}{v_1} = \frac{v_3}{v_4}$

$W = n\,RT_1\mathrm{Ln}\ \frac{v_2}{v_1} - n\,RT_1\mathrm{Ln}\ \frac{v_3}{v_4}$

$W = n\,R(\ T_2 - T_1)\,\mathrm{Ln}\ \frac{v_2}{v_1}$

Fourteen week:

Efficiency of Carnot cycle :

$\varepsilon = \dfrac{w}{q_2} \qquad = \dfrac{n\,R(\ T_2 - T_1)\,\mathrm{Ln}\ \frac{v_2}{v_1}}{RT_2\mathrm{Ln}\ \frac{v_2}{v_1}}$

$\varepsilon = \dfrac{T_2 - T_1}{T_2}$

$\varepsilon = \dfrac{q_2 - q_1}{q_2}$

$\varepsilon = 1 - \dfrac{q_2}{q_2}$

1) Heat cannot spontaneously pass from a colder to a hoter body .
2) The mechanical work can completely be converted into heat , but on the contrary heat cannot completely be converted into work without making other change either in the system or the surrounding in a cyclic process.

a) q is the amount of heat supplied to the gas , the gas will expand and the piston will be pushed , the work done by the gas is (w= pdv) due the expansion .

b) if the work equivalent to the above amount of heat work is done on the gas ,the gas would be compressed and heat will be evolved .

$q_2 < q_1$

- this clearly indicates that the whole of the heat a bsorbedin process (A) has been converted into work .

- when heat is absorbed the gas ,the kinetic energy of the gas molecules will move faster and collide with

- 1) each other

- 2) the container

- 3) the face of the piston

- Only the third type of collision will dring about the expansion of the gas . shown in (b)

- The work due to expansion is not exactly equivalent to the amount of heat absorbed

- The heat goes wast only due the random motion of the gas molecules . so we can correlate the randomness with the unavailable work that is (entropy)

- Under ideal situation if all the gas molecules were striking the piston perpendicularly , the whole of the heat will be converted into work as in (a).

Entropy : is the measure of randomness of a molecular system

$dq_{rev} = dE + d\ w_{rev}$

$\qquad = d\ E + Pd\ v$

$dE = n\ C_V d\ T$

$P = \dfrac{nRT}{V}$

$dq_{rev} = n\ C_V d\ T + n\ RT\dfrac{dv}{v}$

$\dfrac{dq_{rev}}{T} = n\ C_V \dfrac{dT}{T} \quad +nR\dfrac{dv}{v}$ $\qquad\qquad$ dividing the equation ti (T)

$\int_1^2 \dfrac{dq_{rev}}{T} = n\ C_V \dfrac{T_2}{T_1} \quad +nR\ Ln\ \dfrac{v_2}{v_1}$

$\dfrac{p_1 v_1}{T_1} = \dfrac{p_2 v_2}{T_2}$

$\dfrac{v_2}{V_1} = \dfrac{p_1 T_2}{p_2 T_1}$

$\Delta S = C_V \dfrac{T_2}{T_1} \ + \ R\ Ln\ \dfrac{T_2}{T_1} \ - \ R\ Ln\ \dfrac{P_2}{P_1}$

$= (C_V + R)\dfrac{T_2}{T_1} \ + \ Ln\ \dfrac{T_2}{T_1} \ - \ R\ Ln\ \dfrac{P_2}{P_1}$

$C_p - C_V = R$

$$C_p = C_V + R$$

$$\int_1^2 \frac{dq_{rev}}{T} = n\, C_p \frac{T_2}{T_1} - nR\, Ln\, \frac{v_2}{v_1}$$

$$S_2 - S_1 = \Delta S = \int_1^2 \frac{dq_{rev}}{T} = n\, C_p \frac{T_2}{T_1} - nR\, Ln\, \frac{v_2}{v_1}$$

$$ds = \frac{dq_{rev}}{T}$$

fifteen week :

combind of first and second Law of thermodynamics:

$$dq_{rev} = dE + d\, w_{rev}$$

$$= d\, E + Pd\, v$$

$$ds = \frac{dq_{rev}}{T}$$

$$dq = T\, ds$$

$$T\, ds = dE + pdv$$

$$d\, E = T\, ds - pdv$$

Enthalpy and entropy :

$$H = E + Pv$$

$$d\, H = d\, E + Pd\, v + v\, dp$$

$$d\, E = T\, ds - pdv$$

d H= d E + Pd v + Pd v + v dp

$\Delta H = T\ ds\ - vdp$

Entropy change at constant pressure for heating or cooling

$$\Delta S\ = \int_{T_1}^{T_2} n\ C_p \frac{dT}{T}\ \ = n\ C_p \frac{T_2}{T_1}$$

Entropy for reversible isothermal process:

$$d\ q_{rev}\ = dw_{rev} = pdv = n\ RT\ \frac{dv}{v}$$

$$\Delta s = \int_1^2 \frac{dq_{rev}}{T}\ \ = \int_{v_1}^{v_2} nR\ \frac{dv}{v}$$

$$\Delta s\ = nR\ Ln\ \ \frac{v_2}{v_1}$$

$$p_1 v_1 = \ \ p_2 v_2$$

$$\Delta S\ =\ nR\ Ln\ \ \frac{p_2}{p_1}$$

Entropy for reversible adiabatic process:

$d\ q_{rev}\ = 0$ at all stages of the process.

$\Delta S\ \ = 0$

Entropy change on heating or cooling of the substance (change of state):

$$\Delta S \quad = \int_{T_1}^{T_2} \frac{dq}{T} \quad = \int_{T_1}^{T_2} n \, C_V \frac{dT}{T}$$

$$\Delta S = n \, C_V \, Ln \, \frac{T_2}{T_1} \, (\text{ at temperature change })$$

$$ds \quad = \frac{dq_{rev}}{T} = \frac{\Delta H}{T} \, (\text{ at state change })$$