

now we are going to discuss solubility

so let's see we have a solute a which we are being
resolved in solvent b

so we add a little bit of a in solvent b and then we take
the flask vigorously okay until this a is dissolved completely if it is
going to dissolve i mean there might be a case that we keep on shaking the jar
and

it's never going to dissolve there

so uh

so solute which is not going to dissolve in
a given solvent b

so okay but let's assume in this case a is going to dissolve completely
in b now we keep on adding in little by little and keep shaking the flask
and keep on repeating until we reach a point if we add a little bit
more of a it doesn't dissolve in b

so if we add any more of a it's not going
to dissolve in b it's just simply going to perspire out it's just going to
settle at the
bottom of the flask

so we have reached the maximum concentration of solute a in the solvent b
so the maximum amount of solute a which dissolve in solvent b without
precipitating out in the is the solubility of solute a in solvent b

so basically this is the
maximum concentration attainable of solute a in solvent b that is called
solubility

so there

are salt which is very highly soluble and they are salt which is very low have
a very low solubility

in a given solvent for example nscl in water we know it is highly soluble in fact
ah little

less than 400 gram of nscl can be dissolved in one liter of water on the
other hand we have silver chloride only a few milligram around 1.

9

milligram of agcl can be dissolved in one liter water if i add anything more
than 1.

9 milligram of agcl in water in one liter of water it will simply prosper it
out it

will simply settle at the bottom of the flask the solubility depends upon the
nature of solute

and solvent it depends upon the interaction between among the of solute
molecule between

solvent molecules and between most importantly between solute and solvent
molecules okay

let's try to understand it let's see it briefly okay

so we have already seen nacl

so nacl and

sugar they easily readily dissolve in water but another example anthracene does
not dissolve in water at all

but it readily dissolve in bending

so if we try to understand the interaction

nacl is ionic is goes into the solution and dissociate as ion it becomes na
plus and cl

minus gets solvated by water which is polar and that's how it has a very high
solubility

sugar it has hydrogen attached to oxygen and that leads to hydrogen bonding again water has lots of hydrogen bonding and so sugar becomes part of this hydrogen bonding network and that's how sugar get dissolved in water and fashion it is nothing but a hydrocarbon
no any corrector no hydrogen bonding
so this there is no mechanism which will help him to dissolve in water it's basically non polar manual this is also non-polar it's exactly like and fashion both of them are hydrocarbons
so this entrance in dissolving benzene but doesn't dissolve in water
so we can conclude this polar solute dissolve in polar solvent and non polar solute dissolving non polar solvent we can say light dissolves
like when solute is added to solvent to solvent the concentration of solute increases and that is called dissolution but at the same time another process is going on the solute molecules or solutes are going to strike heat ah the other solute solid and in this process there might be some crystallization and it comes out of the solution and that is called precipitation and these two process are happening all the time
so we are we are having solute plus solvent and i am we are getting solution so in the forward direction the dissolution is happening and in the backward direction precipitation is happening and then there is a dynamical equilibrium
so at the rate at which solute goes into the solvent or the rate the solid the solute comes out of the solution when the two rate becomes equal then we have equilibrium and as we keep on adding solute we reach to a stage when solute going to the solvent is no longer feasible and we have no more dissolution and at that time we reached the maximum concentration of solid possible and that is called saturated solution saturated solution is when the solute has reached its maximum concentration we cannot add any more solute in the solution
if we add more solute the solid solute in the solvent or the solution it will simply not dissolve it will simply come out from the solution at this stage this is we can say that solution is saturated uh with the solute cannot add we cannot increase the concentration of solute anymore ok
so now we have to discuss the effect
so this is a reaction we can treat it as a reaction and it should follow what is called leash at earlier principle this satellite principle ah
so we can study the effect of pressure and temperature and temperature on this reaction on this dynamical equilibrium okay lets say solute is we lets discuss first solid and liquid where solute is solid and solvent is liquid and what would be the

effect of pressure there is not going to be a much effect of pressure because most of solid and solvent is usually very highly incompressible

so if we increase the pressure there is no any change in the volume change in of the reaction of the reaction material so there is not going to be much change in the direction of the reaction due to the pressure change but temperature change would have a lot of effect if there is a enthalpy is involved ΔH if this reaction is exothermic that is ΔH is negative that means as the reaction reaction goes forward the heat is liberated we are getting energy

so increase in the temperature ΔH will take the reaction in a backward direction because

it want to minimize the ΔH the effect of temp ΔH we are having to the temperature increase

the if the reaction goes forward if the ΔH is eliminated the system has more heat

so the

temperature would increase but the resettler sail the reaction will move in a direction where

the stress can be minimized

so it has to move in a direction where the heat is absorbed by if we increase the temperature

so it's clear for ΔH for exothermic reaction reaction will go backward will

move in the backward direction from the same logic we can now can conclude if ΔH is greater than 0 that need energy to move the reaction energy is absorbed to move

the reaction forward reaction is endothermic then the reaction will move forward ok now that's that about a solid dissolve

in liquid okay let's now consider ΔH a gaseous solute is being dissolved

in a solvent liquid solvent now same ΔH observation can be made by listeria

principle if the reaction is ΔH is exothermic that is ΔS is less than zero reaction goes backward if ΔH is greater than zero ΔH reaction is endothermic

reaction goes forward but in this special case less condition consider a which is gaseous

goes to a liquid this is a condensation we know to going from liquid to gas that is

basically boiling we need energy

so going from gaseous or liquid the gas energy will be evolved

so this reaction is exothermic and ΔH is less than zero

so we can say as the temperature

is increased solution the reaction will go backward that is the solubility of gas gas in the

solution decreases as we increase the temperature okay now let's think about the pressure so

this is my vessel where i have my solution in this case we have the solid solute particle

and this is the solute particle and gaseous phase and this is a closed flask and i have some pressure pressure applied on the system now if

pressure is increased what is going to happen the solution being highly

incompressible it does not compress but gas will compress and now i have more gaseous particle stored in a smaller volume so what the listed relay will say to reduce the stress we have to go in a direction ah that it can reduce the stress so of course this solute particle which has a concentration has increased in this region even the concentration in this remain constant because not compressible so this will start going to the solution to reduce the effect of stress and it is very clear that as we increase the pressure solubility of gaseous solute increases in solution and this has been formulated is given a mathematical expression for this concern the solubility of gaseous particle in a concentration of gaseous solute in the solution by henry and the law says p is equal to $k_h x$ where p is the pressure of the solute over the solution x is the concentration of solute in solution so as the pressure increase the mole fraction the concentration of solute increases and its clear we can put it to the other way around p divided by k_h higher the henry constant lesser the solubility of gaseous solute in solution okay let's next discuss vapour pressure of liquid liquid solution so lets first consider the pure liquid lets say i have a liquid a put it in a closed flask so i have introduced some liquid over here this is a volatile liquid so at this given temperature some of the this ah liquid molecules is going to escape and they are going to go into this empty space now this gaseous molecule of this same liquid is moving around and they are going to hit back the surface and some of them can start going back into the liquid form so there is a some kind of a ah process is going on where solu so solution liquid a goes to gaseous and then this gaseous comes back so there is a reaction going forward and reaction coming backward and there is a dynamical equilibrium and at the equilibrium the pressure this liquid this gaseous molecule of that same liquid a ah is going to exert some pressure on the surface and that pressure is called the vapor pressure and that we put θ due to this a pure one and same thing is going to if we have another evacuated flask and there we put this liquid b same thing is going to happen is going to fill up this empty space and then again we are going to have a dynamical equilibrium and this gaseous molecule is going to exert the price exact pressure on the surface and this is going to call $p_b \theta$ the vapor pressure of

pure b pure liquid b ok and of course the in this i have considered this is evacuated flask

so only pressure is going to be due to this ah mole gaseous molecule of b and same thing here the pressure is going to be due to only due to only the gaseous

molecule of liquid a now let's mix them together now we are going to mix them together now we

have a plus b here and same thing a plus b we have a and solution of a and b in liquid

form and ah gaseous a and b in gaseous form and now there should be some relationship

between these what is the pressure exerted by a what is the pressure exerted by b and what

is the total pressure t

so this is the partial pressure due to a partial pressure to b and this is the total pressure that is how i can classify the gaseous phase but what about the

liquid phase liquid phase i can classify by mole fraction of a mole fraction of b

so once we

have classified what is the relationship between ah these quantity and this is given by rolls law says that this p_a is proportional to x_a p_b

proportional to x_b we also know when x_a equal to 1 that is when we have a pure ah liquid a then p_a is equal to p_a is equal to p_a zero and x_b is equal to one then we

have p_b is equal to p_b zero

so we get the proportionality constant immediately and i can write this equation in this form

so lets look at this in a in this diagram what i am plotting is the pressure partial pressure of a and b this is a mole fraction

so over here we have a mole fraction x_a is equal to 0 and x_a is equal to one and same

way over here we have x_b equal to zero and x_b equal to one

so when we have a pure b

the partial ah partial pressure due to partial pressure of b is going to be p_b zero

and partial pressure of a is going to be zero what about when we have a pure liquid a then the

partial pressure of a is going to be due to the p_a zero and partial pressure of b is going to

be zero and you can one can see that this is a straight line as i change x_a p_a is going to

linearly change

so if i am going to change x_a from 0 to 1 the partial pressure of a is going to increase linearly sorry this is try to make a straight line ok and

same thing when

the particle press when we have a pure liquid b

so as the parts concentration of b is increasing

the partial pressure of b also will increase ah would have a straight line and we

get this what about the total pressure okay the total pressure we can calculate

from this equation

so total pressure is $p_a^0 x_a$ plus $p_b^0 x_b$ and
i can substitute x_b is equal to $1 - x_a$

so we get $p_a^0 x_a$
plus $p_b^0 (1 - x_a)$

so i get p_b^0 plus $p_a^0 - p_b^0 x_a$
so this is again a linear

function with respect to concentration in a and of course we are going
to get this straight line which is really a sum of these
2 lines this is the p_{total} this is a partial pressure of a
this is a partial pressure of b and
this is p_{total} which is $p_a + p_b$

so that is how the solution would be

let's do an example given in the book let me read it out let me
clear the blackboard first ok let's do the example from the book it says the
example is as follows vapor pressure of chloroform and dichloromethane at 298
kelvin are

200 millimeter mercury and 450 millimeter mercury respectively okay less
so we have

chloroform C_1 let us call that a we have dichloromethane C_2 let's
call that b and we are given vapor pressure of
these of the pure components of p_a^0

so p_a^0 is going to be 200 millimeter mercury and p_b^0 is
going to be 415 millimeter mercury okay okay now number one calculate the
vapor pressure of the solution prepared by mixing 25.

5 gram of CCl_3

so we

are mixing 25.

5 gram of this and 40 gram of salt liquid b and we are asked the vapor pressure
of a and b and

the total vapor pressure okay

so what is the fault now let's go back to the basic and the formula

is $p_a^0 x_a$ plus $p_b^0 x_b$ is equal to $x_a p_a^0$ plus $x_b p_b^0$ now p_a^0 and p_b^0
is given

this is p_a^0 this is p_b^0 one

so i need mole fraction x_a and x_b how the x_n

x_b is defined x_a is n_a divided by $n_a + n_b$ and same way i can calculate
 x_b and

also i can calculate x_b simply by $1 - x_a$ now to calculate n_a i need the
molecular weight

okay

so let's see what is the molecular weight of molecular weight molecular
weight of $CHCl_3$ is 119 and molecular weight of CH_2Cl_2 is 85 gram per mole and
then we can calculate n_a number

of moles of each

so that would be 25.

5 gram divided by 109.

5 gram per mole

that will give me moles of Cl_3 that is a so let's do that 25.

5 divided by 119.

5

and answer we are going to get it 0.

21 and same thing we need to do

for b that is dividing 40 by 85 40 divided by 85 and answer

i am going to get is 0.

470 and now i need to calculate simply x_a mole fraction

so its all given there n_a is two 0.

21 three divided by n_a zero point two

one three plus zero point four seven zero

so using calculator point two one three divided by point six eight three i get answer

three zero point three one two and of course using this formula

1 minus 0.

312 i get 886.

68 now i have all the information

required the p_a would be given by x_a we have calculated 0.

312 multiplied by p_a

0 which is given right here 200

so i get 62.

4 and the p_b okay x_b is given here 0.

688 multiplied

by 4 1 5 answer i am going to get is 0.

688 multiplied by 4 1 5 answer is 285 point five millimeter edge and of course

the total pressure would be simply sum of these two quantities

of the total pressure is going to be 0.

94347.

9

so that is the total pressure

so we have calculated part a now is asking mole fraction of each component

in vapor phase mole fraction of each component in vapor phase now we know this

ideal gas law we are going

to apply that pV is equal to nRT ok and if it is a partial

pressure then $p_a = n_a \frac{RT}{V}$

so we need to calculate mole fraction of a

and b in vapor phase

so mole fraction would be let's call that capital x_a that will be

okay i have already used and

so let's put a pepper okay over here

so n_a in vapor divided by

total moles n_a in vapor plus n_b in web and if i substitute n_a from here the answer would be

simply i will get p_a divided by p_a plus p_b and i have all this information

p_a is given

right here ah pV and p_a plus p_b is nothing but p total

so i get mole fraction of a in

vapor phase and that would be 62.

4 divided by 347.

9

so let's see 62.

4 divided by 347.

9

so 0.

179 and what about x_b that would be 1 minus

x_a

so i get 1 eight point eight two one ok

so we have calculated mole fraction of a and mole fraction of b in

solution mole fraction of a and mole fraction of b in vapor one thing to

notice is this the vapor

has become richer in b see in the liquid phase the mole fraction of b was 0.688 now the mole fraction of b in vapor phase has become 0.821 and that it has something to do with the volatility and you can see v has a higher vapor pressure means it has a higher tendency to go into vapor phase it's it has a higher volatility so it is a volatile compound more volatile compound than a so it has a higher tendency to go into the vapor more than a so it is going to be richer in vapor phase than a okay okay let's do one more problem from the in text question ok let me clean the blackboard first the vapor pressure of pure liquid a and b are 450 and 700 millimeter hg respectively so we have a and b and p_a^0 and p_b^0 is 450 and 700 millimeter mercury 450 and 700 millimeter edge respectively so vapor pressure of pure a is 450 millimeter hg vapor pressure of pure b is 700 millimeter edge now at of course at 350 kelvin find out the composition of liquid mixture or if total vapor pressure is 600 millimeter edge if p_t is 600 millimeter mercury find the composition of liquid mixture also find the composition of vapor phase okay now let's first assume in the liquid phase the mole fraction of a is x_a then of course the mole fraction of b is going to be one minus x_a ok the vapor pressure once i have mole fraction assumed i can write the vapor pressure of a and b in terms of x_a so that is going to be 450 x_a is the vapor pressure of a is 450 x_a and the vapor pressure of b is going to be 700 $(1 - x_a)$ and the question tells me the total pressure so that is this plus this equal to this so i have a one equation that is 450 x_a plus 700 $(1 - x_a)$ one equation one unknown solve it and we have the answer so let's try to solve it what will get 450 x_a plus 700 minus 250 x_a so that is 700 minus 250 x_a bringing the other side dividing by 250 i am going to get x_a is equal to 100 divided by 250 so that is 0.4 so we have found that x_a is 0.4 so pressure the partial pressure of a is going to be simply 450 into 0.4 that is going to be 180 and partial pressure of b is going to be 700 multiply 1 minus axis that is 0.6 so it's going to be 420 so we can check the total pressure is 180 plus 420 that is 600 millimeter

energy now
 in the part b the same question is also find the composition of vapor phase
 and in the last
 example we have already seen the composition of vapor phase we can calculate
 the parts from the
 partial pressure the composition of vapor phase is x of vapor phase okay let
 me clear
 the blackboard a little
 so composition of in vapor phase of a is simply partial
 pressure of a divided by total pressure and answer is straight forward divided
 by 600 and i
 get 0.
 3 i can calculate ah compo the mole fraction of b in vapor pressure either by
 1 minus point
 3 and i can try that one also just for checking 420 divided by total pressure
 that is 600.
 7
 i get same answer by using both the method and i have completed this task
 starting
 from another from the very basic principle okay
 so next topic which we are going
 to discuss is vapor pressure of vapor pressure of sir of solution of solution of
 solid in liquid solid in ok lets examine the rods law one
 more time what it says it says p_a the partial pressure of one
 component lets a component a is equal to $x_a p_a$ zero and same thing p_b is
 equal
 to $x_b p_b$ zero
 so if i have a solid solid what is the vapor pressure over it for most of
 the solid its going to be negligible this solid is usually not volatile i'm
 considering that there
 are some solid which of course have a uh they evaporate and they would have
 some vapor pressure
 for most of the solid there is no vapor pressure
 so if i leave this solid it's not going to
 evaporate if i if i leave let's say alcohol or liquid is going to pretty much
 evaporate
 after some time but if i leave the solid in less a stable or metal object
 it's
 not going to operate in my lifetime so of course there are some solid which
 will evaporate but most of them not in such cases the $p_b = 0$ let's say this is
 a is
 the solvent b is the solute solid solute then in that case $p_b = 0$ is going to
 be
 zero
 so this is going to be zero
 so rod's law in general it says any solution
 for any solution the partial vapor pressure of each volatile component the
 solution is
 directly proportional to its mole fraction in this case the vapor pressure is
 going to be due to only the solvent a it because it's going to evaporate in
 time but b the solute is not going to ah not going to give any component it's
 going
 to be the pressure is going to be zero so all the pressure is going to come
 from the partial

pressure of a okay and this can be understood also by this following diagram
 so we have solvent
 pure solvent and its going it is in a closed evacuated flask
 so in this flash we have
 only this a this solvent a and it is going to evaporate and is going to fill
 in build up this
 whole
 so this is a gas and this is liquid of a and that equilibrium which is going
 to
 happen is from this surface there are some gaseous molecule which is going to
 extract the surface and going into the solution and from the surface some of
 them
 is going to have enough energy to escape okay now if i add solute to this
 what
 is happening there are some molecule of of the solvent and there
 are some molecule of solute
 so the concentration of solvent molecule
 at the surface has decreased of course only it is not going to evaporate
 that's what we
 have considered these are not volatile at all that is the assumption here
 which is true in most
 of the cases but the solvent is going to evaporate but there is a lesser
 number of solvent ah
 molecule at the surface
 so the evaporation has decreased the moment we have added
 the solute the concentration of solvent molecule at the surface has decreased
 but this
 is has not changed let's consider this not the concentration of or partial
 pressure of a has not
 changed
 so it is going to strike at the same rate
 so evaporation rate has decreased but the
 condensation rate has not changed in that case there is going to be more
 condensation than
 the evaporation and as the condensation has increased
 so partial pressure of a is going
 to decrease and we are going to reach to a new equilibrium where the partial
 pressure of a is
 going to be less than what it was and that can be understood again from this
 because since in
 the pure solvent there is no solute x_a is one so p_a is equal to p_a^0 and
 as the x_a has become
 less than one p_a has become less than p_a^0 and the exact relation is
 given over there ok
 next we are going to discuss ideal solution and non ideal solution
 so what makes a solution ideal
 so if a solution
 follow the rolls law over the whole range of concentration then this solution
 is called ideal
 solution but question is what makes them to follow the rolls law and that's
 where comes the two
 very important quantity those are Δv of mixing and ΔH as the enthalpy
 of mixing and they should be 0
 so if i mix let's assume if i mix 1 liter of solvent a plus 2 liter of solvent

b if the total volume after mixing is 3 liter 3 liter of solution then it follows the condition one and the second condition is if no heat is evolved during the mixing that is if the temperature does not change after the mixing then it is a ideal solution i mean during the chemistry experiment i am sure you must have observed if i mix water with concentrated H_2SO_4 the mixture becomes quite warm that is ΔH of mixing is non-zero it is a exothermic reaction if the total volume is greater than or less than three liter or the ΔH heat is evolved then the solution is non-ideal okay let's try to understand uh this with a simple diagram let's see if i have a solvent a in a container and on the this vapor and liquid boundary zone right now i have only solvent uh a now to that i am going to add b but before hand lets try to understand what is happening so the interaction between a and a if it is a pure solvent a now i am going to add solvent b so some of the a molecule at the boundary will be replaced by another solvent b it could be solvent or it could be solute if you are mixing lets say fifty fifty percent of water and ethanol then these are two solvent which we are mixing if i am mixing lets say sodium chloride in water then sodium chloride is going to be solute and water as a solvent so its a ΔH so now so there is a solvent a and somewhere in between is solvent b it could happen ah very often if the concern depending on the concentration now initially the pure solvent a had an interaction between a and a now once the another ah solvent or solute is added b then we also have a interaction a and b and there could have a detection b and b depending upon the concentration now this a and a interaction could be stronger than a b interaction what would happen so initially right instead of this there was a and a and that interaction is stronger stronger than a b interaction so a and a interaction is stronger and a b interaction is bigger so we have replaced a stronger interaction with a weaker interaction now this molecule a is lesser stable so it has a higher tendency to go into vapor phase it requires a lesser amount of energy lesser push to go into the vapor phase so what would happen it's become the vapor pressure will increase so okay let's let me draw uh this diagram which i have drawn earlier so that is ah so we what we are changing is mole fraction of a over here x_a is one over here x_a is zero so vapor pressure of a is going to be this same this is p_a^0 and same thing

if x_b over here is 0 x_b is over here 1 and we get another land this is vapour pressure of b this we have done earlier and this is p_b^0 and the total pressure is going to be this this is the ideal solution but now a a interaction is stronger than a b interaction and the b molecule has interrupted the strong interaction and replaced with a weaker interaction now this a can go into the vapor phase easily and that's why increasing the total pressure or individual vapor pressure so now we have a what is called positive deviation so if a interaction is stronger than a b interaction then we have positive deviation ok and other way around if a a interaction is weaker than a b interaction then we have negative deviation so in this diagram for a positive deviation the total vapor pressure has changed into the positive direction and same with the individual component also would change in the positive direction and for a negative deviation where interaction between a and b is stronger than a a and a we are going to have a deviation another direction and that would lead to negative division okay let's look at the example ethanol and acetone ethanol C_2H_5OH acetone CH_3COCH_3 so this molecule in a solution has a lot of hydrogen bonding in a liquid phase it is going to have a lot of hydrogen there is a polar hydrogen is available there so it is going to lead to hydrogen bonding and there is no such interaction in acetone so now when there is only ethanol present with a strong a a and a interaction due to hydrogen bonding and now when i add acetone to it this hydrogen bonding network is interrupted so this molecule becomes molecule a that is ethanol becomes lesser stable and it has a higher tendency to go into the vapor phase and it leads to positive deviation let's look at the other example that is between chloroform and acetone so acetone that is CH_3COCH_3 and chloroform that is CCl_3H now we can see that there is no hydrogen bonding within acetone or within chloroform but once we put them together there is hydrogen bonding between this a oxygen hydrogen as there is a very powerful electron withdrawing group over here so it will withdraw the electron density making it quite polar and now they can have a a hydrogen bonding so that will lead to stronger interaction so there is a stronger interaction between a and b and as we have discussed that will lead to negative deviation so so we can see by looking at the interaction between the components we can kind of guess that in which direction the a vapor pressure would change whether it is going to be a negative division or

positive

division okay when we have a very large deviation in a binary solution then they form what is called azeotropes ok

so we have seen earlier the

vapor phase is usually richer in more volatile solution

richer and more volatile component and using this property one can devise

a way to separate these two components just by heating the solvent a solution collecting

the vapor which is richer in volatile component condensing back again heating it and the vapor

which we are going to get from this condensate is going to be even richer in volatile component and

we if we keep on doing it we will get we should be able to separate out the two components but as

you drop with a special kind of solution where the liquid phase and the vapor phase had same concentration same concentration of liquid phase liquid phase and vapor phase and its clear if there is no difference

between concentration of a liquid phase and vapor phase if i just collect the vapor phase

it is going to give me the condensate is going to give me the same concentration as liquid

phase and it cannot be i cannot separate a from b

so we have already discussed

weaker interaction between two component compared to interaction between a component a

and or component b leads to positive deviation that is it has higher vapor pressure then it will be if i calculate the

vapor pressure using Raoult's law we know if higher the vapor pressure lower the boiling point higher vapor pressure means

more volatile component more volatile lower the boiling point

so in this case weaker interaction positive

deviation that means higher vapor pressure than calculated by

Raoult's law and it will lead to minimum boiling azeotrope and similarly if we have a

stronger interaction between a and b compared to interaction between a and a or b and b then we have a negative deviation that is the vapor pressure is lower than what it will be if calculated using Raoult's

law then we are going to get maximum boiling azeotrope and the example for such kind

of a binary solutions are if i have 95 ethanol by volume in water it

forms minimum boiling azeotrope and similarly if i have 68 percent H₂O by weight

in water then it forms maximum boiling azeotrope

so that's where we stop thank you very much you