

hello students in the last two lectures we have discussed about basics of ionic equilibrium in this lecture i will discuss problems related to related to ionic equilibrium the questions on ionic equilibrium are of two types one is ph based questions and second is your solubility solubility related problem in this lecture my main focus is on ph based questions

So ph based questions we will try to calculate p ph of a solution in which concept of ionic equilibrium is utilized utilized

So i have already discussed with you what is ph ph is your minus log activity of h plus ion concentration and for dilute solution for dilute solution this is simply equal to ph is equal to minus log h plus ion concentration we have already discussed about how to calculate ph for a strong acid and strong bases here we need not we do not need to apply your concept of ionic equilibrium equilibrium we do not need to apply concept of ionic equilibrium comes when when we are dealing with when we are dealing with weak electrolytes weak electrolytes what does i mean by weak electrolyte which dissociates a salt or a compound which dissociates not completely into water and there is equilibrium between undissociated and dissociated species that is known as your weak electrolytes your weak bases weak acids and salt of salt of v k seed and weak bases comes into this category in case of v cases we have equilibrium between un dissociated species and dissociated species in case of weak bases again we have equilibrium between your dissociated and undissociated species and similarly salt for example your n a plus plus a minus d c irreversible but a minus the hydrolysis of a minus giving you h a plus o h minus i

So the equilibrium exist between these species as a recap of last lecture where we calculated the ph of different solutions or for example for weak acid we calculated h plus 2b k a into c of h

So k is your ac dissociation constant and this is concentration of your acid concentration of acid for weak base we have o h minus ion is equal to root under k b into c b o h again this is your base dissociation constant and this is your concentration of v kc third salt of salt of vkc and a strong base since this is salt of a strong base you we will start with oh minus ion concentration and o h minus concentration will be given by kh into sea salt kh is hydrolysis constant of this salt and this is the concentration of salt and kh in this case will be given by kw by ka since this is salt of vkc this is salt of vkc

So h minus ion concentration is equal to k w by k a since k h is equal to k w by k and c solve is suppose i take logarithm of both side you will get half log kw minus log k a plus log c solved let's take minus sign both side is equal to half this will be minus log kw this will be minus minus plus log k plus minus minus log c solve and we know that this is equal to poh

So poh is equal to half minus log k w is equal to p k w and plus log k is k a is equal to minus p k a plus log this is minus

So we keep it minus log c solved minus log c sol again you see minus log k w p k w plus log k is equal to minus p k and you have minus log c is also minus log c

So so p o h e will be given by half multiplied by p k w minus p k a minus log c solve similarly we can calculate p h of salt of a strong acid a strong acid and weak base weak base for example energy for cl the salt is your salt of a strong acid scale and weak acid a weak base ammonia solution ammonia solution and since this is a salt of a strong acid So light h plus n is equal to your kh into sea salt as in salt is of weak base

So case will be equal to k w by k b into c solid

So if i take minus log h plus i this will give you half log kw with minus sign and then minus minus plus half log kb minus half log c salt c solve

So this is p h is equal to half p k w minus half p k b minus half log c

So half log c sort this is the way we can calculate ph of salt of a strong acid and weak base these four are very important formulas when you are trying to calculate ph uh ph of a solution where concept of ionic equilibria is utilized now let us see this question

what is the ph of 0.5 molar aqueous nsn solution and for this p k b of c n minus is given which is 4.70 now what is given is your concentration of nacn nacn and that is 0.5 molar So this is basically your salt concentration salt concentration is zero point five molar now you see nacn is nacn is salt of a strong base a strong base which is n o h but weak acid which is s n s c n

So in this case we can calculate o h minus ion is equal to o h minus ion is equal to k h into c salt kh into c salt now h minus iron is equal to kh into sea salt sea salt is

given sea salt is given this is your 0.5 molar we do not know the value of  $K_h$  what is given is  $pK_b$  of cyanide which is 4.70

So if we take cyanide ion plus water what we expect that that will give you a  $CN^- + H_2O \rightleftharpoons HCN + OH^-$  and this is also the hydrolysis reaction and since  $OH^-$  ion is given in this reaction  $K_h$  is basically equal to  $K_b$  for cyanide ion now since we know  $OH^-$  ion concentration is equal to  $K_h$  into your sea salt we can write  $pOH$

So let's take  $\log OH^-$  ion concentration is equal to  $\log K_h$

So  $\log K_h = \log K_b + \log C_{salt}$  and this is  $pOH$  and this is equal to  $\frac{1}{2} pK_b - \frac{1}{2} \log C_{salt}$  solve and since  $pK_b$  hydrolysis constant is simply equal to  $pK_b$  of cyanide which is your 4.70

So  $pOH$  will be given by  $\frac{1}{2} (4.70 - \log 0.5)$  since your salt concentration is 0.5 molar if we solve that we can get  $pOH$  and from that you can calculate  $pH$

So  $pH$  is equal to  $14 - pOH$  is equal to  $14 - 7.15 = 6.85$  next question is this dissociation constant of a substituted benzoic acid is at 25 degree celsius is  $1 \times 10^{-4}$   $pH = 0.01$  molar solution of its sodium salt is again dissociation constant of a substituted benzoic acid is given it means that this is solved what we are doing dealing with is sodium salt of weak acid sodium salt of weak acid and  $K_a$  is substituted benzoic acid dissociation constant is given

So  $K_a$  is given  $1 \times 10^{-4}$  concentration of acid is given  $C_{acid}$  is equal to 0.01 molar and what we need to find out is  $pH$  of the solution since this is a sodium salt of a weak acid weak acid this is strong base

So we will write  $OH^-$  ion concentration is equal to  $K_b$  into your concentration of salt concentration of salt and concentration of salt has been given concentration of salt is 0.01 and  $K_b$  again we have  $K_b = \frac{K_w}{K_a}$  we know  $1 \times 10^{-14}$  and this is given  $1 \times 10^{-4}$  into  $10^{-2}$  is  $10^{-2}$

So you see  $10^{-10}$  into  $10^{-2}$  is  $10^{-12}$  and

So this is  $10^{-6}$  under root of  $10^{-12}$  is  $10^{-6}$  and

So which and concentration is  $10^{-6}$  and then you have  $pOH$  is equal to  $pOH$  will be equal to 6 whereas  $pH$  will be equal to eight

So it is very easy first thing you have to decide whether salt is of a strong acid and weak base or weak base and strong acid salt can be from strong between a strong acid and a strong base which we have already discussed and salt can be between weak acid and weak base now next question is this  $pH$  of 0.1 molar solution of the acid  $K_a$  weak acid is three the value of ionization constant  $K_a$  of the acid is 0.1

So  $pH$  is given for the acid and you have to tell  $K_a$  what is the value of  $K_a$  we know that  $H^+$  plus ion is equal to for  $V$  case it is your  $K_a$  into  $C_{acid}$  and  $K_a$  is your you need to calculate  $K_a$  and  $C_{acid}$  it is zero point one ok what is given  $pH$  is given and that is your 3

So  $H^+$  plus ion concentration will be  $1 \times 10^{-3}$  since  $pH = -\log H^+$  and

So this is plus ion concentration

So  $1 \times 10^{-3}$  is equal to root  $K_a$  into 0.1

So  $K_a$  into 0.1 is equal to  $1 \times 10^{-6}$  or  $K_a$  will be equal to  $1 \times 10^{-6}$  divided by 0.1 and this is equal to  $1 \times 10^{-5}$  now what we will do is we will calculate  $pH$  of a solution when we are titrating a weak cell with a strong base

So what you are going to discuss next is titration of a weak acid a strong base weak acid and with a strong base  $V_{seed}$  is suppose acetic acid and when we titrate with  $NaOH$  how  $pH$  changes but before going to that I will next another type of solution which is known as buffer solution buffer solution these are very important solutions they are used to maintain  $pH$  of a solution what does it mean by that that a small addition of small addition of acid or base does not affect the  $pH$  of the solution there are different type of buffer first is your  $BK$  in presence of in presence of salt of weak acid  $VK$  with a strong base

So for example acetic acid with its salt with a strong base it's solved with a strong base that can be  $CH_3COONa$

So this is weak acid and then this is your salt of the same weak acid with a strong base  
ok

So let's talk about this solution

So you have a salt you have a salt and we know that since this is soluble salt it will completely dissociate  $C_s$  is  $U^-$  plus  $N^+$  and concentration of this will be equal to  $C_{solid}$  since all the salt has gone to your gone to dissociated form

So concentration of  $CH_3CO^-$  will be equal to  $C$

So now consider about this as a dissociation of your weak acid this is your  $CH_3COOH$   $C$   $CH_3CO^-$  plus  $H^+$  if you start with  $C_s$  in zero zero then you can write  $C_s$   $CH_3CO^-$   $H^+$   $1 - \alpha$  where  $\alpha$  degree of dissociation you will get  $C \alpha$   $C \alpha$  since we have  $CH_3COO^-$  and

So this will come into picture

So in presence of salt the concentration of  $CH_3CO^-$  is much much greater than  $C \alpha$

So concentration of  $CH_3CO^-$  ion is your  $C \alpha$  plus sea salt but we know that sea salt is very high in compared to  $C \alpha$  since  $CH_3CO^-$  here is generated from a weak acid

So amount of this will be always quite negligible compared to the concentration of  $CH_3CO^-$  which comes from salt here there is a complete dissociation here there is a very weak dissociation

So it is simply equal to  $C$

So so if we write again  $CH_3COOH$   $CH_3CO^-$  plus  $H^+$  at equilibrium at equilibrium we have  $C(1 - \alpha)$  and this is your sea salt and this is  $C \alpha$  or  $H^+$  ion concentration this is also almost equal to  $C \alpha$  since acetic acid is a very weak acid and  $\alpha$  is quite smaller than one and

So we can simply write  $C(1 - \alpha)$  is almost equal to  $C \alpha$  now if we write  $K_a$  a dissociation constant which is nothing but  $C_s$   $CH_3CO^-$  into  $H^+$  divided by  $s$   $t$   $k_s$  if  $CH_3CO^-$   $H^+$  and this we already know this is equal to  $C$  salt into  $H^+$   $y$  this thing is equal to  $C \alpha$

So acid dissociation constant  $K_a$  is equal to  $C$  salt into  $H^+$  divided by  $C$   $C \alpha$  and

So if I want to calculate  $H^+$  ion concentration this is equal to  $K_a$  into  $C$  acid by  $C$  solve  $C$  solved ok

So  $pH$  is equal to your if I do  $\log H^+$  plus  $\log H^+$  is equal to your  $\log K_a$  minus  $\log$  acid plus  $\log$  salt and this is  $pH$  is equal to  $pK_a$  plus  $\log$  solved by  $s$  solved by  $s$  and this is a famous Henderson Anderson Hasselbach equation equation for buffer

So we can calculate  $pH$  by using  $pK_a$  and if you know the concentration of salt and concentration of  $s$

So in the next I will discuss your titration of

So let us go back to titration of weak acid weak acid with a strong base a strong base weak acid with a strong base for example  $CH_3COOH$   $CH_3CO^-$  cases with  $NaOH$  and what will happen when we add  $NaOH$  from time to time what will be the change in change in  $pH$  what we are looking at is change in  $pH$

So let us start with 50 ml of 0.1 molar acetic acid acetic acid ok and then titrate with 50 ml of 0.1 molar your  $NaOH$  for acetic acid acetic acid is your one point around one point eight into ten to the power minus ten to the power minus five ten to the power minus five mole per liter

So first we will start with this solution 50 ml of 0.1 molar acetic acid

So when before the addition of before the addition of the addition of  $NaOH$  we have 50 ml of 0.1 molar acetic acid solution and we have we know that  $pK_a$  is equal to your  $\log$  one point eight into ten to the power minus five which is almost equal to 4.73 almost equal to 4.73

So how we can calculate  $pH$  of this

So this is we know that this is  $V$   $K_a$   $C$

So  $H^+$  will be given by  $K_a$  into your concentration of this  $C \alpha$  and

So  $\log H^+$  is equal to  $\log H^+$  is equal to  $\log K_a$  and  $\log$  half  $\log$

So acid concentration and  $\log H^+$  is  $pH$  is equal to  $\frac{1}{2} pK_a$  minus  $\frac{1}{2} \log$  your 0.1

So we know what is the  $pK_a$  value we know the value of  $\log 0.1$

So we can calculate  $pH$  of the solution  $pH$  of the solution now next step is what we are doing is we started adding we started adding your noise solution suppose we added suppose

we added 10 ml of 0.1 molar n o h

So you have acetic acid plus n o h and what you will get is your  $\text{CH}_3\text{COO}^-$  plus  $\text{H}^+$  two we have initial millimole if we just look at initial millimole of the reactant and product we started with your 0 point this is 50 ml into 0.1 molar

So basically 5 millimole of we started with 5 millimole of acetic acid and we added 10 into 0.1 that is your 1 millimole of n o h

So what will happen is you will get five minus one that is four milli mole and this is zero and how much salt is formed one millimole ok

So all of n o h will react with acetic acid to give one millimole of and then this

So what in the solution you have four millimolar acetic acid and one millimole of your sodium acetate

So again just look at it we started with 50 ml of 0.1 molar acetic acid what does that mean that we have five millimole of acetic acid solids we added ten ml of zero point one molar n o h and that ten into zero point one is one millimole of n o h they will completely react n o h will go to zero

So you are left with your

So one millimole of acetic acid will react with one milli mole of  $\text{NaOH}$  to give you one millimole of sodium acetate and left one is four millimole of acetic acid

So now we have in the solution we have four millimole of acetic acid and one millimolar sodium acetate

So we can apply anderson hasselbach equation which does that  $\text{pH} = \text{pK}_a + \log$  solved by s

So  $\text{pH}$  is equal to  $\text{pK}_a$  which is four point seven three plus  $\log$  to calculate salt concentration will apply concentration is equal to milli mole divided by volume in ml millimole we know salt the number of millimole of salt is one millimole

So one divided by volume is fifty plus ten fifty plus ten 50 of acetic acid 10 of your sodium acetate

So it is simply 1 by 60

So this is 1 by 60 and acid is the amount of acid is four millimole

So four divided by your sixty

So this is four point seven three plus  $\log$  one by four or simply we can write four point seven three minus  $\log$  four minus  $\log$  four now take a case when we added in the 50 ml of 0.1 molar acety cases we had added 25 ml of 0.1 molar n o h again we will go and do same calculation

So you have  $\text{CH}_3\text{COOH}$  plus  $\text{NaOH}$  neutralization reaction will happen and you will get  $\text{CH}_3\text{COO}^-$  plus  $\text{H}_2\text{O}$  you had five millimole of acetic acid in the solution and two point five milli mole of n o h in solution before reaction suppose reaction happens your all n o h will go to salt and since this is the limiting reagent and

So you have two point five millimole of n o h it will interact with 2.5 ml of acidic  $\text{K}^+$  to give you 2.5 millimole of sodium acetate and here left one is 5 minus 2.5 is equal to 2.5 millimole of acidic acid and

So again  $\text{pH}$  can be calculated using henderson hasselbach equation  $\text{pK}_a$  plus  $\log$  solved by acid and  $\text{pK}_a$  is four point seven three for acetic acid

So plus  $\log$  two point five by two point five yeah you can just divide by seventy five you want concentration but as i told you that volume does not matter here because in numerator and denominator both will be divided by volume and they cancels out ok

So what we get is four point seven three plus  $\log$  one and  $\log$  one is nothing but zero

So four point seven three

So this is the way we calculate  $\text{pH}$  for a  $\text{pH}$  in the titration cases ok

So first you have to know what is there in the solution whether there is only weak acid left whether you have weak acid plus salt of weak acid with a strong base you have only solved

So this is the things which first you have to understand then only you can apply the concept of your  $\text{pH}$  calculation

So now take another case when 50 ml you of 0.1 molar  $\text{CH}_3\text{COOH}$  you add 50 ml of 0.1 molar  $\text{NaOH}$

So equal volume is added what will happen let us see here we have acetic acid and you have added  $\text{NaOH}$  it will give you sodium acetate and plus your sodium acetate plus your water

So this is simple acid based reaction acid plus base gives you salt plus water you

started with five millimole of acetic acid you started with five milli mole of noh and zero zero

So when reaction happens all active and no h will go to sodium salt

So what is left is zero mole of this zero mole of this and five milli mole of sodium acetate

So now in a solution we have five milli mole of g h three c o n and total volume is equal to hundred and

So just we saw that that we have five milli mole of sodium acetated solution in hundred ml sodium acetate in hundred ml of solution we have five milli mole of sodium acetate in hundred ml of solution

So concentration is concentration of salt is five divided by hundred point zero five molar now what will the h plus ion concentration

So you just see this this is just salt of v k c and a strong base

So it will be alkaline solution and you have o h minus iron is equal to k h into c solve under root and k h is k w by k a k w by k into c solve

So p o h is equal to half p k w minus half p k a minus half log salt concentration log

So this is your 7 minus half pk half into 4.73 a minus half log salt concentration and salt concentration is 0.05 just put it here you will get poh and from poh you can calculate ph ph is equal to fourteen minus p four

So this is the way you can calculate your

So now neutralization has happened you have added 50 ml of noise to 50 ml of sodium

So acetic acid and almost all acid has gone to your soil all acid has gone to salt no basil left no acidity left now if we further add n o h the suppose 10 more ml of n o h is added

So we are dealing with a solution which are 50 ml of 0.1 molar acetic acid and 60 ml of zero point one molar n o h

So if we again write a reaction c s three c o h plus n o h giving you c h three c o o n a plus water we started by five millimole and this is six millimole zero zero now noise no longer limiting agent acetic acid becomes limiting air again and this will totally go to salt

So what is left out is one milli mole of n o h and you have a five milli mole of sodium acetate plus water plus water now you see in the solution we have weak base strong base we have a strong base noh and naoh and we have salt which is ch3coon

So we have noh plus salt and this salt is of weak acid and a strong base a strong base but since there is no h and this completely dissociates your hydrolysis is not complete and

So almost all o h minus ion will come from this base and this is nothing but your one millimole we know that one millimole is left and your volume is 50 ml of acetic acid a 60 ml of your 60 ml of base noise

So 110 and once we know that what is the o h minus ion concentration we can simply calculate minus log h minus ion and this is nothing but poh and ph can be calculated from ph 14 minus poise

So this is the way we calculate ph when we titrate ah vkc with a strong base similar kind of calculation can be done with a when we titrate a weak base with a strong acid when we titrate we with a strong acid

So let's see one more question what is given is point one molar n o h it titrated with zero point one molar h a till the end point

So h a means weak acid k is also given k for h is five point six into ten to the power minus six it means that your h is a weak acid degree of hydrolysis is less compared to one very very less compared to one then we have to calculate ph of the resulting solution at the end point at the end point okay

So zero point one molar in which is titrated with zero point one molar h a till the end point k for h is five point six into ten to the power minus six and degree of hydrolysis is less compared to one ok

So you see point one molar n o h point one molar h a till the end point

So you have no h plus h a gives you n a a plus s two and

So we are adding zero point one molar zero point one molar and this we know it is giving that till the end point what does that mean that if i start with xml of this i have to start with we have to add x m l of h a x m l of h h

So if you take the reaction n a o h plus h a giving you n a a plus water we started with zero point x m l of zero point one molar n o h and then we are titating with x m l of

zero point one

So we will get end point at when we add x ml of 0.1 molar h

So this will left 0 0 and how much millimole will get we will get milli mol as per two into x into zero point one milli mole of x into zero point one milli millimole of x into zero point one

So if we get point one into x millimole of n o h reacts with point one x milli mole of h a to give you point one x millimole of n a a

So in the solution we have only salt and the solution we have only salt which is basically salt of your weak acid and a strong base a strong base ok this is milli mole of n n a a but what will the concentration of n a this will be your this will be mole divided by total volume total volume is x plus x two x

So zero point one divided by two is point zero five molar of sodium this once we know the concentration of this

So we have salt of weak acid and a strong base since this is salt of a strong base we can calculate to h minus ion this equation  $K_h$  into sea salt and  $K_h$  is  $K_w$  by  $K_a$  since this is salt of weak acid salt and sea salt is given this is  $K_w$  by  $K_a$  into zero point zero five

So p o h will be equal to p k w half p k w minus half p k b p k a and minus half log 0.05 and this comes from your if i take minus log os minus sign this will be equal to this will be equal to minus half log  $K_w$  plus half log a minus half log c solve and minus log k w is equal to p k w minus log k a is equal to p k a and

So we have half p k w minus half p k a and minus r log c solve

So by using this equation you can calculate p o h and from that we can calculate p p h of the solution ph of the solution now take next question calculate the ph of the solution when zero point one molar acetic acid fifty m l and zero point one molar n o h fifty 50 ml are mixed k is 10 minus 5 again you see 50 ml and 50 ml same molar and

So you end up with the salt of v k c dan v k c dan a strong base a strong base and you can calculate your voice minus iron by using  $K_h$  into c salt  $K_h$  we know that  $K_h$  is equal to  $K_w$  by  $K_a$  into c

So once you calculate o h minus ion concentration you can calculate h plus ion concentration and then you can get the ph of the ph of the solution

So today what we saw is how to calculate ph when two solutions are mixed one is acid another is base and what we what we calculated is ph of