

hello students in the last lecture i was discussing about ionic equilibrium as we know that ionic equilibrium deals with ionic equilibrium deals with ionic reaction ionic reaction and when we discuss an ionic reaction that must be reversible then only we can apply the concept of equilibrium for example dissociation of dissociation of acetic acid acetic acid

so this is CH_3COOH when you put in water it dissociates to give you acetate ion and H^+ plus ion

so reaction has ions first thing is reaction has ions and the second thing is there is a equilibrium there is a equilibrium between your undissociated species and dissociated ions dissociated ion only in this case we can apply the concept of equilibrium

so when we apply concept of equilibrium to an acetic acid solution we can simply write the way we used to write for your an equilibrium reaction equilibrium constant equal to product products

so this is the multiplication of the ions in the product side divided by the concentration of reactor

so first thing is ions and what i discussed in last lecture is ions are generated by electrolytes

so when you put electrolytes in aqueous solution ions are generated electrolytes generally we discuss three different kind of electrolytes one is acid another is base and then salt then solve now second part is reversible reversible not all ionic reactions are reversible not all ionic reactions are reactions are reversible lot of them are irreversible for example your dissociation of dissociation of a strong acid a strong acid for example HCl here this completely dissociates it means it is almost irreversible to give you H^+ plus Cl^- minus HCl

so when the reactions are not reversible or reactions are irreversible we cannot apply a concept of equilibrium here similarly we can think of dissociation of dissociation of strong bases strong bases for example NaOH sodium hydroxide and you put in aqueous solution it will give Na^+ plus aqueous plus OH^- minus NaOH and the last one is your dissociation of dissociation of soluble salts soluble salt for example NaCl here this is also irreversible this gives you Na^+ plus equals plus chloride ion across

so dissociation of strong acids strong bases or soluble salts are irreversible and we cannot apply the concept of equilibrium now where we can apply we can apply for dissociation of V cases dissociation of V K_c for example your acetic acid

so it breaks to give you CH_3COOH aqueous plus H^+ plus ion aqueous

so this is your reversible reaction and we can apply equilibrium constant here we are writing equilibrium constant for this reaction which is known as acid dissociation constant acid dissociation constant and this will be equal to your $\frac{[\text{CH}_3\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{COOH}]}$ into H^+ plus by acetic acid concentration of acetic acid similarly we have dissociation of weak bases weak bases for example you have ammonia solids in water it will give you NH_3 plus aqueous plus OH^- minus equals and then again we can write K_b here you can say this is waste dissociation constant constant and that is equal to $\frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]}$

so this is the way we can apply the concept of equilibrium the third thing example is your solubility of a sparingly soluble solid soluble solvent for example AgCl is here as AgCl will give you Ag^+ plus Cl^- minus

so this is an aqueous this is an aqueous form these three types of dissociation are reversible if we takes for example AgNO_3 then it is not reversible because this is a soluble salt and this will give you Ag^+ plus aqueous plus NO_3^- minus likewise it completely dissociates it is soluble it completely dissociates and gives you silver plus aqueous plus NO_3^- minus AgNO_3 plus

whereas if i take another solve a g c l this is a sparingly soluble salt and it will give you a g plus aqueous plus c l minus x

so only a small amount of a g c l will go to solution where is almost all agno₃ will go to solution

so now we know that how ions are generated and when we can apply the concept of equilibrium

so let us go and discuss your degree of degree of dissociation dissociation this will be the term which you will come across quite often when we are dealing with questions of ionic equilibrium

so degree of dissociation is your moles of moles of your acid base or salt base or salt which is which exist in ionic form ionic form ionic form per mole of acid based salt base also for example if suppose i take one mole of acetykc of acetic acid and i put in water i put in water it will give you ch₃co minus plus h plus aqueous

so i started with 1 0 0 some of the mole will go in aqueous form the number of mole the amount in mole which goes in ionic form is called your degree of dissociation for example if alpha mole of acetic acid goes to your ionic form what does that mean that alpha mole of acetate ion will be formed alpha mole of h plus will be formed and what we are left with is one minus alpha

so alpha mole of acetic acid has gone to ionic form and what is left here is one minus alpha and the ions generated are alpha mole of acetate ion and alpha mole of h plus iron

so this is the degree of dissociation here alpha is the degree of dissociation since alpha mole out of total of one mole of acetic acid has gone to solution

so suppose i take another concentration c h three c o h going to c h three c o minus plus h plus i started by c zero zero then we know that alpha is your amount of ch₃cooh which has gone to ionic form per mole of ch₃cooh acid or acetic acid

so if alpha is your number of mole per total mole of acetic acid

so you have c alpha is the used of acetic acid ok and

so we can simply write the remaining acetic acid as c minus c alpha

so what we simply multiplied since alpha is per mole and we have c number of moles of acetic acid

so if one mole gives you alpha mole of your ions c mole will give c alpha mole of iron

so c c minus e minus c alpha and here you will generate c alpha c alpha and another way to write is c one minus alpha c alpha c alpha now we can write k a in terms of your initial concentration and degree of dissociation which is alpha

so how we write we know that this is acetate ion into h plus divided by your c h three c o o h and since this is c alpha into c alpha divided by c one minus alpha

so we can express k a in terms of your alpha which is degree of dissociation for acidity basis

so let us again write this equation c h three c o h giving you c h three c o o minus plus h plus what you are left with c one minus alpha and here you will get c alpha c alpha

so k a is equal to your c alpha into c alpha by c one minus alpha and this is c a square alpha s square by c one minus alpha since this is a very weak acid one is quite greater than alpha

so one minus alpha what does that mean is one minus alpha is almost equivalent to one and

so ka will be written like c a square alpha s square by c one minus alpha is one and

so c cancels out c alpha square c alpha square

so K_a is equal to $c \alpha^2$

so if i know α i can calculate K_a and similarly if i know K_a i can calculate α what will be the α α is simply K_a by c K_a by c if we remember α c is equal to h^+ ion and

so we can also calculate h^+ ion concentration if we know K_a and that is simply c into α or c into h^+ is $c \alpha$ c into α is K_a by c and so you have K_a into c

so if i know α i can calculate K_a on the other hand if we know K_a then we can calculate α and also we can calculate the concentration of ions in the solution for example in this case we i have shown you that how h^+ ion concentration can be calculated now similarly we can take another example of your weak base for example we can start with ammonia solution h^+ four plus aqueous plus o^- h^+ minus x plus

so K_b is equal to similarly here we can write $c(1 - \alpha)$ this is almost constant $c \alpha$ $c \alpha$

so $c \alpha$ into $c \alpha$ divided by $c(1 - \alpha)$ and again since it is a weak base we can simply write $c \alpha^2$ by c or $c \alpha^2$

so α is equal to $\sqrt{K_b / c}$ and now you see o^- is what o^- is equal to $c \alpha$ and

so you have K_b into c

so you can calculate o^- concentration if you know the value of K_b if you know the value of K_b now let us go and discuss about your discuss about salt hydrolysis ah before that lets discuss about dissociation of water

so water is also a weak electrolyte and it gives you in the solution h^+ plus o^- you can also write s^2 o^+ s^2 o^- giving you s^3 o^+ plus h^+ minus n ok

so K is equal to we can apply equilibrium concept K is equal to s^3 o^+ plus into o^- divided by s^2 y^2 this is a constant

so K into s^2 y^2 we also known as K_w and this is equal to s^3 o^+ plus into h^+ minus is s^3 o^+ plus into y h^+ minus r

so K_w is equal to s^3 o^+ plus into s^3 o^+ plus into h^+ minus sign concentration and this is equal to one into ten to the power minus fourteen one into ten to the power minus fourteen your mole square dm^{-6} and 8 ah this is at 300 kelvin 298 kelvin basically for pure water for pure water

so K_w value this is also known as ionic product and if product its value is one into ten to the power minus fourteen mole square per dm^6 at three hundred or two ninety eight kelvin lets write two ninety eight kelvin for pure water now let's think of take a simple example of ph if suppose i need to calculate ph of 10^{-2} molar scl ok

so first we need to know h^+ ion concentration since your h^+ ion is pH is your minus log h^+ plus h^+ plus

so what is the s^+ ion concentration

so h^+ plus can come from scl and we know that scl is a strong acid it completely dissociates

so if you have started with 10^{-2} molar will get 10^{-2} molar s^+ plus ion from scl we can also get s^+ plus from s^2 but this is a reversible reaction and the amount of h^+ plus obtained will be small it is to the order of 10^{-7} certainly it will also depend on your common ion effect it is not exactly equal to ten to the power minus seven impedance of scl ok it will be even smaller than ten to the power minus 7 because of common ion effect which i will explain you later

so 10^{-7} and 10^{-2} this concentration quite less in comparison to 10^{-2} molar and hence almost all of h^+ plus in the solution will be contributed by scl and

so the H^+ concentration will be 10^{-2} at 10^{-2} the power minus two and

so pH will simply be equal to $-\log H^+$ which is $-\log 10^{-2}$ and that is equal to 2.

so pH of 10^{-2} molar $NaCl$ will be 2 but now let us take another example pH of 10^{-8} molar $NaCl$ in this case what will happen again $NaCl$ will completely dissociate and

so if you have started with 10^{-8} molar you will get 10^{-8} molar H^+ however here we cannot neglect the dissociation of H_2O since $[H^+]_{H_2O}$ will now be almost 10^{-7} is now no longer smaller than or can be neglected compared to your 10^{-8} molar got 10^{-7} is greater than 10^{-8} molar

so in this case H_2O will contribute to the pH or H_2O contribution of H^+ from H_2O will not be negligible in this case we must add H^+ from $NaCl$ and H^+ from H_2O you must add this to no exact amount of H^+ here or H^+ exact amount of H^+ you see if we have neglected H_2O then what will we get is 10^{-8} molar and if we calculate pH then it will be equal to 8 it will be equal to 8 which is not right which is not right pH is equal to 8 is not right

so pH of an acid acidic solution can never be greater than can never be greater than 7

so how can we calculate the H^+ ion constants

so H^+ ion is almost equal to 10^{-7} plus 10^{-8} which is around $10^{-7.1}$

and then you can calculate pH by using $-\log H^+$ which will be almost around 6.9 something

so you must remember that H^+ ion can only be neglected H^+ ion from water can only be neglected when it is your concentration of acid or base is quite greater than 10^{-7} molar now let us take a polyprotic acid for example H_2SO_4 now this polyprotic acid the first step can be very

so first dissociation is almost irreversible almost irreversible K_a value will be your large very large however the second one will be irreversible may have some irreversibility it will dissociate lesser than the first one lesser than first one

so K_{a1} this is called K_{a1} this is the first dissociation and there is a K_{a2} which is the second dissociation

so K_{a2} will always be less than a one that is quite simple first you are removing H^+ ion from this H^+ ion from a neutral species where in the second case you are trying to remove H^+ ion from a negative species removal of positive ion from a negative species is really tough

so not that easy process and

so K_{a2} is going to be small

so we have discussed strong acid a strong base a soluble salt weak acid weak base now we will go for salt ok again i told you their salt can be of two types soluble insoluble or we can say sparingly soluble sparingly soluble soluble soluble soluble will completely in the solution completely go to the solution dissociate it goes into solution and completely dissociate solution where as sparingly soluble a small amount goes and then dissociate

so for example $AgNO_3$ if you put in water you will get Ag^+ aqueous plus NO_3^- equals and this is a irreversible reaction it means it is a

HNO_3 is completely soluble it is in solution and gives you ions it completely dissociates to give ions whereas if you take AgCl it does not go into solution only a smaller part goes to solution and that's what we have based first I will discuss soluble salts

so hydrolysis of soluble hydrolysis of soluble there are four different type of we are going to consider first is your salt of strong acid and a strong base second salt of weak acid and strong base in first case you will take the example NaCl the second case we will take CH_3COONa

so sodium salt

so this is a strong base and there is a V^-K^+ now third case discuss salt of your strong acid and weak base weak base and fourth we can discuss salt of salt of a weak acid sorry weak acid and with this

so here example is your NH_4Cl here and has four Cl^-

so it is a salt of HCl which is a strong acid and ammonia solution which is a weak base and lastly this this is your sodium acid ammonium acetate

so this is weak acid this is your weak base salt of these two

so let's discuss first your salt of a strong acid a strong acid and a strong base and we will also discuss first we will discuss how they will behave and then we can discuss what will be the pH of the solution if we have a salt of a strong acid and a strong base

so first thing is your this is your salt which is a salt of strong base sodium hydroxide and a strong acid which is your hydrochloric acid we know that this is a strong electrolyte all soluble salts are a strong electrolyte

so we can simply write Na^+ plus Cl^- and now how Na^+ behaves in water in presence of water it simply gets hydrated Na^+ aqueous and Cl^- again SO_4^{2-} plus X^+

so whatever H^+ ion will get in this solution will come from water and at 298 K we know that K_w is equal to one into ten to the power minus fourteen mole square dm minus six ok

so your H^+ ion or OH^- ion will be equal and that will be under root K_w since we know that K_w is H^+ into OH^- square and

so it is can we simply write H^+ square

so SO_4^{2-} ion concentration will be equal to one to the power minus 7 molar and

so pH will be your simplicity

so for any solution aqueous solution of a strong acid a strong salt of a strong acid and strong waste pH will be safe now take the second case salt of V^-K^+ cases and a strong base for example sodium acetate sodium acetate

so sodium acetate is salt of acetic acid which is a weak acid and sodium hydroxide which is a strong base and I told you that this is a soluble salt and so it will completely dissociates into water

so CH_3COO^- plus Na^+ now if you remember that last time I told you about behavior of ions in the solution in aqueous solution

so let's remember Na^+ plus water what will happen when Na^+ is in water it will give you Na^+ equals Na^+ plus equals what about CH_3COO^- this ion simply does not get hydrated but it does it will give you acetic acid plus OH^- ion concentration and the OH^- concentration which you are going to get in most cases is always greater than OH^- which you get from water and

so if I want to calculate pH of pOH I need to know how what is the value of OH^-

so let's consider again this reaction CH_3COO^- plus H_2O giving you CH_3COOH plus OH^-

so this is your reaction and now I need to calculate what is the H^+ ion if I know acid dissociation constant of acetic acid which K_a we can say

so let us write K_h which is hydrolysis constant this is known as K_g equilibrium for this reaction is called K_h since this is a hydrolysis of your salt

so K_h is equal to $\frac{[OH^-]^3 [CO_3^{2-}]}{[CO_3^{2-}]}$ now again if i assume that your C is the concentration of salt then C will be since this is a again soluble salt

so this is simply sea salt initial concentration is sea salt and if i take that this reaction is this α and we will get $C \alpha$ $C \alpha$ what does that mean is out of one mole of CO_3^{2-} ion α mole has converted to your CO_3^{2-} in this case we can just write simply this equation and we can put it here $C \alpha$ $C \alpha$ by C one minus α ok

so K_h is acetic acetate ion OH^- acetic acid OH^- C ratio minus ion or you can express in terms of α also now let us write K_h is what K_h is $\frac{[CH_3COO^-]^3 [OH^-]}{[CH_3COOH]^3}$ and we also know for acid dissociation constant of acetic acid this is $\frac{[CH_3COO^-] [H^+]}{[CH_3COOH]}$ now let us multiply K_h into K_a what you will get K_h into K_a is your $\frac{[CH_3COO^-]^3 [OH^-]}{[CH_3COOH]^3}$ into $\frac{[CH_3COO^-] [H^+]}{[CH_3COOH]}$ into $[H^+]$

so this cancels out this cancels out this cancel

so this is simply equal to K_w

so K_w is equal to your K_h into K_a

so we know K_w we know K_a

so we can calculate K_h and we know that K_h is equal to $\frac{C \alpha^2}{C(1-\alpha)}$ which is your equal to if one is quite greater than α then we can write simply $C \alpha^2$ $C \alpha^2$ and

so or we can simply write $[OH^-]$ is equal to $C \alpha$ since $[OH^-]$ is equal to $C \alpha$ your K_h will be and K_h is equal to $C \alpha^2$ and

so if i multiply this by C both sides C

so this C into K_h will be $C \alpha^3$ square which is $[OH^-]^3$ square and

so $[OH^-]$ is equal to $[OH^-]$ concentration is equal to K_h into C K_h into C and K_h we already calculate K_h is equal to your K_w by K_a into C

so this equation $[OH^-]$ ion concentration K_w by K_a into C can be used to calculate pH of the solution we can do that here $-\log [OH^-]$ is equal to $\frac{1}{2} \log$ your K_w by K_a into C

so $\frac{1}{2} \log K_w$ minus $\log K_a$ plus $\log C$ this is with the minus sign

so let us put minus sign here and

so pOH will be $-\log [OH^-]$ and from this equation we can ah we can calculate what will the pOH solution and since pOH plus pH is equal to 14 you will be able to calculate your pH of the solution

so this is

so we discussed first a salt of strong acid and strong waste like $NaCl$ and salt of weak acid and strong waste now we will discuss salt of a strong acid and weak base for example we discussed about $NaHCO_3$ here energy force again this is soluble salt when we put into the solution it will break completely

so this is your sea salt then it will give you the concentration of Na^+ CO_3^{2-} also equal to C solved ok

so basically every one goes to NH_4^+ plus one now N is four plus ion with water will give you NH_4^+ plus aqueous plus OH^- sorry ah yes NH_4^+ plus this is your reversible reaction this is your reversible reaction and

so you can write K_h is equal to $\frac{[NH_4^+]^3 [OH^-]}{[NH_4^+]^4}$ plus and we know that NH_4^+ network solution gives you NH_4^+ plus into this is your voice minus ion in aqueous aqueous and

so this is your K_b K_b is equal to your NH_4^+ plus OH^- divided by NH_4^+

and just now we calculated K_h which is $n s^3$ equals into $s^3 o$ plus divided by $n h^4$ plus again if in this case we multiplied K_b into K_h it will be going to be equal to K_w if we know K_w and K_b of your weak base we can calculate K_h and once we note K_h we can calculate $o h$ minus ion concentration and $o h$ minus ion concentration or h plus ion concentration

so lets again write how do how can we calculate this is $n s^4$ plus $s^2 o n$ s^3 equals plus $s^3 o$ plus initially you have sea salt zero zero at equilibrium this is sea salt one minus α and this is $c \alpha$ $c \alpha$ and

so K_h which is nothing but K_w by K_b is just we calculated is equal to $c s^2 \alpha^2$ s^2 this is c one minus α and if α is quite small then one we can simply write $c \alpha^2$

so $c \alpha^2$ α^2 is simply K_h into c and this is nothing but h plus s in square or s^3 one square and this is your h into c

so h plus ion concentration can be calculated by taking a square root of K_h into c a square root of K_h into c and we know that K_h into c K_h is K_w by K_b into c

so it is quite easy if you understand how to calculate how to derive this equation ah how the ions behaves in the aqueous solution it is quite easy to write an equation an equation for hydrolysis constant in case of soil and hydro this is constant is related to your ionic product and your K_a or K_b once we know K_h we can calculate your concentration of h plus ion r o h minus ion in the solution depending on which salt you have taken and once you know s plus iron or is minus ion you will be able to calculate your ph of the solution

so for example here we simply take minus log h plus which will be give you minus half sorry minus half your log K_w minus log K_b plus log c and this is your p h is equal to minus half you see minus half log K_w is your minus log K_w is pK_w or simply you can write your pK_w is

so minus half into pK_w and minus log K_b is pK_b plus log r minus half log c half $p K_b$ plus half log c this is the way we can calculate the ph of the solution if we know which kind of salt is present in the solution now the last one is salt of your weak acid weak acid and weak base weak acid and weakness for example we can take the solution of ammonium acetate ammonium acetate again this is soluble salt

so it can simply right and put in the solution hundred percent it will dissociate it will give you $c h^3 c o o$ minus plus $n s^4$ plus $o k$ and when you put if you think about how can how acetate ion will behave in aqueous solution it will basically abstract $h^3 c o o$ h plus $o h$ minus n and K_h will be equal to your $c h^3 c o h$ into $o h$ minus divided by $c h^3 c o$ minus when ammonium plus ion will hydrolyze ammonium plus ion will hydrolyze this is this in water will give you ammonia ammonia plus s^3 plus solution h_3o plus solution

so based on that again you can write K_h for your acetate ion and K_h for your ammonium plus iron and then finally you can calculate h plus i the way i have done for other salts

so thank you you