Environment Engineering: Chemical Processes

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Module No # 03
Lecture No # 14
Acid –Base Reactions

Hello everyone so welcome back to our latest session so until now we have been discussing the fundamental aspects and what are they I guess equilibrium and kinetics right equilibrium gives us an idea about how far can be system travel let us say and kinetic will gives us an idea about how fast will the system go right. So we discussed the relevant aspect in detail so now we have done with the fundamentals.

Now we are going to on with the applications and let us look at what they are in general before moving on into greater detail into one of these aspects which is going to be acid and base reaction right.

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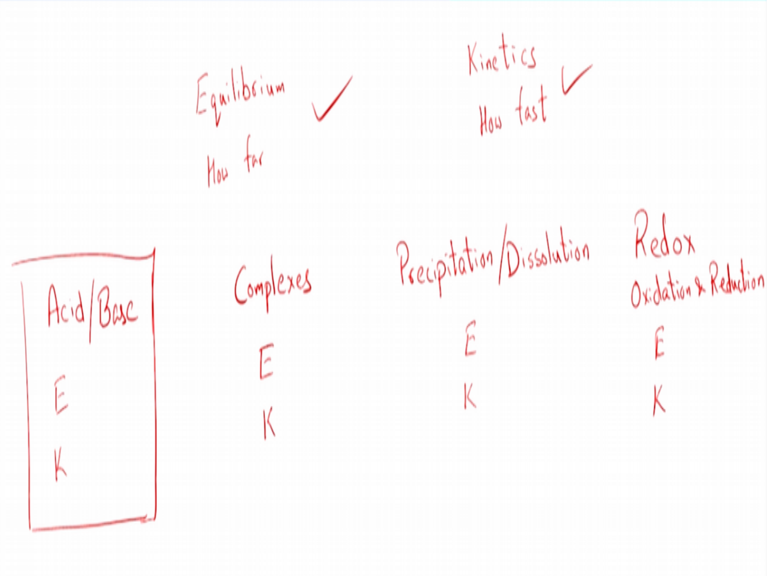

So the bigger picture here is that we looked at equilibrium and we looked at kinetics right how far and how fast and we are done with these two aspects. And now we are going to look at the applications and what are the usual applications we come across environmental engineers I guess or acid base reactions we come across complex formation or formation of complexes.

And we also come across precipitation or the dissolution of the relevant solid and more importantly we will look at redox process two and or the oxidation and reduction process right. So these are what we are going to look at so in each of these cases going to look at their effect of equilibrium and kinetics and each of these cases right. So acid and basis are an important aspect with respect to environmental engineering why is that we are going to look at that in next couple of slides.

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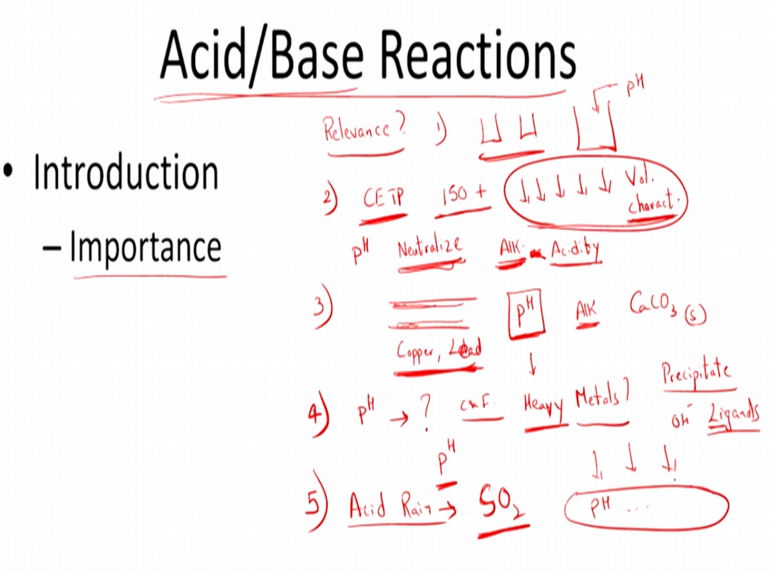

Acid/Base Reactions

- Introduction
  - Importance

Relevance?
1)
pH
2) CETP 150 + Vol. charact.
pH Neutralize Alk. Acidity
3) pH Alk $CaCO_{3}(s)$
Copper, Lead
4) pH → ? c.f. Heavy Metals? Precipitate
OH^- Ligands
5) Acid Rain → SO_2 pH
pH ...

So I guess first acid base reactions are the major heading here or major topic of discussion so we are going to talk about the importance right so what is the important I guess so I look at the relevance we always need to look at the relevance why do we need to discuss what it is we are discussing now why talk about acid base reactions now right. So in general let us say lab you know I am mixing 2 solutions you now I have two beakers mix them up right and I want to know what is the final PH as simple example I guess.

Again what do I need to look at? There are relevant acid base reaction right for example though if I am looking at the common affluent treatment plant let us say right and here you have let us say 150 or 100 industries or greater than 100 industries dumping their waste to this affluent treatment plant right they are different kinds of waste with different volumes. So volumes are different and the characteristics are different right.

So you might end up with the PH that is relatively abnormal let us say right and you want to neutralize that right before you either send it to biological treatment right and so on. So how do I look at these or how do I go about neutralizing this particular waste water that has consequence from different kinds of industrial waste right.

So I need to look at the relevant aspects like (()) (03:59) certainly acidity which I guess is relatively what do we say determine or you know is correlates not correlates I guess you can understand in the context of ((()) (04:12) itself so I will not go further here. So I need to look at (()) (04:15 and acidity and so on and then look at the amount of acid or base we need to put in to be able neutralize you particular waste water.

So that is 1 particular example their another example you can look at is let us say you have pipes let us say right and in general you have either copper or lead pipes I am talking about distribution pipes not may be why we copper or lead so if you want to avoid corrosion going to have corrosion due to chemical process you want to avoid corrosion you can maintain a specific PH right either to form a protective layer above this particular surface right.

If there is certain futility in your particular system you can form a purtive layer with carbonate precipitate for that you need to look at PH or by adjusting by PH itself you can what do we say lesson the kinetics with respect to the corrosion of copper and layer right this is another practical example so other aspect is that let us say you know that PH affects your treatment efficiency of various unit process right so how is my PH going to affect various treatment or various process like let us say coagulation or flocculation let us say right or heavy metal removal.

How do I remove heavy metals in general how do we remove them let us say try to form precipitates or we try to precipitate them out you now either OH – (()) (05:51) or any other ligands I guess that we add or existing in solution so for that what is the critical aspect now it is going to be PH right. So that is another aspect that we need to look into is so again what else let us look out some that people look at let us say.

So under what conditions are such will acid rain be formed right of sulphate dioxide let us say or what concentrations are required let us say and let us if this particular acid rain falls on particular lake what is going to be effect of that particular acid rain on the particular lake what is it going to be so that something that I need to look at right.

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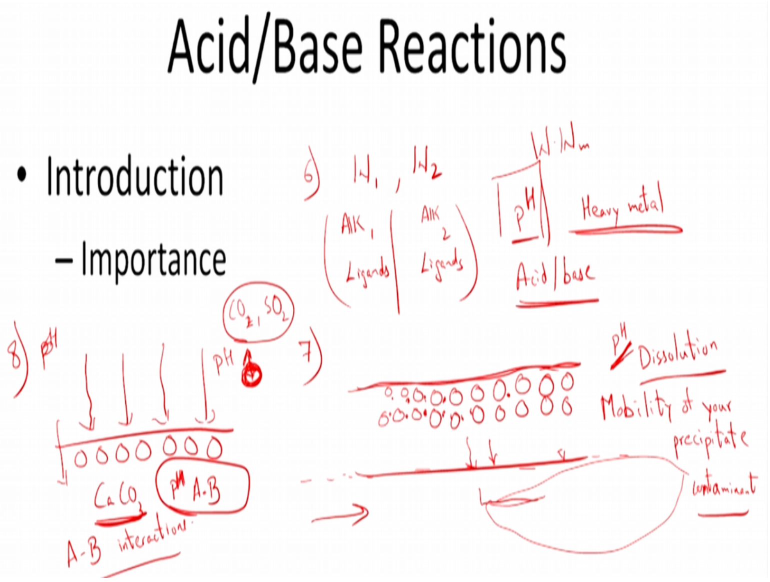

Acid/Base Reactions

- Introduction
  - Importance

So and again let us say I have two waste water I am mixing now waste water 1 and waste water 2 and now I have let us say different alternatives in both the cases and different kinds of ligands for both the waste water so now I have mixture waste water mixture so I how are this particular variables which are again going to depend upon the PH of the system right going to affect my heavy metal remover this is another aspect.

Obviously again I need to look at right again the key aspect here is PH or obviously acid base reaction again right and let us look at one another aspects. So let us say you have a contaminated salt right with heavy metal and let us say you know again this is surface of if your soil or earth and this let us say soil please excuse my poor soil skills and this let us say my soil and let us say I have precipitate of various heavy metals right.

So for now let us say precipitate out it is relatively immobile though right and this let us say the ground water level okay. And for now we have precipitates and their immobile right and you do not want them to contaminate your ground water that let us say if it comes in contact with relatively acidic PH water.

Let us say what is going to happen now in general depending upon the kind of contaminant I guess their can be dissolution now right depending on the PH of the water that it comes in contact with it can be dissolution and then that can reach again into the ground water and again contaminate the ground water this is the ground water flow direction you are going to have a contaminated (()) (08:40) right.

So again what is the important aspect here PH or acid base reactions would determine the mobility of your precipitates let us say or contaminant I guess better word in this constant context would be contaminant right. So that is one particular case let us look at the last aspect may be what else can I look at let us say okay let us say there is rainfall let us say again right and I try to get that this particular extent here example here and this is my soil right and for example it comes in contact with rainfall.

And let us say PH of raindrop is particular value right and this will be after equilibrium in particular consequence in the air right you will have again acid base transformation here and again you will have calcium carbonate let us say and deposit in particular soil and now you are again going to have acid base interaction here right.

And again you want to then be able to calculate what is the final PH of this particular soil here once you take into consideration the interaction between the relevant consequence in gaseous phase with the water droplet and then with the water droplet again once in comes in with contact of lime or calcium carbonate deposits in the sub surface. Again what are the concern with again acid base reactions right.

So again the importance of acid base reaction is (()) (10:32) even in our gut right in our stomach I guess right you know there is specific PH that is maintain in the gap either to propagate the growth of specific bacterial colonies or to restrict the growth of species of microbes here let us say again the whole body or the system that we look at in nature it is going to be dependent upon acid base or PH reactions.

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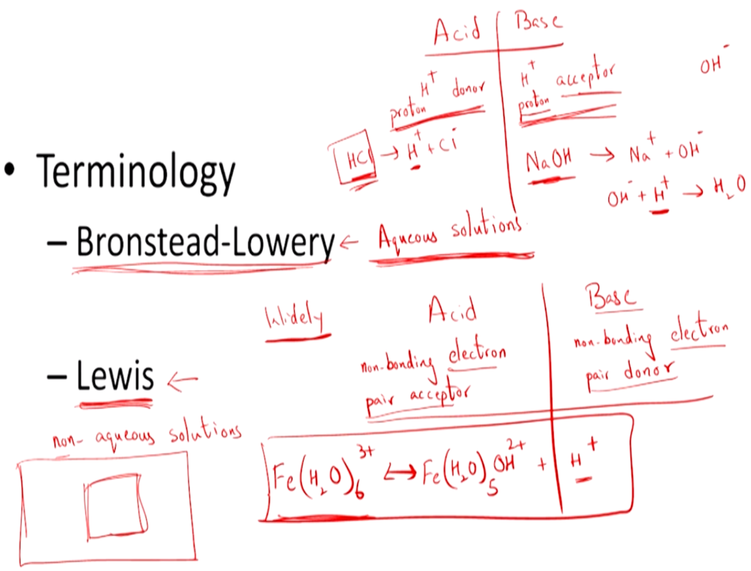

- Terminology
  - Bronstead-Lowery
  - Lewis

So let us go through and look at what we have later so again here we have terminology and here we are going to look at 2 ways to understand or define what acid is or base is right? Here we have acid and here we have base yes and let us see what we are going to look at let us say. So here we have Bronstead lowery theory so this is applicable to aqueous solution right yes so how do define that let us say?

We define acid as a proton H+ or a proton donor right and how do we define base as obviously the inverse H + or proton acceptor. So the example will be HCL and acid (()) (11:55) relatively neutral OH or most PH it will dissociate into H+ and CL – so as you see HCL is donating a proton right as would say HCL is acid yes and here with respect to base when usual example of obviously sodium hydroxide I had crystals of sodium hydroxide to water.

Let us say what is going to happen here it is going to release NA + which – and OH – again what will that do consume the H+ in particular solution and go to H20 seen effects it is mean that is going to consume or accept a proton so that is what we say here or you can even call donor of the H – I guess right so again let us clear up what we have whenever you have a particular compound releasing protons or proton donor we call that acid and whenever it is accepting a proton we say that is base right.

So this is for your basic knowledge I guess but in general this as we talked about is only applicable in your aqueous solution so let us look at wider more widely accepted right theory that is the Lewis based situation of acid and base which is not only applicable to aqueous solutions but even when you have solvent and such involved right so are you know this is applicable to non-aqueous solutions too.

So with Bronstead Lowery theory you will be able to explain bit of few acid and basis but the Lewis give a bigger set right. S more or less Bronstead and Lowery definitely will give a sub set of a Lewis acid and basis so again what is the Lowery acid I guess right we are going to say it is going to be non-bonding electron pair accept so it is an acid is one which would accept a pair of non-bonding electrons.

And same case base non-bonding electron pair donor right as it one that accept the pair of electrons right and base is one that would donate a pair of electrons non- bonding pair I guess right. So this is one example I guess so we are going to usually be concerned at least in this class the Bronstead and Lowery because we are mostly going to look at non-aqueous and aqueous solution pardon me or with water as a solvent.

So we have non aqueous solutions we look at Lewis theory and that is the generic definition here so we can look at one example here and that is ferric H2O and 6 and 3+ and that is going to dissociate into FE H2O 5 and what else if it is going to dissociate OH 2 + H + in effect the FE or ferric is lulling electrons from H2O and there by releasing H+.

So it is an acid here why is that it is pulling the electrons from water so it is a electron pair accepted and that is why you can call this particular compound here or complex here to be a acid here and this is one particular example so we do not need to go into that in greater detail though.

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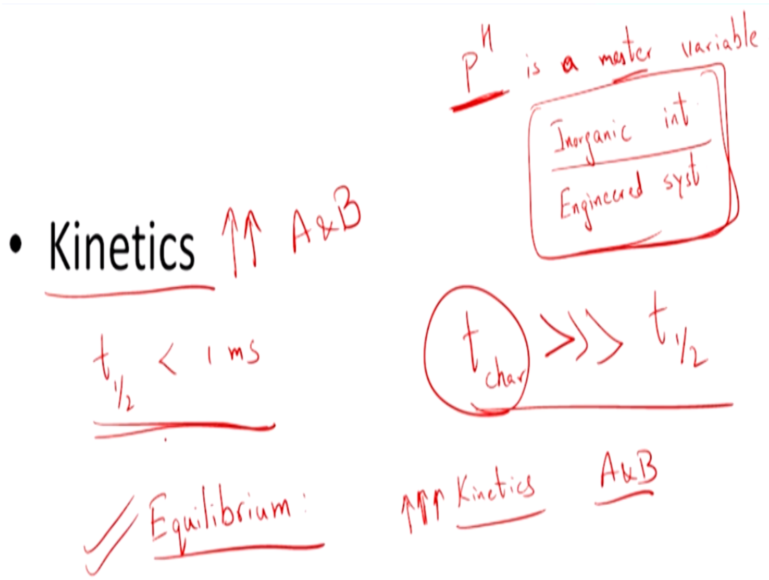

- Kinetics ↑↑ A&B

pH is a master variable

Inorganic int

Engineered syst

$t_{1/2} < 1\ ms$

$t_{char} >>> t_{1/2}$

✓ Equilibrium : ↑↑↑ Kinetics A&B

So moving on what do we see I guess we see that PH a master variable is a master variable and what does that mean it means that the context of almost of all inorganic interaction let us say or most other system or engineering systems PH as a key variable or master variable especially with respect to in organic interactions and most of our engineering systems PH or the relevant acid base reaction are going to be the key.

So right and now we are going to talk about kinetics in the context of acid base yes so in general half-life of acid base reactions are typically less than 1 milli second let us say right. So the kinetics is relatively fast or remarkably fast in general so what is that mean now so for all practical purpose the character time or the time that we look at with respect to our systems is much greater than the reaction time or half-life here.

So what does it mean in effects means that the kinetics is so fast that the system will almost always end up reaching equilibrium right so that is what we are talking so what is that mean so we do not need to look at kinetics in general with respect to your acid and base reactions right why is that the kinetics are so fast that for most of your characteristic times you will end up reaching equilibrium yes so what are we going to do.

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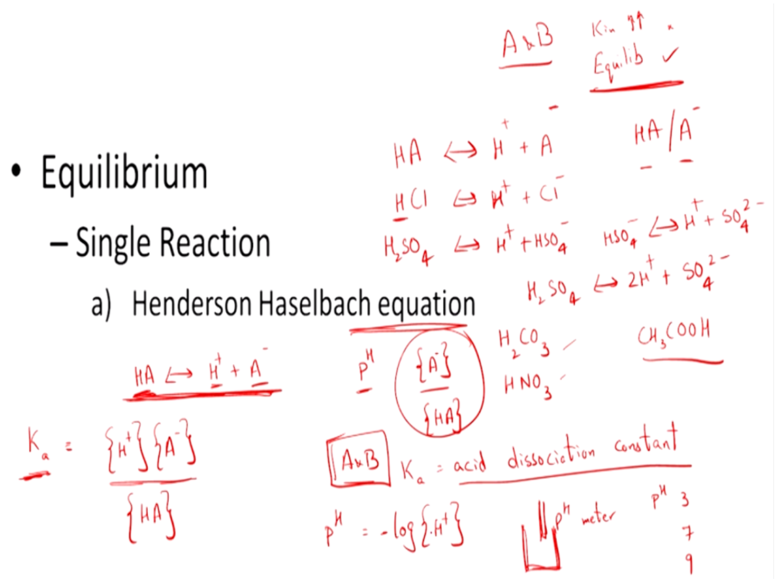

- Equilibrium
  - Single Reaction
    - a) Henderson Haselbach equation

We are going to talk about equilibrium in greater detail from the for throughout acids and basis I guess and again the reason is that kinetics are so fast that we are more or less neglect that and always almost always equilibrium is reached by the time you trying to look at your system or analyze the system right.

So here we are going to look at single dissociation reaction let us say I have an example of HA let us say an example I guess hypothetical example I guess and that can dissociate into its conjugate base let us say pardon me right and HA and A – this pair we call it conjugate acid and the conjugate base right. So let me just clear up this up I guess H+ and A – so examples I guess.

There are many HCL can go to H+ and CL – right or you can have this only one proton donate or I can have H2SO4 and that can dissociate into H + and HSO4 – right and HSO4 – can again dissociate into H+ and SO4 2 – right so more or less net reaction would be something like H2 SO4 can give out 2 protons depends on PH will look at in greater detail later on and So4 2 – and various examples of acids that we come across usually are H2CO3 right.

And HNO3 nitric acid right HCL H2SO4 H2CO3 the nitric acid and in general in waste water you come across CH3 COOH the acetic acid so we will talk about that in greater detail later on so what is that Henderson Haselbach equation about I guess. So let us see what it is first and then we are going to try to derive e that so this will give me an idea about how the PH right would define the concentration of conjugate base and the acid so let us try to derive this.

So for that particular case we are going to look at hypothetical acid dissociation so the acid here on the left hand side initiating H + conjugate base that is what we have represent here right so here let us say and for equilibrium equation we know that the equilibrium constant is going to activity of H+ times activity of A – right activity of HA again this is from our equilibrium equation.

And what is that I guess right this is the equilibrium constant but for acid and base reaction we typically call equilibrium constant as the acid dissociation constant say acid and base you see that acid is dissociating into H+ and A – so the relevant equilibrium constant is called the acid dissociation constant and that is the term we are going to use with respect to our acid and base system right.

So here we have KA = activity of H+ into activity of A – by activity of H so right I am trying to get the relationship between PH and the ratio of these two of these variables so obviously as we know PH = negative logarithm of activity of H+ and how can we in general measure the PH you have an electrode with the standard or PH meter principle being a standard toward or a reference electrode and you will give or you lead the machine know potential difference is that various known PH values based 37.

And let us say 9 right and the machine that can calibrate and then measure the PH of your particular solutions anyway we diagnose there so coming back to what we are looking at.

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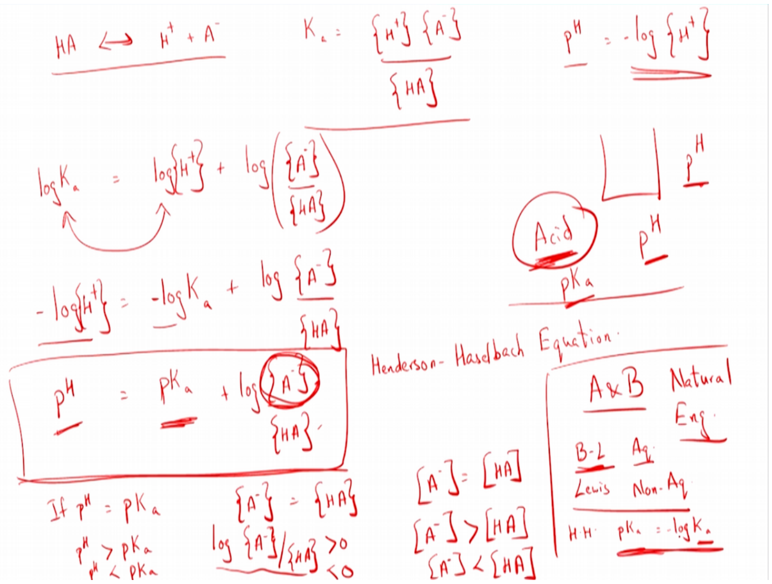

So for HA dissociating into H+ and A – and we have acid dissociation constant this is constant for particular reaction obviously right or the equilibrium constant for this case activity of H+ into activity of A - / activity of the acid.

So because I want to get at PH which is negative log activity of H+ right so I am going to take this logarithm of H+ so what is that going to be? Log of KA = log H+ log of activity of pertinent form of by activity of HA right that is what we have here. So here I am going to have I am going to swap these two variables so – log H+ = - log K A + log activity of A- / activity of HA and this is what we have.

So what is this particular term here as we know that = log activity pardon me here I am missing the terms here activity of H+ as we know is PH so PH and similarly we call or we going to represent – log KA as PKA right and this is something we are going to keep in mind that is going to be remarkable important in acid and base systems + log A - / HA right.

So this is the Henderson Haselbach equation and this is remarkably important why is that because it tells you at a given PH right what is the ratio of your conjugate base and the acid why is that because now you want to let us say look at you know I want to get a solutions to a particular PH let us say I want to know the amount of acid that I need to put in to be able to get to that PH right.

So depending upon the choice of the PH pardon me the acid and the current PH of the system so choice of the acid means depending on the PKA and current PH you are going to only have the release of certain amount of H+ right. So for that particular case we are always going to look at the Henderson Haselbach equation yes so does this mean though so it means that it PH = PKA right.

What is that mean the activity of the conjugate or deprotonated form is going to be = the activity of your acid and if I am going to approximate it by concentration is going to be A- and HA is and if PH is greater than PKA right what is that mean? It means the log of activity of A - / activity of HA is greater than 0 what is that mean it means the concentration of activity of A – is going to be greater than concentration of H here.

And same case if PH is less than PKA this particular variable is going to be less than 0 and what is that means the concentration of the conjugate base is less than the concentration of the acid right. So with that I will end today's session.

So will just have a brief review I guess right so we have looked at the important of acids and basis both in natural and engineering systems and then we looked two particular definitions of acid and bases and their Bronstead Lowery and Lewis this is applicable in aqueous and then it is something we are going to use widely throughout the class and this Lewis theory is applicable in non-aqueous solutions right.

And then we came across the Henderson Haselbach equation and we looked at new terms PKA which is more or less – Log KA and what is KA the acid dissociation constant. So PKA will give you an idea about how strong or weak is the relevant acid right so we will discuss this in the next class and for this session that is it from me and thank you