Environment Engineering: Chemical Processes

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Redox Reactions and its Applications

Hello everyone so again welcome back to latest session so I guess we introduce ourselves to the concept of redox of reactions last time in the last session anyway. So we are now dig deeper into this reactions and look at the relevant kinetics and then the relevant equilibrium or if the redox reaction reach equilibrium you know what would you expect I guess right and then we look at obviously the relevant application I guess right.

So again before we dig deeper into kinetics in the relevant aspects of obviously we need to look at some of the basic terms that are you know blinded about or thrown about when we talk about the redox reaction right. So let us look at what they are here.

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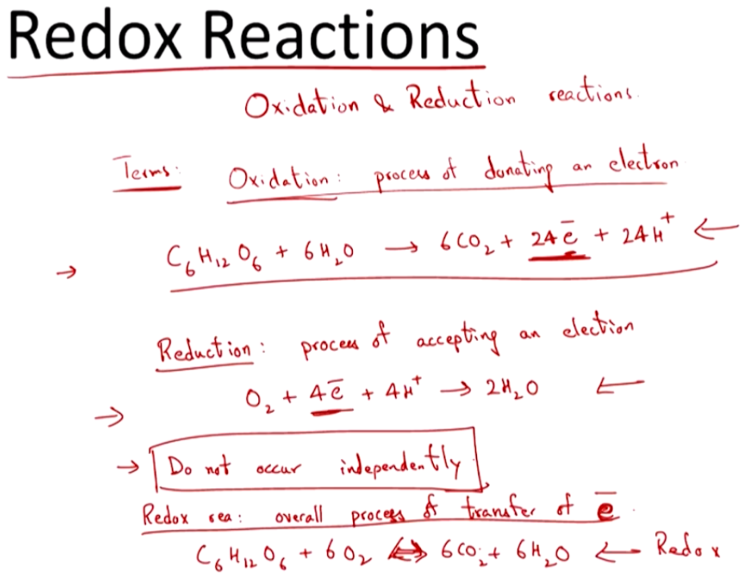

Redox Reactions

Oxidation & Reduction reactions.

Terms: Oxidation: process of donating an electron

→ $C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + \underline{24\bar{e}} + 24H^+$ ←

Reduction: process of accepting an electron

→ $O_2 + \underline{4\bar{e}} + 4H^+ \rightarrow 2H_2O$ ←

→ $\boxed{\text{Do not occur independently}}$

Redox rea: overall process of transfer of $\bar{e}$

$C_6H_{12}O_6 + 6O_2 \leftrightarrow 6CO_2 + 6H_2O$ ← Redox

So obviously we have redox reactions right redox what are we talking about we are taking about oxidation and reduction reactions right so whenever someone refers to redox reaction more or less obviously talking about oxidation reaction which involves the transfer of electrons from one compound to the other right. Well it is transferred or you know it is going to be sharing strictly speaking but we are going to talk about that and relevant detail in the next couple of session I guess right.

So here are talking about electron transfer here with respect to redox reaction so obviously if there is electron from one compound to another the oxidation state of relevant compound is going to chance right the relevant element going to the atom is going to change right. So again here we are going to look at some of the terms and obviously you know we have oxidation and reduction so we are going to look at what oxidation is about right so this is the process of donating an electron right.

Process of donating an electron and again see this widely we are going to look at it in conjunction with reduction later on but keep in mind that we obviously talk about oxidation it means there is a process of you know it is leading to donating an electron right. So we are going to look at an example I guess of oxidation that we briefly considered in one of our initial classes right and look us and this process let us 6 CO2.

So we are now donating the electrons right and for obvious charge balance we are going to obviously have H+ right and here this release of electrons that we see in this particular reaction right with respect to glucose let us say or you know the other oxidation reactions can be partial or completely right so keep that in mind that the electron release can be partial or complete here right. So obviously this is about oxidation so if you talk about reduction and obviously it is going to be the inverse of this let us say right process of accepting the electron.

And relevant example let us say you know let us look at what we usually come across say you know we always have oxidation present in the atmosphere so the let us look at one particular relevant example here right. So again we are done with it so more or less oxidation as process of donating an electron and with respect to relation process of accepting an electron right. So obviously redox action when we refer to redox reaction we have both the oxidation and reduction reactions going through simultaneously or occurring simultaneously yes.

So the reason why we stress upon simultaneously is that these relevant half reactions are has not half reactions are those when we write them as the oxidation or reduction here these are the half reaction where you see either the donation of the electron or the gain of the electron right. So these half reaction right they do not exist in nature let us say or in general out right and why is that because the electrons these aqueous electrons right they do not accumulate in your particular solutions or such right.

So for redox reaction to go through the key is that you should have both oxidation and reduction reactions occurring simultaneously right so you will have a collusion let us say conductor right so that you will have the transfer of electrons right yes otherwise you cannot say that okay.

Let us say my oxidation half reaction is going to go through and the from time 0 to T1 and from T1 to T2 my reduction is going to take please let us say based on the electrons that we have accumulated during 0 to T1 that does not happen because you know electrons do not accumulate in the aqueous solutions right I mean they have half but they are remarkably less.

So again for a redox reaction to go through you always have both oxidation and reduction reactions so but you usually come across terms like okay this reaction is the oxidation reaction or this particular reaction the reduction reaction what the people refer to I guess.

So in that case people are referring to what is happening to the relevant target compound when you have particular reaction right so what do we have now what do we know that redox reaction is one we have oxidation reduction obviously happen I mean there is an electron transfer right from one compound to other and we know that it does not occur independently they occur simultaneously or in congestion with each other right but still people differ to reaction as oxidation or reduction let us say but why is that.

Because let us say you are people talking about what is the happening to the relevant compound here they target compound is being oxidized or reduced and based on that they look at the relevant reaction as oxidation or reduction or such right. But keep in mind that they do not occur independently right the whole key is that they do not occur independently right.

So obviously redox reaction is the composite reactions here let us say right redox reaction what is that about over all transfer over all process of transfer of electrons right so that refers to the redox reactions right obviously we have two particular oxidation and each I guess of oxidation reaction.

So let us look at the oxidation reaction by balancing the number of electrons for the balance reaction here I guess right C6H12O6 + 6O2 we want to balance the number of electrons right wellbeing an equilibrium is 6CO2 + 6H2 and this is a redox reaction right this is a reduction half reaction this is oxidation half reaction right. So obviously as you see the redox reaction you are not going to have or what we say electrons in the relevant equation let us say I guess right.

So again the whole key is that electron is not accumulated in the solution right for example how would your redox reaction is go through now right they would go through let us say when one molecule equalize with the other and then going to be the transfer of electrons here let us say physical collusion of the relevant molecules is not feasible let us say one other why that these redox reactions can go through is when you have a conductor of electrons that is what you would see in your electro chemical cells or such right.

So we have cathode and anode let us say where you have let is oxidation or at the relevant electrodes and then you have conductor which is what is the purpose of this conductor obviously for the transfer of the relevant electrons right. Again let us keep this moving and look at some of the other aspects I guess right.

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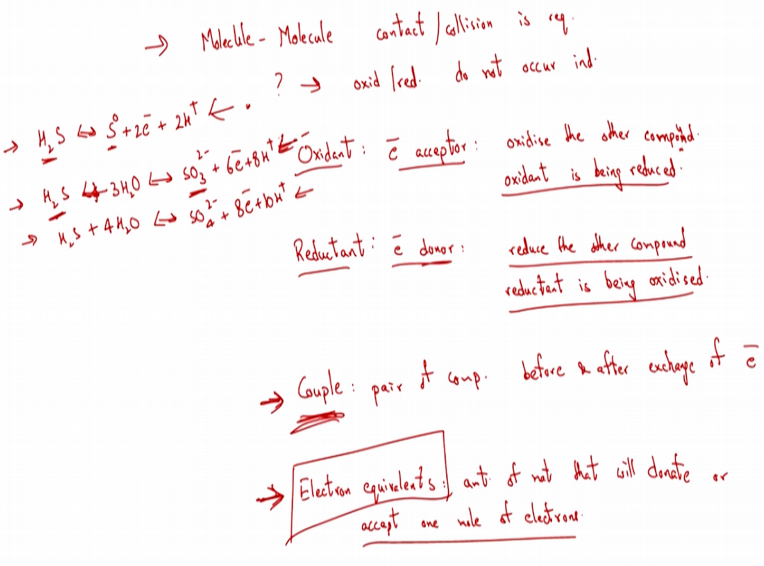

→ Molecule - Molecule contact / collision is req.

? → oxid / red. do not occur ind.

→ $H_2S \leftrightarrow S^0 + 2\bar{e} + 2H^+$ ←

→ $H_2S + 3H_2O \leftrightarrow SO_3^{2-} + 6\bar{e} + 8H^+$ ←

→ $H_2S + 4H_2O \leftrightarrow SO_4^{2-} + 8\bar{e} + 10H^+$ ←

Oxidant : $\bar{e}$ acceptor : oxidise the other compound.
oxidant is being reduced.

Reductant : $\bar{e}$ donor : reduce the other compound
reductant is being oxidised.

→ Couple : pair of comp. before & after exchange of $\bar{e}$

→ $\boxed{\text{Electron equivalents :}}$ amt. of mat that will donate or accept one mole of electrons.

So here we just mentioned that molecule collusion is required and why is that again obviously because the oxidation or reduction reactions do not occur independently right. so this is one particular aspect that you should always keep in mind so for example an analog or reactions for set of reaction would be your acid base reaction there you have let us say transfer of H+ right at the protons.

But their though as in the acid base reactions you have the accumulation of H+ or such that is why obviously when you see accumulation or loss of H+ from the solutions right you are going to have change in PH right so H+ increases PHD decreases and as an H+ is removed from solutions or OH- increase in concentration.

We are going to see a PH what do we say increase in PHA their right in the acid base it is an analog or set of reactions but keep in mind that unlike the acid base reaction you cannot have accumulation of electrons that is the key here right so let us move on to some of the other terms. So you might have heard oxidant right and reduce agent of reductant and in the content similar to what we want to have for conjugate base pair for conjugate acid base we are going to have couple here right.

And then going of have electron equivalence I guess right so let us look at what this aspect are right. So again for redox reaction to go through we have what do we say transfer of electrons so obviously you need compound that acts as electrons accepts and at the same time if you electron accept you need a compound that would acts as a electrons donor so here we have relevant aspects and as we discuss obviously if you have an electrons acceptor right they should be a compound available for accepting the for donating the electron pardon me.

So here if an oxidant is electron acceptor reducing agent or reductant is the electron donor right so oxidant I guess what does that cause another compound to the so it is going to oxidize the other compound right again and oxidant accept it is accepting the electrons so in that process it is oxidized in the other relevant compound right.

So obviously in the same process through the oxidant this particular oxidant is being reduced right in the process of accepting the electrons right we see that the oxidant is being reduced and obviously one example that we looked at is this particular reduction right. So oxygen is electron acceptance that is what you see here and in the process of accepting of accepting an electron is being reduced right hopefully if make sense again.

So one particular oxidizing agent that obviously is our present is oxygen right and it is an electrons acceptor or oxidant right so is that the relevant reactor we see out here right and in the process of accepting the relevant electrons right or the electrons number of protons in this case is 4 electrons I guess right we see that it is being reduced yes so we are done with that again reductant.

Obviously it is going to reduce the other compound other compound and let us look at relevant electrons that we had earlier and the reducing agent or reductant is in the process being oxidized right. And let us look at what we describe here so here this is the relevant reaction let us say and now obviously you see that this glucose can act as an electron donor and which is what we describe here.

So thus in this particular case glucose or $C_6H_{12}O_6$ is that reducing agent or reductant right reducing is that one would donate the electrons right and in this case we see that the relevant what do we say half reaction we look at the relevant half reaction we can see that glucose can what do we say donate the relevant electrons right.

So that is why in this particular constants here I guess glucose is the reducing agent right but as you see in this process right it is being oxidized glucose is being oxidized right so that is what we see and obviously if we look at this particular composite reaction of overall reaction I guess what we see here with respect to this particular case oxygen is oxidizing or particular glucose molecule I guess right.

So oxygen which is an oxidized agent is oxidizing your particular compound which is glucose in this particular case while being reduced that is what we see here so oxygen is acting as electron acceptor glucose and electron donor. And in general because let us say we are our target compound here in this particular glucose molecule I guess right so we refer to this particular reaction as oxidation but I general obviously as you see you have both oxidation and reduction occurring simultaneously right.

So I guess that is one particular aspect here again oxidant is electron acceptor reductant is an acceptance donor so couple i guess also similar to conjugate acid base that we have looked at earlier so we this pair of compounds which would represent let us say before and after exchange of electrons let us say right.

So similar to the conjugate acid base pair we know which are what do we say the compound before and after let us say exchange of protons or H+ here we have we say a couple redox couple pair of compound should represent what do we say before and after stages of electrons transfer. So obviously here I guess there are different types of couple right different kinds of couple I will come to that later on.

So again one aspect here is keep in mind in is equivalence so we talk about equivalence you know or we talked about or looked at different aspect with respect to equivalence earlier but most of them with respect to charge let us say right most of them and here also we have relevant aspect of equivalence but here we talk about electron equivalent right not with respect to charge.

But I guess the concept is similar to so it is the amount of material right that will donate or accept one mole of electrons right so obviously with respect to charge I guess with we defined it in terms of per mole of the charge I guess right and here obviously we are looking at compound that will donate or what do we say accept one mole of electrons so that we would refer to as electrons equivalence.

So obviously there is a particular example we are looking at with respect to COD test and in COD is the chemical oxygen demand right but you are using potassium dichromate to be able to measure this so obviously there is going to be a what do we say transformation relevant units from the chromium or di-chromium that you measure for it is loss to the oxygen demand so that is what we are going to look at later on and this contest we are going to look at electron equivalent later on I guess right.

So again but one aspect with respect to electron equivalence is that right we are talking about electron equivalence now right and keep in mind that it can vary now why is that I guess because difference compounds for example look at this particular example with respect to sulphide I guess right you know these particular case right and from this particular aspect you can identify one set of couple right.

But again keep in mind that they hydrogen sulphide can also let us say and now keep in mind for this particular half reaction right you have a different couple H2S and H2O- we had H2S and this sulpher here and another aspect let us say is H2S + 4 H2O right and SO42- + 8 electron I guess + 10 H+ right. So here we are come across examples I guess right three examples right where let us say the couple right we have the couple I know it is obviously dependent upon the type of half reaction right.

So in this particular case what is the couple H2S and sulphur and the second case H2S and SO32- right and again in the third case the couple is H2S and SO42- so again I guess why we looked at some of the example is that when we are looking at electron equivalence I guess it is also depends upon the half reaction that you are you are looking at I guess right.

So for example the number of moles that is being donated for H2S right is different for this particular reaction and let us say it is 2 electrons here and it is different here for the six electrons here and different here in the third case because 8 electrons here.

So when you are looking at defining what do we say the electron equivalence as in the amount of the material that will lead to loss or gain of one mole of particular what is this now the electrons right. So you need to look at consider that relevant half reaction because of same compound or molecule you can have different kind of half reactions right or different reaction right leaving to different electron equivalence yes so that is reason I guess why we looked at this particular set of examples.

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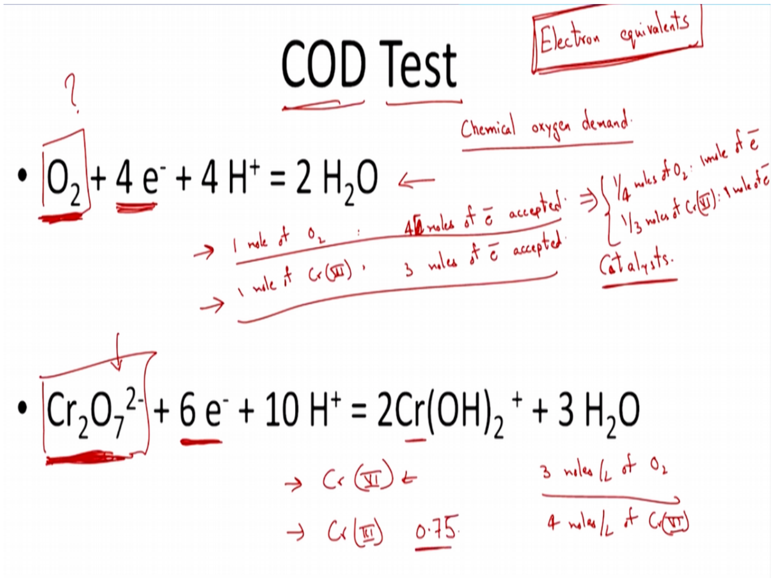

COD Test

Electron equivalents

Chemical oxygen demand.

- $O_2 + 4\,e^- + 4\,H^+ = 2\,H_2O$

?

→ 1 mole of O_2 : 4 moles of $\bar{e}$ accepted. ⇒ { 1/4 moles of O_2 : 1 mole of $\bar{e}$

→ 1 mole of Cr(VI) : 3 moles of $\bar{e}$ accepted. { 1/3 moles of Cr(VI) : 1 mole of $\bar{e}$

Catalysts.

- $Cr_2O_7^{2-} + 6\,e^- + 10\,H^+ = 2Cr(OH)_2^{\ +} + 3\,H_2O$

→ Cr(VI)

→ Cr(III) 0.75

$\frac{\text{3 moles/L of } O_2}{\text{4 moles/L of Cr(VI)}}$

So I guess we will now move on to application let us say right and I guess in this context let us go ahead and look at this particular COD test that we talked about earlier I guess I want to talk about it in the context of the electron equivalence so what is this particular COD test about we know that this is the chemical oxygen demand right.

So for example if I have certain kind of waste I want to know obviously let us say because if it discharge it into the water let us say and it can consume the oxygen the dissolve oxygen in the water so I want to be able to get an idea about it is oxygen demand right so in that obviously people look at biochemical oxygen demand the BOD or obviously the COD too the chemical oxygen demand right.

So obviously I guess you know we are trying to understand the amount of O2 right but this particular material or less us say the waster would consume let us say if it was let out into the streams let us say in into the nature right but obviously the COD is chemical oxygen demand both biodegradable and non-gradable fractions are going to be considered or you know looked at in this particular experiment right.

Anyway so again we are trying to understand how much oxygen will this particular material required right or you know consume what do you mean by consume for example here we know that oxygen is electron acceptance the waste that we are looking at we are more or less we have reduce that forms of carbon right you know in our particular waste anyway obviously there are other examples too so you have the reduced form of carbon and you have electron acceptor or oxidizing agent which is oxygen.

So obviously this particular oxygen will oxidize your particular waste that or sewage let us say that you let out into your particular nature let us say so obviously your concern with how much oxygen will this particular waste or stream let us say consume because obviously dissolve oxygen for certain threshold you are going to effect the aquatic eco systems. So what are we doing this particular test would to be able to measure the bio degradable and non-degradable fractions in terms of the amount of oxygen that they will consume.

But how do we do this test though so we add potassium or you know the dichromate or in form of potassium dichromate in your particular what is it now experiment. So why this that is strong oxidizing agent you know if I want to conduct the test with O2 the kinetics would be slow right at take let us say for considerable time impractical or in feasible amount of time right.

So obviously we are going to add and oxidizing agent right strong oxidizing agent pardon me and that is going to be let us say CRDO2- and we are also going to add a few catalyst right yes we are going to add catalyst too yes and obviously I guess heat it up to you want to increase the rate of your reactions and such right and again what is the role of this dichromate here as you it is accepting it is electrons right.

Again it is similar to oxygen and it is an oxidizing agent or it can accept electrons from your particular waste that you are talking about which is either your bio degradable or non-bio-degradable compounds right but here because this is the strong oxidizing agent right but here we are going to look at later on why we call up particular compound relatively strong oxidizing agent or particular compound a strong reducing agent.

I mean there should be similar to what are discussed with respect to acid as in we had strong acid or strong basis or week acid and week basis and so on right. So in this case too we are going to I look at I guess relevant simple aspect we are going to have strong oxidizing agent or you know strong reducing agents but again keep in mind that all these are relative right. So we are going to look at the relevant redox potential or such but later on though.

Again keep in mind that we just adding form oxidizing agent in the form of CRO272- so it can take an certain number of electrons right and this let us say is your relevant reaction that you see so how do you go about your COD test I guess either measure the decrease in this CR2OH27 I guess the oxidation state is 6 right. you either measure the decrease in chromium 6 or measure the increase in this particular form chromium 3 I guess right the oxidation state chromium 3 I guess right the oxidation state chromium 3.

So by calculating the loss of this CR2O27- or chromium in its oxidation state 6 you can calculate the number of electrons that this particular solution would require but to make more sense to calculate the number of electrons for example a particular what so we say solution can donate I guess right but I want to be able to understand what happens in the natural system is that means the amount of all that can conceive right.

So here the concept of electron equal comes into picture as in you see that 1 molal what do we say oxygen you know at as it can consume or 4 electrons it can accept 4 electrons but here as you see for one mole let us say here I can going to work it out for one mole of SO2 right I have 4 electrons or 4 moles of electrons being accepted right.

But in this case let us say for 1 mole of chromium 6 let us say us CR2 6 electrons for just 1 CR state of 6 chromium oxidation state I will have 3 moles or it can accept 3 moles of electrons right yes. Again now I want to be able to use this particular information about the amount of chromium 6 that is consume right to be able to come up with equal amount of oxygen that would have been consume.

So obviously I need to look at I need to look at the electrons equivalence right so from that aspect obviously how can I go about this I can say that 3 moles per liter of oxygen right 4 moles per liter of chromium 6 would be the relevant equivalence right. So again if you want to balance it number of electrons I guess right.

So obviously here what is the electrons here 1 third of mole of oxygen lead to accepting 1 mole of 2 fourth pardon me what is this mean 1 fourth moles of O2 would mean 1 mole of electrons being accepted and the case of chromium 6 1 third of moles of chromium 6 would lead to acceptance of or can accept one mole of electrons or the electron equalize here we express them in terms of equivalence.

So obviously from this particular information we know that 3 moles per liter of oxygen right would be equivalent to 4 moles to the meter of chromium 6 right so that is what we have here. And so obviously you see you have a factor of 0.75 I guess right and that is what you see in your COD test to be able to come with your chemical oxygen demand as in you are titrating and then or I guess using the spectro meter getting you the amount of chromium 6 that being consumed so by using this particular factor.

Let us say then you are going to come up with an estimating not estimation I guess calculation of how much is going to be consumed let us say and that is going to be equal to the COD or chemical oxygen demand right so that is your particular what do you factor and where do we look at or what do we look at obviously the electron equivalence right. So now let us look at start discussing the few of applications right I believe we are going to look at a few applications here.

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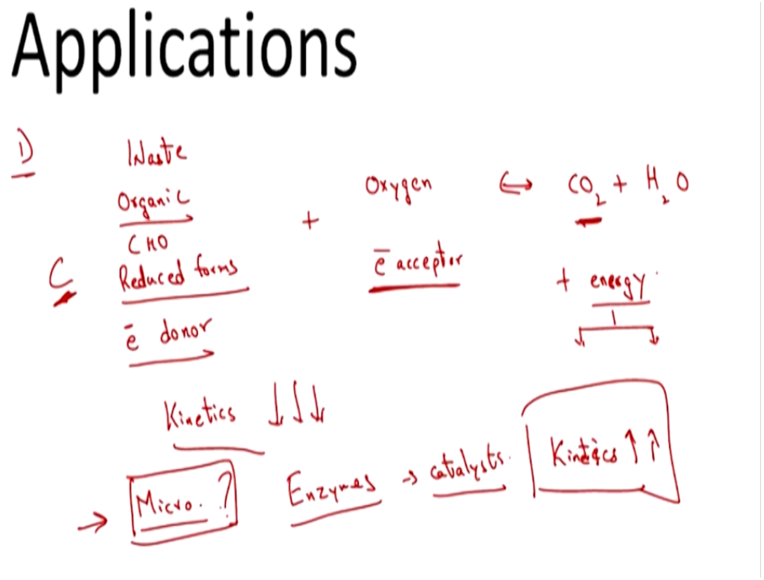

Applications

And let us look at redox reaction I guess you would usually or commonly become across. So obviously one example we looked at was waste water treatment plant or sewage treatment plant right. So you have your waste or your organic forms or your organics right.

And now let us try to understand the in terms of the terms that we have you know looked at thus for the organic compounds usually let us say CH and O usually they are reduced forms right their reduced forms and now we also have oxygen or we add oxygen irate the relevant waste and what is the process and why is that I guess going to add oxygen which is your electron acceptor right. So oxygen again is oxidizing agent and it acts as an acceptor and obviously thus your what do we say organic which is in the reduced form will act as a electron donor right.

So now you have the relevant building blocks I can say that I guess for your redox reaction there the redox acceptor or presence of the redox acceptor which is the oxygen that you putting in the waste and the waste itself is the electron donor right and so this can if you can look at complete mineralization I guess transform to CO2 and H2O obviously CO2 is the oxidized form here you are looking at I guess right again here C is in its relatively reduced form and C here is in its oxidized form.

So what is happening to this particular carbon C as an carbon it is been oxidized by relevant carbon but again in nature it does not take place the relevant rates you know it is not fast enough right and why is that as we discussed the kinetics are relatively slow so what are you doing obviously to you know fast in this process obviously you are going to add your seat right and more or less the micro-organism and what are the role of these micro-organism they produced the enzymes right which then act as catalyst right thus increase in the kinetics of this particular process right.

So that is what your more or less you know leading to right and again keep in mind that why do these micro-organisms obviously take part in this particular redo reaction well they need to gain some benefit to right so in general let us say energy is released from this particular redox reactions and this particular energy is used either for synthesis growth or such right again that is the reason.

Again that is the reason why micro-organism would degrade your particular waste so when we degrade we obviously talking about micro-organism you know trying to what do we say extracting the energy if I can through this particular redox process. So that is obviously what do we say example that you know people at least look at or can look at but there are obviously many more applications right.

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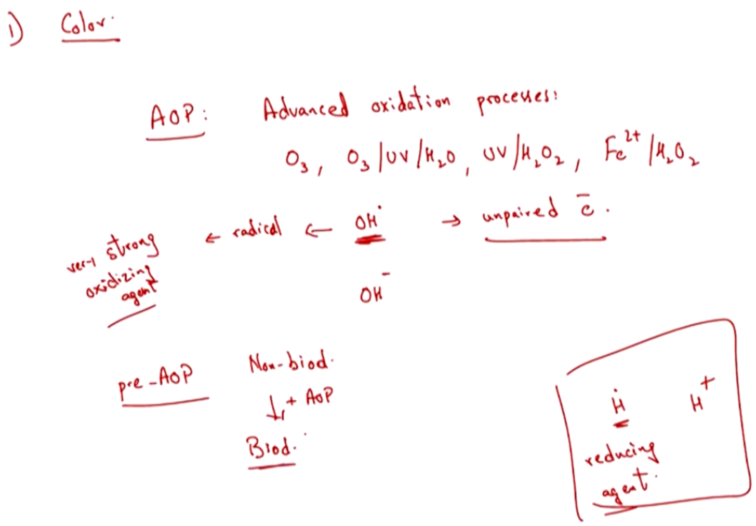

So I guess people talk about removing color let us say right what do you look at again this is redox process again based on let us say adding reducing agent let us say or if you are looking at dying industry let us say color and reverse you know surface water that is the different aspects again color from dying industry that is again a different aspect right.

But more or less what do you add you need an oxidizing agent I guess right an oxidizing agent as an electron acceptance and that again when we talking about color removal in general again obviously talking about your redox process say again when people talk about taste again I guess certain compound that is meaning to this particular taste or such and you can add the relevant oxidizing agent or such to be able to remove this what do we say oxidized like this particular contaminant right.

So in this context again you know people come across oxidation process right so advanced oxidation process and obviously we guess we are calling its advanced oxidation process because we use usually lead to or you now these particular AOP's lead to there are difference kinds of a AOP's I guess I should have listed first let us just ozone if you just vary the PH right depending upon the change in PH and ozone with respect to UV or H2O2 or in-congestion I guess all the three of them.

And obviously again UV/ H2O2 process CV as an ultra violet right and H2O2 and I guess (()) (32:55) to right FE2 + H2O2 these can lead to formation of your radicals most specially your hydroceles in radicals right and what is this radical again it is an unpaired it as an un paired electron. So these hydrocele radical has not unpaired electron so it is remarkably unstable it wants to what do we say trends to tries very hard let us say if I can use the layman's terms accept electrons and go to its most similar state which is going to be OH – right.

So thus OH radicle so this is radicle and in this context the radicle let us say is the strong or very strong very strong oxidizing agent right. Again similar to these hydrazine radicle depending on the relevant what do we say mechanism we look at you can produce this reducing radicle which is the hydrogen radicle and obviously you know hydrogen radicle would want to go to its most stable state which is H+ as in it want to release or donate its electrons thus H the hydrogen radicle act as the strong reducing agent right.

Again this is different aspect I want to highlight that because you are talking about the oxidizing agent because which is the hydrocele radicle here and the hydrogen radicle can also be formed in different what do we say process. So again these AOP have what do we say application with respect to situation let us say when your particular ways or relatively naught by degradable.

Obviously if you are using biological process and let us say your particular ways are bio-degradable let us say then I guess the relevant efficiency process is would be good enough but let us say if it is not if you want to increase the efficiency of the process one way you would be to have pre AOP let us say AOP right so then your non-biodegradable waste will be transformed after application of these advanced oxidation process into bio-degradable waste right.

So let us say if you have bio-no degradable waste for which let us say you are particular ASPR or SPR let us say is not efficient let us say or kinetics thus taking the way too much or way to long kinetics is relatively slow right and also let us say even your final product is not up to your standard so what can you do you can either just use advance oxidation process let us say but there might be practical limitation with respect to cost involved.

So with relevant process of AOP let us say right you can transform this non-degradable waste into biodegradable waste right and then I guess use your biological process to what do we say degrade or memorize this particular biodegradable waste so in effect you are increasing the efficiency of your process I guess there are many more application process so we will look into few more in next session and then we will move on to next understanding this concept of oxidation state right.

So we have oxidation state or oxidation numbers so what is this and how do we calculate that I guess it is relatively simple but and may be people have looked at in great detail. But I guess this is what do I say at the crux of what do we say we are going to look at in this particular couple of set of sessions so we are going to look at that in greater detail and I guess with that in today session and we will continue the relevant aspects in the next session and thank you.