Environment Engineering: Chemical Processes
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Module No # 10
Lecture No # 49
Balancing of Redox & Development of Half Reaction

Hello everyone so again welcome back to the latest session lecture session so I guess we have understood the relevant terms that you would come across with respect to the redox reaction as in what do you need to understand the oxidation and what do you need to understand if someone is referring to oxidant and reducing agent right oxidant electron acceptor reducing agent electron donor right and so on and hence so forth.

And one major aspect that I guess that we understand I guess with that oxidation redundant reaction do not occur independently right they need to simultaneously right so that is why you always have redox reactions right and next I guess started looking at a few applications and the one I guess that we looked at in more detail with respect to the waste water treatment right where you have the organics which are relatively reduce forms and you have the oxygen which is the electrons acceptor right.

And thus obviously you need an electron donor so thus we identify the organic compound is electron donor right and then you can have relevant redox process to go through yes. And I guess let us look at few more applications and then move on to balance in redox reaction or how to develop let us say this half reaction depending upon the kind of reaction that are going through right.

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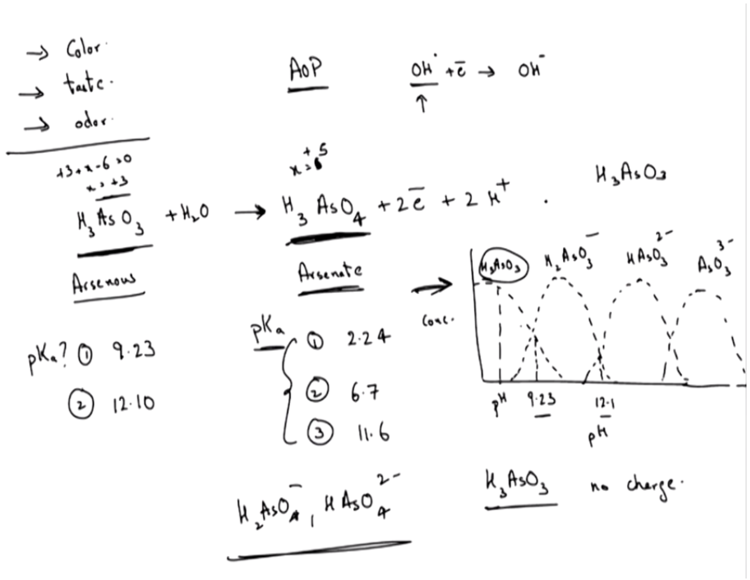

So let us look at couple more aspects I think we talked about color right color removal we talked about taste right and again I guess odor 2 I guess in general oxidizing agents are added I guess you know depending on the kind of matter you look at right and I do know that we have also discussed AOP right where you have formation of this strong oxidized agent hydroxide radical which would want to accept and electron and then what do we say move towards transform into its more stabbler states which is OH- I guess right.

So that is what you see here that is why OH radical is the very strong oxidizing agent so if you promote those condition which can be to formation of these hydroxide radicles you will have the relevant what do we say kinetics to the relatively fast.

So again let us move on and looked at one particular aspect right I think we looked at this particular aspect earlier too I believe with respect to the removal of arsenic as in arsenic is present in different oxidation states but you I guess let us say want to identify which particular form of oxidation state of arsenic would it be more easier to remove by usual process used for arsenic removal exchange or absorption or such right.

So let us say here we are going to look at the two forms of arsenic and look at which particular form would be easier remove based on the aspect back and that knowledge that going to use and exchange process I guess right. So I guess the relevant half reaction that I am going to write now

H3ASO3 + H2O and that is going to be the half reaction is going to be I guess H3ASO4 right H3ASO4 and it is obviously going to be 2 electron transfer + 2H+.

So I guess this is the relevant half reaction here right for arsenic this is the form of arsenic I guess right arsenate and this is for arsenous i guess. So from this particular half reaction and now I guess you want to be able to decide in which particular form would it be easier for you to be remove arsenic what do we say with arsenic process. So here I guess I need to dig into our particular background with respect to acid base chemistry I guess right.

So keep in mind that ionic change you want to have relevant charge on the relevant that you want to remove so how can you have charge here with respect to either arsenic or arsenic if you see that their what do we say protonated forms here so if you can deprotonated you can have the relevant let us say negative charge or they can be exist as anions in the relevant solution right and then you can remove them by relevant what do we say anions exchange or such right.

So here let us see what do I need now I obviously need the PKA values so let us say for this there are three PKA values but the relevant values for PKA 1 and PKA2 we look at that and same case here so 1, 2 and even say 3 in this particular case I guess so values that I have are so arsenic 9.23 and 12.10 and for arsenate they are going to be 2.24 6.7 I think and 11.6. So obviously you do not need to mug them up you know the relevant PKA values at the dissociation constant will be available in your particular standard books I guess.

So here i have the relevant aspects so let us look at again or what do we say now relevant background let us say for HCA SO3 let us say this is the concentration of Y axis and PH on the X axis so I want to look at how will be concentration of the relevant compound change with PH so for look it for this particular case they are arsenous H3ASO3 you know from your environmental chemistry background in acid base this is going to be the relevant what do we say the distribution.

And this obviously is going to be the next deprotonated form AH2ASO3 – and the next one would be the how about deprotonated form DHASO32- right and this one going to be your completely deprotonated form which is going to be ASO33- right again keep in mind that we are writing down for this particular form H3ASO3 now but the information we have is PKA1 it seems is 9.23 right and PK2 is 12.1 and PK3 is obviously higher than 12.1 I guess I think 14 or (()) (06:44) I guess right.

So here what does I tell you now at neutral PH let us say of this is PH7 or around PH 7 anyway right and all the acetic region and you know considerable basic region 2 or in when it is solutions is basic 2 not considerably though and certainly in the neutral region when the PH is around 7 what do you see now that it is present as H3ASO3 right and obviously what does it mean now it no charge right.

So obviously your what do we say your ionic exchange process would not be feasible here but obviously if I look at it with arsenate H3SO4 right the more oxidized form arsenic here is more oxidized I guess right and here it is relatively less oxidized right and here is the ASO3 and ASO4 obviously arsenic in this arsenate form is more oxidized form and oxy state what would be +3, +X and -6 = 0 X = +3 if it is 2 electron transfer here is going to be +5.

So oxidization state of arsenic here is +3 and here it is +5 right and now keep in mind that if you look at the PKA values for H3AO4 you see that the more oxidized form at neutral PH around 7 will mostly be in the form of H2ASO4 – or HASO42 – near the neutral PH right as you can see from the PKA yes near the PH value right so obviously what will that tell you about the system now so if you using ionic change process and the PH is neutral region.

So obviously you want to have the more oxidized form of arsenic which is what do we say ASO43- I guess right or the arsenic form and only then as you in the neutral PH will it be will it have the charge right the relevant molecule will be charged and so with your anion exchanger right you can then remove your particular arsenic from your particular solutions.

But it is present as arsonous or H3SO3 or oxidation state of +3 you saw from this particular figure right how do we observe here that is no charge on the relevant compound at the neutral PH right thus you cannot obviously remove it by your relevant ionic change process. So that is one particular as object obviously guess we need to look at both the redox chemistry and acid base chemistry.

So obviously if you are guess the take home message in this case is if you are trying to remove this particular arsenic by ionic change I would be more efficient obviously if you have more oxidized form and thus you want to promote for information of arsenate rather than arsenous in your particular solutions so you want to oxidize the compound right okay.

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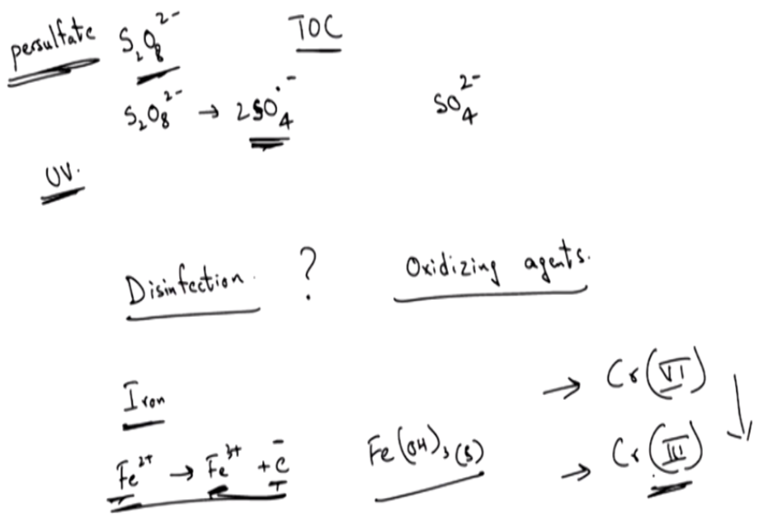

So let us move on to one another example I guess that you might look at so we have persulphate right and where do you come across this I guess right usually people might have heard of this TOC machines total organic carbon right where you measure the organic carbon present so again the principle here is that you have radical being formed S2O82- and I guess it forms this particular radicle right the sulphate radical and obviously it would want to go into its most stabbler form SO42-.

So again it would want to accept and electrons it thus you are trying to form strong oxidizing agent and that in your TOC machine I believe it is done in the presence of ultra violet right so you are going to bombard the particular persulphate solution which I guess will exhaust if people sunning with the TOC machine or you know keeping a track of it anyway right and you are forming these oxidizing agent right the sulphate radicle sulphate anion radicle which is oxidize your particular solution.

So again one particular application that I want to wanted to talk about in that case so obviously disinfection again right so what do we try to do or what are we trying to add in your what is it disinfection is to add oxidizing agents right which oxidize the relevant bio chemical that you are that would exist in solution right so again you add oxidizing agent again let us again the process of electron transform again right.

So what else let me can we usually look at we want to remove iron let us say what is the relevant reactions FE2+ goes to FE3+ right this is the relevant half reaction and from our aqueous complex chemistry and precipitation and dissolution chemistry are know that FE2+ stays as FE2+ is relatively more solvable but FE3+ as you know as I form complexes or mostly precipitates out at most PH right.

So obviously if you want to remove iron you can oxide it or it will precipitate out right FE I think OH thrice the solid form right. So obviously if you want to remove or else you can oxidize it right obviously FE2+ is it the agent because it is the electron donor here so again different aspects here.

So again what I was trying to I guess that the application for redox reaction or endless or you know I guess as I speak let us say I am consuming let us say energy let us say when again relevant redox reactions occurring and relevant energy is being release and that is being consumed by me right.

So again redox reactions are our presence and they play huge roll in your particular environmental chemistry as in let us say environment chemistry environment process or environment engineering right. So obviously let us say it can also used to reduce the toxity of this particular compound or such example chromium 6 I guess right in the oxidation state 6 is highly toxic.

But chromium 3 is not as toxic right and also as you know I think we looked at brief example where chromium would precipitate out in the form of if it is in the state number 3 but if it is chromium in the form of oxidation state 6 it is going to be more solvable so again you need to look at those aspects too so you can either reduce the toxicity are also remove the relevant compound by reducing chromium here right to oxidation state of 3.

So obviously here we are using this particular term oxidation state of oxidation number lot so let us look at what this is about I am sure people have look at it but there are few fundamental rules are aspects that govern how to calculate these oxidation states or numbers. But what do I understand you know what should i understand let us say about oxidation states now. First I guess the aspect that we need to understand is this theoretical or hypothetical variable now right.

So it is theoretical that is something that you need to understand now but how would you assign the oxidation states or such let us say there is a molecule let us say let us say you have covalent bonds and let us say the dissociate and then you know hypothetical dissociation and then if you look at the relevant on this particular elements on this particular dissociate let us say right and then assign the oxidation number based on this hypothetical charge if these elements dissociate right.

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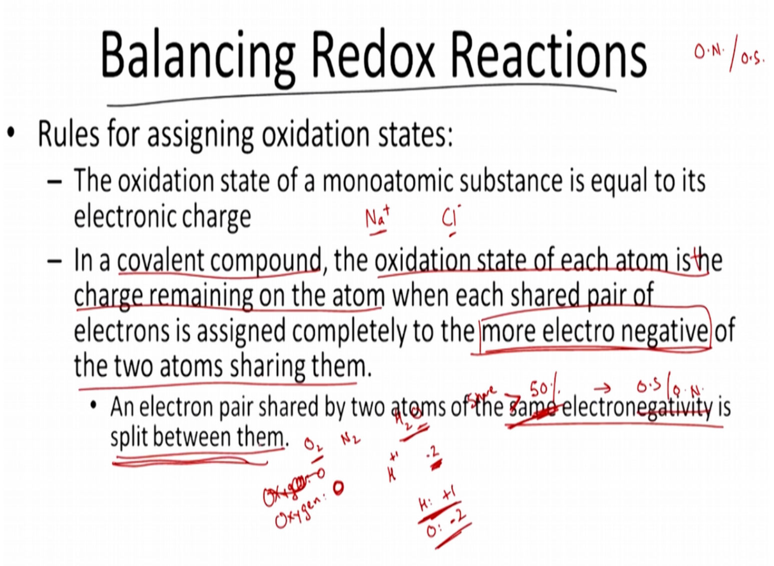

Balancing Redox Reactions

- Rules for assigning oxidation states:
  - The oxidation state of a monoatomic substance is equal to its electronic charge
  - In a covalent compound, the oxidation state of each atom is the charge remaining on the atom when each shared pair of electrons is assigned completely to the more electro negative of the two atoms sharing them.
    - An electron pair shared by two atoms of the ~~same~~ electronegativity is split between them.

So again we are going to have a few rules to understand this particular situation better so obviously we are going to talk about balancing redox reaction in great detail later on right yes but obviously we need to look at a few particular rules as in first how to calculate the oxidation number or the oxidation state. So let us look at a few aspects so first one is for a mono atomic substance the oxidation number or state is equal to it is electronic charge.’

For example here we have let us say NA+ or CL- let us say right and let us understand the solution and so obviously state of this oxidation particular sodium here is +1 and for CL+ -1 right So that is pretty simpler again this charge balance nothing else there. But this something that you need to understand as in what if you have covalent bond let us say right.

And in covalent compound let us say so as we talked about we are going to attain the oxidation state such that if the molecule associate right you are going to look at the hypothetical charge that each element would have than that particular charge would be the relevant oxidation state of that particular element but now if dissociates let us say how would you calculate how can you estimate the hypothetical charge now.

So for example if the compound is more electro negative right so it will pull the electrons more towards itself rather than the other compound here. So obviously what we have the oxidation state of each atom is the charge remaining on the atom when each shared paired of assign completely to the more electronegative of the 2 atoms sharing them right.

So what this means is let us say if you have two what do we say atom sharing electron let us say right and sharing right what is this mean you know both of them sharing it right but obviously what it means is that in this particular context of particular atom is more than 50% share let us say right and you are going to assign though although electrons of such have 50% or greater than 50% share let us say to that particular atom and then if you calculate the what do we say relevant charge is going to be your oxidation state of the oxidation number.

Again how can you go about that I guess so obviously more electron over the compound will pull the electron more towards itself for example we have H_2O right oxygen is more electro negative compound right so with theoretically has what do we say more than 50% share of the electron that it shares with the hydrogen so if I let them dissociate let us say right. so obviously oxygen will have -2 charge why is that it has more than 50% share of both the electrons that it is sharing with hydrogen.

So that is why oxygen will end up with if I look at the hypothetical dissociation here the oxygen will have N number of -2 in this particular case and obviously H because it is losing its share of electron to the oxygen it is going to obviously have +1 and oxygen will have -2 right. Again just to refresh our understanding I guess right we are going to look you know the hypothetical charge to be present on that atom if all the electrons that which it has greater than 50% charge share I guess right.

Greater than 50% share if the share of that electron by that particular atom is greater than 50% or in other words if it is more electro-negative right is assign to that particular atom then the relevant charge right you know the charge remaining on the atom would be oxidation that and one example that we looked at was H2O. So oxygen is more electro negative it has greater than 50% share of each of the electron that it is sharing with let us hydrogen let us say so it is going to pull these electrons towards itself.

So thus let us say that charge is going to be the minus to the hypothetical charge and that is why oxidation state is -2 and similarly H I guess it is less than 50% share so when we are calculating this particular oxidation state we are losing what to we say H is losing its particular state of electron to oxygen here and so thus obviously the charge on H would be +1 and thus the oxidation state would be +1.

So again something to keep in mind or the basics to relevant basics here I guess so obviously though if it is particular if the electrons is shared by two atoms of the same electro negativity right so clear between them so if the both the electrons or atom as the same electro negativity the share is 50% each right so it is split between them so obviously for example we look at O2 or N2 or such let us say both the oxygen atoms have the same electro negativity so they have each have the 50% share.

So obviously in this case oxygen oxidation state would be 0 here right so oxygen thus you see that oxygen state if oxygen NO2 would be 0 right why is that because both what do we say both oxygen atoms right have the same electro negativity obviously and that is why the charge is split between them or the electron pair is split between them right so thus obviously the oxidation state is 0 right of oxygen in O2.

But obviously in H2O it is relatively different why is that oxygen compared to hydrogen more electro negative and it would have greater than 50% share of the relevant electron and obviously the last aspect I guess right so the sum of oxidation state = 0 for molecules it is nothing but charge balance and for ion = formal charge of ions and in let us say H2SO4 right.

So what is this mean let us say this as no charge so oxidation two times of oxidation state of this particular hydrogen plus 1 times oxidation state of the sulphur + 4 times oxidation state or this oxidation number pardon me of this particular oxygen will be equal to 0 right sum of oxidation states = 0 for molecules and let us say if I look at the relevant deprotonated form SO42- right what is this mean so 1 oxidant state of sulphur + 4 times oxidation state of oxidation number of oxygen right is going to be equal to the formal charge of the ion that is the equal -2.

Again I guess people are well verse with this particular aspect but this obviously again touch upon the relevant basics like this is one aspect I guess you need to be able to understand better when you are liquid compound. So here obviously what is the information you need know how electro negative is a compound relative to the other non-compound pardon me other atom compared to the other atom sharing it is electron with right.

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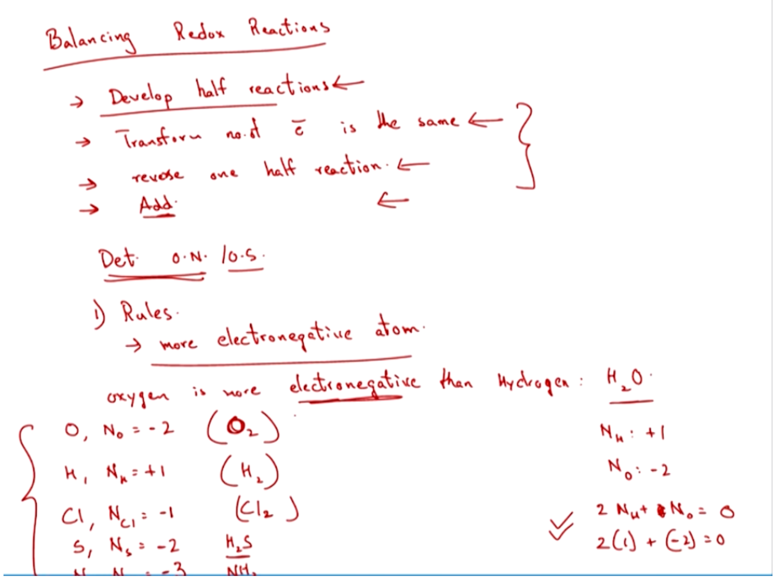

Balancing Redox Reactions

→ Develop half reactions ←
→ Transform no. of $\bar{e}$ is the same ←
→ reverse one half reaction. ←
→ Add. ←

Det. O.N. / O.S.

1) Rules.
→ more electronegative atom.

oxygen is more electronegative than Hydrogen : H_2O.

O, $N_O = -2$ (O_2)
H, $N_H = +1$ (H_2)
Cl, $N_{Cl} = -1$ (Cl_2)
S, $N_S = -2$ H_2S

$N_H : +1$
$N_O : -2$
✓ $2N_H + N_O = 0$
$2(1) + (-2) = 0$

So again now we going to look at balancing the redox reaction in greater detail so let us just try to have the summary before we go further i guess right. So how do balance half reactions now right? first you need to be able to develop half reactions right first you want to be able to develop the half reactions yes then what do you need to do now? You are going to transform them such that the number of electrons is the same right.

So that key is that are going to transform or modify them such that the number of electrons being transferred or either let us say gained or lost of on the each reaction in the same and then obviously for getting the overall reaction I guess you reverse one half reactions right and then to get the overall reaction you just add the half reactions right. So I guess all these reactions are relatively simple but I guess again the key is that you know the electrons do not what do you say accumulate in solutions.

So obviously the number of electrons being donated from particular half reactions right need to be equal in number to the number of electrons being accepted in the other half reactions. So thus obviously you need to see it such that the number of total number of electrons that is being accepted or gain from this each of the half reactions need to be the same because when you reverse and sum or add the relevant half reactions the overall reaction should not be obviously any electrons present in that particular overall reaction.

So again this is relatively simple but obviously we need to look at developing the half reactions I guess so let us see how to go about that so first I guess let us understand I guess how to be able to let us say assign oxidation number now right. So first I need to be able to determine oxidation numbers right so again we need to obviously determine the oxidation number of oxidation state of the particular relevant numbers right.

So obviously we looked at relevant rules until now right thus in that aspect we know that we need to identify the more or the electro negative atom right so let us look at some of these aspects I guess right. So in general I guess we know that let us say oxygen is more electro negative than hydrogen and that was in the example so thus with respect to H2O so we know that the oxidation state for hydrogen would be +1 and for oxygen it would be -2 right.

And obviously as we look at it some should also be equal to 0 because there is no charge here so that is what we see here two times MH + two times or 1 times oxygen state of oxygen is going to be have to be 0 and you see that two times 1 + - 2 and that is equal to 0 so that is again the relevant rule as obviously been what you say followed right.

Let us look at some of the other aspect I guess so earn as you know oxygen or the what do we say oxidation state is equal to -2 unless obviously it is not as O2 right because then both the electrons I guess as the electron pair is split between each oxygen atom so thus is no what do we say there is no hypothetical charge where we split this hypothetical an atoms so thus the oxygen state of oxygen NO2 will be 0 but in general it is going to be equal to -2.

If Hit is usually =+ 1 right other than unless it is in aspect as H2 again same explanation as earlier so CL some other compound that we usually come across I guess oxygen state is equal to -1 right unless again obviously it is present as CL2 right again these are the usual oxidation states or number that we come across of usual atoms we use in or come across in environment engineering i guess right.

So first sulphur it is going to be equal to -2 as in once example is H2S right as in H2S and let us for nitrogen right and let us say nitrogen it is going to be equal to -3 as in for example NH3 I guess one example I guess so with this background and electro negative stats or electro negativity of relevant atoms that we looked at is hydrogen chloride sulphur and nitrogen I guess right.

So we can also now apply the relevant tool as in the sum of oxidation numbers or states for the neutral molecule should be 0 or I should be equal to charge on that ion and get the relevant oxidation state of the relevant atoms.

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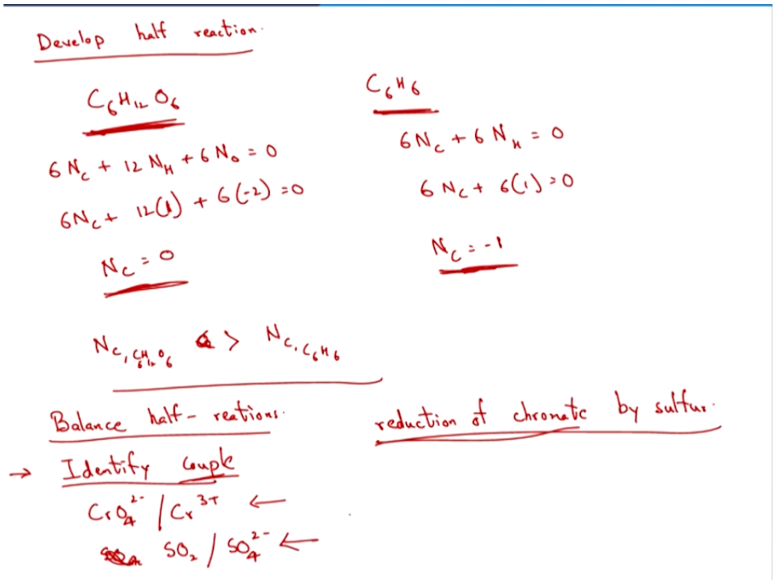

Develop half reaction.

$C_6H_{12}O_6$

$6N_C + 12N_H + 6N_O = 0$

$6N_C + 12(1) + 6(-2) = 0$

$N_C = 0$

C_6H_6

$6N_C + 6N_H = 0$

$6N_C + 6(1) = 0$

$N_C = -1$

$N_{C, C_6H_{12}O_6} > N_{C, C_6H_6}$

Balance half-reations.

→ Identify couple

CrO_4^{2-} / Cr^{3+} ←

SO_2 / SO_4^{2-} ←

reduction of chromate by sulfur.

So again let us going through I guess we are trying to again develop the half reactions right and that context we are trying to calculate the oxidation states so for example C6 H12 O6 and also C6 I guess so glucose and benzoin so let us try to calculate the ionic state of carbon and both these cases.

So I guess you know people can do it in simple manner and let me write down the basic format right this 12 times formulation number of hydrogen + 6 times of oxidation what do we say number of oxygen is = 0 right and here it is again 6 times oxidation state or of carbon + 6 times oxygen state of hydrogen should be = 0 so 6 times and C + 12 times 1 + 1 which we know from our previous knowledge right + 6 times -2 right = 0 and here it is going to be = 6 times NC + 6 times 1 = 0.

So here I guess 12 – 12 cancel out so NC the state of carbon and it was obviously now 0 one particular glucose molecule I guess right and here in this particular case ahh we see that it is going to be equal to right -1 is so obviously what do you need to understand from here particular now so we see that NC or oxidation state of carbon and C6H 12O6 right is less than or is should say greater than it is positive I guess oxygen state of carbon in C6 H6 right.

So again what do we see now so thus obviously we see that carbon is more oxidized when it is in the form of but it is more reduced when it is in the form of benzoin again looking at the oxidation state that is the relative what do we say compassion that we can draw it is again I guess carbon as oxidation state when you from +4 to -4 I guess so I guess this is the way you can calculate for the oxidation state of carbon and various particular molecules and in this case obviously you see that it is carbon is more oxidized in the glucose molecule.

Again so let us look at relevant so we are going to now develop let us say or balance half reactions right and for that I need to identify the couple as in so what is the couple now I know we are referring to those compound from molecule let us say with before and after transfer of the relevant electrons right so for obviously we need to look at one particular what do we say now example so we are going to look at the example of reduction of chromate let us say reduction of chromate by sulphur right.

So let us say this is the information that I have and from here let us say I need to be able to come up with develop the relevant half reaction balance them and then get the overall reaction that correspond to reduction of chromate by sulphur. So obviously in this case or the first aspect is that I need to identify the couple so here let us say CRO4- more oxidized form it is going to be reduced to TR3+ so that is because obviously reduction of chromate and sulphur again SO2 let us say right because it is initially reduced and it is oxidized related SO42-.

So these are my inputs right so again we need to identify the relevant couple because we know that it is chromate by sulphur I guess with some background we know the CRO42- will be reduced to CR3+ and SO2 obviously will cause this particular reduction while being oxidized itself to SO42-.

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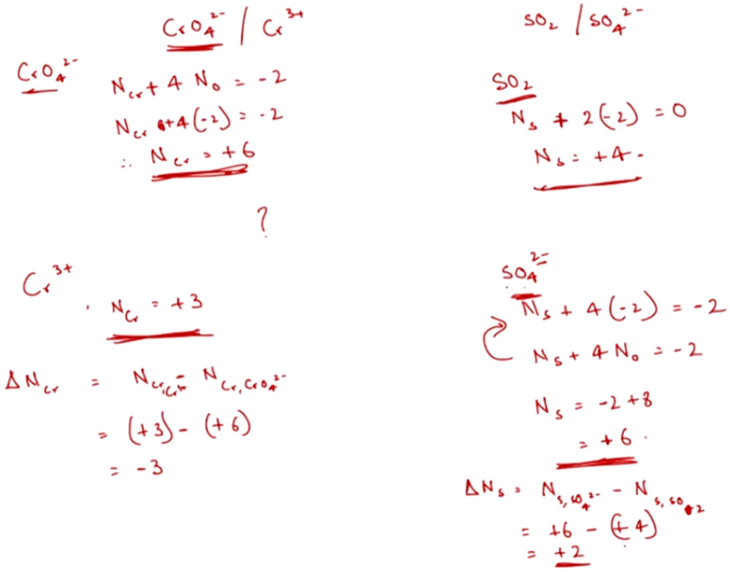

CrO_4^{2-} / Cr^{3+}

CrO_4^{2-}

$N_{Cr} + 4N_O = -2$

$N_{Cr} + 4(-2) = -2$

$\therefore N_{Cr} = +6$

?

Cr^{3+}

$N_{Cr} = +3$

$\Delta N_{Cr} = N_{Cr,Cr^{3+}} - N_{Cr,CrO_4^{2-}}$

$= (+3) - (+6)$

$= -3$

SO_2 / SO_4^{2-}

SO_2

$N_S + 2(-2) = 0$

$N_S = +4$

SO_4^{2-}

$N_S + 4(-2) = -2$

$N_S + 4N_O = -2$

$N_S = -2 + 8$

$= +6$

$\Delta N_S = N_{S,SO_4^{2-}} - N_{S,SO_2}$

$= +6 - (+4)$

$= +2$

So let us list this up and go through CRO42- and CR3+ and again SO2 to SO42- right. So obviously now I need to be able to calculate what do we say first identify which one is going to oxidized or which one going to be reduced and write the relevant half reaction so let us say if we do not have the obviously we need to be able to calculate the oxidations state and anyway you need to calculate the oxidation states because you need assign the electrons or the number of electrons being transferred right.

So we are going to do that so obviously now I am going to calculate the oxidation state of chromium right and that I do the for CR42- first and then obviously for a CR3+ oxidation state of chromium and same case here in SO2 oxidation state of sulphur and again here in SO42- and oxidation state of sulphur right and again how do I calculate here I know that NCR or oxidation state of chromium + 4 times oxidation state of oxygen should be equal to -2 right.

So oxidation state of this + 4 into -2 = -2 so we see that oxidation state of chromium in CRO42- is = -2 and +8 so right is going to be +6 and obviously here nothing but the charge on that particular what we say ion so that is going to be equal to +3 right and so here it is +6 and here it is +3. So what is that I will tell you now it is obviously more oxidized when it is in the form of CRO42- so looking at the oxidation state right we see that chromium is more oxidized in the form of SO42- compare to CR3+ so that is one particular information that we have.

So again here coming to this particular case the sulphur so plus two times of -2 = 0 right so -4 the oxidation of sulphur here is +4 right and in this case what is it going to be + 4 times of -2 is going to be equal to = -2 right again nothing but I guess I have written it down = charge on the particular ion that is equal to -2 and from here we know that oxidation state of oxygen in general is -2 right it is more electronegative compound here.

And so with that I can get the relevant what do we say oxidation state of sulphur state that is going to be equal to -2 +8 that is going to be equal to + 6 right okay. So obviously from this particular information what do we that the information we have that is sulphur is more relatively more reduced in SO2 and it is obviously more oxidized in what do we say as SO42- that you can lead from this particular oxidation state right or you can also understand that here for one atom of sulphur you have two oxygen atoms.

And here in SO42- for one atom of oxygen you have obviously four what do we say atoms of oxygen while having only 2 negative charge right. So obviously you can you know develop the intuition that it is going to be relatively more oxidized in SO42- form compared to SO2 I guess right. Anyway or obviously we can calculate the relevant half reactions here and then what do we need to do?

We need to be able to calculate the change in half reaction not in half reactions pardon me the change in the electrons right or how do I get that change in the oxidation states. So I am going to calculate change in oxidation states for what do we say chromium that let us say I am going to write NCR – N as CR3+ oxidization state in CRO42- right and this is nothing but going to be change in oxidation state as equivalent to the number of electrons being transferred right.

So here it is +3 -+6 right so that is equal to -3 here and in this particular case remember change in what do we say the oxidation state which should be the equivalent to the change in or transfer of the number of electrons I guess right SO2 here right it is going to be +6 - +4 that is equal to +2 right.

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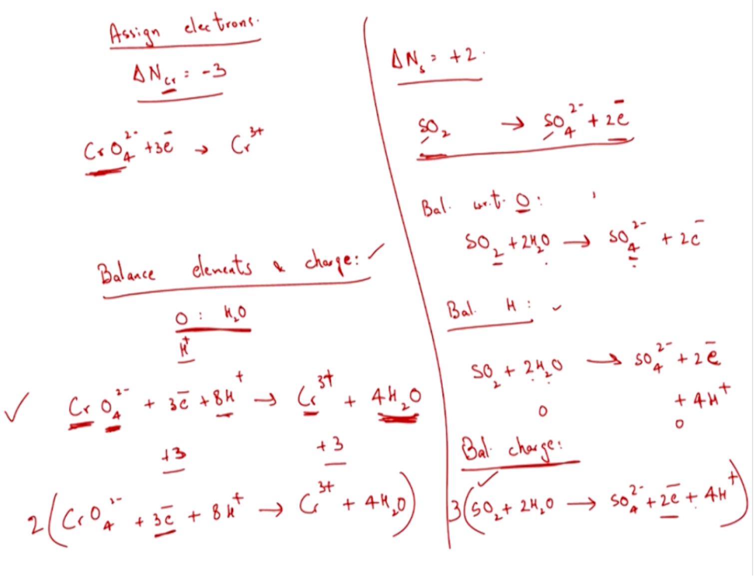

So this is what I have here so the next step is going to be have to assign the electrons right so the next step would be to assign the electrons and in that context we calculated the change in oxidation what do we say oxidation state for chromium and change in oxidation state for sulphur and I guess we looked at – 3 here and here it was +2 so -3 and +2 here.

Obviously now I am going to assign the electrons and I know that we start up with CRO2 – right CRO42- is going to what do we say CR3+ right yes and here obviously here it is towards with respect to SO2 right going to SO42- so obviously now I need to explain the electrons so here obviously what do we say adding -3 here would be in effect +3 electrons here right so obviously how did we get this by subtracting the oxidation state of chromium in CR3+ pardon me not other way wrong subtracting the oxidation state of chromium CRO42- from CR3 + right.

So in effect with we need to have -3 electrons or obviously +3 electrons on the left hand side right. So I am assign the electrons here so here though here it is +2 so I am going to have + 2 electrons here right and obviously what do we see here you know sulphur dioxide here is the reducing agent here because it is donating the electrons and that is what you see and CRO4- is the oxidizing agent because it is accepting the electrons or itself is being reduced right so that is what you see here.

So SO2 is the reducing agent which is reducing CRO42- right so that is what you see here so here have assign the relevant electrons and then we need to balance the elements and change right so usually I am going to balance oxygen by adding H2O let us say and balance charge by adding H+ okay and I guess that by then you should be able to see a balance half reactions so let us do that out here so CRO42- + 3 electrons goes to CR3+.

So one what is the mole of chromium and chromium so that is fine here so chromium is balance I do not need to do that here but for the oxygen here I guess there are 4 atoms here right but none here so let us say here 4H2O out here 4H2O so not the oxygen atoms not stoichiometric is balance with respect to oxygen right again as set the balance oxygen the element we are going to have to usually used let us say H2O2 balance that and that is what we did here.

And let us say what else I need to do now and charge would not be balance now I am going to look at also the amount of ahh H+ hydrogen element so here I have 8 right so I am going to balance hydrogen by adding H+ so because here i have 8 I am going to plug in 8H+ here. So by now let us say of the charge is balanced so -2 -3 is -5 and here is +8 so in this left hand side ahh the charge is +3 and on the right hand side to see the net charge is +3.

So by now we have the balance half reaction with respect to the chromium reduction here right again how did we do that the first saw to it that the number of elements of chromium where the same so I do not need to balance that but see that there is a mismatch with respect to the ahh number of atoms of oxygen right so that is why added 4H2O to the right hand side 4 ahh atoms of oxygen here to balance out the 4 atoms of oxygen here and then I see that now I have mismatch with respect to hydrogen.

So to balance hydrogen I had H^+ right $8H^+$ check for charge I saw that you know that is being satisfied and now I am going to move on to this particular case here with respect to sulphur dioxide. So here I guess just look at oxygen or the sulphur balance so the balance with respect to sulphur yes so I am done with that and now I am going to balance with respect to oxygen let us say right and how do we do that let us say by adding H_2O right SO_4^{2-} + 2 electrons.

So here I guess I have 4 oxygen atoms while here I have 2 so to balance that out at $2H_2O$ right so here 2+ 2 atoms of oxygen so 4 atoms in total on both the left hand side in relevant right hand side right and now we say balance hydrogen and how do we do that by adding H^+ so let us look at the relevant reaction here.

So + $2H_2O$and let us say $H_2SO_4^{2-}$ +2 electrons right and obviously there is a mismatch with respect to the hydrogen so here I have 4 atoms and here I have none so I have to plug in $+4H^+$ here and the right hand side and then balance charge or by now it is hopefully be balance actually so I am going to look at the charge here so no charge here on the left hand side and here it is 2 negative and 4 negative and 4 positive from H^+ so it is 0 on the left hand side and 0 on the left hand side.

So it is already balanced with respect to charge so it is SO_2 + $2H_2O$ right goes to HO_4^{2-} release in 2 electrons and 4 hydrogen atoms. So these are the balanced half reaction that we have (()) (42:42) right. So I guess initially I suggest that I would balance step side then I can obviously balance to balancing out you know in one step I guess right so obviously to should suggest this manner as an balance with respect to oxygen after assigning the electrons and then I guess balancing hydrogen in the relevant charge right.

So again let us have this particular half reactions here we are done with have in the relevant half reactions right. But obviously now we need to be able to able to develop the overall reactions right but obviously what is the key with respect to develop in the overall reaction now that you need to be able to balance the number of electrons being gained or lost.

For example here you see for one mole I guess anyway half reaction there are 3 electrons being gained but here there are only two electrons being gained right so I obviously be able to match the number of electrons being gained and accepted in the overall reaction I cannot have any electrons either being accumulated or being accepted let us say. So thus I am going to have to multiply these particular reaction by 2 and this particular reaction by 3 right.

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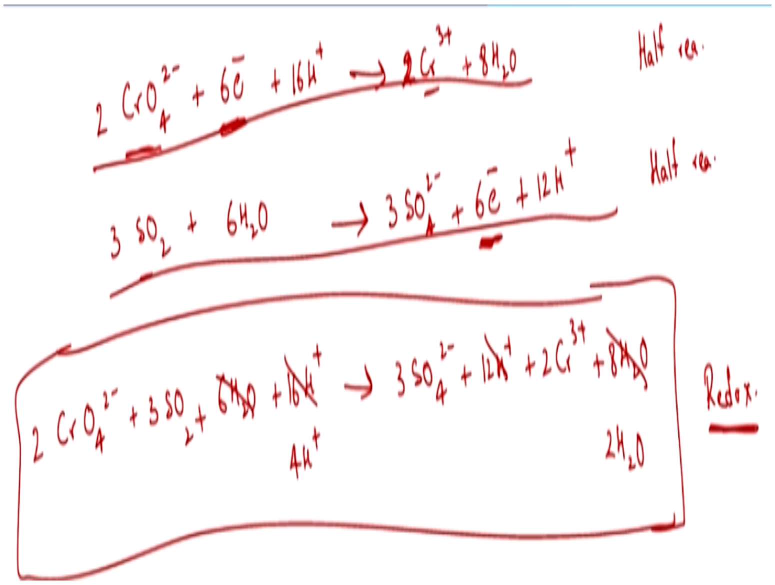

$2CrO_4^{2-} + 6e^- + 16H^+ \rightarrow 2Cr^{3+} + 8H_2O$ Half rea.

$3SO_2 + 6H_2O \rightarrow 3SO_4^{2-} + 6e^- + 12H^+$ Half rea.

$2CrO_4^{2-} + 3SO_2 + \cancel{6H_2O} + \cancel{16H^+} \rightarrow 3SO_4^{2-} + \cancel{12H^+} + 2Cr^{3+} + \cancel{8H_2O}$ Redox.

$4H^+$ $2H_2O$

So let us try to write these down here I guess right 2CRO42- + I guess now it is 6 electrons right +16 H+ goes to 2CR3+ +8 H2O right okay and the other half reaction I guess is obviously going to be 3SO2 + 6H2O right is going to be equal to 3SO42- + obviously 6 electrons right now you see that the number of electrons being gained and last is gain right + 12 H+.

So obviously we get the overall reaction I need to look at what do we say swap the relevant half reactions right and if I write that down in is that I do need to swap it here I guess not it is relevant half reactions in such way that I have the electrons being accepted on the left hand side and what do we say do it on the right hand side if not I need to swap it so which is not the particular case here.

So I am going to have my overall reaction 2CRO42- +3SO2+ 6H2O + 16H+ right it would go to 3 SO4 2 - + 12 H+ +2CR2+ + 8H2O and obviously I need to now balance out with respect to H2O and such right so here I have 8 and 6 so in effect this would end up being 2H2O here right and here I have 16H2O + and 12 H+ in effect to this would end up being 4H+ so this is my overall redox reaction right.

And here we have the chromium being reduced and what is sulphur being I guess it is oxidized so the relevant half reaction these are the half reactions and this is my overall redox reactions let us just to identify what is happening here so the sulphur is donating its electrons right and these electrons are being accepted by chromium in the form of CRO2-and it is transforming into CR3+ right.

So again you can identify the relevant reducing agent here so the reducing agent is nothing but a SO2 her because it is donating the relevant electrons and it is going to be CRO2- which is obviously now going to be reduce from oxidation state +6 which we calculate earlier to oxidation state of +3 which is CR 3+ form I guess. So I guess this is way or you know once you are to be able to overall redox reactions.

So obviously we looked at redox relevant aspect step wise so once you are relatively constant you can obviously do them in once step right so now we are going to move on to the kinetics right again we did mention that kinetics plays an important role with respect to out particular redox reaction why is that because the relevant time frame involve right usually do not reach equilibrium the kinetics are relatively slow compared to what you observe with respect to acid base complexes are or precipitation not precipitation again each with respect to acid basis and complex formation.

So the kinetics is relatively slow and rarely to reach equilibrium so usually when we talk about redox process we must always almost always talk about talk about the kinetics now right and that is what I guess we are going to discuss in the next session and then want to applications of what you would expect if it is meta stage equilibrium or other equilibrium have been reached and how to understand the system. And I guess with that I will end today’s session and thank you.