Chemical Principles II

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Module 03

Lecture 19

Adiabatic Irreversible Work

Ok so you have seen how to calculate the work done for a reversible adiabatic processes, now we are going to talk today about how one can calculate the work done for irreversible adiabatic process and then we will compare the work done in irreversible and reversible manner for adiabatic processes and see that which work is more and which is less given that the final pressure is same for all the processes.

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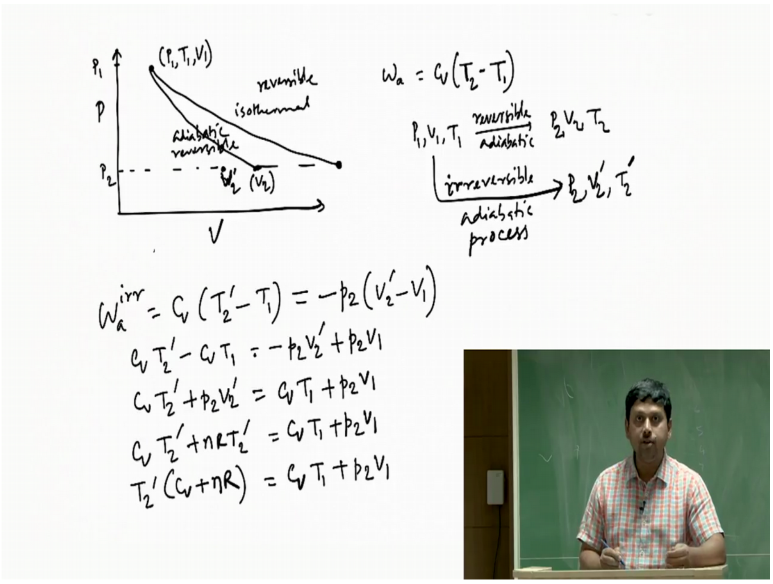

So now we have already discussed that for a PV diagram let us say our initial point is P1 V1 at this point and then let say the final point is somewhere P2 and I draw that by this line this is P1 pressure and this final pressure is P2 that is drawn by this line this dash line. Now if the process is carried out in isothermal manner, you know the final volume will be much more such that the work done is more than a corresponding reversible adiabatic process. So let us say this is isothermal reversible process and this is adiabatic reversible process. Now we would like to know that what will be the work done for irreversible adiabatic process given that the pressure final pressure is P2 and that in the reversible process as well.

So let us say that for reversible process the final volume is V2 but for irreversible process let us say the final volume is V2 prime. So then we know from the formal of work done in adiabatic process is it is C v d T C v Delta t or let us say the final temperature for a reversible adiabatic process is T2 and initial temperature let us take as T1, so let us say initial point is P1, T1 and V1 and is going to V2 and T2 for reversible process so let us say P1, V1 and T1 P2, V 2 and T 2 for a reversible adiabatic process and it is going to same pressure same final pressure but maybe a different volume V2 prime and different temperature T2 prime in irreversible adiabatic process, so we are going to calculate the work done in both and you are going to see that which work done is more and which is less.

Although we already know that work done for an isothermal reversible process is more than that of adiabatic process. Also we have shown that irreversible process in isothermal process has you know work done by the system is less than work done by the system when the process is reversible in an isothermal case, we are going to compare here only the adiabatic case ok. So let us start with the calculation of adiabatic work done and we know that adiabatic irreversible work done, so let us write that adiabatic irreversible work done will be C v T2 prime minus T1 prime which is again of course same as minus P2 which is the final pressure and the volume is V2 prime minus V1.

Now if you write down the equation will be C v T 2 prime minus C v T1 equal to minus P2 V2 prime plus P2 V1. And then we rearrange the equation, we will write C v T 2 prime plus P2 V2 prime is equal to C v T1 plus P2 V1. Now we know that from ideal gas equation of state that P1 V1 equal to N RT 1, P2 V2 prime will be N RT 2 prime so you can write C v T2 prime plus N RT 2 prime is equal to C vT 1 + P2 V1, so we can take T2 prime common and write C v plus N RT is equal to C v T 1 + P2 V1.

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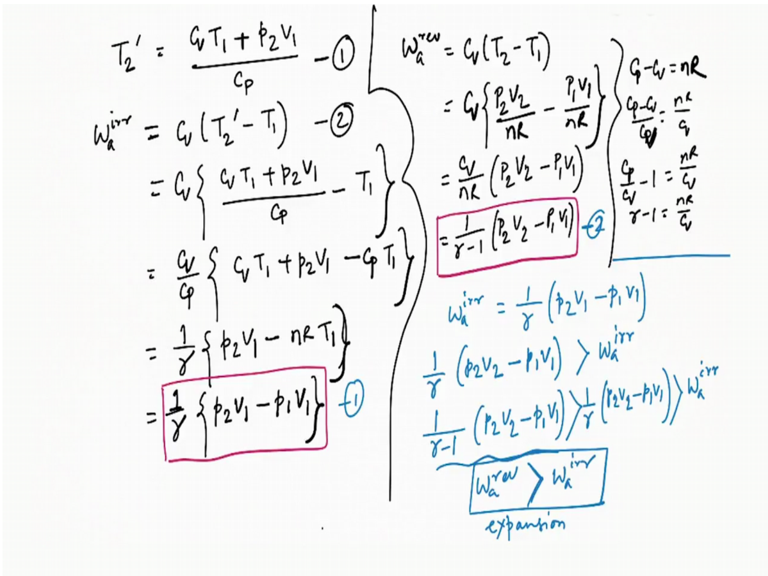

Now we know that C v plus N R is C p or T2 prime is C v T 1 plus P2 V1 by C p, so we got our final temperature T2 prime for an irreversible adiabatic process. Now let us calculate the work done in adiabatic irreversible process will be C v T2 prime minus T1 which will be the same for again the reversible adiabatic process as well, but in case of reversible adiabatic process the temperature itself will be different final temperature when the pressures are same between reversible and irreversible processes. So let us do that then so C v, now I will put the equation 1 in equation 2 and write that C v T1 plus P2 V1 by C p minus T1 C v by C p and C v T1 plus P2 V1 minus C p T1 and C v by C p will be 1 by gamma and you will get P2 V1 minus and you know C p minus C v is N R so we will get N RT 1.

Now again using ideal gas equation of state we can get N RT 1 is P1 V1 so we get P1 V1 so now this is the work done for an irreversible adiabatic process, let us compare that with reversible adiabatic process. So work done for reversible adiabatic process is again C v T2 minus T1, remember the pressure is same P2 between reversible and irreversible processes however, the temperature may or may not be different so we designated that by T2 for reversible and T2 prime for irreversible processes and then converted everything in terms of uh known quantities for example P1 V1 is known because that is the initial state and P2 is also knownand gamma is also known so therefore we have converted that way, now let us see what we get from this.

Now C v T2 minus T1 we can say that that T2 is again we can use ideal gas equation of state and write T2 as P2 V2 so you know PV equal to N RT so by N R minus P1 V1 by N R. Now

N R I can take it out and I can write C v by N R and then write P2 V2 minus P1 V1. Now what is N R C v by N R? So we know that C p minus C v is equal to N R so if I divide by C v both sides then I will get C p minus C v by C v equal to N R by C v so which means 1 - 1 by gamma is N R by C v or let say I just backup this step and we write, we can invert that and we want C v by N R right so we can do the inverse of that and we can write, C p minus C v is N R we know, we have to divide by C v so it should be C v correct, so C p minus C v by C v equal to N R by C v and which means that this C p by C v - 1 equal to N R by C v or gamma - 1 equal to N R by C v.

So C v by N R is 1 by gamma - 1 P2 V2 minus P1 V1, now we got the expression for reversible adiabatic process and irreversible adiabatic process, now let us compare between them and see which is more and which is less. Now once you compare that we see that, let us start with irreversible adiabatic process. Now we see that irreversible adiabatic process is 1 by gamma P2 V1 minus P1 V1, now if I replace V1 by V2 since V2 is larger in volume that will be a bigger quantity. So you can write 1 by gamma P2 V2 minus P1 V1 is greater than the irreversible adiabatic work done. Now we can replace gamma by gamma - 1 which will increase it further so you can write 1 by gamma - 1 P2 V2 minus P1 V1 is larger than 1 by gamma P2 V2 minus P1 V1 which is larger than adiabatic irreversible process.

Now you see compare that with the above expression from equation number 2, so this is same as equation number 2 and so therefore this is same as work done in a reversible process, so therefore work done in a reversible process is greater than work done in irreversible process given that both the processes reach the final pressure. And this is truly for the expansion process why, because we have already assumed that V2 is larger than V1 so we are only talking about an expansion work.

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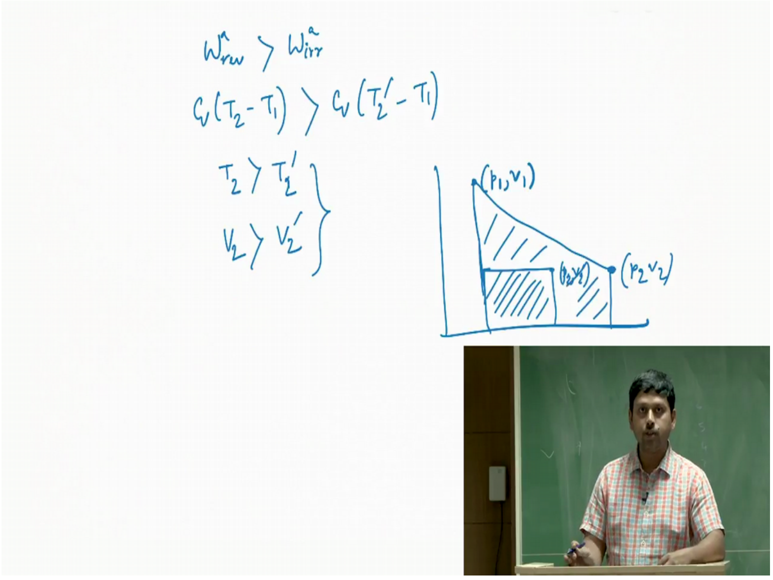

So only for the expansion work in a reversible process adiabatic work done will be greater than work done in an irreversible process. And we know it is C v T2 minus T1 will be greater than the C v T2 prime minus T1, which means T2 will be greater than T2 prime. So the temperature will be lowered more in case of adiabatic processes and therefore we can say that final volume V2 that will be obtained in a reversible process will be because we know that V is proportional to T right because T V is equal to N RT so V is proportional to T, when the pressure is constant then V2 will be more than V2 prime.

So the volume also will be more final volume will be more in case of reversible process than in irreversible process. So starting with P1 V1 let us say if you reach a volume V2 then the adiabatic volume will be somewhat less than that, it will be P2 V2 prime and the work done for an adiabatic process in a irreversible way will be this much that is work done for an idea reversible process will be that much ok so that is very stuffs