Indian Institute of Technology Madras

NPTEL

National Programme on Technology Enhanced Learning

COMBUSTION

Lecture 3
Sensible Enthalpy and Adiabatic Flame Temperature

Prof. S R Chakravarthy
Dept. of Aerospace Engineering IIT Madras

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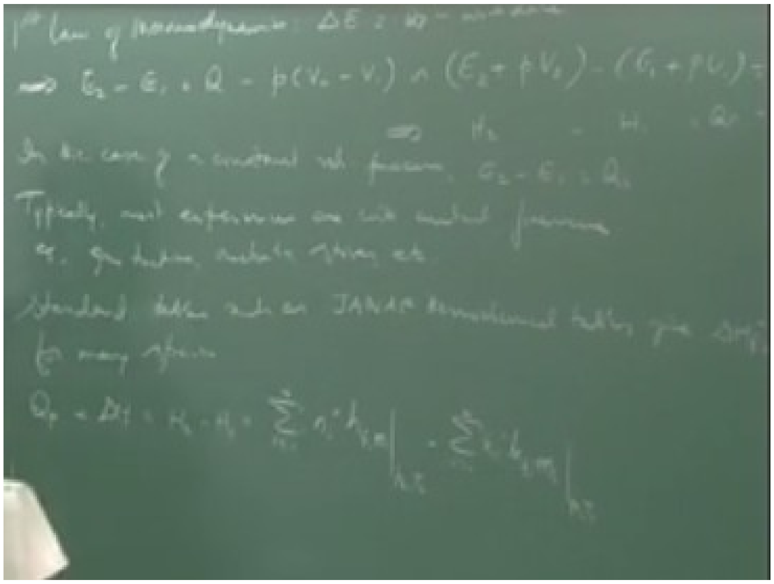

So typically we could just simply call this as reference temperature, it does not have to be 298 and there is an example, I have written a couple of things here one is the automatic hydrogen formation reaction. So we noted that H2 is like the reference element for H, therefore half H2 giving H is the formation reaction for automatic hydrogen. And so there are the H of norm 298 for H.

So you look at the notation here, so in fact you could improve on the notation by saying 298, script MI on the subscript there where script MI refers to the species for which you looking at the information standard heat deformation. So here for deformation reaction of automatic hydrogen you get a number that looks like this. Where on the other hand if you now look at the formation reaction for the high H2 molecule, the formation reaction is H2 gives you H2.

And obviously, you are now having looked no change across this reaction. Therefore, it makes sense for us to take the standard heat deformation has 0. The last class what are the questions that came about for a definition of a heat of reaction and more so for deformation reaction was, if you now take the initial state pressure and temperature, and then you now wait until you come back to the same pressure and temperature for the final state and look at the heat there is being removed or added to the system during this process.

What about the expansion work okay, because we now keep the pressure constant that means we could allow for the volume to change and the pressure work that the system does because of the volume change that there is allowed. So what we have to recognize now is, note that all heats or enthalpies okay, that means it is not for nothing to be chose a symbol H that would imply that the heat is an enthalpy or the reason why the symbol H is associated with enthalpy is looking at the other way it is actually a heat okay.

So this is to say all the heats that we are looking at are not internal energies but enthalpies okay. So these are enthalpies that mean that is they include the expansion work all right. So for example, if you now say suppose we now have a container and a piston, and a weight W, weight W indicates constant pressure right. And suppose, initially which makes H2 and half mole of oxygen molecule.

And suppose, we now have a heat interaction across the system boundary, and finally we now have a different volume right at which you now get a H2O the final. So here we have a T=298K, P=1 bar, and here we have T=298K, P=1 bar right. So the convention that we use, the convention is, so heat transfer is positive when into the vessel. So positive and into the vessel right, so we now take Q to be positive, if it is going inside.

And so, for here is in this example, where we are taking a H2 and half O2 initially and then becomes H2O, the heat is liberated that is leaving the system, leaving the vessel, leaving out of the vessel okay. And that is we will also try to now make it like QP, QP refers to, there is a subscript P here for the Q refers to the heat transfer at constant pressure right. So that is QP=negative 240 KJ/mole right.

So when you are saying per mole it is actually per mole of what is formed. So in this case there is one mole of automatic hydrogen that is formed incurring 217.999 KJ, here you are looking at 1 mole of water that is formed liberating 240 KJ/mole right. So this means negative means exothermic right, positive means endothermic right.

And so, what is happening here is, first law of thermodynamics applied to this system means that Δ E which is the internal energy change is = Q_P – the work done it is the you could write the other way that is heat = ΔE + the work done or ΔE = Q_P- the work done and this means E_2- E_1 is equal to Q_P – p times let us say V_2 – V_1 or you can also now rearrange things so you can say E_2 take this pV_2 to the left hand side.

So it becomes a + pV2 then you have a – (- pV_1) so you have + V_1 on the right side which taken to let to the left hand side becomes okay now try to group it with E1 with a negative sign that is = to Q_P so from here you can that this is actually $_{H2}$ – H_1 = Q_P that is equal to the Δ H, so this is actually for any heat reformation or any I am sorry any heat of reaction okay so for whatever you mean by heat of reaction has defined with respect to having a constant pressure and temperature at which you start out and coming back to the temperature and pressure and the n will basically give rise to this because we now keep the pressure constant right and you get back to this thing.

So effectively what it means is the heats that you are looking at is essentially an enthalpy right that is what your or an enthalpy change in the reaction in the case of heats of formation you will find that your looking what reference elements to start with okay which are assigned a 0 heat deformation therefore you can directly say the heat deformation of a what should I say of any species is essentially it is enthalpy.

Okay because it is not really an enthalpy change any more because it is changing from 0 for the reference element alright therefore you can simply say that all heats are enthalpies right now in the case of a constant volume process of course. The case of a constant volume process we will have $E_2 – E_1 = Q_V$ which means we do not keep the pressure fixed the pressure will vary to the volume will be fixed okay.

So I will lead the 2 to actually find out whether Q_V will always be greater than Q_P or not okay that is something that you can try to find out for self and you will also look at some puzzles in the end between Q_E and Q_P that will try to point out if we get some time, but let us just continue at the movement, okay and the other point I wanted to make is constant typically most experiences or with a constant pressure right.

Example let us say gas turbine, rockets, stoves etc fairly different once like gas tribune and rocket make like aerospace but stoves is not necessarily aerospace fieriness also all things we typically have the constant pressure situation in things like piston engines so pressure the pressure keeps varying the volume keeps changing okay so it need a constant pressure nor constant volume but let us not bounder about it at the movement for many applications constant pressure compression is a good approximation.

Okay the other thing is so standard tables now standard tables so just what is called as the JANAF thermo chemical tables catalog or give simply can say simply give Δ Hf0 298 for many species. In fact this tell you why we need to actually have a standard heat deformation so it is possible now if you standardize the conditions at which you want to catalog or tabulate the heat defamation.

Then it is possible for you to actually have tables like the JANAF thermo chemical tables which will give this for many species okay so it is not available so if you now look at the heat that is realized Q_P as essentially a ΔH which is a nothing but $H_2 – H_1$ right that is what we had here just coming back to that after these notes so we have this can be written as then Σ i = 1 to n, ni’’ let us say Hf mi at P_2, T_2 – Σi=1 to n, ni’ Hf mi HP will come at u which is the same you could not consider.

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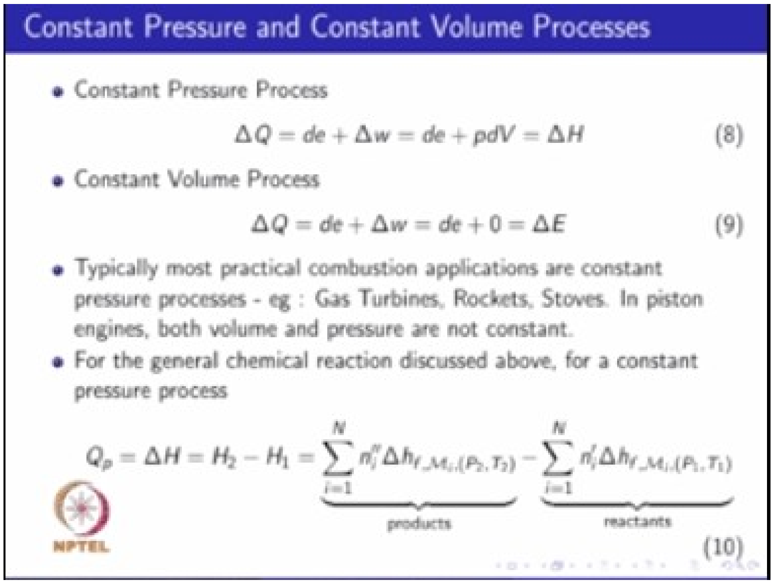

Constant Pressure and Constant Volume Processes

- Constant Pressure Process

$$\Delta Q = de + \Delta w = de + pdV = \Delta H \tag{8}$$

- Constant Volume Process

$$\Delta Q = de + \Delta w = de + 0 = \Delta E \tag{9}$$

- Typically most practical combustion applications are constant pressure processes - eg : Gas Turbines, Rockets, Stoves. In piston engines, both volume and pressure are not constant.
- For the general chemical reaction discussed above, for a constant pressure process

$$Q_p = \Delta H = H_2 - H_1 = \underbrace{\sum_{i=1}^{N} n_i'' \Delta h_{f\_M_i,(P_2,T_2)}}_{\text{products}} - \underbrace{\sum_{i=1}^{N} n_i' \Delta h_{f\_M_i,(P_1,T_1)}}_{\text{reactants}} \tag{10}$$

Any process where we started out with certain pressure P1 and T1 does not have to be standard okay and we now go through the process of the reaction to completed and you know, you which a different state P2 and T2 which is not nothing to standard alright if there is a case then we note that we are not using the standard heat of formation here, okay we are saying what is the heat of formation of all this species that involved in the reaction take care that if you, if Ni doubled prime was 0 that means it is not really a product okay.

I am sorry ni doubled prime that x practice if ni doubled prime was 0 when it is not a product if ni single prime was 0 then it is not a reactant, so that will take care of that so we essentially can somehow here all the heats of formation not a standard heat of formation but heats of formation at certain pressure and temperature that is the for the products and minus the heats of formation for the reactants, so effectively this is like free products and this is for the reactants or change nutrition little bit here for you and I am going to explain this.

For the round we now began into use small h okay because particularly because this is a basis associated with whole unit amount you multiply by the number of modes okay, so ni in a sense some sense we can now call this is a more express enthalpy that means we are talking about it does per unit mold okay, of course we have been talking about having this as per/m as well okay but this is a standard heat that you are looking at this is not the standard heat of formation it okay, I do not know have this make sense by the way if I now write like this.

I am actually trying to do something if that circuit is the sense if I have a reaction that is going on that suppose that I have methane plus oxygen gives carbon dioxide and water let suppose where that is reaction that we are looking at, now we are looking at here the formation a heat of formation of carbon dioxide then heat of formation of water here we are looking at heat of formation of methane and heat of formation of oxygen okay, now we know that this timer heat of formation of oxygen is 0 and.

The heat of the formation reaction for methane for example would be like carbon at solid form plus hydrogen into two hydrogen get CH_4 that is the reaction that we have to go through for the heats of formation reactions for carbon dioxide and water or like CH+ O_2 give CO_2 and H_2 + ½ gives H_2 and so on, these are not the reactions that we are finally looking at right so we are finally looking at CH_4+O_2 gives CO_2 + H_2O so why did we actually have to get into formation enthalpies.

So essentially what waves is we have a beginning a hypothetical process in our minds were you are writing this and I want you to do this sort of get to understand that which is whereas suppose that you started out with some reactants in this states in this example hydrogen and oxygen or the other example I mention as methane and oxygen what does means is and then they are at some pressure and temperature okay, so what we have really basically saying when you are re including the heats of formation.

Is we are now going through un bounding their bonds okay so CH_4 we now want actually in part some heat to system to form a C and H_2 which are the formation continents so that is a difference elements O_2 is a reference element already okay as well as see and then we now have the reference elements we now regroup the reference elements, so we now have CH_2 and O_2 these are the reference elements with you could now form your carbon dioxide and water so it is set id like you got the reactants you now impact this or this de bound and then get back the reference elements.

That means you have exchange some heat in this process keep that as account okay and then get the reference elements to form the products that you are looking for right and you will now that some heat out source – heat that is supplied is the net that you are going to get, so you are going through a hypothetical reaction mind through a reverse formation reaction for the reactants to form the reference elements and then a formation is set of formation reactions for the products to get some heat transaction in both the steps.

Okay and then you are looking at the in net heat transfer to get you this keep this is as it is beginning to get you into some hypothetical reactions that happening at all okay the next step for us is so here HF small hf ni as I said was specific more our enthalpy.

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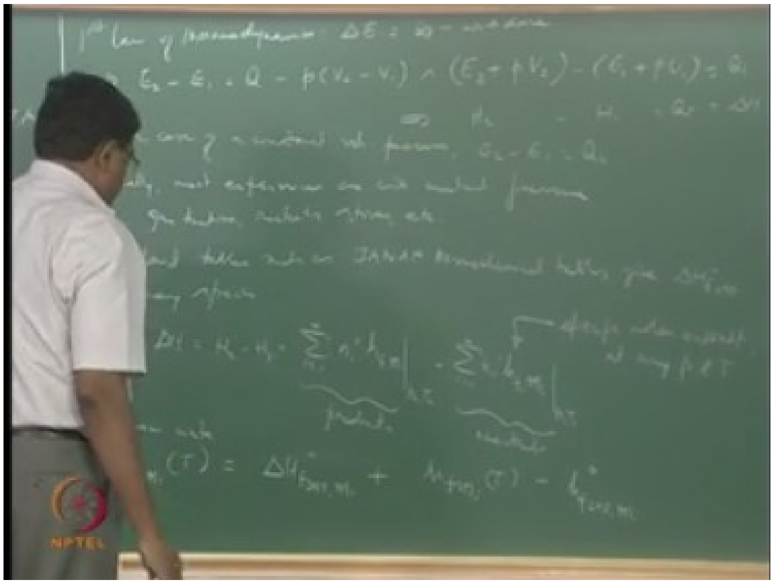

Enthalpy at any Particle and T okay in this case it is P_1 and T_1 in this case P_2 and T_2 okay so here we can now write the now write hf mi or reverse temperature and now that I am basically writing it only as a function of temperature why because we assuming a ideal gases okay and because we are assuming ideal gas which is some will perfect the expect to the enthalpy of the heat is shown to be an enthalpy and then the enthalpy should be only a function temperature okay we can now write this as Δh of 298 of this species + $H_f mi(T)-h_f^0 298mi$ if you do not like 298 you can replace this by T_{ref} any reference temperature.

That you want but you should look for standard tables that give you these things at that temperature that you are looking at it is sort of like unless stop it is not exactly algebraically adding and subtracting things you would find there this is showing up in these two places so it is sort of like I am adding something and subtracting something in some sense yes, but there is a physical meaning associated with this, what we then saying is this is the standard heater formation right, and then this is what is called as the sensible enthalpy.

Let me draw it in capital letters sensible right that is what is called the sensible enthalpy. So what is going on, why are we talking about something called a sensible enthalpy is not because that is the one that make sense whereas the other one is not sense any ideas. Yes, yeah, yeah, yeah so algebraically this is not going to make sense so do not worry about it okay, so what is your essentially doing this we are splitting this into two parts one is what is called as the standard heater formation that we are in talking about all the time okay.

And then the next one is what we call as sensible enthalpy. Somewhere explained to you what these two mean, so here we are writing it in this way primarily from a notation point of view okay, so you do not go ahead and stop cancelling things from left hand. Here, no then it cannot be this symbols this and this you could say that, you could say that okay, you could say that because as I told you this h is not necessarily I mean this is suppose to be like a change okay, that is why we have the Δ alright, but it change from 0 okay, so this is like enthalpy if heater formation of h minus heater formation.

So if you can apply this equation and this equation to the formation reaction itself what will happen is this is the heater formation of h minus heater formation of h2 which is 0 right, therefore the change is nothing but the value itself because here basically taking the value and subtracting 0 from there okay, so you can write it so this is a good question. Because it also firms up the notation that we using so the change as well as the value are pretty much the same, okay because if you take the value and subtract 0 from this for the reference elements heater formation you get the change.

So this is essentially the same okay, but what is more important for us from now on is not how we split this it is about what they need okay. So you now looking at this particular thing as one term called the sensible enthalpy the other one is called the standard heater formation which we enough familiar with. The question is why, what is meant by the sensible enthalpy right, so what is sensible about this enthalpy.

Further, why further this any increase in enthalpy that the sensible enthalpy shows is showing because of a temperature raise okay, in another words when you not talk about enthalpy of a species you can now say this species now has a basic enthalpy associated with it at standard conditions okay, you can take this standard at whatever level you want okay, your P and standard, standard pressure and temperature can be whatever it is and then you say if the standard heater formation at this pressure and temperature is this, this arbitrary the assignment of the pressure the standard pressure and temperature at which the and the standard heater formation is measured that choice is somewhat arbitrary.

But at that condition, those conditions you now have a standard heater formation that refers to the energy that is contained in the bonds by itself for simply for it to simply remain in that particular molecular combination of atoms at that particular standard temperature and pressure they need some energy okay that is what this is. Any further change in the enthalpy of the species from there on is purely by a change in temperature okay, so that means you now taken a thermometer or a thermocouple or anything and then you measure the temperature you should be able to tell what the sensible enthalpy is.

So another words this is a, they use a part of the enthalpy that can be sensed by a thermometer or a thermocouple so sense it is sensible by a temperature measuring instrument we call these sensible enthalpy. So many times when you pretty much regressively invite that the enthalpy is directly proportional temperature we are always talking about the sensible enthalpy we are not talking about heater formation. The heater formation is hidden okay, so when you are talking about non-reacting fluid mechanics where you are not bothered about chemical reactions and so on you simply saying you know h is $\Delta h=C_P\Delta T$ that is because the change in enthalpy is only coming out of only the change in temperature.

And therefore we are essentially interested only the sensible enthalpy, and you do not even bother about the formation enthalpy because the formation enthalpy is there the speech is not going to change you are not looking at in the chemical reactions certain changes species but here we are board on this situation where the species is growing to change it is going to get the reaction is going to get deeply there is a product is going to get produced.

Where therefore we have to now began to pay attention to the energy of the species itself because it just exists at a standard temperature and pressure and that is by virtue of the bonds and we arbitrarily assign the bonds represents in like these dioramic molecules like H_2 and so on to have 0 in G, that is why get it data. Refer to which a atomic species does not have any bonds actually accuses some energy for a to be remaining on atomic stage because it is not naturally existing the force some energy Mr. Beam given to him get it to that state is he?

So that is even I lakh of bond in that sense actually has some energy associated with it because of the reference element that we take to be viewer this, so this is the very important concept here that we have looking at where this could not be caper all in this tables and then we finally look at only the change in temperature for the rest of the enthalpy change for any species right.

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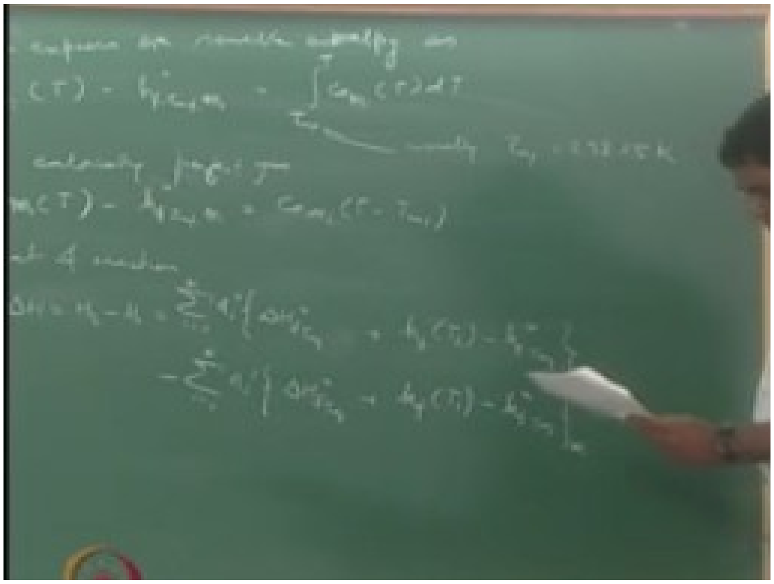

So we can express the sensible enthalpy as Hf Mi of t – hf 0 t dash Mi ti bh t = ∫t` to t from Cp Mi of T Dt that comes from the definition of Cp so Cp is a partial derivative of enthalpy is respect to temperature and therefore if you want to get the enthalpy back then so it give you know think about this like a constant intervention if you are not in training integrate Cp with respect to temperature for a calorically perfect gas we can write this further as Hf Mi of t – Hf 0 t Mi or Cp Mi t – t`.

Now I want to you to note that first for the first time we are recognizing that each and every species we have different Cp than the other okay. So cp is actually species specific keep this in mind it is going to now haunt you through the rest of your life if you are doing comparison for the rest of your life okay. Usually we are saying T ∫ is 298 .15 ki so usually t ∫ 298 . 15 k if you want two decimal place actually on the temperature there.

So therefore heat of reaction this is any reaction that we are now looking at but for example I say methane oxidation to carbon dy-oxide and water you can get Cp = Δh = h u H1 = Σ I = 1 to n ni open your curly brackets here and then write Δ h f0 t` Mi + Hf T2 – Hf0 t` right or take the back little bit so you can write blindly for this free species Mi – Σ I = 1 to n, ni’ Δ h f0 t` + Hf t1 – Hf0 t’ 4 species Mi right.

So you can see that t2 and t2 are showing up expressly when we had these things for emphatically there okay, but what about p1 and p2? They are on show up you are looking at ideal gases where the enthalpy is only functions of temperature therefore the sensible enthalpy depends on the temperature.

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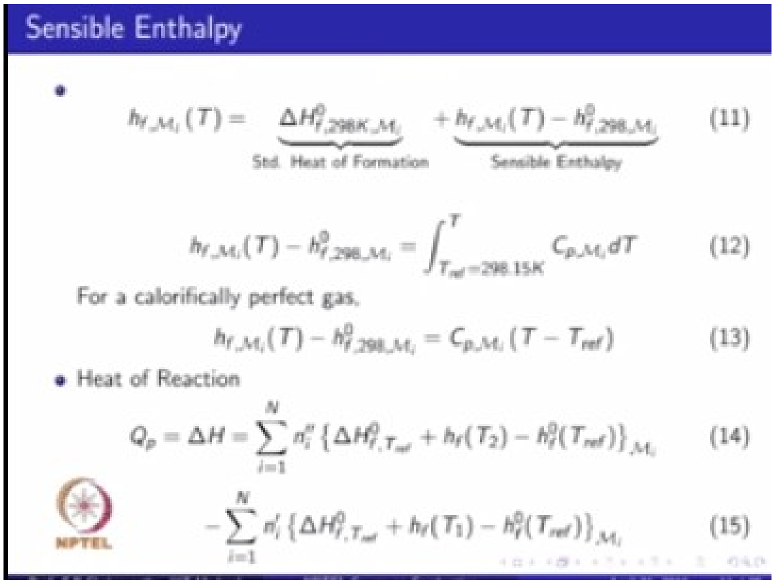

Sensible Enthalpy

- $$h_{f,\mathcal{M}_i}(T) = \underbrace{\Delta H^0_{f,298K,\mathcal{M}_i}}_{\text{Std. Heat of Formation}} + \underbrace{h_{f,\mathcal{M}_i}(T) - h^0_{f,298,\mathcal{M}_i}}_{\text{Sensible Enthalpy}} \qquad (11)$$

$$h_{f,\mathcal{M}_i}(T) - h^0_{f,298,\mathcal{M}_i} = \int_{T_{ref}=298.15K}^{T} C_{p,\mathcal{M}_i} dT \qquad (12)$$

For a calorifically perfect gas,

$$h_{f,\mathcal{M}_i}(T) - h^0_{f,298,\mathcal{M}_i} = C_{p,\mathcal{M}_i}(T - T_{ref}) \qquad (13)$$

- Heat of Reaction

$$Q_p = \Delta H = \sum_{i=1}^{N} n''_i \left\{\Delta H^0_{f,T_{ref}} + h_f(T_2) - h^0_f(T_{ref})\right\}_{\mathcal{M}_i} \qquad (14)$$

$$- \sum_{i=1}^{N} n'_i \left\{\Delta H^0_{f,T_{ref}} + h_f(T_1) - h^0_f(T_{ref})\right\}_{\mathcal{M}_i} \qquad (15)$$

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So it can express c t2 and t1 show up here okay, what about pressures? Do you have bother about them or we do not have to bother about them keep bothering about whether we want to bother about them or not again, so we will just proceed to what we want to do which means look at the adiabatic flame temperature we are now ready to look at the adiabatic flame temperature.

So what we understand by adiabatic flame temperature, what is it call adiabatic? You still do not know why it is call flame temperature or do we? So in the first we said the flame is nothing but reactions own and we are basically looking at any reaction which is happening to start with that p1 and t1 and ending at p2 and t2 and we know how divide an expression for the heat released in this reaction given the heat formation the standard heats of formation of the species and the sensible enthalpy is of the species which are suppose to be tabulated. So these tables will actually contain left hand column of temperature starting from the 298.16 and then keep on going up to high temperatures may be 4000 Kelvin to that 3000 Kelvin of something like that okay and then for every row of temperature you will now get the sensible enthalpy for that species right.

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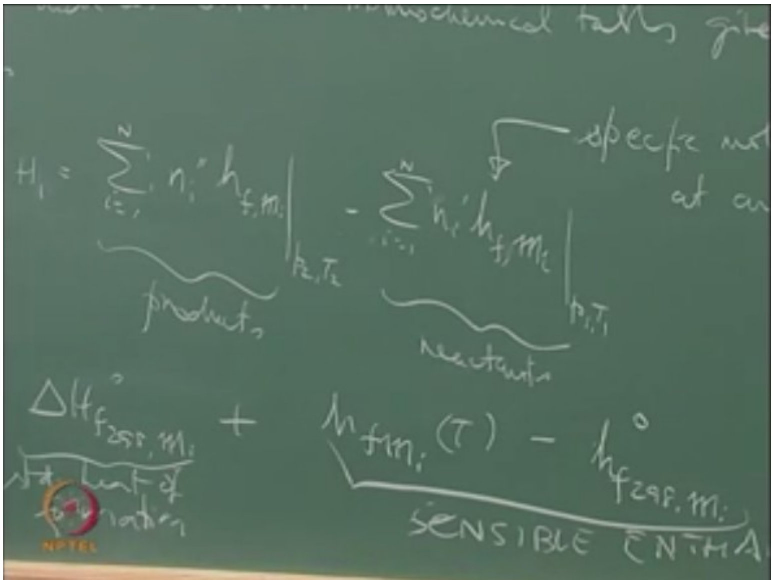

So you have the sensible and enthalpy species and function of temperature all if you do not want to read this sensible enthalpy now you can deal with CP's and the way you want to dea with CP as the function of temperature we can hidden polynomial and do the integration or if you want to assume like calorically perfect gas you can now consider CP the constant move the range of temperature that is interrupt that is interruptible right.

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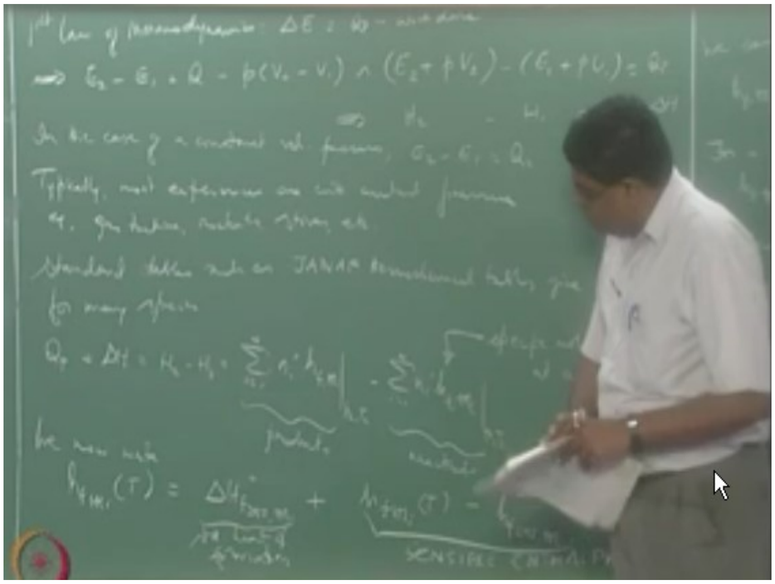

So we can do all this things so if we given the NI double primes and the NI single primes okay and the heat affirmation the standard heat affirmation and the sensible enthalpies you could in principle find out the QP or works the situation here what are we looking for what we are trying to find out.

We are trying to find out the adiabatic flame temperature okay that means we do not know the temperature at which the products will be when the reactance have burned that we get the products okay and we want to actually find out what will be the temperature attain by the products when they have reacted from the reactance without losing heat to the surroundings with all therefore they get the maximum temperature possible because if you lose some heat to the surroundings the products will attain less temperature okay.

So not losing heat to the surroundings is what we mean by adiabatic so if you know how the adiabatic situation then you get the maximum temperature that is in principle possible for the products to attain from the reactance so what would be want to do is this equation what do we know, what we do not know ?

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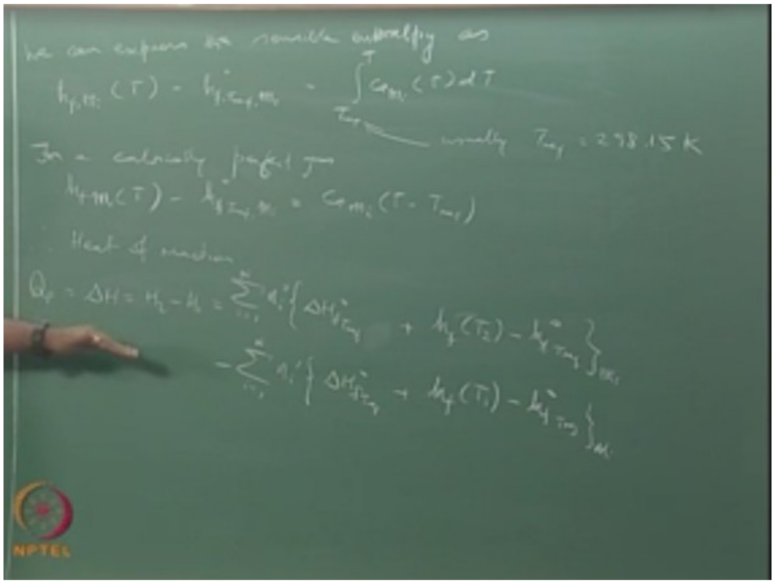

We can express the sensible enthalpy as

$$h_{f,M_i}(T) - h^{\circ}_{f,T_{ref},M_i} = \int_{T_{ref}}^{T} c_{p,M_i}(T)\,dT$$

usually $T_{ref} = 298.15$ K

In a calorically perfect gas

$$h_{f,M_i}(T) - h^{\circ}_{f,T_{ref},M_i} = c_{p,M_i}(T - T_{ref})$$

∴ Heat of reaction

$$Q_p = \Delta H = H_2 - H_1 = \sum_{i=1}^{n} n_i''\left\{\Delta H^{\circ}_{f,T_{ref}} + h_f(T_2) - h^{\circ}_{f,T_{ref}}\right\}_{M_i} - \sum_{i=1}^{n} n_i'\left\{\Delta H^{\circ}_{f,T_{ref}} + h_f(T_1) - h^{\circ}_{f,T_{ref}}\right\}_{M_i}$$

Here so let us see here t2 and t1 on p1 and p2 and N1 double primes and N2 double prime and you get these sensible enthalpy from the tables and the heat sub formation from the tables you could find QP but here what is given and what is not given, and NI double prime P2 if we assume constant pressure P2 is not and T2 is unknown, T2 is unknown what else is given Cp is given that is fine that we will given in the form.

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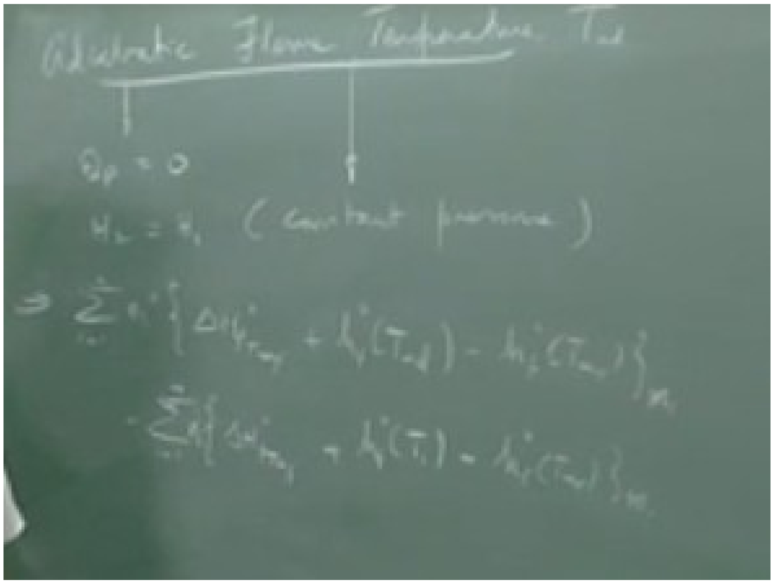

Adiabatic Flame Temperature T_{ad}

$Q_p = 0$

$H_2 = H_1$ (constant pressure)

So we have to find T2 is the question? Right. So previously given T2 and we could find QP here what we do we have to find T2 so what about QP, QP is taken as 0 so sudden point for S is to take QP= 0 so adiabatic simply means QP=0 right that means H2=H1 right and when we say H2=H1 the implicit assumption is cost and pressure okay.

So if somebody does not mention cost and pressured and talks about adiabatic flame temperature it is impressively assume that you are basically hearing about the constant pressure process okay so unless you want to expressively talk about constant volume adiabatic flame temperature then you have to save surf okay because we have that we simply going to be equation H2 to H1.

We want to look at constant volume adiabatic flame temperature what do we want to what do we want to see we want to say QV=0 that means we have to be equating E_{2D} E1 okay here we are looking at QP=0 for H2=H1 impressively using constant pressure so adiabatic flame temperature assumes a constant enthalpy and constant pressure a constant enthalpy given by H2=H1 and the definitions of heats is essentially having constant pressure in built in them.

So what this means is $\sum$=1to n N1 double prime open up the curly brackets then say ΔH^o Tf+hf^0 at Tx okay and Hf^0 tf all for species MI=$\sum_i$=1 to n ΔH^o a sign remains the same as before T1 HF I am sorry okay that is fine tf MI okay now calorically perfect gas of course we can assume CP as a constant and then again expressively.

So now what happens is Tad is showing up what we want; it is actually a function ensemble and therapy and so what we have to look for is, now know you can find what is the right hand side is. The right hand side is known you know n_i and you know your T1 you can calculate these. So what you have to look for is you knew your n_i prime okay, n12prime the first to composition of the products.

Given the components of the reactants and we will talk about that soon okay, if you give ni2prime you have to find out, you know now you have to actually look at one particular temperature for which you could now look at the tables for the different spices okay at that temperature find out what this is and see if it matches with the RHS and then the temperature that you choose for looking at the tables for each and every species is right.

If not is not a benefited temperature, so you can do okay or if you now assume a Cp as a function of temperature you will now get polynomial in temperature and you have to solve this polynomial, so now you will get a temperature explicitly showing as a polynomial which as to be solved to get this temperature. If you want to get rid of all these hassles and hopefully that is what you will face in things like exam because you can do this very quickly, we assume a clinical perfect gas.

Which means we can simply say Cp_{mi} of T ad – Tref and here you are going to have Cp_{mi} T_1 – Tref, so Tref verdict is showing up nearly as suppose to a polynomial okay and then you can just rearrange and get your temperature alright. So that is easy for a clerical perfect gas but not otherwise. So given ni prime and ni2 prime one can find Tad from the above equation right okay. so sensible enthalpy is also tabulated as I said, tabulated in tables as I function of temperature is now available on the web for typical species that you would be interested in.

Now I want to talk about two things here and these will be two most important things as far as this is concerned, so you now say this is = here because Qp = 0 previously we had – sign and then whole thing would be = Qp but now we have set Op = 0 split this part. So this refers to products, this refers to reactants yeah, so we have to keep this in mind we are thinking about combustion. In combustion is about doing fields okay and we want to identify but then the reaction that we took was something very algebraic general. Like something like σ i = N ni 1 prime, σ = N, ni 2 prime.

Where was the filed there? How is that getting oxidizing? How do you know which is the field? How do you know which is the oxidizer? So we have this question so we want up to be able to tell a fuel when you see it how do you do this? What we are looking for when we burn? What happens when we burn a fuel? It reduces heat, so how do you feel it? It is pretty hot okay, so we are basically looking for a fairly high value of theory adiabatic.

What are the values of theory adiabatic? Any idea or figure about theory adiabatic, we do not even known whether you are having heat loss and flames if you normally encounter, can you guess that you have in the flames that you encounter. Let just take an example of the flame that you encounter, example let us pick a flame that you encounter. Anything, I do not even know what the flame explain us, it is 2nd or 3rd class.

I want to talk about something that I encounter, candle flames you now burn a candle okay, where you think the temperature is there? But the peak temperature anywhere inside the candle flame, or anything or few degrees, Celsius or tons of degrees Celsius 100^0celsius or 10000^0celsius, what are we talking about? Right a few degrees Celsius are just.

This more than ice obviously it is not that cold okay, few tens of degrees is big basically just value more than body temperature or around body temperature but, when I touch it is pretty hot so I cannot touch anything more than about 70,80 degrees I am going to get burn human body is so fringed you cannot dip your finger into boiling water with this 100^0c so we are not even talking about getting touching a flame that means a guess the temperature is now getting greater than 100^0c right, so it is 100s call even words 1000s so you learned about candle and you can get and forget you have to light up a candle.

If you have to light up a candle you have a strike a match stick, you strike a match strike okay you get a little fire there that flame is actually going to have a temperature that is of the order of 2000kelvin, 2000 to 3000 it is so hot okay but if you Pismo physics and so on it is only so hot it depends on what kind of person you are okay but, we are talking about temperatures that are of the order of 2000c,2000k when you are in 2000 whether it is c or k okay it is the matter of same odor okay so that is what you are looking at if you want to get that, higher temperature here.

That means the sensible and lengthy has to be high, okay if your sensibly and lengthy has to be high the heat of formulation here has to be low that is the reason why we said the traumatic mixture is the one where the products will have the highest negative heats of summation so, now we have getting back to why we are talking about that okay so, we want to have formulas that have the highest negative values here so that this will be high to compensate and get you the total.

And then, we have to look at the total the total will be given by the right hand side okay so the right hand side is already given you take a particular mixture of sudden composition of methane and oxygen let us say okay this right hand side is fixed at a particular portion and temperature you take everything a temperature, portion, composition these is the specifies everything this right hand side is fixed then how do I know that I am actually working with the fuel and not some garbage.

That means, how do I know that methane is actually good work like a fuel that means, I want to have a high total to begin with that this right hand side should be folic high total and keep in mind t1 is not going to be very high for you, you do not want to actually heat up methane to 2000kelvin and then burn to get a carbon di-oxide and what are that 2000kelvin does not make sense.

So what is our methane at room temperature okay so room temperature is like okay 298 Kelvin let us say if you are not talking about a fairly no sensible enthalpy how is it possible for us to now have a very high total of the sensible therapy and the heat of formulation together only if you have very high heat of formulation for the reactant okay.

Now if you have methane and oxygen, oxygen is now going to contribute to your standard heat of formulation at all because, it is reference element and then therefore we take it as 0 okay so, the only way you are going to make sure that t is high yes if you work with a particular species which gave you a very high standard heat of formulation.

So you now look at a species and find that it has a high standard heat of formation you know it is a fuel you see that is really the catch you did that and then we can go then we can get very high temperatures and that is the equations but else you got to do this.

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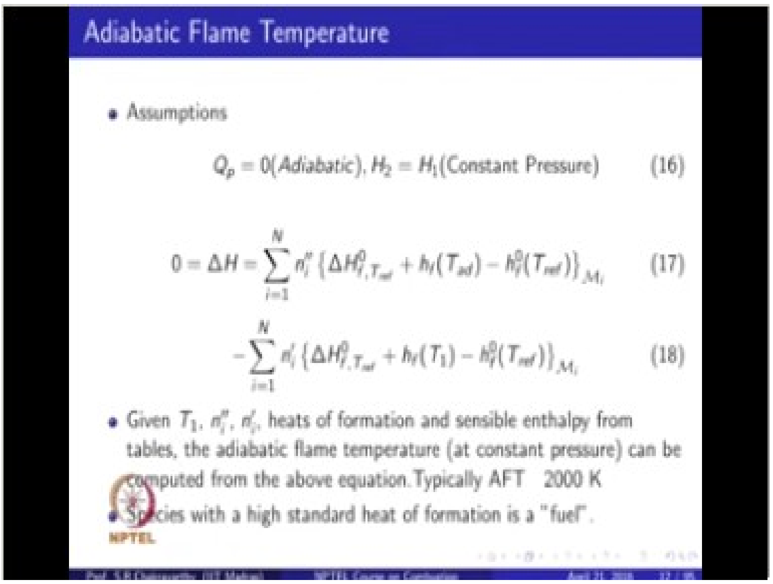

Adiabatic Flame Temperature

- Assumptions

$$Q_p = 0(Adiabatic), H_2 = H_1(\text{Constant Pressure}) \qquad (16)$$

$$0 = \Delta H = \sum_{i=1}^{N} n_i'' \left\{ \Delta H^0_{f,T_{ref}} + h_f(T_{ad}) - h_f^0(T_{ref}) \right\}_{M_i} \qquad (17)$$

$$- \sum_{i=1}^{N} n_i' \left\{ \Delta H^0_{f,T_{ref}} + h_f(T_1) - h_f^0(T_{ref}) \right\}_{M_i} \qquad (18)$$

- Given T_1, n_i'', n_i', heats of formation and sensible enthalpy from tables, the adiabatic flame temperature (at constant pressure) can be computed from the above equation. Typically AFT 2000 K
- Species with a high standard heat of formation is a "fuel".

Right so, this is pretty much contains like the lot of information about compulsion which is very, very interesting okay the second question but I have is I can give you an single prime alright do I know when I double prime what is that a piece if I took a certain composition of reactants how do I know what would be the composition of the products is it straight forward so it is like.

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