

Engineering Thermodynamics
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Week-12
Lecture-55
Chemical Reaction

Welcome to the third lecture of Chemical Reaction. In this lecture, we will study Enthalpy of Reaction, Enthalpy of Combustion, and Heating values of fuel. And also, we will study about Adiabatic Flame Temperature of Reactive System. Let's start with the different forms of energy in our molecular system. Let's study about that first. You have already studied that any molecular system has its own microscopic forms of energy. For example, nuclear energy is connected to atomic structure, chemical energy is connected to chemical structure, and latent energy is connected to phase change. If you change the temperature of any substance, and phase is the same, then the change of energy is connected to your sensible energy. And when there are reactions, then the bonds in molecular structure and new structure and new bonds are formed. So, in this process, the sensible energy is absorbed or released in large amounts. In this lecture and in this course, we will not study nuclear energy. We will only consider chemical energy, latent and sensible. If there is a process in which we disregard, that is, we do not consider the kinetic and potential energy, then the change in the energy change system, the state will be either due to this or due to this. If the state is not changing, then it will be zero, no change in state. No change in phase. So, ΔE system will be ΔE chemical, which will be due to the change in chemical composition.

In thermodynamics, we don't talk much about the total energy. Whenever we talk about enthalpy, or internal energy, we always take a reference. We have taken reference in the table, whether it was water or other systems. We have discussed it before. The reference will be cancelled out And especially if there is no change in the chemical composition You can take any reference And it will not be accepted But when you are analyzing about the reactive system Because the composition will change So the property you will use should be calculated by some standard reference state We have designed a nomenclature for this, which defines a standard state. And that state is 25°C, 1 atmosphere. We can remove the relative values of this state whenever the chemical composition changes. So, this chosen reference state is 25°C, 1 atmosphere. This is called a standard reference state. In such a case, the property that we remove in this condition is H_0 25-degree atmosphere. Now you will think that the table is ok, you will have to make it again. In fact, there is no need for that. You can use the tables that you already have. And you will just subtract the values of the standard state. You have to extract any specific value from there. So, as an example, if you want to extract the N_2 at 500 Kelvin. Relative is the relative of standard reference state. So, what will you do? You have to take out this value from the table. $H_{500\text{ K}} - H_0$. So, you will take out this value from the table. And from the table you will take out this value. This means this is 25 degrees Celsius. 1 atmosphere. Which is this. So, this value will be taken out. So, what will happen? This is your ΔH . Means $H - H_0$. So,

this is you. So. You don't need to use any other table. We have used the existing table. Now let's talk about the enthalpy of formation and enthalpy of combustion. For that, we take the example of CO₂. If you consider this reaction in CO₂, what we are doing in this reaction is that we have continuously flowed 1 kmol C and 1 kmol oxygen flow in this chamber. Both the conditions are set on the standard state, which means 25 degrees Celsius in one atmosphere. And in the combustion chamber, it is burning, it is making CO₂ from C plus O₂. And in this process, this much heat is coming out, 393520 kilojoules. And later when CO₂ is coming out, 25 degree Celsius and 1 atmosphere is also on the standard. So, the product is also on the standard. And reactant is also on the standard. But your heat is coming out. So, if you analyze it by using the first law, then there is no work. So, $Q - W = H_{\text{product}} - H_{\text{reactant}}$. And work is zero. And Q in this. When you extract net Q in, since net Q in is not there, this is basically Q out, so this part will be negative. So, $H_{\text{product}} - H_{\text{reactant}}$, ΔH is negative. And since this process is negative, we call it an exothermic reaction. That is, the energy is released. So, this is your basic reaction, and this is your basic equation. Now you can also extract H_{product} and H_{reactant} . We will talk about that later.

First, you understand that you can extract this from a basic energy balance. Now let's talk about enthalpy of reaction. Because you have already given this, why? So, we will use two definitions in this. One is enthalpy of reaction, and the other is enthalpy of combustion. Now what is the enthalpy of reaction? This is the difference. This is the difference between enthalpy of product minus enthalpy of reactant. So what is this difference? Enthalpy of product minus enthalpy of reactant but specified state. Both the product and the reactant should be in the same state. Meaning that your gas will remain as it is, and this for complete reaction. This is also important that the reaction should be complete. What is the enthalpy of reaction? This is your enthalpy of product minus enthalpy of reactant at the same state for complete reaction. It means that the difference between enthalpy of product and enthalpy of reactant is at the same state and complete reaction. So, in this case, in this case, the CO₂ was the complete reaction. So, Q is basically H_r . This is H_r . This is the value of the heat of reaction is coming out. We can call this bar because we have written kilo moles in bar. If this was in kg instead of kilo moles, then we would have written simple H . The second definition is enthalpy of combustion. What is this? This is enthalpy of reaction. So now you understand the definition of enthalpy of reaction. You will understand that this is a complete reaction. And this product and reactant should be in the same state. Enthalpy of combustion is the enthalpy of reaction for combustion process. The combustion process is the enthalpy of reaction. What does it represent? It represents the amount of heat released during a steady flow combustion process when 1 kg of fuel is completely burned at a given specified temperature or pressure. What is the enthalpy of combustion? Enthalpy of reaction is the amount of heat released on steady flow and when it burns completely, it is at a TOP. So, this is the value. The bar is one kilo mole, so Q is equal to minus 393520 kilo joules per mole. So, this is your basic definition. The third definition is very important, which is enthalpy of formation. We can also take this per unit mole per unit kg. What is enthalpy of formation? The amount of energy absorbed or released as the component is formed from a stable element during a steady flow at a specified time. What does this mean? that H_f is the amount of energy that will be absorbed or released when the component, suppose H_f is CO₂, then what will be the heat of formation of CO₂? This amount of energy absorbed or released will be when this CO₂ is made from its stable element during a steady flow process. So, this was a steady flow process. and if you see this stable element of CO₂, CO₂ is C and oxygen, so we added C and oxygen as a flow process and when we made CO₂, how much energy was produced in total? 39352 kJ and this is also per mole

per kilo mole. So, the amount of energy absorbed or release as a component formed from a stable element during a steady flow as a specified state means how much energy is absorbed by the component during a steady flow and how much energy is absorbed by the component in the reaction which is a stable component in the elemental form and how much energy is absorbed by the component in the elemental form or you can take something else but in general we are using CO₂ as an example so how much amount is this? this is your Q so HFCO₂ This is Q which is your value of minus 393. And this is also because if it is at 25 degrees C, then we will say that we will apply 0 superscript because this will be the standard heat of formation. Right? So, in such cases, if you ask us, we can also get HF out of a simple energy balance. But another important thing is to ask you what HF is? heat of formation of carbon, heat of formation of oxygen, these are all stable elements, so we will always consider its heat of formation as zero. So, we will consider enthalpy of formation as zero, enthalpy of formation of stable elements like oxygen, nitrogen, hydrogen, carbon, will be considered as zero in standard difference state. 25 degrees Celsius and 1 atmosphere, enthalpy of formation is your We will consider the stable element as zero, whether it is oxygen or nitrogen. So, if you consider it as zero, then if you calculate the energy balance, then this delta H will be HF minus the rest will be zero, and this will be 393520. So, let's do this exercise in a little while.

As an example, you can see that table A26 has written about enthalpy formation. So, carbon is here, S₂, N₂, O₂, see here it is 0. Whereas CO is different. CO is minus 11530. CO₂ is used now. This is in water gas, and this is in the liquid. So, we made tables like this. Similarly, your GIFS is the function of formation and absolute entropy at 25 degrees Celsius, 1 atmosphere. Let's move forward. Now, the second question is that, as I said, two values of water are given. Why are they given? Here you notice that its final state is different. There is gas in one and liquid in the other. This means that the amount of heat released, or the heat absorbed will be different if the state is changed. Now, the heating value comes from there. The heating values are of two types, high and low. Let's read the definition first. What is the heating value? The amount of heat released if the fuel is completely burned, and the steady flow is in process and the product is returned to the state of the reactor. Enter amount of heat released when the fuel is completely burned. When the fuel is burnt, it is not necessary that the product is in the same state in which the fuel was entered in the combustion chamber.

So whatever product is coming out, we may have to cool it down. And to cool it down, we will have to cool the temperature. And in such a case, the effective energy will change. And finally, the product will come under the condition in which your reactant is. So, this way the total amount of heat release will change. That's why we are writing the definition of heating value. So, the amount of heat released when the fuel is completely burned in the steady flow process and the product will also return to the state of the reactant, that is what we call as heating value. Now, heating value for fuel is what we call the absolute value in thermal and combustion. But the heating value will normally be delta hc. So, this is the normal value of the heating value, hc. And how do we extract it? This is a bomb calorimetry. So, there you can extract it through it. You can keep the fuel; it normally burns and gives these values. so bomb calorimetry is an experimental technique. And there is a device which can extract these values. So, as I said, there is a higher heating value and a lower heating value. The higher heating value, so this water product, the form will be in liquid form and lower heating value will be in vapor form Why lower heating? Because the heat released in the combustion The value HV The heating value is basically Qout The heat released is Qout If the water vapor is released in Qout then extra energy will be taken So less energy can be released in the combustion ok and if there is a vapor in the liquid form fuel

you are putting here and plus air fuel normally in this type of fuel will be C_xH_y type right and so water in it can be in vapor form or liquid form if it is in liquid form then your Q will be more if you want to vapor then some part of Q will go away Let the water evaporate through the latent heat High heating value is the low heating value plus the latent heat which is m times H_{fg} This is H_{fg} and this is H_g minus H_{fe} This is basically the latent heat again. So, you must have understood that if the product is made of vapor, the heating value decreases. Because some part of the latent heat of Q will be extra spent to convert water from liquid to vapor. That's why your Q value is minus let's say L , the latent heat. And this will come out, this will be your low HV. Let's use the same method. In the example, which you have understood. The first question is that Enthalpy and combustion should be of liquid octane at 25 degree and 1 atmosphere, i.e. at the standard condition. And we have to use the enthalpy formation data of table 826. I have already shown table 826. Most of the molecules are there, but it is not very exhaustive, we will not get all of them. But our question is that and this table is sufficient for that. So, we will use it. So, we have to use it because this C_8H_{18} combustion will be done, water will be made. So we will assume it in liquid form that the product is in liquid form. Let's start with the reaction equation. We have to write the stoichiometric equation. So C_8H_{18} plus the coefficient A theoretical value and since we are injecting air so what is air? O_2 plus 3.76 nitrogen and this is your CO_2 plus water plus 3.76 A times TH so this is your A how is this? So here 8 CO_2 will be present. And with the addition of H_2O , we already know that it will be 9 times H_2O which is in the liquid. And the rest will be your nitrogen which will be 3.76 times A . So, this way you can analyze and extract the value. You can extract only one value. Now pay attention to this, that the reactant and the product will be at your standard strength. And since N_2O and O_2 are your stable elements, half of the formation is zero. So, the question is, what will be the combustion? Is your combustion value this? So, we will assume per unit mole. So, we will understand this by using per unit mole. We will take 1 mole. This is given as SC , but this is given as 1 mole. This is not written anywhere as 1 mole. But we will assume that the fuel is actually 1 mole. and this will be H product minus H director now total enthalpy of H product is sum of enthalpy of product so sum of enthalpy of product means your enthalpy of formation because everything is in one atmosphere at 25 degrees Celsius which means this is your product so sum of enthalpy of product is this is its plus this plus this and this is its enthalpy will be heat of formation and enthalpy of formation of CO_2 because we have to multiply it plus enthalpy of formation of water plus the pressure of nitrogen it is zero because it is an elemental form minus the pressure of fuel we assume that the fuel has one mole minus the pressure of air so air also We will take 0 because oxygen and nitrogen are also needed. So, this way, you will get H product, minus H reactant, or further your CO_2 plus water, minus only fuel, because the rest is 0. Otherwise, what would have happened? This would have been your CO_2 , HF . And N , whatever you have to put, you have to kill, so this is 8 times, plus 9 times your HF_0 , plus 3.768 theoretical HF nitrogen minus like this and this is zero basically similarly $HF_0C_8H_{18}$ minus your air will be zero so this will be your air equation now we can plug in these values Because it is per unit, we can see that it is just 1 times. Because this is also 1, if it is 1 time, then it will be per unit mole of the fuel. Which is 1 mole, the rest is in reference to it. So, this is your CO_2 , this is your water, liquid water and this is your fuel. Where did you get this? You have to take this table. So, if we look at the water, let's look at the CO_2 first. This is the value of the CO_2 in the gaseous form. Water is in liquid form, so this is liquid, so this is minus 285830 And similarly, your C_8H_{18} is of different type, the one below is in rose So this is your C_8H_{18} So this is your heat of combustion per unit mole of, per unit kilo mole of C_8H_{18} And these are the values, you can write it in kg also like this And this was the

question So you wrote the basic stoichiometric equation using table After that you used the expression we had taken using simple energy balance And then you expressed it using table.

Now let's move forward Now let's talk about what will happen to Enthalpy in any chemical component or any state And this is very important because we will do analysis in first law in the reacting system So we will use all these things So, as in enthalpy, any component, as it is called H, suppose, we were talking about 25 degrees Celsius in one atmosphere, but if the state changes, then how will we do it? So, we will start with $H_f - H_0$ means standard reference state, which is 25 degree Celsius 1 atmosphere Plus, the changes that are going to occur, which we change in temperature, or the state we change, that change will occur from H minus H_0 . So, this is your sensible enthalpy, relative to standard state, and this is the heat of formation, which is at the standard state. So, this way, you can get H out at some other state, with a little bit of care. Now let's talk about General Close System Energy Balance We will assume this as stationary chemical reactive system So we will apply the normal expression $E_{in} - E_{out} = \Delta E_{system}$ But your reaction is in ΔE_{system} We will write $Q_{in} - Q_{out}$ and $W_{in} - W_{out}$ If it is a closed system, mass is not flowing In this case, ΔE_{system} is $U_{product} - U_{reactant}$ When this type of system is available, then how will we extract U? So, to extract U, since you have the data of heat of formation, it would be better to convert U through heat of formation. So, if we talk about simple definition, then H is $U + PV$ or $U = H - PV$. Why is it called a bar? It is per unit mole. We are taking the molar value, molar volume, molar enthalpy, molar internal energy. Now, if you want to get this U, which is any other than the standard state, then we can write U as follows. $U = U_f + U - U_0$. So, this is your U. is n times this is you're ok so now if we want to write this in enthalpy form then we write like this $u_f + u - u_0$ what is this we write this thing h_f part minus pv . So, this is the thing we can write in this case so this $q - kw$ We can write this as net $Q_{in} - net W_{out}$ is equal to, we write this term in this form $\sum N_p U$ So what is this U bar? This is reactant, this is n_r , this is, U And we wrote the reaction as heat of formation plus changes minus pv as we wrote this So, we have used enthalpy in the close system energy balance, but we have separated it by minus PV. So, it should be by definition. Why did we use it? Because we have tables in the form of heat of formation whenever there is a reactive system. And that's why it will be easy for us to use the table and try to solve the chemical reaction system. When we talk about PV, it is normally very negligible. If we are using solid or liquid, then we can neglect the PV term. And if we use gases, then we can use $RU/2$ PV. If it behaves in the form of ideal gas, then you can also do it by assumption. If kinetic energy and potential energy change is negligible and there is steady flow, if we take the flow system, then E_{in} is equal to E_{out} . In E, $Q_{in} + W_{in}$ plus flow system, so naturally we will get enthalpy, so there is no tension that you have to apply enthalpy directly, you don't have to do minus PV. And here the number mode is rate of change mode, we will use rate. This is your R, this is the rate of net energy transfer, this is your rate of net energy transfer out. So, this is your reactant, this is your product. So, this is your basic equation. You can also write it in the form of per mole. I can write the same thing in the form of $Q_{in} + W_{in}, N_r, H_f$. If you want to write it in the form of mole, then you can write it like this. In this case, if we take N_r equal to 1 of the fuel and readjust the rest, then you will get a balanced composition equation. Then you can get results in the form of per unit mole. So basic equations are very simple. There is no question that it is very simple. You just need to know how to write a table. And it is important that when you are using it, then you are using 0.8 mol or 0.8 kg. By using that, you should pay attention to multiplication. And usually, we always take 1 kg or 1 mol of fuel as the basis. And we scale the rest of your stoichiometric equation. With that, you can

take out the rest of the things. So, if we simplify this thing and write it as net Q_{in} minus net W_{out} work done by the system this is q_{net} heat transferred to the system and net work done by the system if we use sign convention then q_{net} minus w_{net} will come out this will be your N_p product This is basically nothing, this is product, this is $H_{product}$, this is $H_{reactant}$. And we have done the same thing, we have rearranged it. So, Q is here, and H is written here, and R is written here. If we know the enthalpy of combustion, i.e. enthalpy of combustion is at the standard state, then Q_{in} minus W_{out} will be here and the other sensible part will be added. So, summation $N_p H_{product}$ minus H_0 minus $N_r H_{reactant}$ minus H_0 . Because H_0 is the part that will be separated from the rest of the reactor. You know this if you know about heat, enthalpy and combustion. Now, in general, when a reactor is a fixed volume, the boundary work is negligible. So, we can ignore W . In this case, you can ignore W . and you can write Q_{in} and Q_{out} is usually involved in heat output so it is called Q_{out} Input is not normally in reactive system we can do that but in our case, we will assume that heat output is coming out in combustion in combustion chamber, heat output is always coming out means Q_{out} we can assume until it is told so now we use this information This is your combustion chamber, in which you have given propane which is entering at 25 degrees Celsius at this rate and this is doing at 7 degrees Celsius This is mixed and this is 50% excess air 50% excess air The product is out of the box. It has reached 1500 Kelvin. If we analyze it, we will find that all the hydrogen in the fuel burns to CO_2 . The hydrogen is burnt, but 90% of the carbon is in CO_2 . The remaining 10% is in CO . So here we have CO_2 and CO . If the exit temperature is 1500 Kelvin, then the mass flow rate of air, Rate of heat transfer from the combustion So this is what we have been asked Let's try to solve this question For this, you have to first take out the theoretical amount Because it is said that 50% is excess air So, first take out the theoretical amount of air For this, you first write an equation $C_3H_8 + a O_2 + 3.76 a N_2$ This is $3CO_2 + 4H_2O + 3.76a$ theoretical value N_2 If you do O_2 balance here So on the left hand side you have ath What will come on the right hand side? 3 plus 2×3 is from here and 2 is from here So what is the theoretical value of A ? So, what does 50% of this mean? This is your 50% of this. This means 5 plus 2.5 is 7.5 . So, you can write your final reaction is $7.5 O_2 + 3.76 N_2$ It is also written that 90% is CO_2 and 10% is CO . So, 90% is 3 carbon atoms, so 2.7 is CO_2 , plus 0.3 is CO , plus $4H_2$ is water. plus 3.5 plus the remaining oxygen which will be 2.765 plus the nitrogen which is 7.5 multiplied by 3.76 multiply it and you will get 28.2 so this is the equation now you can get Mass flow rate of air Means that For mass flow rate First of all Because this is given to you 0.05 kg per minute Here we have written in moles 1 mole This is the reaction of 1 mole So for this you should take out the air fuel ratio. In the L4 ratio of this compression process, you will get M of L . So the mass of air in this stoichiometric relation will be 7.5×4.76 kmol And 1 kmol is 29 kg per kmol 3 carbons and 8 hydrogen or in molecular form $4 H_2O$ so 3 times 3 kilomole 12 kg per kmol, this is the contribution of carbon plus 4 kmol for hydrogen and 2 kg per kmol for S_2 note that we are taking S_2 here so this is 25.53 kg air divided by kg of fuel You already have AF. So, you can extract a mass of air from here. Because it is per unit. in kg form so this is your af multiplied by the fuel rate multiply it so you will get this so this is your 25.53 kg of air divided by kg of fuel multiplied by 0.05 kg of fuel per minute So, it will come out from here, 1.18 kg air per minute. So, this is the first question. Now, the second question is the rate of heat transfer from the combustion, that is, to get the \dot{Q} . Basically, do not balance the energy for \dot{Q} . So, what will be the \dot{Q} ? \dot{Q} dot will come, because there is no work here, so we can simply write E_{in} is equal to E_{out} . equal to E_{in} . So, what is key out? Key out plus product is H_{F0} plus $H_{product}$ minus $H_{reactant}$ product is equal to reactant. Now you can cut it out. You can easily take it to the right-hand side. Then it will come to you. Now, you can take out

the values of the Alarms. Take the basis of 1 Kmol. We took it here. If we take the basis of 1 kmol, then you start with the reactant. So, 1 kmol, your C₃H₈ is done. In this way, you have to, because it is in the reactor, this is in the reactor. Then your oxygen comes, then your nitrogen comes. So, I would like to show how it will come. So, you have to write HF in C₃H₈. Here I have given the table. This is the HF of this. So, this is now minus 118910 ok, plus what is the temperature? the temperature is given here is 25 degrees, Celsius So this is H₂₉₈ and what is reference? Reference is also H₂₉₈ so that is cancelled So this is propane plus you have to write that oxygen so how much is in oxygen? 7.5 kilomoles This is the VAC, and this is the HF. This is the HF of 7 degree, and this is the HF of 25 degree. So, this is 8150 minus 8682 this is kilo joules per kilomole plus you have to do nitrogen this was oxygen, so you have to do nitrogen plus this is your reactant this is your reactant Now you have to do the product. In product, you will get minus sign. As you can see here, it is written as minus. So, you have to do the product in this way. First of all, let's take CO₂ in the product. So, how much is CO₂? CO₂ is 2.7 Kmol. So, 2.7 Kmol. and CO₂ HF will be minus 393520 plus CO₂ is coming out product is in 1500 Kelvin so this will be HCO₂ 1500 Kelvin minus HCO₂ 298 so this is the value This value is at 1500, this value is at 298, so this will be minus 9364. In the same way, you have to do the rest. So, when you do these values, you will get Q_{out}. is 363880 kJ per kmol of C₃H₈ means 363880 kJ per kmol and this was the question in the form of Q that is the rate of heat now to calculate the rate you can say it like this because this will come out this is Q out if you calculate it then it is Q If you want you can also call it kilo juice per kg. Because if you convert it, now this is the form, if you convert it, then 363880/44 because in one propane, in one mole, 44 kg is in one kilo mole. So, 36880 divided by 44 is kilo juice per kg. So, this is your Q. and you can call the dot out as m dot q out which is 0.05 kJ per minute multiplied by this value which will come out which is 8.270 kJ per kg 8.270 kJ per kg so your value will come out from here 413.5 KJ per minute. This is your rate. So, the exercise gets longer in such cases because you have to write in some form. Now, we will talk about a different topic which is adiabatic flame temperature. If we assume that your combustion chamber is insulated, then your heat loss will be zero. In such cases, the temperature the product reaches the maximum temperature, and that temperature is called adiabatic flame or adiabatic combustion temperature. Flame or combustion temperature means the temperature is maximum, the product reaches the maximum temperature on which it is at. That is called adiabatic flame temperature or combustion temperature. This happens when the combustion is complete, and the heat loss is zero. So, the temperature of the combustion chamber becomes maximum when combustion is complete, and no heat is lost. So, this is the condition where your combustion is complete and there is no heat loss. In this case, we give H product is equal to H reactant because Q is equal to zero and W is equal to zero. So, this becomes your equation. Now, what is the problem in this that how to get the temperature? because you have to do it on the left hand side equal to right hand side so it will be iterative in a way that you guess that this is the temperature of the reactant and this is the temperature of the product so you should match this condition for maximum temperature so you basically keep changing the temperature so that the left hand side is equal to right hand side so this is the iterative technique and this is also a little time consuming for this normally You can use it in programs, excel sheets or other codes Now, at every flame temperature, it depends on the stage of the reactant i.e. in which state the completion of the reaction is, whether it is fully completed or not and how much amount of air is used, so you have to use these three things. It depends on this For a specified fuel at a specified state burned with air at a specified state means if the fuel is given and its state is specified and is burning at a specified state then adiabatic flame temperature will maximize

when it is completely combustion and it has theoretical amount of air so this is the condition adiabatic air temperature attains its maximum value when complete compression occurs with the theoretical amount of air. So, this is your basic definition. Adiabatic temperature is an important consideration. It is very important. Normally, when you design a combustion chamber, whether it is a gas turbine or a nozzle, you should know how much maximum temperature can go. According to that, you will choose the material. How much material should be there. Because if the temperature is too high and the material does not resist, then the equipment will be damaged. The combustion chamber will be damaged. It can be a disaster. So, it is very important for engineering design to know the adiabatic film temperature and which material to choose according to that and how to make the reactor. So, there are two things. First, we should know how to solve it. Second, your commission will never be completed. So, the maximum temperature you will get will be less. and the temperature of the gas is also different. Because combustion is usually incomplete, and the heat is lost. And some gases when they are at high temperature they start to disassociate. So that's why T_{product} is less than T_{maximum} . Your design should be on T_{maximum} , but T_{product} is usually less than T_{maximum} . So, Maximum temperature of the combustion chamber can be controlled. If we adjust the amount of excess air, we can control the temperature. Because we can use excess air as coolant and cool it down. So, the reaction will be complete, but the remaining air will absorb heat. So, the overall temperature will be reduced. So, you can use it like this. So, let's understand in a way that Let's understand how to remove the Atmospheric flame temperature. This is another question of steady state combustion. In this, liquid octane enters the combustion chamber, which is the combustion chamber of the gas turbine. This enters the one atmosphere at 25 degrees Celsius. Air enters the same state. We have to remove the adiabatic flame temperature when it is completely combustion Second question is complete combustion with 400% theoretical air and incomplete combustion with 90% theoretical air. So, this question will not be completed in this lecture because it is difficult, and it will have to be done in an iterative form. But you can understand how it can be solved and there are many detailed examples in the book. So, you can do it through the assignment. Assume this as a stoichiometric relation. Write the equation for stoichiometric and balance equation. And this is the balance equation given to you. So, if you want to get the adiabatic flame temperature, then what is the relation for it? H_{product} is equal to H_{reactant} . Means this is your relation. So, H_{product} is equal to H_{reactant} . We have this reactant. Because the rest is elemental. Reactor side of the cable will not be octane and product side will be CO_2 H_2O So if you solve this then you get this relation 8HCO_2 plus 9HO_2 plus 47HN_2 This is your relation plus We know the value of HF C_8 from table We can take it out And this is the value of 5646081 kJ I have simplified a lot of things Because we have also given HF values I have used HF value CO_2 , HF value H_2O , HF value C_8H_8 And H is written here H means that the temperature is different I have to take out the temperature So the temperature is different So this is the temperature where the enthalpy CO_2 will be This is T , this is also T , this is also T So it is taken out like this Now, this is your relation. Now, the question is how to solve it. If we assume that it is an ideal gas, then H is ST . The variable is the same, but we have to guess it. So, you can take out this iterative process. You can guess it and assume that if it is 100% nitrogen, you can guess the amount of nitrogen by using the table. For that you can assume that if 8 plus 9 plus 47 moles of nitrogen are there and if you divide it, then you get this much amount. So, you can check it on the table. So, you can get it from the way that it matches at this particular temperature. So, this is a little iterative process. And if you already have a table in this process, you can plug in and directly take it out. So, you can read the textbook we are using and

understand how to get the ST iteratively. Similarly, you can take the balanced equation and take 400% theoretical error. The same process will be done in that equation. Then you guess it and check it iteratively that the left-hand side is equal to the right-hand side. Similarly, you can do C part. I will not ask this question here. I want you to see in the book how to do some examples and practice it to understand. You can also use Excel. I summarize this particular lecture. I hope you have time to learn about fuel and combustion. What are theoretical and actual commission processes? What is enthalpy of formation and enthalpy of commission? And how we have to use it in the first law analysis of reacting system in which we have considered two systems, steady flow system and closed system. And in the end, we studied about adiabatic flame temperature which is very important and the people who will study in the reactive system will use adiabatic flame temperature a lot. I hope you understood the lecture. I would like you to give more examples of how to solve the interactive system in the thermodynamic way. This is the last lecture of the thermodynamic course. I hope you liked the course. We will meet again in some other course. You can reach me anytime to understand. So, enjoy Thermodynamics and use it in different applications. This is a very big platform for basic engineering applications. So, once you understand it, you can apply it in many places. I hope you enjoy it and use it in different engineering applications. So, I take leave from you. and then we will meet in another course.