Engineering Thermodynamics
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Week-12
Lecture-53
Chemical Reaction

Hello and welcome to Chemical Reaction part 1. In this lecture we will understand about fuel and combustion. And how to apply conservation of mass concept in reaction and reacting system. By which you can find out the balance of reaction system. After that we will understand how to apply it. and we will understand how to apply conservation mask to remove it. Then another important part of this analysis is air fuel ratio. Because it is also very important to know about it to complete the combination. So, we will know about that and how to apply it in any example or problem. So, we will understand that by using an example. So, let's start. Till now, what we have studied was a non-reactive system. Meaning, the breakage of chemical bond or the formation of it. We have not used any energy for it in our previous analysis. But, in chemical reaction, bond breaking, chemical reaction, chemical energy will be used. But the other concepts that we have studied so far, we will apply them all. So first let's understand what fuel is. Fuel means that any burn that happens, it will release thermal energy. That is called fuel. So, this is the basic concept, the basic definition of fuel. That any material that burns and releases thermal energy, we will fuel it. For example, hydrocarbon fuels like gasoline, kerosene, diesel, etc. are all fuels because they burn and release thermal energy. The chemical energy released by them is released in the form of thermal energy. What is common in this? It is a hydrocarbon fuel. Carbon and hydrogen are all common. But the ratio or coefficient of carbon and hydrogen is different. For example, in gasoline, you will get the maximum octane, $C8H18$. Similarly, in diesel, you will get 2 decanes, which is $C12H26$. So, but there is not only one component in it. Normally, there are other components in it. But usually, we call gasoline octane because the majority is the same. Now if we talk about natural gas, then in natural gas $CH4$ will be methane or smaller gases will be in smaller amount than methane. But smaller are in composition but because of this majority is $CH4$ so we can approximate natural gas as methane. But all these things, which contain carbon and hydrogen, are hydrocarbon fuels. And how do we get rid of it? By distillation. So, this distillation has a very simple diagram. In distillation, only the boiling point is utilized. By which we will remove the vaporized one first. And we will give them later. We will not discuss distillation much, you will get it in other topics like chemical engineering, thermodynamics. But these are separated using different properties of different components. And we separate it using heat and energy in distillation. So, this is one type of fuel. There are many types of fuels which are available in today's time. We are talking about alternative fuels. The basic reason for this is that we have to reduce $CO2$ emissions. That is why alternative fuels are becoming more popular and required. In fact, the government is imposing it. Some alternative fuels are alcohols like ethanol and methanol. And it is mixed. The minimum composition of gasoline is fixed. which will reduce your effective carbon emissions. So, these are alternative fuels, its energy content means amount of energy per unit volume. Normally, if we talk about methanol, it is less than gasoline. So, gasoline is still your most energy content, but since CO_2 emission will also be high, that's why it is not used anymore. It has more energy content, but it has more CO_2 emissions. So, its use will be reduced in the coming days. And especially we use CNGs and LNGs. So, these are in different conditions. This is compressed in 200°C atmosphere. And this liquid will be in minus condition. It is condensed at minus 162°C. It is used in different ways, normally in homes or in cars. The government is relying on these mixed conditions to use ethanol and methanol with gasoline and other off fuel. Hydrogen will be the most used fuel in the future. It is going to be used in vehicles, so hydrogen-based fuel is a very interesting future. So, this is a comparative of all these fuels. Now let's talk about combustion. To do combustion, you have to oxidize the fuel. This means that you have to use oxygen somewhere. So usually, we use air. Since there is nitrogen and oxygen in the air, it is usually used in normal combustion. Only pure oxygen is used where you have to cut or weld. There is no air used there. So, as we say in the air, 21% oxygen and 79% nitrogen. But normally, there are other gases in it, like argon and all that. Other gases are in small quantities. So, this is an approximation. This is an approximation that we use. In this course, we will use the same equation that air is 21% oxygen and 79% nitrogen. In its basic composition, if we take 1 mole of O_2, then 3.76 kg mole of nitrogen will be taken. Then 4.76 kg mole of air will be connected. Now nitrogen reacts with oxygen in the air. Nitrogen is an inert gas. It can only react at high temperatures. Nitrogen can also make nitric oxide. It will only be at high temperatures. Nitric oxide is hazardous. So, we will assume that the problems we are facing in this course are inert. Inert means that it does not react. The more we insert it, the more it comes out. Now, the second thing is that the moles are not conserved in the reaction. For example, if we add oxygen to C carbon, then CO_2 is formed. Carbon reacts with 1 mole of oxygen, and this makes 1 mole of CO_2. So, what you see here is that there is no mole conserved in this. But mass is conserved. So, if the mass of carbon is on the left-hand side, which is called reactant, and this is the product. If you have an atom C, then you have an elemental atom C on the right-hand side. If O_2 is on the left-hand side, then O_2 will also come on the right-hand side. You can do this in the form of mass. This is 32 grams of oxygen, so here also you have 32 grams of oxygen in the form of CO_2. So, as it is 12 grams, these 12 grams will be here. So, in this way, we can balance the mass and solve the unknown parameters. So, the mass will be conserved for each element during chemical reaction. So, we will solve the problem using this concept. So, this is a typical reaction chamber representation in which your reactants come, and the product is made later. You must be aware that the relation of mass is the number of moles. multiplied by molecular mass. But combustion, as we said, as soon as we add oxygen or air, it happens. That is not true. A minimum temperature is needed to have combustion. That minimum temperature is called ignition temperature. It is not like we mix carbon and oxygen, then automatically CO_2 will be formed. There will be a condition on which it will burn. So, an important concept is ignition temperature. Ignition temperature varies for everyone.

For gasoline, it is 260 degrees Celsius. This is the minimum temperature where if we put A, it starts to burn. For carbon, it is 400 degrees Celsius. For hydrogen, it is 580 degrees Celsius. 610 degrees Celsius for carbon monoxide. 630 degrees Celsius for methane. Apart from this, the ratio of air and fuel is also very important. It should be in the right range and in the right quantity. For example, if we talk about methane, natural gas will not burn if the concentration of air is less than 5% or greater than 15%. So, it means that the concentration of air should be between 5% and 15%. with methane, natural gas, then it will burn. So, in a way, this fuel-air ratio is also very important. Okay. And that's why we read it and understand it, how to use the air-fuel ratio. The air-fuel ratio is normally expressed on a mass basis. And its ratio is simple, m air divided by m fuel. But this is mass. Mass of air divided by mass of fuel is the air-fuel ratio. So, we will use this. Then you can reverse it or reciprocal it. Reciprocal, what is reversed? The air-fuel ratio is the fuel-air ratio. So, in which fuel and air came and the combustion happened, and the product was made. So, like this is the air-fuel ratio. This is 17, which means 17 kg air is being used with the fuel. So, this is what it means. Then this product is made. Let's assume 18 kg.

So, Air-Fuel Ratio represents the amount of air used per unit mass of fuel during a combustion process. Air-Fuel Ratio means the amount of air used per unit per kg or per unit mass of fuel during the combustion process. This is an important thing. We will use this AF ratio later. Let's understand this. We have just read and understood how to use this in a combustion problem. We have to do this in the combustion chamber where we have used 1 kilomole of octane. We passed A as well. And in the product, CO2, S2O, O2, and N2 are coming out. But we don't know the moles of these. That's why it's written XYZW. And we have to balance these and get the unknowns. So, this is important. It says that it's burned with air. Which contains 20 Kmol of oxygen. 1 kmol octane, air used with 20 kmol oxygen and passing through the combustion chamber. And the final product is CO2, H2O2, N2. And its moles are unknown. So basically, we have to extract the moles of every gas that is being made. And also extract the air-fuel ratio of it. We have to extract the air-fuel ratio too. Let's understand this first. First, let's take the molecular weight of air. The molecular weight of air is 28.97 kg per kilomole. So, in 1 kilomole, air has this much mass. We can also approximate it. Normally, we take 29 in the approximation. Now, we will assume that the reaction is happening in this way. Air contains oxygen and nitrogen. So, we are assuming this. And to do the reaction, we will do C8H18. In 1 kmol, if you see the air, since oxygen is 3 kmol, so if it is 20 kmol, then how much will be the air? If it is 20 kmol, then if we multiply it by 20, then 20 kmol will be there, then corresponding nitrogen will also be added, so according to that, air will come. We have added 20 Kmol oxygen in H8. 20 Kmol oxygen. Because this is 1 Kmol. So, this is 1 Kmol. This is 20 Kmol. It's oxygen. Plus, because we are adding this, if 20 Kmol oxygen is there, then how much nitrogen will go with it? 20 multiplied by 3.76 nitrogen will go. Okay? And what is being done about this? CO2 plus YS2O plus ZO2 plus WN2 So this is your reaction Now what you have to do is you have to do mass balance everywhere So let's start with mass balance First you have to do C mass balance C for which one? C Then you have to do H So, if we do C, then in the left-hand side, how many C's are there? Total element, how many atoms are there in C? In the left-hand side, i.e. in the reactant side, how many are there? There are 8. There are 8 in C8. And how many are there on the right-hand side? Here you can see C1 multiplied by X. x into 1. So, this means that x is 8. Now let's talk about H. H is hydrogen. How much is hydrogen? On the left-hand side, it is 18. And on the right-hand side, it is 2y. So how much is y? 9. We can do oxygen like this. How much oxygen is on the left-hand side? 20 into 2. 2 is for elemental balance 2 is 20 x 2 and what will be in right hand side? CO2 is oxygen so 2 x 2 is here plus water is oxygen plus y and in O2 is 2z and if x and y are already out then you can extract z from here which will be 7.5 then comes nitrogen so we write it in N2 because N2 will remain firm So, this is 20 times 3, because it is inert, so it will be in the N2 format, so it is W. And this is 20 times 3.76 on the left-hand side, and W on the right-hand side. So, how much W did you get? 75.2. So, this is your relation, this is your final expression. So, in a way, you have removed all the modes, which So you can write it in the form of equation. If we substitute, then C8H18 plus 20 O2 plus 3.76 N2 This goes 8CO2 plus 9H20 plus 7.502 plus 75.2 N2.

So now let's talk about the air fuel ratio. So, this is your mass of air and mass of fuel. Now, what is mass of air? This is the number of moles of air multiplied by molecular weight of air. Similarly, mass of fuel. Now, what is mass of fuel? You can also write the number of moles of fuel multiplied by molecular weight of fuel. Now, the number of moles is 1. Or we can write it as carbon. Both of them contribute to carbon and hydrogen. So, this molecular weight will come from one side. Because if we do a simple number of moles, 1 kilo moles per this, then this number of molecular weights will come. We can write it as simple 1 mole, 1 kilo mole, multiplied by m of fuel. Or we can write it as Carbon plus Hydrogen If we calculate molecular weight, 12 kg per kmol multiplied by 8 plus So this is the answer. So, I can write it like this. Finally, this is 20 air multiplied by 4.76. This is a kilo mole. This is kg 4.76. 20 is kilo moles. 4.76 is your molecular weight per kilo mole of air. So, this is air. and this is your 8 x 12 plus 9 x 2 so this is 25.2 kg air per kg fuel ok so I hope you understood this it is very simple you can do it in two ways, one is from here and the other is that you directly take out the molecular weight of the fuel so you know what will be the molecular weight of C18H18 12 x 8 plus 18 so this is your expression so this is the molecular weight multiply this with 1 kilo mole so you will get this denominator one way is this another way is to separate carbon and nm of hydrogen so this means that you are taking out the molecular weight so I will stop here. In the next lecture, we will basically study percentage theoretical air and apply the energy balance of reacting system which has steady flow and fixed mass system. So, I will take your leave. See you again in the next lecture. Till then, bye.