Engineering Thermodynamics
Dr. Jayant Kumar Singh
Department of Chemical Engineering
Indian Institute of Technology Kanpur

Week-01
Lecture-2
Thermodynamics Property

Hello and welcome to this second lecture on Thermodynamic Property, State and Equivalent Process. Apart from this, we will discuss the Intensive and Extensive Property of the System and in general, First, let's understand the properties of a system. As you saw in the last lecture, in a thermodynamic system, mixing of gas can also happen, reaction can also happen at any temperature and pressure. And to understand this, to design it, we need to understand the state of the gas mixture, i.e. in what condition it will be in. of the material, i.e. property of the gas or liquid, we cannot design it. We cannot do analysis. That's why it is very important to understand property in thermodynamics. So, the key feature of property is that like any property, like density, energy, it has a definite value.

If the system is in a specific state, like your gas is at a temperature or pressure, then the specific property of the gas will be fixed. It has a definite value, a particular value. and that value will not change if you have reached that state however you have reached from any medium you have brought oxygen to room temperature or it is at some temperature pressure then at that time the property of oxygen will be fixed so the value of the property should be determinable irrespective of how the system is brought to the particular studies means that the property of the system it will be fixed irrespective of the state it has reached. So, if we want to find out the difference between properties, then if z is the representative of the property, if z is called property, then any property, this differential element dz, integration from initial to final will be simple zf-zi and delta z. The path of how we have reached from initial to final will not matter. Because whatever was in the initial will be the value of the property and whatever was in the final will be the value of the property.

So, there is a very important element that we will use in this particular course. Suppose we have defined our property z and z depends on x and y. x and y can be temperature, pressure, anything.

$$dz = \left(\frac{\partial z}{\partial x}\right)_y dx + \left(\frac{\partial z}{\partial y}\right)_x dy = Mdx + Ndy$$

If

$\left(\frac{\partial M}{\partial y}\right)_x = \left(\frac{\partial N}{\partial x}\right)_y$ then dz is said exact differential equation.

This means that, simple thing is that tau z by tau x So this will not come here, it will come here. Correct? This is you dow by dow x This means that the order of differentiation does not matter.

If you look carefully, this statement means that the order of differentiation does not matter. When this statement is true, we call it the exact differential. In this way, we can easily integrate it.

$$\Delta Z = \int_i^f dz = Z_f - Z_i$$

So, in this way, when this statement is seen, this discussion comes out that this path is independent. So, the property we normally call as the path is independent and is a point function. So, z is a point function. If there is a state point of gas at any temperature or pressure, then the property of that gas is just one point. No matter how much volume it occupies. So thermodynamic properties are very important elements. So what property are we talking about? This property is the same as the pressure, temperature, volume, mass. These are the examples of the properties. Energy is also a property. We can also call it Intensive Some particular property can be Intensive or Extensive

So let's try to understand what these two terms mean. So, if you take an example of a container, and you put a fluid in it, whose mass is m, volume is v, temperature, pressure and density, this is your density rho. Okay? And you divide it into two parts, you divide it into equal parts. So the left one has half the mass and half the volume The right one also has half the mass and half the volume But temperature, pressure and density will remain the same So the intensive property is called the independent of mass Like this, it doesn't change And the extensive property is the dependent on the size it depends on the size if you divide it, it will be half right? So, apart from this apart from this, there is a specific property Okay, which is extensive property divided by mass. So, this is nothing but extensive property. divided by mass. Example is specific volume. The specific volume is small v and V divided by m. So, we call specific volume as specific property. Similarly, your energy can be specific energy. Suppose we did energy E. Like if you see here, if this was energy E, then this part would be energy E by 2. Right? If we take specific energy here, then this E by m. So, this is your e. e becomes kind of intensive because it becomes mass independent. Or v becomes intensive, becomes mass independent. Another important concept is Continuum Hydrolysis Thermodynamics. Now, if you think that gas is very far away from particles, like if oxygen is taken, then if you consider 1 atmosphere and 20 degrees Celsius, then it will have about 10 to 16 molecules per millimeter cube, in such a small volume, so many molecules. If you zoom in, you can see that the particles are not close to each other. But the particles are so high that you can assume that they are almost continuous. I mean, they are completely filled and homogeneous. There is not much change. There is not much change from one point to another. So, this is called Continuum Idealization. And in this, they assume that there is no hole. There is no here also the density is same so this Continuum Idealization which we have approximated because of this we can call the property as point function that the whole space its property is density row and there is no discontinuity from here if we can calculate from our medium then density more or less if we let's say this is x and this is y So if we take it out at any point, then the local density is also considered as rho. So, there is no jump in it. And we will apply this in this particular course continuously. And what is the reason for this approximation? The reason is that the distance is very small. Compared to the volume. Suppose this distance is delta and volume are V. So, delta... by volume V of the container is approximately 0. I mean, it will be very small. So, order 10 to the power maybe. It will be quite large, around 10-20 cm. It will be so small that we can assume that the distance is very small compared to the volume. And that's why we can say it is a pass-pass. It's a relative term. It's important to understand this because you will understand that we are taking only one property of density in any continuum. density variations have continued.

Now let's talk about density and specific gravity. We know that density is mass by volume. And specific volume is volume by mass which is 1 by density. We have converted the extensive property into intensive property. The density of liquid is incompressible in this course. We take temperature and pressure in any condition. We usually approximate it as incompressible. It means that the density is not changing. We assume that the density is not changing even if we put pressure. Other than density and specific volume, one more term is useful, specific gravity. Specific gravity is the ratio of density of the matter with respect to density of the water. Density is divided by density of the water. So, for example, if we take water as specific gravity, then it will not come because we are dividing it. Thicker and lighter Relative term for water Now let's talk about state and equilibrium condition.

Now, when we define the state, then in this way, The system is not changing. So, in thermodynamics, whenever we define a state, that means the system is not undergoing changes. What does it mean? That the system has no changes. Whatever changes are there, they have been upside down. So, for example, if you say that the mass of the system is 2 kg and the temperature is 20 degrees Celsius and the volume is 1.5 meter cube, then the mass is fixed and the volume is also fixed, but the temperature is 20 degrees Celsius and it is throughout. There is no change in this. If you take the same system for the other system, and you change the volume of the same system, and take some other fluid, and here comes the second condition, state 2, in which the mass is the same, the temperature is the same, but the volume is different. This is possible when you are using any other fluid. So, this is a different state, state 2. But equilibrium is the same throughout the whole system It means that there is a kind of equilibrium So for example, if you have a system where initially it is closed and then it is 20 degrees or 30 degrees, it is a variation It is not locally stabilized, it has been changed locally And when the equilibrium comes, the temperature is the same throughout So this is called thermal equilibrium. The system is in equilibrium and the temperature throughout is the same. So, the word equilibrium is a state of balance where there is no driving force. In this case, the temperature difference was driving force due to which the heat is transferred and eventually the final temperature comes where your driving force is zero. Equilibrium means no driving force, no unbalanced force, no potential unbalanced potential Specifically, isolated system at equilibrium does not change for example, if you have isolated a system and when it reaches equilibrium, then there can be no changes A system at equilibrium has 2-3 conditions.

Particularly, we will discuss 3 important things. 1. Thermal equilibrium. Thermal equilibrium means that there should be no temperature gradient in the system. If there is a temperature gradient, then there will be a driving force of heat flow. So, there should be no driving force. So, first, there is a temperature, and second, there should be no variation in the force. That means there should be no variation in the pressure as well. There should not be any change in the pressure. There should be no variation in the pressure from one point to the other. And third is chemical equilibrium. It means that there should be no variation in the composition of the system. There should be no further reaction. Everything should be done according to the time. At that time, where you have said, there should be chemical equilibrium. After that, there can be no changes in the chemical composition. These three things are very important in the definition of thermodynamic equilibrium.

Other than this, you will get phase equilibrium where you have two phases. Let's say this is your system and it has two phases. So, this is your liquid, and this is your vapor. So, when there is phase equilibrium, then the mass transfer will also be stopped. Effective mass transfer will be negligible. So, thermal equilibrium is important, mechanical equilibrium is important and chemical equilibrium is important to define equilibrium of a system. You can find out the phase equilibrium later. So, these are the basic definitions. We will try to understand more about this later. But for now, when we talk about equilibrium, there is an important element that there should be no driving force. There should be no driving force of any form. Now, let's talk about the state postulate.

If you want to define the state of a system, then you will have to give some conditions. For example, if this is a room and this is air, then the question is what is the state of air? you will say that air is at this temperature pressure then we will know the property of that particular air so state processor says that state of a simple compressible system like air for example is completely specified by two independent intensive properties so two important two intensive properties which can be temperature pressure, temperature specific volume You will define it as simple compressible system What does simple compressible system mean? It means where your electrical, magnetic, gravitational motion is not applicable So in this type of system If you define two intensive properties, then your state is defined for example, state of a hydrogen is fixed by two independent intensive properties Here is your temperature and specific volume Apart from state, process is also important. In process, you can present it in process diagram. Like this property as function of property. It can be temperature, pressure, volume, anything. Take any specific property and plot it against it. that initially there was a system in state 1, and how it is going towards state 2. And the path that goes from here to here, this is called a process path. Okay? And when we draw in this process path, then at every point, the system is in equilibrium. This is also very important. So, process, is any change from one equilibrium state to another? Okay, when we draw, then it becomes a path. Path is a series of the state through which the system passes through. It means that the path is a series of the state. For example, from this point, it came here, then it came here, then it came here. If we add these dots, then the curve is closed. Correct? And it is important that we assume that it is equilibrium at every point. This assumption and concept is called the Cause-Static or Cause-Equilibrium process. What does it mean? That we... sufficient time and time to change and then change little by little it is infinitely long time to achieve example if you take piston cylinder and do very slow compression Suppose this is the equilibrium point, it is very slow, so at every point it went from here to here. At every point we allowed the system to achieve equilibrium. And this whole process took a lot of time, but we call it the quasi equilibrium process. That every point is changing slowly and allowing every point to come into equilibrium. This will be completely different in your non-quasi equilibrium. you can't draw it because you know this state and that state you know these two points but you can't draw it whereas in this case you can draw it and create a process so this quasi equilibrium process is an idealized process it is also very valuable to do analysis it is very idealized, what does it mean? which you will get in a very ideal condition. And this is a very valuable assumption that we have a device where we have a work producing device like we So, we will discuss this later.

This is the definition of the work that is produced by the device. Approximation becomes very valuable for that. Okay. So, we will discuss this later. This is the basic definition that we are trying to do. As I said, if we take pressure versus volume, then this is the PV diagram of the compression process. So, this is a process path. And if we draw this, which means that we have assumed that we have achieved every point very slowly. We have achieved it slowly and we have given time to achieve the equilibrium of every point properly. So, this is a very simple process path and this diagram is called a process diagram. And it becomes very relevant and important. It is very important in analysis. So, this is a summary. In summary, it says that the process diagram is important to see how the process is moving in visualization. And the common diagrams we do are TV, PT or PV. And process path, as I said, is used for the quasi-equilibrium process only. It is not used for non-equilibrium processes. Some processes are very unique. After this course, we will discuss isothermal process in which we fix temperature Then comes isobaric process where pressure is fixed Then comes isochoric process where we fix specific volume Then comes cycle where initial and final state of the system is same means if you take the PV diagram and start from here and come back to the same so this is 1, this is initial and this is final so this type of process is also called cyclic process apart from this you have steady and unsteady process so what is the definition of steady? that if something is steady, there is no change at that point or that point. Time is changing but there is no change in the system. Uniform means that if you change the location in one point or another, there is no change. In study, there is no change in time. If you change the location, there is a chance that there will be a change. But if you change the time, there is no change. For example, if you have an open system with an inlet and outlet, here the temperature is 300 degrees Celsius, this is around 250 degrees, and this is 200 degrees and this is 500 degrees. The total temperature is 225 degrees. Now, if you look at the time, it is 1 PM. Even if we check the PM at 3 pm, it is still the same. This process is basically a steady process. This is the flow, because it is a open system, it is flowing. So, this is a steady flow process. This is a very common process. In which the fluid changes within the control volume. But it doesn't change with time. So, this type of process, steady flow process, is very common in continuous operation devices. And these devices are very common.

We simplify it in such a way that the mass will be fixed, and the energy will also be fixed. So, under steady flow condition, the mass and energy are constant. And these types of devices, these types of processes will be used in our turbines. in pump, boiler, condenser, heat exchanger, power plant, refrigeration system we will discuss more about this in the next video, so this was the topic of this lecture what we covered was your state postulate equilibrium process intensive and extensive property, density, specific gravity I hope you have got time to do so. If you have any questions, please do message me. See you in the next video till then bye See you.