Material and Energy Balance Computations
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Lecture –31
Introduction to Energy Balance - I

Well welcome to this course on materials and energy balance com computations I will be talk teaching as it has been my probably has been told by professor Atta. The second part of the course that is the energy balance part. I am Rabibrata Mukherjee a professor at the Department of Chemical Engineering at IIT, Kharagpur. Hope by now you are quite well conversant with essentially the mass balance and material balance techniques but it is also extremely important for any energy system or any chemical system to also look at the energy balance of it.

And so, essentially this part of the lecture is very preliminary thermodynamics and very simple essentially looking into different aspects of energy balance. We will get started with basic concepts of energy that is the basic thermodynamic terminologies, concepts, and units

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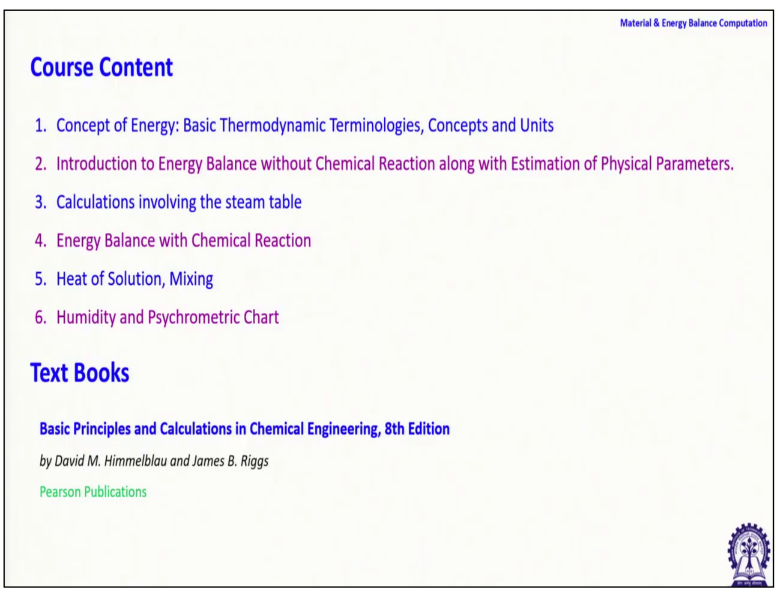

which will be followed by introduction to energy balance without chemical reaction which is the simplest thing like heating up of water or melting of ice and stuff like that which all of you know. But it is it also as we will learn more we will also learn as engineers this is extremely important on what is known as estimation of physical properties and physical parameters. Then we will learn to handle in detail the steam table and we will learn how to do calculations involving steam tables.

This is something that is extremely useful for not only chemical engineering graduates but people from other disciplines also. And then we will talk about energy balance with chemical reactions little bit of thermodynamics of solutions and mixing and finally another very interesting and interdisciplinary area we will cover that is humidity and we will learn how to handle the psychometric chart.

If you follow my lectures and do the assignments in time it is good enough. I will follow a textbook which is basic principles and calculations in chemical engineering by Himmelblau and Riggs published by Pearson publications it is a cheap Indian edition is available. So, you can buy one and sort of it is good to have this book. As a part of this course I understand most of you will be interested in doing this course in your early undergraduate years.

So, I think we will do it in that way and we will have some detailed tutorial classes also in which I will pick up take up some problems and I will solve in front of you how to solve such problems particularly using steam table and how much information you can extract from the steam table. Now even going before into any detail going into any detail before that let me tell you the steam table exist because of the fact that steam which is widely used in many, many areas from engines to thermal power plants everywhere steam is not an ideal gas.

So, this is maybe one take home message you may want to remember because I have seen lot of people making this mistake that they consider steam as ideal gas and calculate or use the ideal gas law and things like that which is not the case and therefore you have a very detailed steam table. So, the way I will teach is very simple its very similar to a classroom experience you can say I will be using this Power point slide itself as a as a whiteboard.

And I will not show or read out from any preexisting Powerpoint slide I will use this as a blackboard and therefore from there you can just pick up. So, just follow my writing and the best way to follow my lectures would be to sit with a pen and paper. And just the way you take scribbles and notes in a classroom. it would be best in your best interest to sort of just copy the scribbles.

Of course, as you know that through this platform you will have access to all the videos so, which you can always refer back, but I think that it is a best idea to take some scribbles and notes. Also, when the course runs through the appropriate platform the details about the TAs will be informed to you and the first slide already contains my mail id. So, the practice is that if you have doubts regarding anything you are most welcome to contact the TAs and if you are not satisfied with the response that you get from them you can directly contact me through emails.

So, with that I wish all of you happy learning experience and together I hope that you will learn something interesting and something new.

So, let us see how we go about it. So, this is how we will do our course. So, we will start from here and the year we are recording the course is 2021 and we are starting on 16th march. So, let us document that but there can be rerun courses and where this date will be quite useless.

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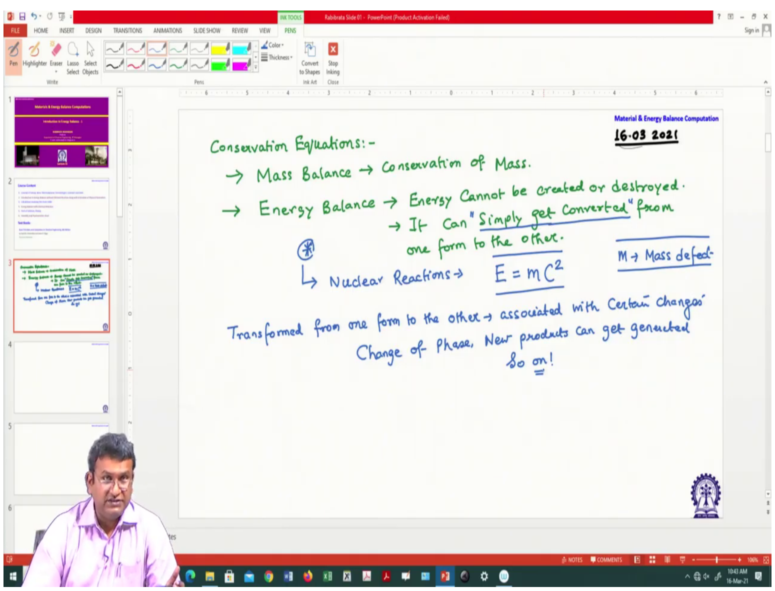

So, when we talk about energy balance ah. So, even before that let us start with what is known as conservation equations. So, what are the conservation equations we know about you have already talked or learnt about mass balance or which comes from conservation of mass. The other conservation equation is energy balance. The statement that you all know is energy cannot be created or destroyed it can simply get converted from one form to the other I guess you all know that.

And let us also put the exception where this individual energy balance is not valid the only situation where it is not valid is nuclear reactions. So, energy balance is not valid you say essentially have a combined mass and energy balance and much before we started learning higher science we all tend to know this equation equal to mc square and just a; so, we all understand that this is the amount of energy that gets generated in a nuclear reaction c is the velocity of light.

So, that is enormous amount of energy gets generated but one quick thing to remember what is m? and m is not exactly the mass it is essentially the mass defect. So, this is a mistake many people make it is not the mass or the molecular weight or atomic weight of the atom that is participating in the reaction it is after it is broken down whatever is the mass defect that gets converted gets multiplied by c square and gets converted into energy.

So, anyway in this particular course we are not going to talk about nuclear energy. So, we are going to talk about the con conventional forms of energy balance a conventional form of energy and therefore energy balance is going to be perfectly valid. ah. So, as I gets as I have written that simply gets converted or transformed from one form to the other this is also associated with certain changes for example there can be change of phase, new products can get generated like fuel burning and so on.

So, some of the examples we will pick up as the course unfolds; but before moving on and talking in detail about the energy balance and the principles associated with energy balance.

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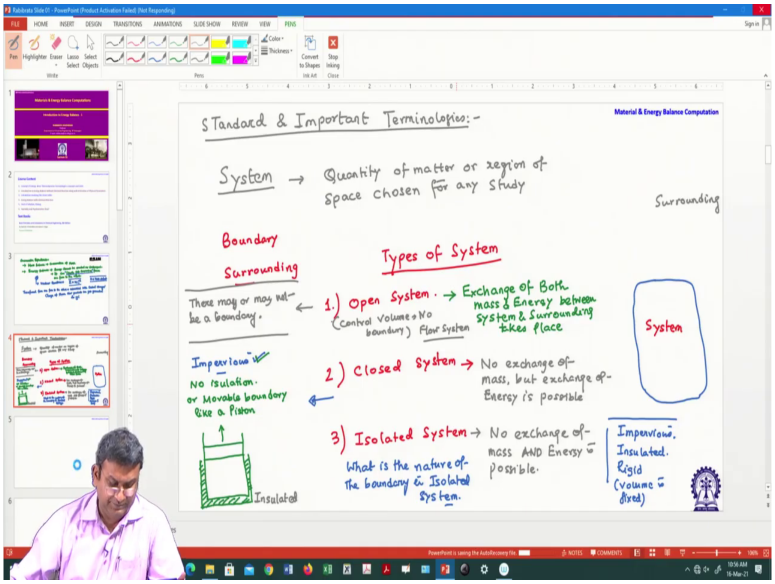

Let us look into some very simple pedagogic simple terminology standard terminologies and definitions and very important also these concepts. So, the first thing that we will talk about is essentially the definition of what is known as a system I guess all of you have some idea about thermodynamics some basic concepts. So, we will also I mean almost repeat the same thing but we will add a slight bit of new flavour in understanding and enjoying some of the very, very simple aspects of how to distinguish between different types of system.

I know I am teaching to at least second year undergraduate engineering students. So, you all know from your high school days that there can be different types of systems let us not get into the definition of what systems are. So, we all know that there can be open system closed system and isolated system for the sake of completeness we will write them down but I will give you a little bit of additional insight into how the physical nature of the boundary can actually define or lead to a transformation from one system to the other.

So, what is the system? System is a quantity of matter or region of space it is the quantity. So, this is a definition from Himmelblau's book. Since it is the first lecture we are going a little slowly and little conventionally. Slowly we will see that whatever is there in the book it is more important than a classroom right you can always read the book but it is more important in a classroom we create or make the concepts and that is where we are going to spend more and more time.

But to get started let us get started slowly; so, quantity of matter or region of space that is chosen for any study. So, you are not essentially studying the whole universe for everything you are looking at some particular part of the universe and the moment you say that you are looking at some particular part of the universe you are essentially segregating your system from what is known as the surrounding.

So, here you have a system and outside the system is as you all understand is the surrounding and what separates out the system from the surrounding is again everybody knows is known as the boundary right. So, this is clear to all of you in fact some of you might have already started to get bored that you are not learning anything new. hold on. So, not only we are defining system the definition of system also brings in or allows you to understand what is boundary? and what is surrounding?

Now let us straight away go to the types of system and we all know that there are three types of system open system, closed system and number three is isolated system I guess most of you also know what these systems are. So, open system can be is a system where exchange of both mass and energy between just give me a minute please system and surrounding takes place. So, in a closed system, what happens there is no exchange of mass but exchange of energy is possible and in an isolated system you all know no exchange of mass and energy is possible.

So, I guess this is clear to all of you. So, in the light of this understanding let us now let us just redraw the system a little bit let us create a little bit of space for our self; let us continue with the same slide and let us ask a slightly different question which you typically do not understand typically do not ask. So, if this is the boundary let me ask you or let me have a initiate a discussion on what is the nature of the boundary in isolated system. see it says no exchange of mass and energy is possible.

So, therefore the boundary must be impervious, no diffusion nothing is possible or there is no opening and it must be insulated that fully defines. well please do add another term the boundaries are fixed the boundary cannot expand. Because if you take please try to follow because this is interesting if you take a let us say insulated chamber which one side one end may be is attached to a piston which can move.

So, you have taken an insulated chamber which is impervious there is some gas. So, nothing comes out nothing comes from in there is no exchange of temperature it is at a different temperature but the piston can move up or down. So, therefore you are transferring energy how because if the if the piston is moving up in that case the system is doing some work on the surrounding if it is going down the surrounding is doing some work on the system.

And therefore, work is associated with transfer of energy. So, therefore the necessary conditions for or the nature of the boundary for a closed system are impervious insulated and rigid. Rigid means it there can be no movement of the boundary the boundary cannot change or the volume is fixed. So, I guess it is clear to all of you and once you understand this. So, what can be the nature of the boundary of a closed system?

For a closed system it can be impervious it has to be impervious because even a closed system does not allow exchange of mass therefore you cannot have a system from which is leaking or something is diffusing out or something is coming some mass is coming from outside to inside none of them are allowed. So, it has to be impervious as like a isolated system I am also coming to some examples of this closed system isolated system etcetera. But you can have there can be either no insulation.

So, that would allow exchange of heat. So, if for example you have a system and the outside temperature goes up or you place it over a hot plate the system inside can also get heated up or you can have movable boundary like a piston for example which can move up or down for example it can do some mechanical work or you may have both. So, please try to understand I will give a minute for all of you to understand this can be insulated right.

So, it can be insulated. If it is insulated, then you of course have to understand that for an insulated closed system there the boundary must be movable. Otherwise for an insulated system please try to understand and follow for an insulated system where the walls are impervious you cannot have if the boundaries are fixed then you cannot have a closed system it will become an isolated system is it clear.

So, if you are somehow if you are preventing transfer of heat then the only way work ah. So, energy can be exchanged between the system and the surrounding is through work and in order to either the system doing work or work being done on the system it is absolutely as mandatory that there is some movable component of the boundary. is it clear? So, you can have for a non insulated chamber, you can either have a movable boundary or you can have a rigid boundary, it both will be considered or candidates for closed system.

However, if I say that I have given you a closed system with impervious walls; obviously and it is insulated. So, under what condition the system can be a closed system the answer to that is in that case the boundary must be having some movable parts is it clear to all I hope it is clear to all. these are important interesting things which you typically do not discuss and what about an open system. So, for an open system you either.

So, there can be a boundary, or there may not be a boundary. This is a slightly tricky statement those of you have some idea about fluid dynamics for example a control volume is example in many ways of an open system. So, control volume for example the boundaries are hypothetical there are no boundaries. So, open systems are very common for flow systems where there is flow also you can have open system for non flow systems.

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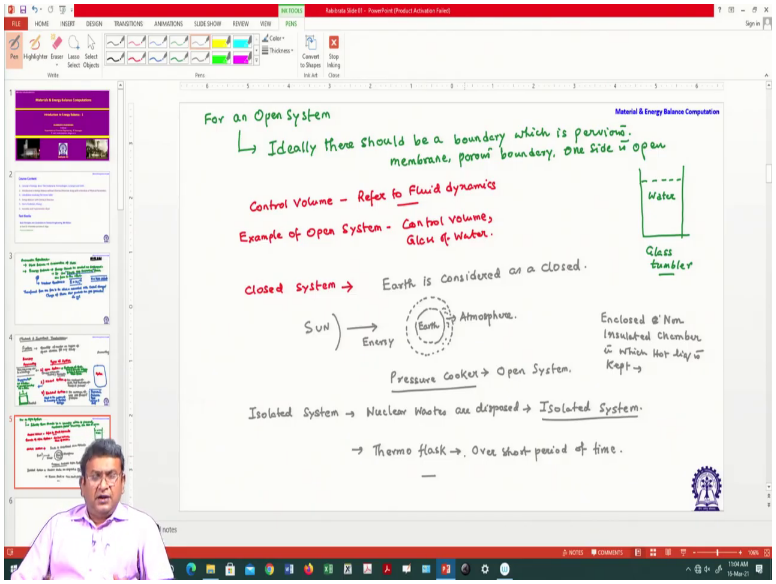

For an open system, either ideally there should be a boundary which is pervious. So, you can have a membrane for example you can have a porous boundary or maybe one side is open and so on. For example, a glass tumbler containing water. This is a perfect example of an open system because you see that these part of the boundary and none of them are impervious however one side is open. So, therefore transfer of you can add more water you can drink water out of it.

So, therefore you can transfer mass and you can heat it up and do whatever. So, this is an example of an open system a specific example of an open system is control volume those of you have some idea about fluid dynamics please refer to fluid dynamics. Control volume is of course an example of an open system but the important thing to note down is control volume does not have a physical boundary there the boundaries you define an area in the space where you do all your calculations.

So, it is indeed a system and it is a hypothetical boundary is hypothetical and it is a classic example of an open system. So, example of an open system for example anything and everything almost. we talked about control volume it is a special example I would say glass of water and whatever that of a closed system that of a closed system well there are many there are actually many for example a closed container containing hot water for example if you keep it and slowly its losing heat.

So, that is an example of a closed system there is no loss of mass but the temperature changes of course an insulated or a non insulated piston cylinder where there is no leakage or whatever is also an example of a closed system another very interesting classic example of a closed system is earth itself is considered as a closed system. So, here essentially by earth we mean this is earth and this is the atmosphere and the assumption is of course there will be lot of comments on that.

So, because some gases do escape to the surrounding the universe but in classical thermodynamics and we all know that it receives energy from the sun. So, earth along with its smart atmosphere is considered where it is assumed that the mass is conserved and however it keeps on receiving energy from the sun because therefore this is a this is all often considered an example of a closed system isolated system.

Of course, another example one can ask is pressure cooker do you think it is an example of a closed system well it is very similar to a closed system remember that a unfortunate cooker has that pressure release knob. So, if there is a progressive pressure build up you have all seen that some amount of steam comes out from the pressure cooker and since it vents from time to time to maintain the pressure inside the chamber.

So, that it does not exceed the critical value which leads to material failure and things like that with a knob if you consider the knob and the vent valve pressure cooker actually becomes an open system because not only there is exchange of heat because what is coming out is hot steam. So, there is exchange of energy; but some steam is coming out or purging out or venting out and therefore that is actually exchange of mass.

So, please do not confuse I have seen many people telling pressure cooker is an example of a closed system it is not it is actually an example of an open system. A enclosed non insulated chamber in which hot liquid is kept is a much better example of a closed system and finally the examples of isolated system nuclear wastes are disposed in some specific way in some matrix of ceramic material etcetera and they are very close to isolated systems.

So, I would request if you people have got interested kindly look into the Wikipedia because

Wikipedia is a great place to learn. And all these one on one type of the elementary examples of everything you can get reasonably good idea by reading at Wikipedia. A thermo-flask is also a reasonably good example of an isolated system. For a short duration of time where the heat loss is actually minimized and you essentially take care as you all know about the structure of a thermo-flask there is a vacuum layer.

So, you essentially take fact or take advantage of the fact that the thermal conductivity through vacuum is very, very less the temperature difference is not very high. So, therefore the radiative loss is very less and since the air molecules are not present there, there is no convection. So, over a short period of time of course thermo-flask is a very good example of an isolated system but as we all know that you actually cannot make it hand the insulation is not that good and over a prolonged period of time the temperature progressively drops.

So, I think we have sort of come to an end of the over short period of time. So, with this I will finish this first lecture where we started to learn the course and we just had a good discussion on system boundary and surroundings. And in the next class we will start building more concepts based on whatever concepts we have developed. So, far thank you.