Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

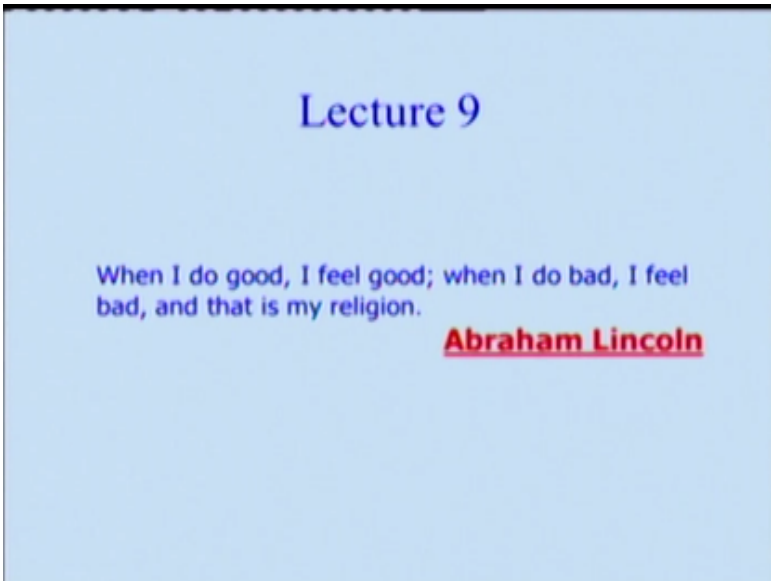
Course Title
Engineering Thermodynamics

Lecture – 09
Thermodynamic Properties of Fluids 2

By
Prof. D. P. Mishra
Department of Aerospace Engineering

Let us start this lecture with a thought process from Abraham Lincoln he says when I do good I feel good.

(Refer Slide Time: 00:24)



When I do bad I feel bad that is my religion Sager very great thought and similar thoughts are also there in our scriptures and which you may not be aware as such but you know it is the important thing to ponder and let us now get into our discussion on the thermodynamics and in the last lecture if you look at I started with the defining a pure substance right and we looked at the definition of your substance which will be having uniform chemical composition right.

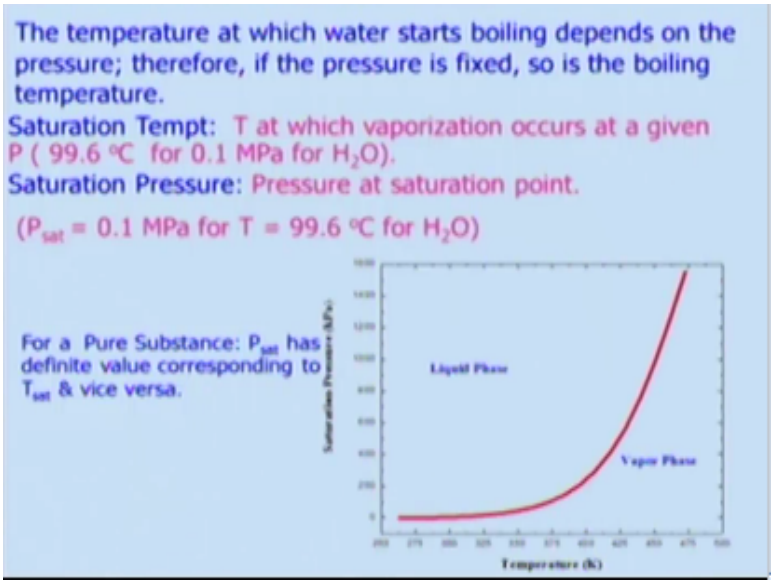
And we also look at the phase change processes and we started taking the water as a pure substance as an example and then we keep the you know temperature constant and look at what

is happening and we found that that there is a change of phase in that case liquid is converted into gas and then it will be you know whenever it will be attending you know saturation temperature right and saturation temperature is dependent on the saturated what pressure saturated temperature will be dependent on the saturated pressure and we looked at about the saturated liquid line saturated vapor line.

And then we learnt also how to handle the weight mixture or a mixture of vapor and it is liquid right, so for that we define a term which is known as quality right and by knowing the properties at the saturated liquid point and the saturated vapor point we can evaluate the properties of the mixture that is liquid and vapor, and let me just ask few questions about like what is what are the implications of the saturated vapor pressure and temperature right.

Can anybody think about the, what are the things I mean what are the applications implication means I mean like what are the applications kind of things one can think of right.

(Refer Slide Time: 03:14)



So we looked at this curve that is basically you know saturated temperature will be dependent on if I look at you know let us say for a temperature particular temperature here and it will be having certain pressure you know that is and it changes right so what is the implication of heat and can I use this, so you know some kind of device one can think of right for example I in the last lecture I gave an example of what you call cooking the food suppose you are cooking put on the sea level right.

And using the same stuff let us say LPG stout and you go to the higher altitude let us say Himalayan region right the people do live in that place right I our altitude MRI and which is quite pleasant and they do leave that place particularly in summers it will nice and if one to cook for what problem are we will face any idea what happened the boiling temperature because this agitated you know temperature which is correspond to the boiling temperature is not it for a one atmosphere pressure what will call around something 100^0Celsius the water will start boiling right.

If I go to the higher altitude let us say 2000 meters what will be its boiling temperature will it be higher or will it be lower it will be lower, so that you know generally per thousand meter of height you know as you go along the altitude higher altitude right then something around 3^0 Celsius difference will be there right. Suppose you go for 2000 meter higher altitude then what will be the temperature, temperature will be something 94^0 Celsius right.

So if that is the case then you will take more time for your food to cook and as you go little more higher altitude it will be you know difficult to cook as such because it will take a lot of time of course if you look at it takes more time to cook the food at a lower temperature like if you use your solar cooker it will be having what we call lower temperatures it will be attending the lower temperature.

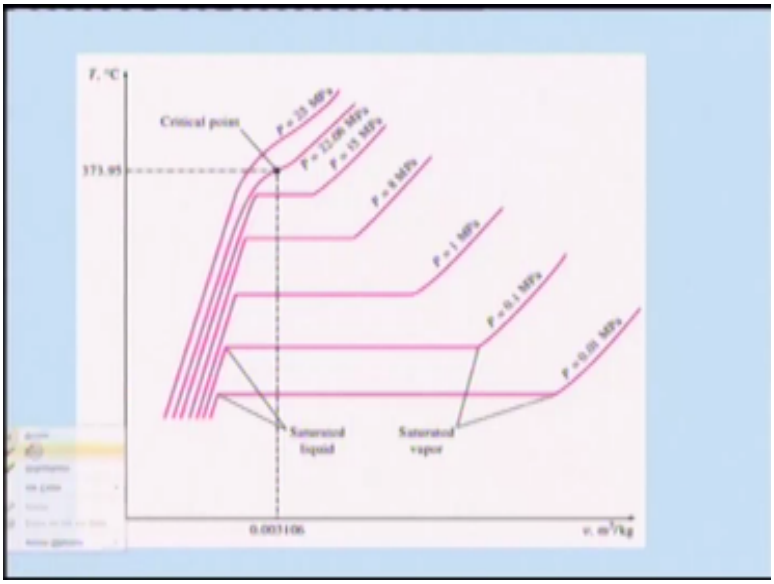
So therefore it will take less time sorry it will take more time for the food to cook but however it will it will be very testing you know because the nutritional values will be remaining intact so therefore that is the one application one can think right, so what else other things comes to mind any idea for example like you know in the last night there was a thundershower right. So what happens to atmospheric pressure at that I am like after that not at that time because at that time it was turmoil you know there will be lot of wind is moving and then you know lot of thermal was there yesterday night.

But suppose after that lot of moisture has come into the atmosphere am I right, yes or no and what happens to the net must be pressure will it change what happens to the temperature will it change, change or not there will be also change in the temperature but that change in temperature is very very small because that depends on the moisture content right. Let me give you another example which is just crossing my mind you know in IIT Kanpur we get very hot water even in

summer because what is happening we are taking the water from a, what very deep down the arc right.

So therefore the water has to travel for a longer length it may be something around 800, 900 feet kind of things, so then you know like you will get water which will be warm and in summer if you want to take bath in warm water it is not really very what you call enjoyable am I right of course I do not know whether you people are feeling or not but I do feel but I want to solve the problem how I am going to solve the problem that is a question I am asking because I have solved that problem without expending any energy is there any way I can do that think about it. So let us look at what we discuss in the last lecture right I will continue on that.

(Refer Slide Time: 08:58)



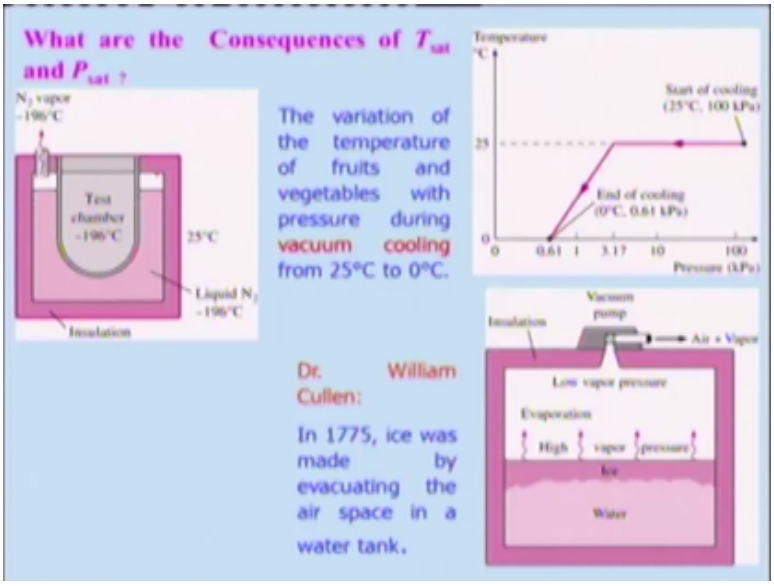
So if you look at let us say this is my point zero mega Pascal pressure and this is my almost atmosphere pressure point one mega Pascal approximately if you look at I need to give this heat

here and this I call it as a basically what you call wait mixture wet mixture means is a combination of the vapor and it is liquid or liquid and it is vapor but if you look at this length is goes on decreasing and what is it implication its implication that the amount of heat what I will be giving for the lower pressure here let us say will be much higher as compared to the latent heat what I will be giving at the higher pressure.

Because I call it this is the latent heat portion like temperature is remaining constant however you are you are adding heat to the you water your am I right. So that latent heat goes on decreasing and it becomes zero at what at the critical point like that you should keep in mind I thought I did not emphasize in the last lecture this point I thought let me emphasize again this is a very important point right.

And as I told in the last lecture the lot of you forts are being going on you know and it is not that going on alone and people have already developed superheated boilers and which is you know very efficient as compared to the what you call wait mixtures are steam boiler right. So now coming back to that will dwell little bit upon this what you call.

(Refer Slide Time: 11:07)



The consequence of saturation pressure and temperature right let me just tell you that this temperature as I told that saturated temperature will be dependent and pressure and vice versa right so if you look at like suppose can I use this thing for producing eyes right or cooling it and how we can do if you look at like what I will do I can go on reducing the pressure right when I

am redoing let us say start you know like if I am go on reducing the pressure from100 kPa almost atmospheric pressure and what will happen temperature will be remaining constant right.

But after when I am reducing the pressure then it start lowering the temperature and at 0.61 kilo Pascal the what you call it will attain the 0 degree Celsius and you know you can get the eyes being formed and this kind of cooling is known as vacuum cooling right and it is let me tell you it is quite costly than that of making other refrigeration and other kind of weight cooling right this is also the what you call vacuum cooling.

But however it will be very important for preservation of some certain kind of foods like particularly the vegetables which will be having what you call higher surface area per unit mass let us say lettuce or spinach right. So those will be can be cooled very easily whereas you know if you put tomatoes and other things which is having lower surface area per unit mass then or cucumber tomato or cucumber or any other kind of matter vegetable then it will be you know spoil itself.

So therefore this is having lot of applications as such in the things but particularly in the food processing industries and other places but it is a very costly affairs you know to do that and this was done basically long time back what you call by Dr. William Culien in 1775 and he had made some eyes by evacuating the air space in a water time if you look at I do dabble in some kind of NCN science and since Indian science and technology and I also learned that people were in this country we are making eyes right.

And without your refrigeration systems right how they were making that was interesting thing and if some of you are interested I can you know discuss that later on. So this is the one of the application one can think of and let us look at there is a another application I would like to you know discuss that is suppose you want to keep a taste chamber at a very low temperature like you know then what we will have to do we will have to use the liquid nitrogen right and we can have a chamber here right where it will be insulated properly and this is liquid nitrogen at minus 19^0 Celsius and ambient temperature let us say 25^0Celsius.

I want to keep this chamber at a constant you know which will be test chamber you can say that at -19^0celsus, so if I want to maintain that what I will I have to do right, the best way one can think of doing you know without intuitively that I should close this you know there is a vent here

right it could you know you to design will say look I will keep this vent close or this is a closed chamber I will take and then put this thing nitrogen liquid nitrogen on the top of it I will put this test chamber and close.

But however if I want to keep at a constant temperature of -196 then I will have to give this event why it is so what is the reason why should I give a wind ideal one should they close it you know so that knowing insulate. I mean it will be insulated properly and then no heat will transfer so that you know you will keep the temperature. But if I will close this wind here what will happen? Is actually if you look at this portion is its vapor you know that pressure will go on increasing because whatever the insulation you do there will be some heat leakage.

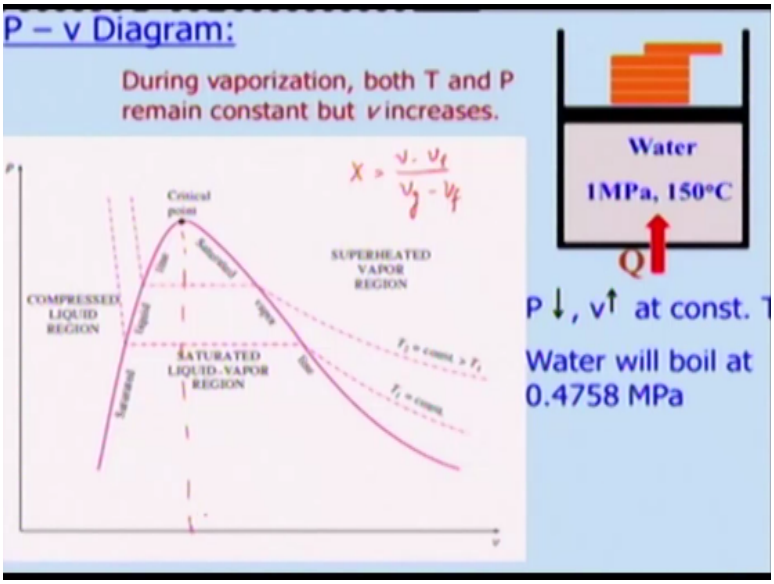
Okay so then it will start boiling and the pressure will go up and then the saturated temperature at which the liquid nitrogen is converted into vapor will be changing. So therefore you cannot keep it at a constant temperature so therefore we will have to give that things and so that is there for you now to use you know the things the various concepts and knowledge of thermodynamics while designing a system.

You might be knowing like nowadays you people are more worried about your faces and other things to keep your this thing you know you can use also liquid nitrogen as a what you call substance to be to remove some of the extra growth what you may have. You know what you will do you will take a swab dip into liquid nitrogen and just put it here in you on your face and then what happened that Porsche which is protrusion coming out of that you know will be freeze and then you will get the blood circulation and other things and then that will be removed very easily. So your face became very if it is rough it became very smooth right so this is the cosmetic what you know what people use are you so this again is a science and if you look at you might beware we are having a liquid nitrogen plant am I right. You are aware that we are having a very big liquid nitrogen plant and it was recently inaugurated by our director of course we are having earlier now it is a big plan we use liquid nitrogen for our experiments and then one has to design similar kind of you know chambers to keep it in the kind of a carry out experiments.

So there are several consequences of you known the saturated you know relations between the saturated temperature and pressure. One can think of that depends on your imagination I have just given you few glimpses of it. So what we had done in the you know till now is that we

looked at the temperature and the volume and keeping the pressure constant now we will look at a situation where we will consider the again.

(Refer Slide Time: 19:15)



The piston and cylinder arrangement and where we will take a water and at one mega Pascal's and 150^0 Celsius and we will take our this is our system and it is if you look at it is already loaded with tiny weights and if I remove this small weight what will happen to this water which is had 150 degree Celsius you know at one mega Pascal. What will happen? If I remove this way the pressure will be decreasing.

Right if the pressure will decrease what will happen? To the specific volume it will change right it will be basically X increasing and so also there will be decrease in the temperature am i right there will be slight decrease but if I want to keep the temperature constant because now we will be considering the isothermal process right what we will do? We will have to give some heat so that that means I will have to supply certain amount of heat to the water so that temperature will be remaining constant.

In this case what is happening? The pressure is changing so also the volume. So if you look at if you go on doing that then what will happen the pressure is decreasing in this case one mega Pascal it is you know earlier but as you go on removing these weights that will be pressure will be decreasing if it will attain 0.4758 mega Pascal you know it is basically 4.75 what I me like 40 necessary 4.75 something around atmospheric pressure ten times in a night of this.

So that time the water will start boiling right okay and if it will start boiling then what will happen then what will happen? So it is you know pressure will it be decreasing further or it will be remaining constant? What will happen? Once you start boiling the temperature will be remaining constant so also the fascia right yes or no because once if you look at the other things what we look at is your TV you know when the pressure is remaining constant their temperature is remaining constant.

When you started boiling right so if you look at I mean like this thing that means what I was telling like let us say I am here at a pressure of let us say 1 mega Pascal right kind of things here at this point and as it goes what you call decreasing the pressure there is a change in specific volume but however this specific volume change is very small. So for example if I look at here and if I look at this or some point here this changes is very small.

This change is very small right and this is the point what I call it basically saturated point and saturated liquid point you can say and at this point the what will happen water will start boiling is it at this point and after that this will be liquid and vapor region right and where the pressure is remaining constant and so also already you know this isothermal process what we are considering so temperature is remaining constant but however there will be rapid change in the specific volume from this point to this point.

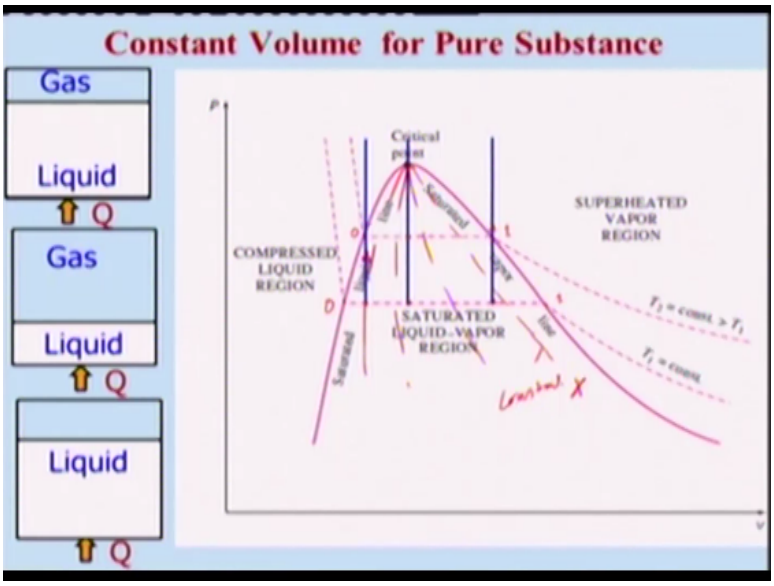
And as you what you call the rate and this point we call it as a saturated vapor point and this line we call it is saturated vapor line and at this point what will happen? The liquid is converted into vapor right and then of course as you go on decreasing the pressure then what will happen? That keeping the temperature constant then it will follow these ways and you can conduct the similar experiments at a different temperatures and you will get this point and then again you can get the critical point where the what you call liquid will directly converted in to its vapor.

As I told earlier that this point this line below which we call it as a compress liquid region or we call it a sub cooled liquid and here above it is basically vapor region and if you look at if we heat further. You know like kind of thing this is known as superheated vapor region and in between these two points are these two lines rather saturated liquid line and saturated vapor line there will be the mixtures which will be having what you call different quality values.

As I told for example at this point this point corresponding to quality x = 1 here right and this point the quality that is the x = 0 correct .So in between it will be varying between 0 to 1 and by knowing that we can what you call use these properties and evaluate the properties of various thermodynamic properties. I had asked you what is the quality inn at the critical point if you look at the quality at the critical point we can really look at it by looking at the basic definition of the quality and quality is basically V- V F / VZ -VF the specific volume of the liquid VF + VZ the specific volume of the gas.

At this critical point if you look at right this is basically V F = VZ so then what will be having quality at critical point CP I am saying that X will be infinity are you getting or not because at the critical point the specific volume for the liquid is equal to the specific volume of the gas. So therefore the quality at the critical point will be infinity and along the saturated liquid line it will be 0 rights each point will be 0 and along the saturated vapor line it will be 1.

(Refer Slide Time: 27:59)



So let us look at now a certain situation of constant volume process for pure substance right for example if I take a certain amount of liquid and certain amount of gas in this case if you look at here the liquid is larger quantity right yes or no and the gas is smaller quantities. What is the meaning of this will be if you look at in terms of X will be closer to what 0 or1 it will be closer to 0. It cannot be 0 it will be definitely greater than 0 right so it will be a small you may be let us say something point one or point 2X will be and.

If I will go on heating this you know what will happen what will happen? If I will go on heating is it like liquid we will be converted into gas or the gas will be converted into liquid it can happen because we are considering two-phase only right so what will happen what will happen? The weight mixtures you know like if you look at quality what will be happening to the quality. So for that what we'll have to look at we will have to look at either the PV diagram or the TV diagram we it can be very clear.

For example like if I am here let us say I am at this point right with this what you call so if I am heating it at a constant volume that means I am moving in this direction what will happening? I will be getting at this point whenever it is having you know pressure of course in a constant volume if I am heating the pressure will go up and then I will be going in these directions and then add certain things I will be getting all the vapors right.

Similarly if I will get the other way around that is very less amount of liquid and more amount of gas right which you can think of that you are here in this region right you are again going up as

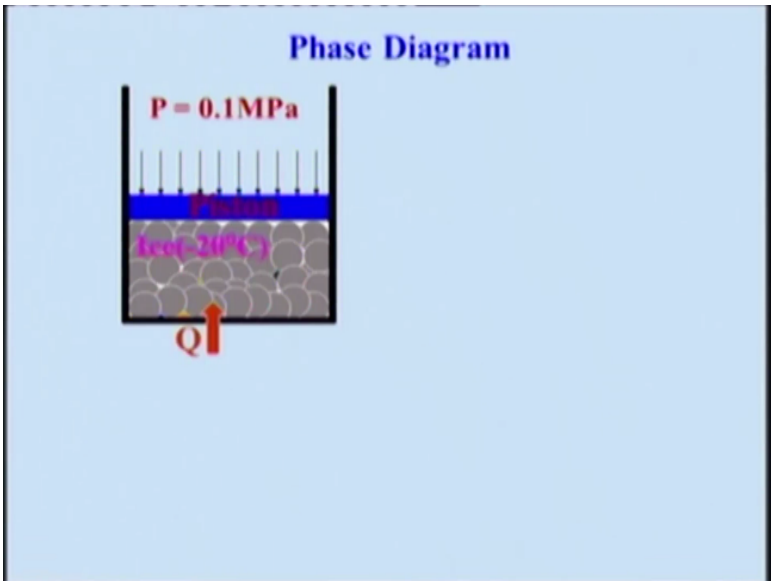
you are giving the heat that means you will be getting basically the vapor. But I can think of another condition where you know there will be in between that means you are think of considering a situation where you are thinking of you know making this mixture you start with this mixture here and you will go on there will be Wed mixtures if you look at the x value will be changing right.

If you look at the X at this point what it would be at the critical point what it would be at this critical point what it would be I am like you know if you look at my X is in this case if I X is 1 here right and this point it will be 0 and similarly this will be 0 and this will be 1 what will happen at critical point so it is all 0 and this 1. So it will be basically if you take this considered it will be 0 rights? All it will be vapor at that point but if you are here little down at critical point it will be having infinity.

So therefore if consider this thing and the if I draw these curves here like that this is letups say what has this line this line corresponding to constant X quality lines. So if you look at you know it will be something point 1 and then point2 or maybe something point 3 like that it goes on so if I look at what is happening here if I am going that means my what you call quality is changing quality is becoming going towards zero right similarly here right .

So let us now look at other aspects of that we will we have till now looked at two phase one is liquid and it is vapor now we will consider eyes which is at minus 20degree.

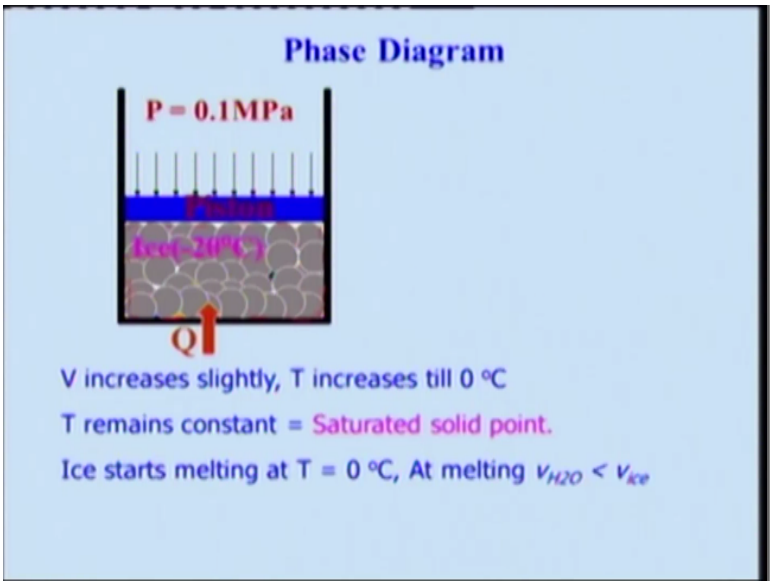
(Refer Slide Time: 33:14)



Celsius and 0 point one mega Pascal's right and in a piston cylinder arrangement because so that we can keep our you know a pressure remaining constant kind of things or it can be varied very easily any one of them can happen so that I can have a control over this i can have a system if I will go on adding heat what will happen to this ice what will happen ice will be what happens to the ice temperature it will go on increasing that is obvious thing right and as a result the volume increases slightly is it the volume will increase or not.

What will happen because if it is eyes and of course if it will be what you call converted into liquid then what will happen the volume for the same mass what will happen tote volume I think you think about it you are not you know thinking please think about it what will happen if I see is converted into liquid what will happen for the same mass about its volume decreases okay so then you know temperature.

(Refer Slide Time: 35:11)



It will be goes on increasing and ice will start melting at 0 degree Celsius and at the melting what will happen this specific volume of theater you know who is less than eyes so that what will happen the ice will be floating right and water will be down this is a beautiful thing special about the water facility about the water so whatever the you know living things what we could see because of these properties of the water which are made as to thinking other words.

If you consider the Ice Age if you believe that you know there was a I says and after that all males suppose you imagine it could have been other matter like another material most of the material except water you know which what you call specific volume of its liquid is less than that of the solid right okay that means all other matters will be other way around the specific volume will be of the liquid will be greater than the specific volume of the ice so that it will be having higher density no solid will be having higher density than that of the liquid right as a result you imagine.

It could have been happen for the water then what it could have happened ice could have been on the bottom of the lake or a sea or any other place you know are you getting then what could have happened to the living beings there is a lot of you know in your see there is a lot of living beings on the beneath that could have died or could have not there.

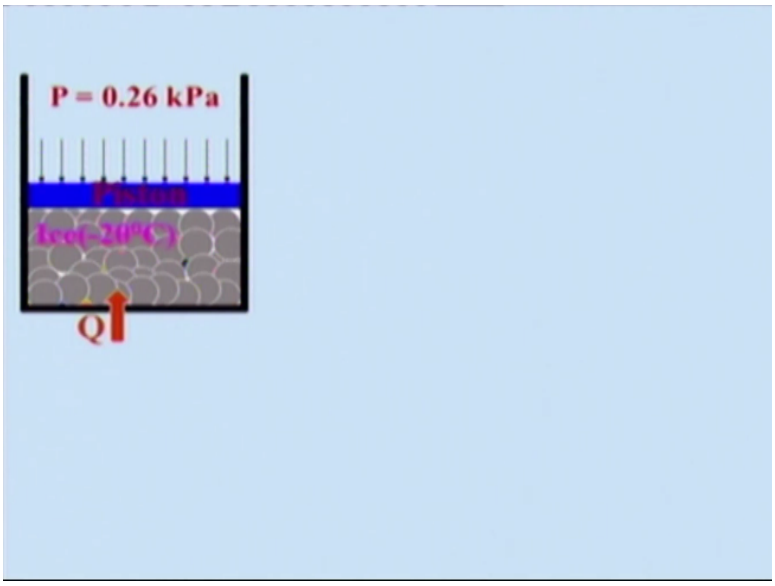
Let me just tell you it is crossing my mind our over the coastal area are in deep trouble because we are dumping a lot of materials and their biological life is affected by that and we are all connected with the biological life what is there in the sea right we should not spoil it so coming

back to that that is the beauty like that has created a life in this beautiful art because of properties of the water that is the specialty of the water.

So and that is what I was telling that is the vital for nature's evolution is a very important point that is vital for nature’s evolution otherwise we could have not been here right talking about thermodynamics if we have not evolved out so now let us look at another situation we will consider the semis start with minus 20 degree Celsius and but we have changed the pressure here Hotpoint to 65 right and I will go on adding heat so what will happen the temperature definitely will go on increasing right.

But will it converted into the liquid or not what will happen because we have seen that when the pressure is point one mega Pascal’s right and it was also at minus 20 degree Celsius right and we found that as it goes on temperature of ice will be go neon increasing and then when it reaches zero degree Celsius it will be converted into the water right and then but in this case it does not happen if the you know temperature will be goes on increasing but till it attains the minus10 degree Celsius .

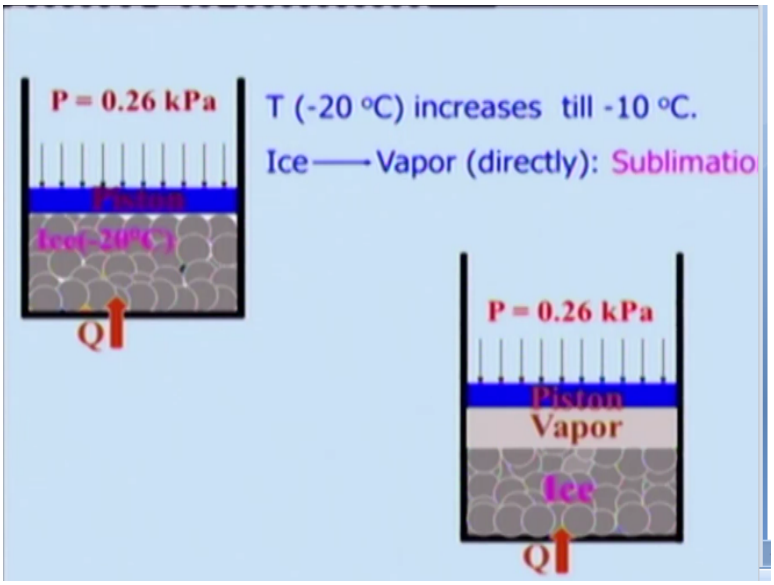
(Refer Slide Time: 39:04)



And eyes will be converted directly into vapor what we call sublimation right this is a very you know interesting phenomena which occurs for others also other material pure substances right so and if it is vapor has come and I will go on what you call adding heat what will happen then of course the ice will you know converted directly into the vapor then the further heating you know this thing first all the ice will be converted into vapor.

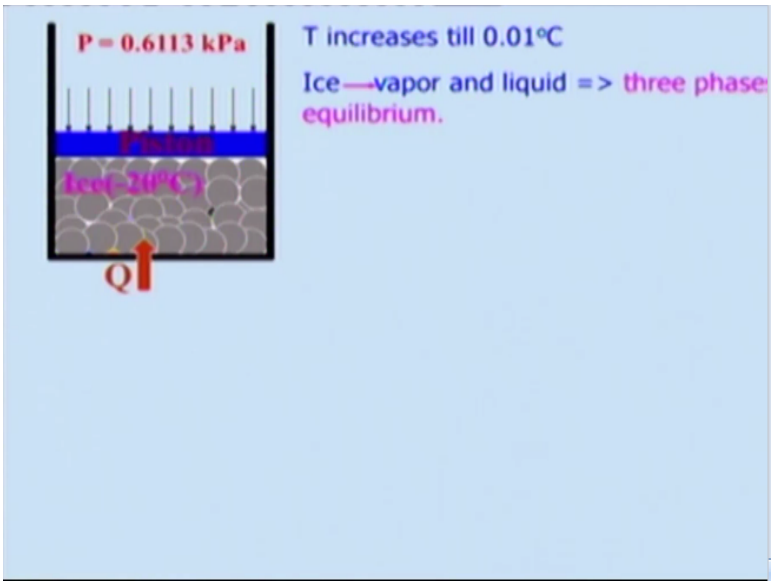
Then if you go on adding heat you know then it will be converted into superheating vapors kind of things so let us consider the energy situation again we will start with the same what you call the temperature ice that is minus 20 degree Celsius that means ice is at minus 20 days else's but the pressure we have changed to do Oh point6 11 3 kilo Pascal then if I will go on adding heat.

(Refer Slide Time: 39:44)



What will happen see in all these process what we are trying to do we are trying to keep the pressure constant you know like so what will happen to the ices in just now we saw that the ice was converted directly into the vapor earlier we have seen ice is converted into liquid right when the pressure is changing of course that this temperature of the ice will go on increasing till it attains 0.01 degree Celsius and ice will be converted into vapor and liquid state and this we call it a three phase equilibrium .

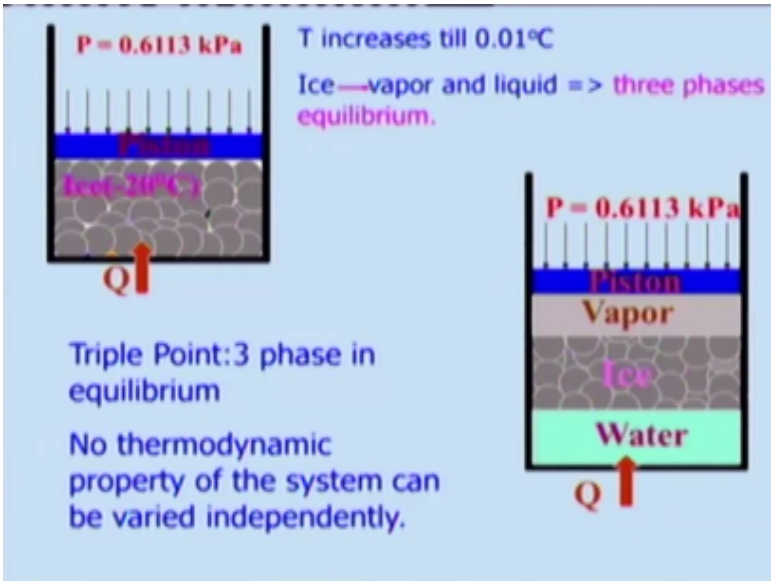
(Refer Slide Time: 41:25)



That means all the three phases will be at the same point you know it will be simultaneously being present so this is a very important point I had emphasized in the last lectures that this triple point was being used as a reference point for the temperature measurements high temperature scale to make it that because it is invariably there is small change in that temperature then you know you would not get three phase you know immediately.

Look that is not accurate so therefore to get a very precise reference point this is being internationally accepted so if you looks I told that you know all three phases will be remaining at this point and these is called three phase equilibrium.

(Refer Slide Time: 42:26)



Three phases are in equilibrium there is actable point and let me emphasize also this point that no thermodynamic property of the system can be varied independently at this point at this triple point right so this is a very important point you should keep in mind and we will stop over here we have seen this change SS and other things and we will be discussing in the next lecture about the phase diagram.

Because we have looked at the various phases considering pressure what you call volume diagram while keeping the temperature constantan temperature and volume diver will the pressure constant you know like all those things we have seen but we will have to look at a diagram which will be important giving all three phases you know then only we call it as a phase diagram now let me ask a question then we will stop over that is what would bayou know variables in which I can see.

For example I am having three variables in this case pressure temperature and volume right now what I should plot so that I get all the three phases together right so we will stop over this question we will continue again with the what you call the space change process in the next lecture thank you very much you.

Acknowledgement

Ministry of Human Resource & Development

Prof. Satyaki Roy
Co-ordinator, NPTEL IIT Kanpur

NPTEL Team

Sanjay Pal
Ashish Singh
Badal Pradhan
Tapobrata Das
Ram Chandra
Dilip Tripathi
Manoj Shrivastava
Padam Shukla
Sanjay Mishra
Shubham Rawat
Shikha Gupta
K. K. Mishra
Aradhana Singh
Sweta
Ashutosh Gairola
Dilip Katiyar
Sharwan
Hari Ram
Bhadra Rao
Puneet Kumar Bajpai
Lalty Dutta
Ajay Kanaujia
Shivendra Kumar Tiwari

an IIT Kanpur Production