Phase Equilibria in Materials (Nature and Properties of Materials - II)
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Lecture - 14
Phase Diagram Construction: Partial Soluble Phases

So, now, let us again begin with the new lecture, which is lecture number 14, and in this lecture, we will talk about, we will further delve into different kinds of Phase Diagrams and the correlation the free energy composition plots. So, in the last lecture, we just have a recap of the last lecture.

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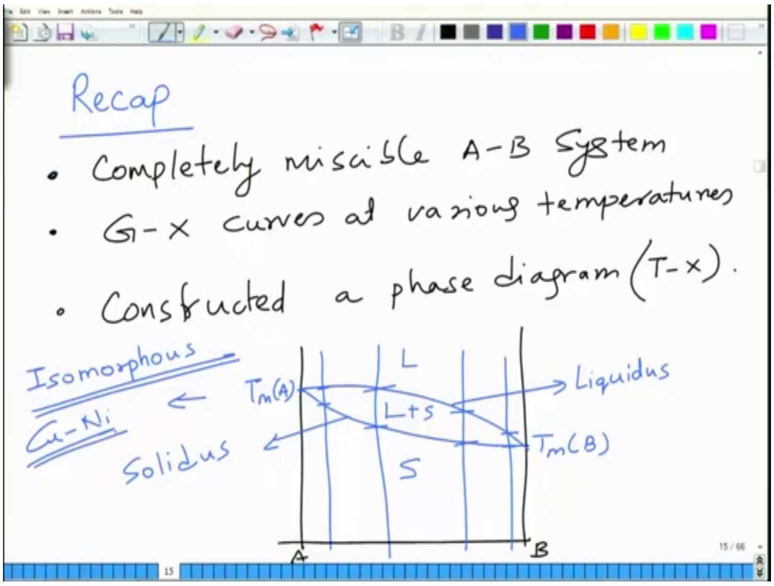

So, in the last lecture, we only talked about we just looked at the completely miscible A B system. So, where A and B were completely miscible into each other and we plotted G X curves at various temperatures and then, looking at the profiles of these temperatures, and how different phases came to coexist with each other, we constructed a phase diagram. A phase diagram is basically a landscape of in two dimensions for binary system. It is between temperature and composition.

So, you take the information from, free energy composition curve at all temperatures then, you eliminate the temperature and construct eliminate the free energy and construct the temperature versus composition diagram. So, for this kind of completely miscible system between A and B, we had a phase diagram something like that all right. So, above; so, we had T m sorry; so, this is T m A, this is T m B.

So above, T m A, for pure A and for all compositions above this boundary, which is, curving upwards, which is called as liquidus, only the liquid phase exists. Between this phase boundary, called as liquidus and the other boundary which is called as solidus, you have a two-phase coexistence for any composition, except pure A and pure B, between T m A and T m B you will have only two-phase coexistence

So, for this composition you will have between this temperature, and this temperature you will have two-phase, for this composition between this and this you will have two-phase, for this composition between this and this you will have two-phase and for this composition between this and this you will have two-phase and below this solidus boundary, for all compositions you will have, solid phase, which is S.

Now, this is, this phase diagram is obtained by drawing free energy composition curves with various temperatures and this was valid for systems, which are completely miscible in each other, which were so soluble into each other in both liquid and solid state, and this is this generally happens for systems, which are very, which do not have large difference between the melting points. They have a similar structure, similar variance, similar nearly similar ionic radii and so on and so forth, basically they follow the, rule of Hume Rothery rules very well.

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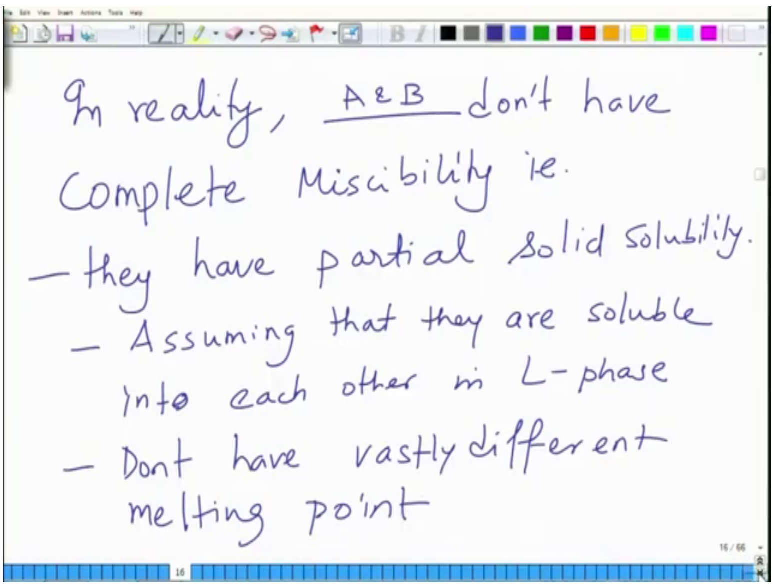

Perfect examples of Hume Rothery rules now the moment, but life is not easy in most cases. In reality A and B are hardly soluble in to or they do not have complete solid, solid solubility. A and B do not have complete miscibility, that is they have partial solid solubility especially in the solid phase. So, assuming that they are miscible in.

So now, we assume that, they are assuming in liquid phase, but they have partial solid solubility or partial solubility in solid phase. So, partial solid solubility, but complete solubility in liquid and they do not have vast differences in melting point. So, A and B like each other's company, but only to a certain extent. In solid phase, in liquid phase, they are completely miscible, right that was the scenario.

So, basically the first type of phase diagram that we had, that we looked at this phase diagram is generally called as isomorphous phase diagram. So, it is a phase diagram for isomorphous system, such as Copper, Nickel; best example of this kind of phase diagram. Now, let us look at this example, where A and B have partial solid solubility. In solid partial solubility into each other in solid state and in liquid state they are completely soluble.

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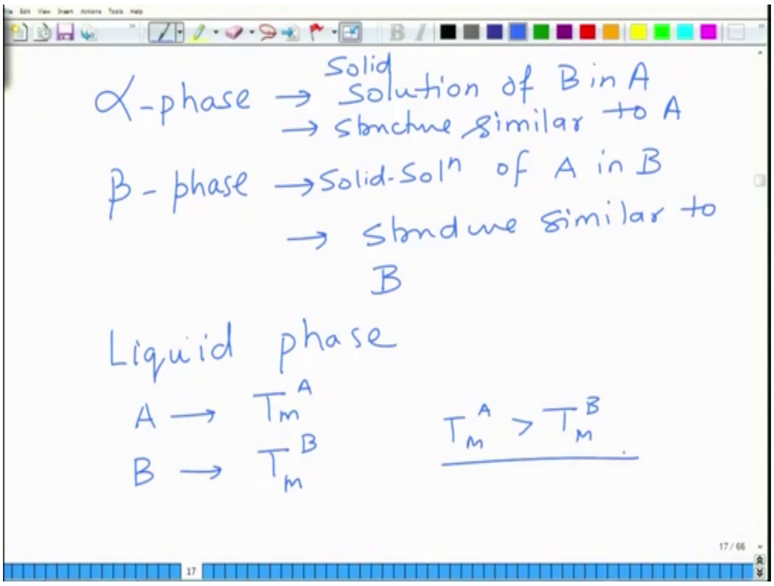

So, they make first phase called as alpha, which is basically solution of solid solution of B in A ok. It could be interstitial solid solution, it could be substitutional by and large it would be, depends upon the atomic size and so on and so forth, if it is A in most cases, it would be substitutional. In case of phase diagrams, where the sizes are not very different then beta phase is solid solution of A in B.

So, basically alpha phase follows a structure. So, structure similar to A, so and, it has a structure similar to B, right solid solution of A and B and then we have liquid phase. So, these are the three phases, which are present in the whole composition free energy temperature landscape.

So now, let us begin with first temperature T 1 ok. So, we take a temperature T 1 and this T 1 and also we say that, melt again you know, A has a melting point of T m A, B has a melting point of T m B and let us say, T m A is slightly higher than T m B. They are not vastly different from each other, but there is certain difference.

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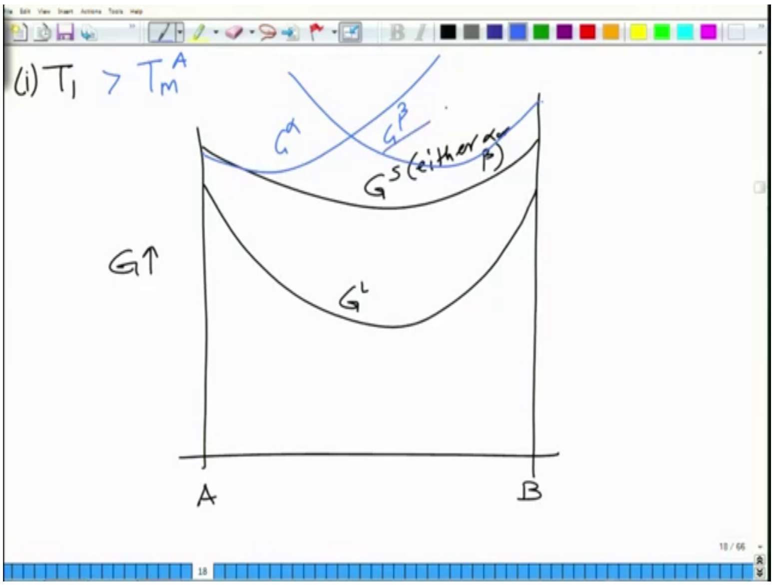

So, what they have here is first the alpha and beta phases here, they have similar structure, but or they may have different structures also. So, let us let us look at the case, where they have, they have different structures. So, at temperature T 1, which is higher than melting point of A, we first draw the free energy composition curve A and B and to G. So, as it happens as you would expect the liquid will be stable as compared to solid. So, this is G L this is G S for all compositions your liquid is stable as compared to solid all right this is at temperature T 1.

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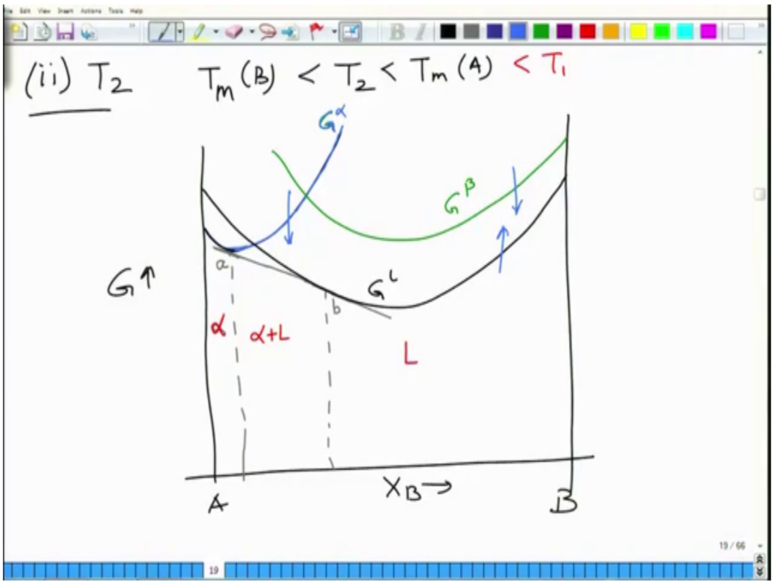

Now, let us look at temperature T 2 and T 2 is less than T 1 and as greater than but it is it is, it is less than melting point of a, but greater than melting point of B. So, I am not going to draw and now at T m, because you know that what will happen at T m A similar to previous case.

So, now let us make a; so, this diagram again just all right. So, at this temperature, when you plot free energy versus composition, what happens at this temperature is, that your, this is your liquid free energy and your solid is somewhere this is your alpha, let me just use a different colour this is alpha phase, the beta phase will be somewhere. So, let us say, the green one is beta phase, this is your beta phase and for these two phases. So, you can see that at certain composition. So, let me just first identify this is G L, this is G beta and this is G alpha ok.

Now, let me draw the common tangent between these two. So, corresponding to these two points. So, what you see here you see that, below point a your alpha phase is more stable than liquid phase ok. So, this will be alpha we use a different colour now. So, this is alpha between A and B you can see that, you can draw a common tangent between the two curves and this is going by the previous, rules this would be alpha plus liquid and in this region, you will have only liquid all right. So, this is the, phase diagram versus, phase free energy versus composition at temperature T 2.

So, you can see that as you have gone from T 1 which was completely liquid you have gone to now, T 2 which is lower than T 1, lower than T 1 you have entered into a phase regime, where you have for certain composition you have single phase alpha and for certain compositions intermediate compositions, you have alpha plus liquid coexistence and then above certain composition B you have complete liquid phase. So, you have solid is starting to appear ok.

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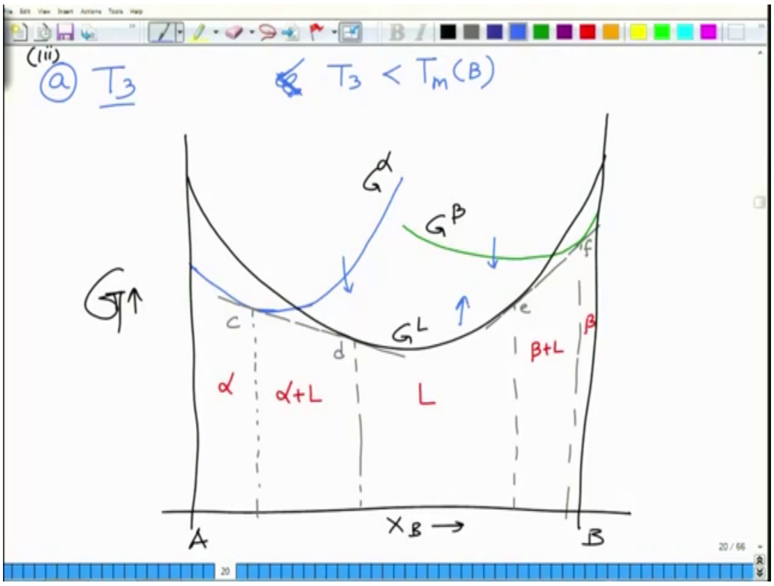

Now, as you further reduce the temperature. So, now let us go to temperature T 3, this T 3 is of course, lower than T 2. So, let us say it is now lower than T m B. So, in the previous case T m B was lower than T 2. In this case T 3 which is lower than T m B. So, naturally it is lower than T 2, but it is, let us not define it you know there is another temperature that will come I will define that later on.

So, it is lower than T m B and your situation is like this, now you have a phase diagram which is something like that you have pure A, pure B all right sorry G not T. So, your that as you further reduce the temperature from T 3 to T 2. So, this was your liquid curve. So, let us say this is the liquid curve.

Now, what happens is that, the solid curve which colour was it the blue one the blue one starts to lower even further and what it starts happening is that your the green one starts lower below liquid curve. So, you have this is G L, this is G beta this is G alpha. So, we can see now G alpha has shifted further to the right the minima of G alpha G liquid with respect to G liquid on the other hand on the right side, in your in the pure B regime the G beta has started lowering itself with respect to G liquid.

So now, what you see is that in certain regimes alpha phase is more stable in the certain regimes you have beta phase, that is more stable and the region in which liquid is stable will shrink. So, how do we do that, we again draw the common tangent and again we draw the common tangent here all right. So, this is let us say, so previously we had point a and b, now let us say we had point c d e and f and if you apply the similar logic. Now in this region you will have alpha in this region you will have alpha plus liquid in this region you will have beta in this range you will have beta plus liquid and within this region, what will you have within this region only liquid is stable phase you will have only liquid.

So, you can see now you have three phases coexisting, with either. So, three phases are there with five regions. So, the first region below composition C is alpha where solid alpha is more stable between C and D you have alpha solid phase coexisting with liquid phase above the composition D only liquid phase coexists and then when you move on to further decomposition. The beta phase starts to appear and this beta coexists solid beta is the solid phase that coexist with the liquid phase until reach point f and above point f only beta phase coexist, exist in the solid phase.

So, now you have entered into a temperature regime which is lower than lower than the, melting points of both A and B yet you have a problem or you have interesting scenario that liquid is still there. So, what happens in certain cases? So, now, you reach a specific temperature. So now; so, this is let me just label it number 1 number 2 number 3.

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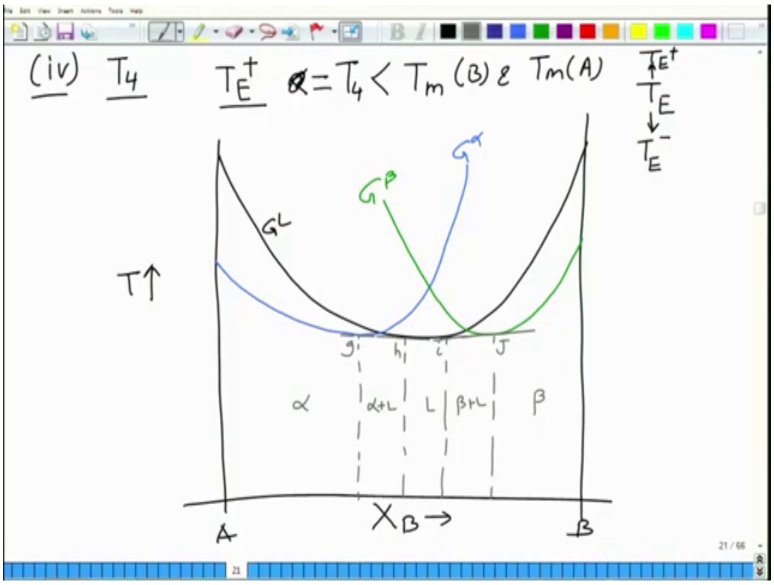

So, this is number 3 and now we come to number four which is temperature of T 4 and at temperature T 4 what happens is that temperature T 4 is lower than T m B and T m A of course,, but it is equal to a temperature called as eutectic temperature. This is a new temperature, which I am introducing just called as eutectic temperature, what happens at this temperature is as follows. So, you have A, you have B, you have X B and this is the temperature T.

So, let us now draw the liquid free energy curve this is a liquid free energy curve and what happens at this point is. So, the blue one is the alpha one. So, that put this. So, which is let us say slightly higher than the sake of clarity let me just make slight changes here the T 4 is only slightly higher than. So, I would say there is a temperature T E. So, let us say we are at T E plus ok. So, TE is the temperature called as eutectic temperature if you are slightly above this you are at T plus and if you are slightly below this you are at temperature called as T E minus.

So, we are at a temperature which is called as T E plus. So, at T E plus what will happen is that the green one. So, we can see that this is G liquid this is G alpha and this is G beta and what you have here is you have a common tangent, which is like this sorry.

So, we have now point; so, we have a b c d e f, now this is point g h i j. So, we have moved from alpha-alpha plus liquid-liquid beta plus liquid and beta. So, what you see now, here is beta alpha have broadened liquid has shrunk and. So, are the two-phase regions beta and liquid which are shrunk which are not and then you reach a point T.

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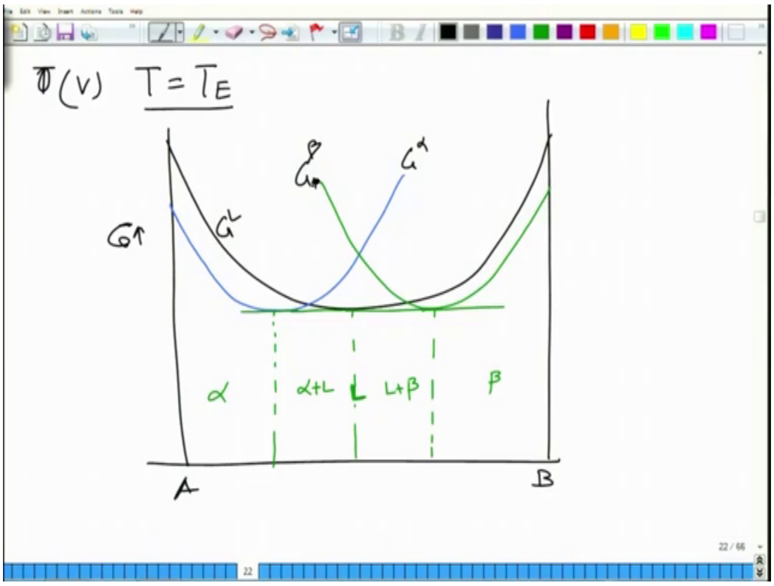

So, we were at number four we will be now at number five which is t is equal to t e. So, at T is equal to T E this is your free energy curve, this is your. So, they, so, actually at T is equal to T E these phases will coexist with each other. So, as a result you will have, so now, you will have liquid alpha-alpha plus liquid liquidliquid is very just a straight line and then, liquid plus beta and beta. So, this is of course, G liquid G alpha and G beta. And then you go to a temperature which is t is equal to te minus the situation is very different then you have a scenario.

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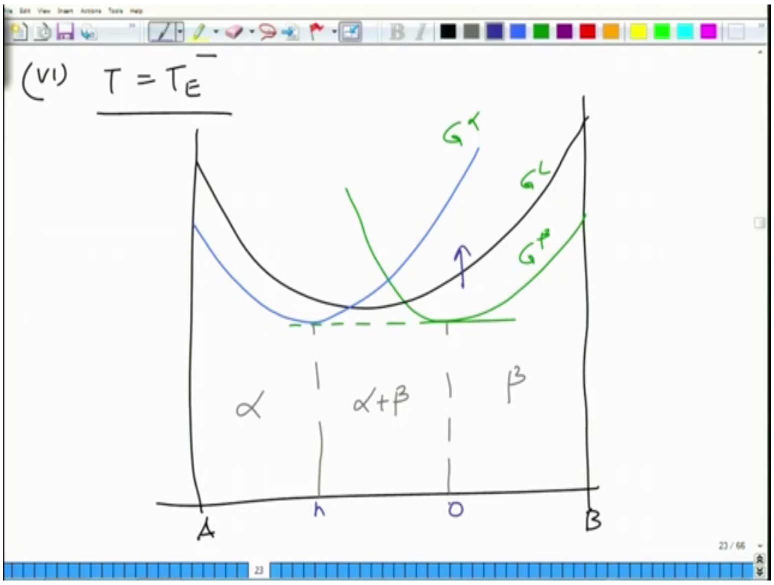

So, now, if you mark these regions, so, this G E basically are fairly similar. So, you have you have this is. So, we had g h i j let us say these are k l m this is x p and at t is equal to t minus scenarios very different scenario is this is your G L and this is your this is G L this is g beta this is g alpha and what we have here is we have A alpha region we have a beta region and we have alpha plus beta, because liquid free energy has now gone above.

So, we can see that, as we gone down as we have gone down in temperature. So, this is T 1 where the solid free energy curve is higher than the liquid. So, we can say in this case, instead of drawing the solid one i should have drawn. So, both the solids which means both either alpha or beta. So, I have not drawn both of them, but both of them will be above. So, if you wanted to draw both of them one would be like this another would be like this ok. So, this would be G alpha this would be G beta they will be above liquid

Now, what we have at temperature T 2 the G alpha and G beta start shifting down they go down this goes up this. So, this is relative movement with respect to each other. So, you can see that as you cross the melting point of a the alpha phase stabilizes slowly, when you further enter into two phase when you further in to enter into lower temperatures below the melting point of b even beta phase starts super starts to form get stabilizes and you have different phases regimes now.

So, again this is lowered this is lowered with respect to, G L, what happened here is at T plus which is just when liquid is about disappear you have alpha beta and liquid free energy curves standing almost at the same level the minima's are almost at the same tangent, but slightly different. So, you still have very thin liquid region, but, but liquid is a, but still there and then you came to a temperature T E where minima's are absolutely AT 1 lines we can draw a common tangent which means liquid only exists at this in at this boundary.

So, this is the liquid boundary and again you have two phase region single phase region in the similar fashion and the moment now you go below this temperature T E liquid phases liquid free energy curve has gone up with respect to solid and liquid, what you stabilize. Now, is a mixture of alpha and beta and this further this goes on until now you are in completely solid phase and this goes on until you decrease. So, if you further decrease a temperature it will further keep evolving

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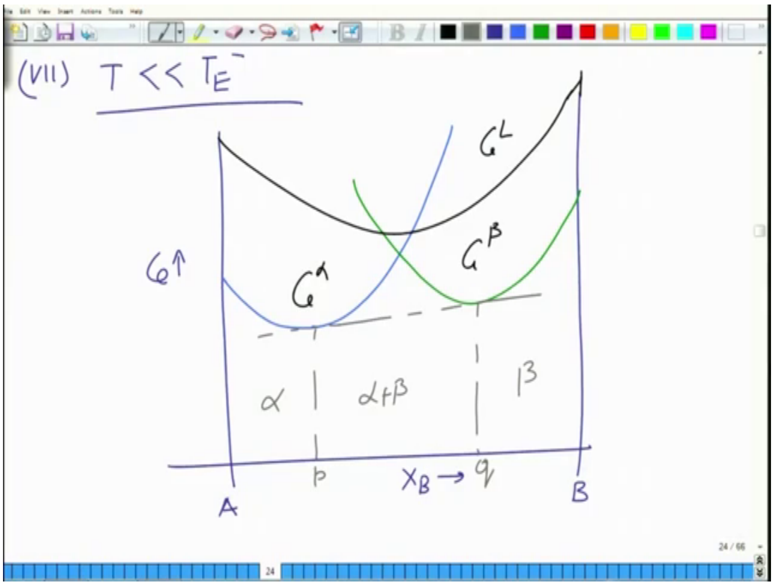

So, now let us draw the phase diagram. So, this was k l m n; let us say o n and o and if you go to even further temperature. Let us say seven T is less than T E minus. So, if you draw the free energy curve then. So, A B your this is g this is XP. So, your solid free energy curve somewhere here liquid free energy curve is somewhere here this is beta sorry and your liquid has gone way up this is gl this is G alpha this is G beta and it can draw a common tangent and these are two points. So, it is a l m n o. So, that say this is p and q. So, now you have alpha, alpha plus beta and beta you only have solid regime.

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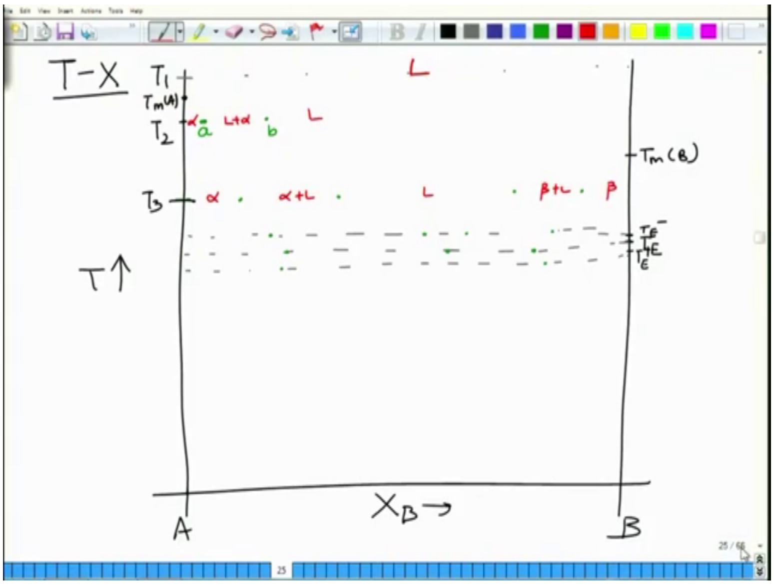

Now, we need to connect the dots. So, when we connect the dots. So, now let us say T X diagram a b you have X B this is temperature start from temperature start from T 1 or liquid.

So, let us say it is all liquid start from T 2. So, this is T 1 sorry all right and then we looked at T 2. So, somewhere here you will have T m of a we are at T 2 at T 2 we had two phase coexistence. So, we had one point here and another point somewhere here which is a and b a b then we were at. So, T 2 had only just go back T 2 had only alpha, alpha plus liquid and liquid then we come to T 3 we had this kind of system ok.

So, we had five regions. So, in this case we had only alpha liquid plus alpha and then liquid and now we are at T 3 and this t m b is somewhere here ok. So, this is T m B. So, now, we are at. So, this temperature is. So, let us say this is first temperature this is second this is the composition and this is other composition. So, we are I have just drawn a little (Refer Slide Time: 28:04) So, let us see oops undo. So, let us say this T m B was somewhere here.

So, this is T m A. So, this is T 2 T m B all right, and now we are at a temperature, where we have it is T 3 somewhere ok. So, this is T 3 and we draw these points again. So, we were at this composition let us say, we were at this composition we were somewhere here and we were somewhere here and then let us say another define a temperature called as T E. So, let us say this is my this is T E. So, at T E minus. So, this is T E minus and this is T E plus. So, just above this temperature and it is T.

So,. So, let us draw three lines. So, in the first case, we were here and here and somewhere here and then here and at this point we were here we were here we were somewhere here and then at this point T E minus we were very close to this point earlier and we had only. So, what we had in the phase regions was. So, this is alpha, alpha plus liquid liquid beta plus liquid beta.

So,, we will finish this in the next class we do not have sufficient time to finish in this lecture it will take about five minutes. So, we will further draw this, completely basically, what we have done is we have drawn free energy compositions of various temperatures, we will put them together to get rid of free energy and plot them a temperature composition is skilled do a phase diagram to draw a phase diagram.

Thank you.