Phase Diagrams in Material Science Engineering
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Lecture - 21
Free energy Composition diagrams for Monotectic systems and Syntactic phase diagram

We are going to finish today the monotectic and syntectic phase diagrams and I have already discussed the phase diagram of monotectic systems and their solidification behaviour of different alloys. So, I am going to today talk about the free energy phase composition diagrams of these typical monotectic phase diagram and subsequently I will discuss about the syntectic phase diagrams.

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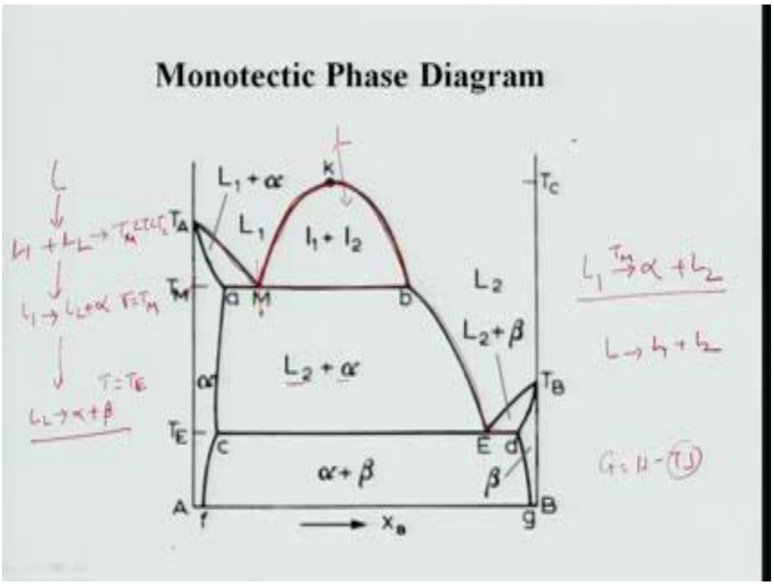

So, let me just go to the board and show you how this free energy phase composition will look like. So, first I will draw the same monotectic phase diagram which I have drawn in the last class.

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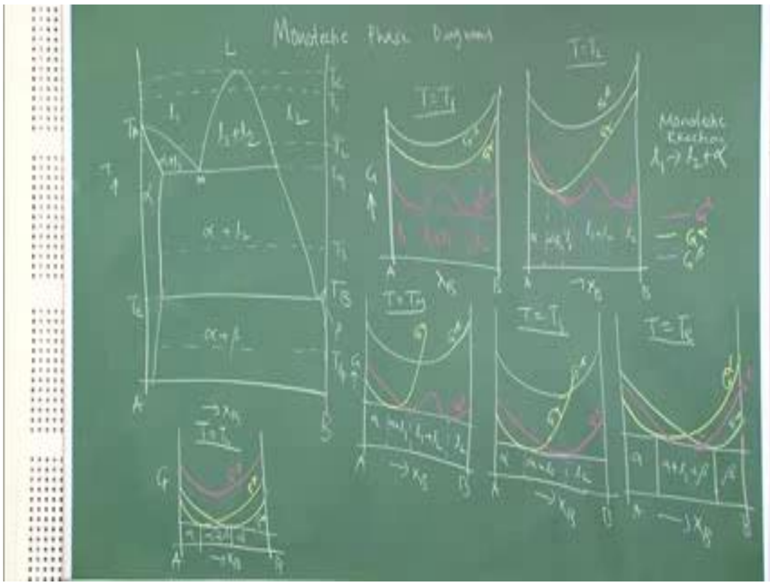

This is for any system A and B as a function of composition temperature. So, this is the melting temperature of pure A, melting temperature of pure B liquid and this is the T c above which single liquid present below, which it separates the 2 liquids alpha plus L 1 alpha plus L 2 and alpha plus beta and this is beta. Now, there is some problem here let me complete it. So, this phase field is beta.

Now, I am going to basically draw the free energy phase composition diagrams. So, G versus x B diagrams at different temperatures. So, let me just draw the temperatures, this is at T 1. So, then this is at T 2, this is T m, T 3, T B and A temperature T 4. So, there are five temperatures T 4. T t this is eutectic temperature at T e, T 3, T m, T 2, T 1 correct. So, as I told you that when you draw the free energy phases composition diagrams we need to consider all the phases.

So, what are the number of phases present here alpha beta L 1 and L 2 and liquid. So, you could understand 1, 2, 3, 4, 5 phases, but basically L 1 L 2 is a decomposition products of the same liquid l. So, we will draw 1 plot or 1 curve for both L 1 and L 2 and we will show how it is possible as you probably seen in all my last plots. This is G this is versus x B and this is at T equal to T 1. So, what happens at T equal to T 1 at T equal to T 1, you see from the A reach end to the B reach end L 1 is stable for a particular composition range then alpha L 1 plus L 2 and then liquid L 2.

So, let us use the different colour chalks today. So, I will use a red for liquid and green for the beta and yellow for the alpha. So, alpha will be above, this is G alpha or rather and then this is beta will be well further above because beta is not stable at all at this temperature and for the liquid this will be like, this is G l. So, as you clearly see this is the relative dispositions of these free energy curves now liquid curves looks like a typical it has a typical hump, it is just like a hump or bump on a road.

This indicates that the liquid yes. So, I draw a common tangent. So, this is L 1 this is L 1 plus L 2 and this is L 2. So, this is at temperature T 1 in which only 2 liquid phase L 1 and L 2 has to above. Now, let us draw it at temperatures at T 2 at temperature T 2, you see here this is temperature T 2 alpha is stable for a small composition range a reach end and alpha plus liquid and then L 1 L 1 plus L 2 and L 2 looks like very complex, but it is not what will happen is that alpha will come down and have a cross over with the liquid curve that is what is going to happen because as you know when there is a 2 phase field 1 solid plus 1 liquid you are going to have crossover of solid and the liquid free energy curves. So, let us do that. So, yellow for the alpha.

So, alpha curve will come down and then go up and beta anyway will be much above. So, let us not even talk about it let us increase this little further. So, that it looks better this is G beta G alpha and liquid curve will have a cross over, but it will remain similar step retain the step like that hump. Now, what I will do I am going to draw a common tangent between this is for the liquid, common tangent between this and this sorry. So, that is tells me, this is alpha, this part alpha free energy it is the lowest position, this is for alpha plus L 1 and I again have to draw this kind of common tangent here between in this what is called in the for the liquid and then I got this.

This tells me this is L 1 plus L 2 L 2 L 1. So, you got it right alpha alpha plus liquid L 1 L 1 L 1 plus L 2 and L 2, but very easily obtainable why all the change between from these to these is that here the alpha free energy curve has come down on the a reach end you can see here at a reach end and have a cross over with the liquid curve I hope that this part is clear now next about 3 curves I will need to draw it here otherwise you will not be able to appreciate all 3 of them I will draw here.

So, this is at temperature T equal to T m temperature T equal to T 3 and temperature T equal to T E correct. So, if possible I will draw T 4 also. So, at T m what happens at T m, actually we have the monotectic reaction. This is T m, you have a monotectic reaction taking place and monotectic reaction is given by L 1 going to L 2 plus alpha, this is the monotectic reaction. I have discussed a lot about this in the last class. So, this is the monotectic reaction at T m this is what is going to happening.

So, what will happen all the 3 phases will co-exist alpha L 2 and L 1, these phase phases will co-exist. Let us draw that beta will not at all be present. So, beta curve will remain above, now alpha is this. So, alpha this is G alpha and this liquid. So, what I do I draw a common tangent between all the 3 then I get into it. So, you can see this is alpha then this is alpha plus L 1 L 1 plus L 2 and L 2 that is what I see alpha plus L 1 L 1 plus L 2 and L 3.

Sometimes you will see the in some of the books they will write the whole region this is a common tangent common tangent between G alpha and G L we will find they will write alpha plus L 1 and L 2 that is also correct. Now, it is clear that how this position of the alpha curve is taking place alpha curve is slowly coming down. Now, at T 3 also is very simple T 3 is basically there is no L 1. So, liquid curve will change. So, let us do that this is at T m, this is at T 3, this is at T 1, this is at T 2. So, what will happen at T 3 again beta will be above I do not need to think about it what will happen I need to draw it you cannot skip the beta curves on the on the diagram.

Now, alpha; obviously, is present here at T 3. So, alpha will be coming like this is G alpha and liquid curve will change the shape, what the shape change will happen this will not be in this kind of shapes. This will have only this cross over and little bit slower slope lower slope. So, as you see there is a cross over between the liquid and alpha curve and this requires you to draw a common tangent common tangent between them and this is alpha plus liquid L 2 and this is L 2 because at this temperature L 1 is not at all stable at T 3.

In fact, below T m L 1 is not stable. So, that is why it is single liquid L 2 which is stable and that is why these free energy curve of the liquid will be having same shape like alpha and beta it will not like a hump anymore that means, it does not have any miscibility present all the miscibility what was present miscibility is present all the miscibility what was there miscibility I dealt to it at the temperature above T m. So, what will happen at T E very simple, T E is same what I have drawn there is alpha alpha plus beta both the phases are present at T E and liquid; obviously, here your beta curve will go down. So, first is alpha sorry alpha alpha is in yellow and beta will be also like that, but before that you should draw the liquid, this is G L and subsequently I draw beta beta is present at the right hand side yes this will be little bit down otherwise common tangent cannot be done.

So, this one these things you should practise then only you will get. There is a common tangent between G alpha, G beta and G l. This is G beta the green colour text and you draw a common tangent here. So, this is alpha alpha plus L 2 plus beta and beta that is what you see here in the T. So, at lower temperature the liquid curve will go above and both alpha and beta will be crossing out there is nothing else will happen. So, that is that is it.

Let me also draw it because some of you may be having problems and T equal to T 4. So, liquid curve will be much above this is G L alpha and beta will make a cross over and you draw a common tangent, sorry colour needs to be changed right, this is alpha and this one is beta and I then I draw a common tangent between them. So, this is alpha alpha plus beta and beta.

So, from this onwards this is same as same as your eutectic phase diagram I hope it is clear. So, if you look at a snapshot if you look at a snapshot of these pictures together then you will be understanding remember I will again write this colour is for liquid and this colour is for alpha and this colour is for beta, this is the colour code. So, if you know that then you can easily understand this that is all for this monotectic reactions.

So, now we will discuss about syntectic reactions and I will quickly go back to the syntectic things syntectic reactions are also you know phase diagrams or syntectic phase diagrams where liquid feasibility is present. So, let us look at it so that this is the typical phase diagram of syntectic reaction anyway.

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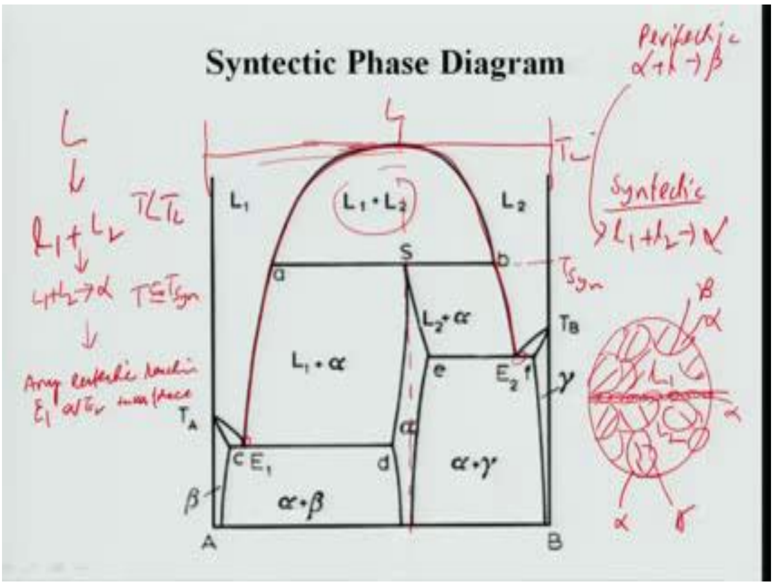

By the way synthetic reaction is similar to like peritectic reaction it is like L 1 plus L 2 giving rise to alpha here giving rise to alpha phase. So, you know the peritectic reaction, this is syntectic reaction, the peritectic reaction is what alpha plus liquid going to beta same like this is a similarity like this is a peritectic reaction. This is a similarity with peritectic reaction monotectic reaction is similar to eutectic reactions in the eutectic phase diagram. On the other hand, syntectic reaction is similar to syntectic reaction.

So, let us look at the phase diagram similar to monotectic phase diagram. It has a dome you can see this is the dome. So, dome is the signature of liquid immiscibility. So, here also there is a T c, this is the T c, you see here T c above which single phase liquid is stable and below this T c this liquid L separate into L plus into. So, L separate into L 1 plus L 2 below T c this happens T less than equal to T c.

Now, at a syntectic reaction, this is a syntectic reaction T syntectic. So, T equal to T syntectic equal to less than syntectic will happen T syntectic that is where L 1 plus L 2 reacts and form L 1 plus L 2 will react and form alpha phase at the syntectic reaction temperature. Now, if you go down, this is how things are happening if you go down nothing else will happen for the syntectic alloy, but depending on the hyposyntectic or hypersyntectic the eutectic reactions can take place there is 2 eutectic reactions on the both sides one is E 1 other is E 2 this is the E 1 this is the E 2.

So, depending on composition any eutectic reaction either E 1 or E 2 take place, nothing else will happen you can also have peritectic reaction on the both the ends I will draw the phase diagram which will have peritectic reactions. Now, to show you because that is not very difficult things to do and while before that let me just clarify to you that there are very few systems which as shows this kind of phase diagrams.

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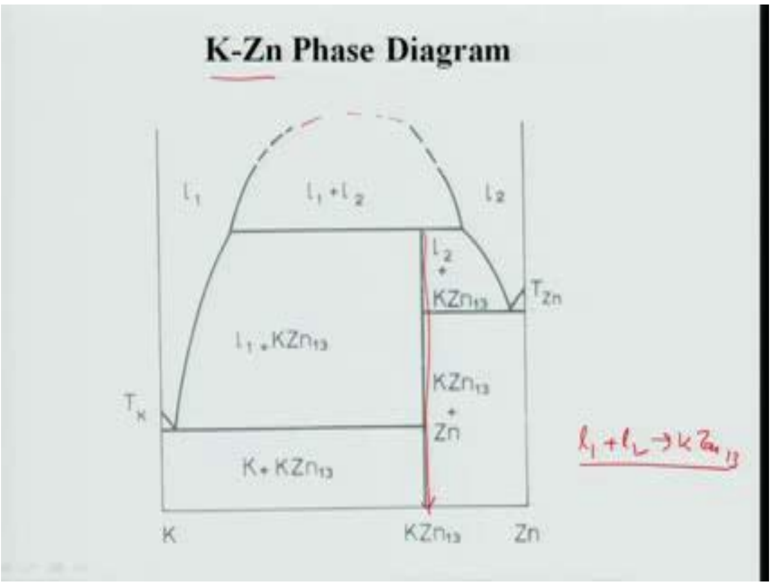

This 1 is a potassium zinc system, which is not at all used in the real applications and you see here this is the dome and then there is a line compound K-Zn 13. It forms by the syntectic reaction K-Zn 13. So, again align compound and these forms this, this we have discussed in the in case of peritectic reactions.

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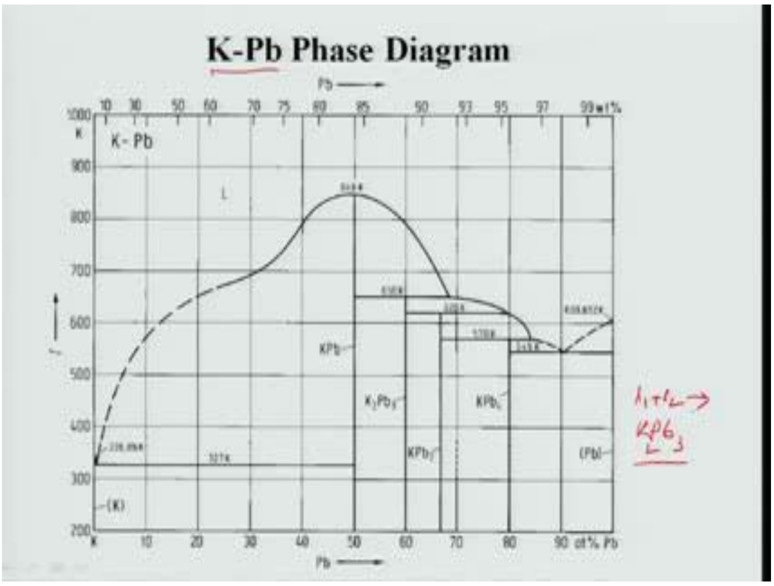

This is a cop potassium lead system there is compounds here I guess K 2 Pb 3 2 Pb 3 is forming by syntectic reactions again here L 1 plus L 2 giving rise to this.

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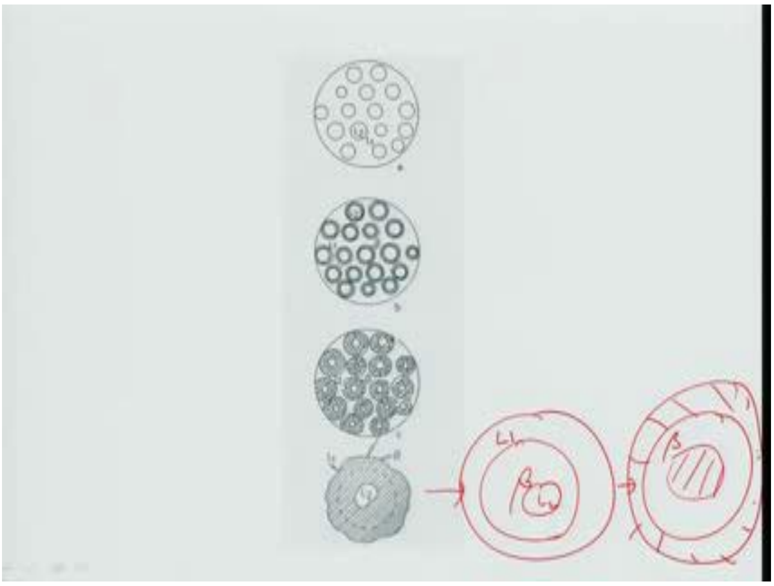

Now, how the things happens in a syntectic reactions. So, before I do that let me go back here and I take this alloy this alloy and I discussed you can see here this alloy and below T c, you will separate into L 1 plus L 2. So, below T c it will have 2 liquids L 1 and L 2 and both of the liquid will have different densities depending on density either L 1 will float or L 2 will float, let us suppose L 2 L 1 floats on L 2. Now, what will happen that the syntectic reaction will happen beta phase alpha phase will form at the interface this is the alpha and there is no further contact between these 2 liquids. So, reaction is going to stop at this at as this at below syntectic temperature and these 2 liquids will undergo nothing else, but these 2 eutectic reactions.

So, you have eutectic reactions forming here between beta and alpha like this and this 1 will have between alpha and gamma alpha and gamma. So, this is alpha and this is gamma and this is alpha, this is beta that is what going to happen and this is exactly shown here you can see here these 2 liquids forms L 1 and L 2 L 2 dispersing L 1 well there may be situations where rapidly solid cool it then it will form a emulsion type of flux then L 1 and L 2 reacts form beta around it and you can see once it form beta grows and finally, L 2 and L 1 as soon as beta forms contact between L 2 L 1 is over. So, L 1 and L 2 both remains and finally, from this you have beta particle and you have a centre you have L 1 and outside you have sorry centre you have L 2 outside L 1 and then this L 2 will undergo eutectic reaction and followed by beta and then you have another eutectic reaction in L 2 that is what I am drawing.

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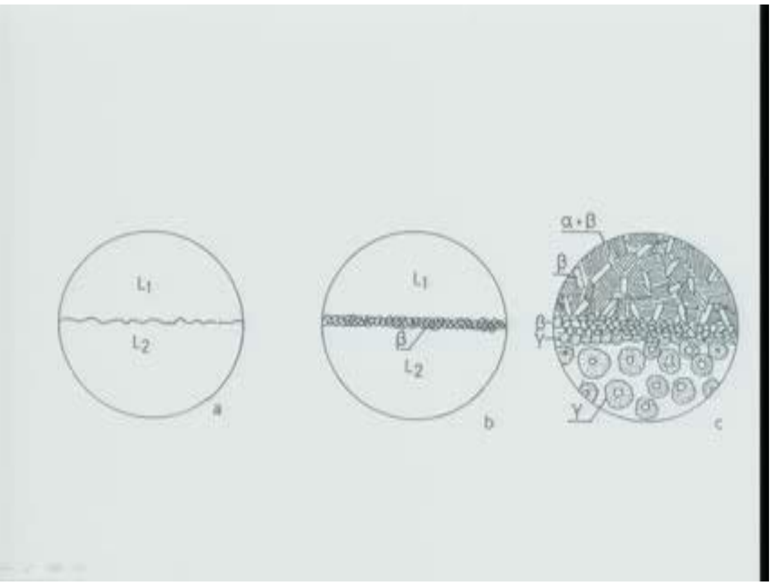

This is what is shown here L 1 and L 2 I just discussed the beta forms and then depending on what kind of things inside it seems there is peritectic reaction at the right side and eutectic reaction on the left side that is why L 1 under goes eutectic reaction and L 2 undergoes peritectic reactions that is what it is not very important phase diagrams, but I will just draw these 2 phase diagrams for your interest and wind up this part of the course.

Let me just remove all the stuff and draw the both the phase diagrams. We are not going to discuss about the free energy composition diagram because this is not a very industrial important alloy system or phase diagram system. So, therefore, this is not interesting enough we are simply you should know it how actually things happen. So, you can see here.

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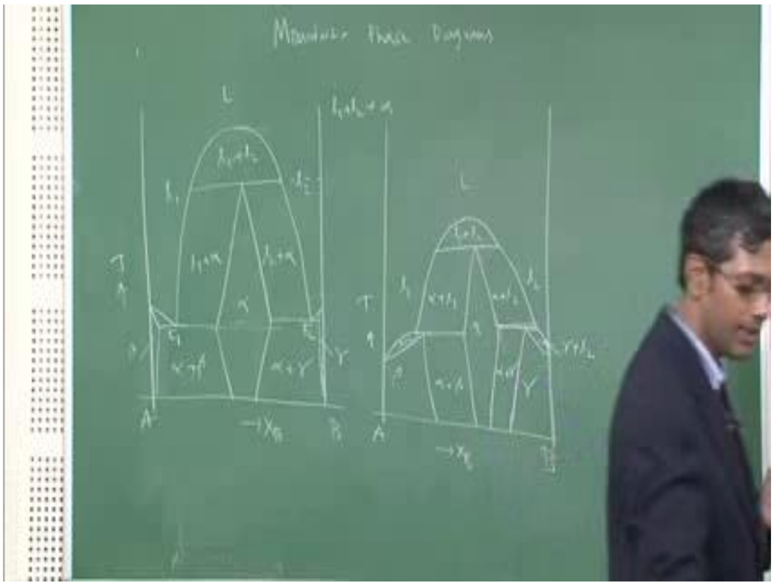

You can see here that this is the phase diagram with eutectic systems. So, you have eutectic right you have eutectic mixture and so this is L l 1 plus L 2 L 1 L 2, this is your alpha, this is your beta, this is your gamma, alpha plus beta alpha plus gamma and this is L 1 plus alpha L 2 plus alpha this is where you have syntectic reaction here syntectic reaction is L 1 plus L 2 giving rise to alpha and eutectic reaction on the both side this is T 1 this is T 2.

Now, you can also have you can also have peritectic reaction on both sides. So, let me just draw it see because sometime I also forget. So, this L l 1 plus L 2 this is alpha this is your alpha this is your beta beta plus L 1 and alpha plus beta this is L 2 alpha plus L 2 alpha plus L 1 this is your this is your this is your gamma gamma plus L 2 and alpha plus gamma. So, you see here the difference between these 2 are nothing, but here you have 2 eutectic reaction on the both sides there you have 2 peritectics on the both sides and you can also have peritectic eutectic mixtures on the both sides, but phase diagram remains almost similar the centre part of it while the syntectic reaction happens.

So, that is what I wanted to you to concentrate rest of the things are not required for these phase diagrams and therefore, we will not discuss further. So, this winds up our discussions on the phase diagrams of liquid systems. Liquid systems means the systems in which your liquid phases is and now, we are going to discuss solid phase diagrams and before that also I should tell you the quasi chemical theory of how this kind of phase diagrams, different types of phase diagrams forms and in the next class I am going to discuss the quasi chemical theory and after that only we will move to the solid state phase diagrams.