Phase Equilibria in Materials (Nature and Properties of Materials - II)

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Lecture – 34
Ternary Phase Diagram

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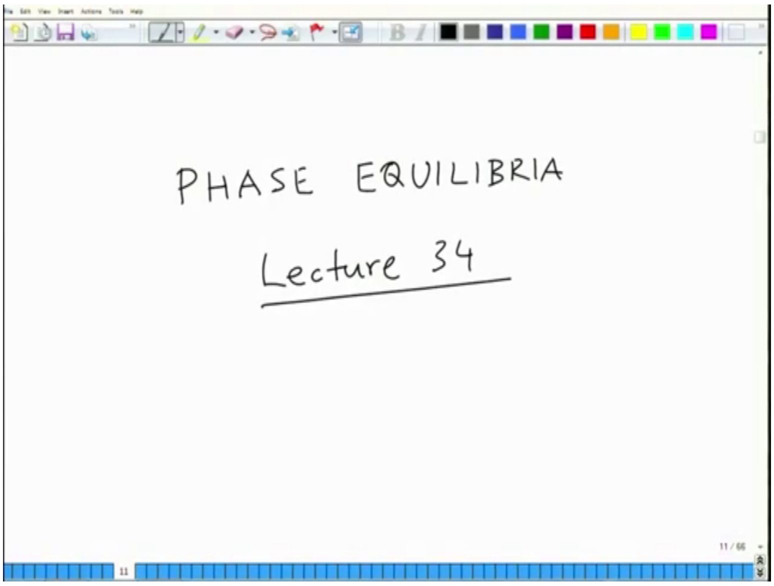

Ok. So now, again we come to a new lecture, lecture number 34 in phase equilibria course. So, we now first go through the recap which is very brief in this case.

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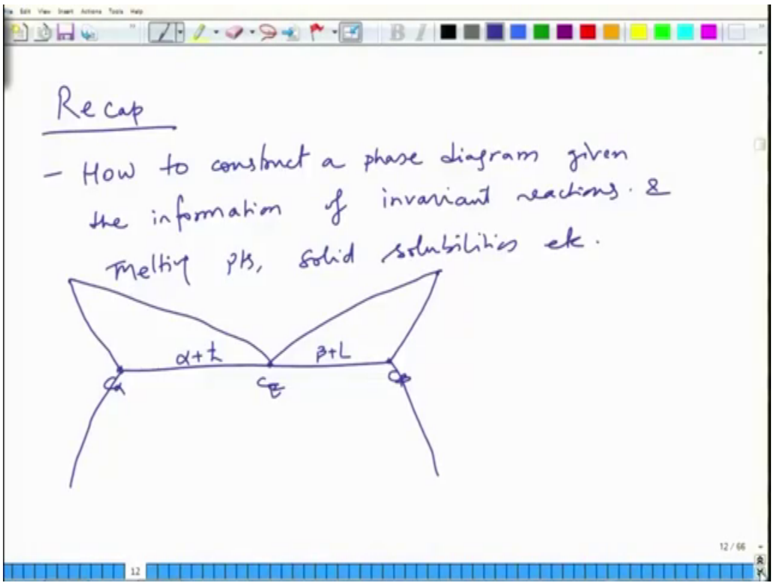

So we learned about, how to construct a phase diagram given the information. So, how to construct a phase diagram given the information of invariant reactions and melting points, solid solubilities etcetera?

So, the first thing in this is to identify the invariant reactions correctly. So, you must identify the reactions, whether they are eutectic in nature and by and large you will find reactions, which are eutectic and peritectic in nature. So, remember the distinction in the eutectic reaction, the liquid composition is in between the 2 solid phases on that end. So, in the eutectic, you will have composition solid phase at the is at the ends, whether liquids in the middle and the peritectic reactions are the way round liquid is on the extreme another solid is on the extreme, which both give rise to a solid whose compositions intermediate. So, these are the major distinctions between the 2 invariant reactions, you should also watch out whether you have solid state reaction or not if you have solid state reaction, it is likely to be eutectoid a very ductile.

Then once you got the hang once, you identify reactions you can mark the reactions with their compositions temperatures and since you know on the eutectic. So, if you have a eutectic phase line you know that between. So, this is C alpha, this is C 0 C e, this is C beta, you know that this phase field is alpha plus liquid this phase field is beta plus liquid. So, connecting the phase boundaries to various terminals. So, you know that this is melting point of one, this is melting of other. So, you know that since beta and liquid have to coexist, the phase boundary should be like this similarly the on this side phase boundary should be like this.

So, you can construct this is how the phase diagram and then you construct this solver's line with respect to the solid solubility in the solid phase, and that is how you construct a phase diagram and phase diagrams can be generally complex. So, it is not that you will have only eutectic phase diagram or you can have part of the phase diagram as eutectic part of the phase diagram can be peritectic, you can have eutectoid reaction the solid state just like you know iron, carbon, steel diagram. So, essentially the idea is to first identify the invariant reactions, the mark the compositions, mark the temperatures and then identify the phase fields and then connect the boundaries and while connecting the boundaries, make sure you do not violate the Gibbs phase rule and thermodynamic principles.

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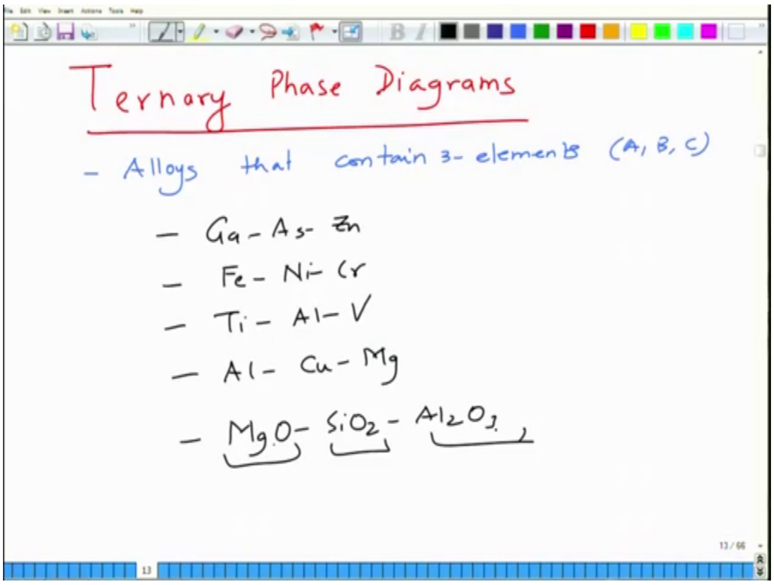

So, this is how you construct a phase diagram, as we saw in the last lecture. In this lecture we will start a new topic in which is a slightly complex topic as well in phase equilibria, which is ternary phase diagrams. And ternary phase diagrams as the name itself suggests is of alloys that contain 3 elements. So, you can have A, B and C and there are many examples, life is not always easy we have many systems with multiple elements. So for example, gallium, arsenic, zinc you can have a phase diagram, is the phase diagram that is possible on iron, nickel and chromium.

So, these three make phase diagram together, you can have titanium, aluminum, vanadium, you can have aluminium, copper, magnesium, aluminium makes an alloy with copper and magnesium both whereas, copper and magnesium themselves are certain reactions, then you have pseudo ternary phase diagrams, you can have phase diagram between Mgo Sio 2 for example, Al 2 0 3.

So, ceramics systems have wherever you have more than 2 3 ceramics present, they tend to make a pseudo binary or pseudo ternary systems. So, this is for example. So, each of these is an element and so Mgo is an element, Sio 2 is an element, Al 2 0 3 is an element it is a bound, it does not Mg and Si and Al 2 0 3 are not present at as free ions represent in the form of oxides and these are the 3, these are taken as 3 components.

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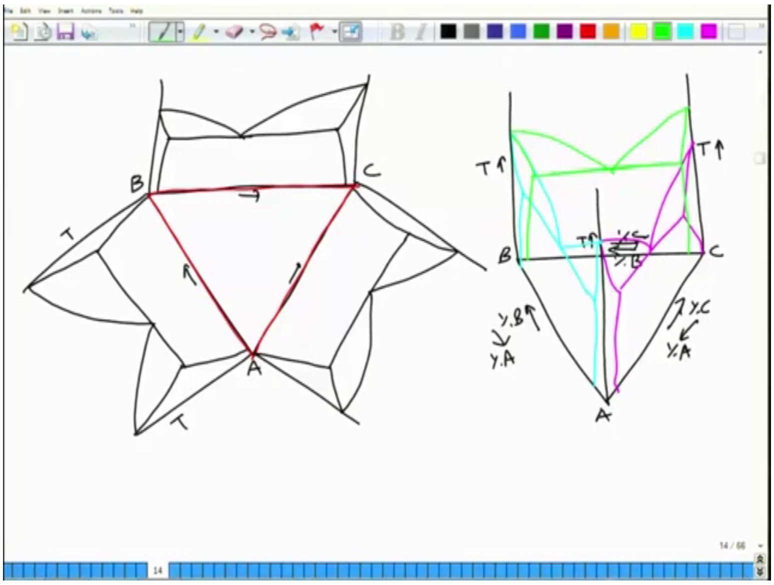

There are multiple systems which show. So, these are only a few examples there are multiple systems, which show phase diagrams essentially, what it means is that you have you have a phase diagram in which let us say, you have a phase diagram like this ok. So, this is let us say between A and B then you have a phase diagram between B and C. Let us say, B and C make another phase diagram to keep the life simple, I have chosen all of them to be eutectic and then you can have another phase diagram between. So, these are all temperature axis and this is composition, this is composition, this is composition then you can have another phase diagram, let us say like this.

So, you can see that you have so this is A B, this is B C, this is C A. So, let us say all 3 of them make eutectic phases, when mixed together and when you mix all 3 of them together. What you need to do is that you need to just fold them together so essentially, the phase diagram will be something like that you have a is triangle the, these are the vertical axis. So, this is temperature and then you have A, B and C and on these axis you will have percentage B on this axis, you will have percentage A, percentage C, percentage A and here you will have percentage C, this is percentage B. So, you are just putting them together and that is how you then construct a phase diagram. So, what it is going to look like is something like this. So in the first case, let us say it was something like this ok.

So, it would not be very accurate because, it is not very easy to draw. In the second case, it would be something like this, let us say and at this point there will be a common melting point because, of it being pure A. Similarly on the back, you will have something like this, this will have a common melting point here and these 3 together will make a surface all 3 mixing mixed surface, there will be a top surface which is like a liquidus surface, it is like the curve, it is not a flat line, it is a curve, 3 dimensional curve and within this you will have different phases now. So, this is what a ternary phase, it is very complex to draw, that is why ternary phase diagram is always presented as a pseudo binary diagram, there are sections that we intersect.

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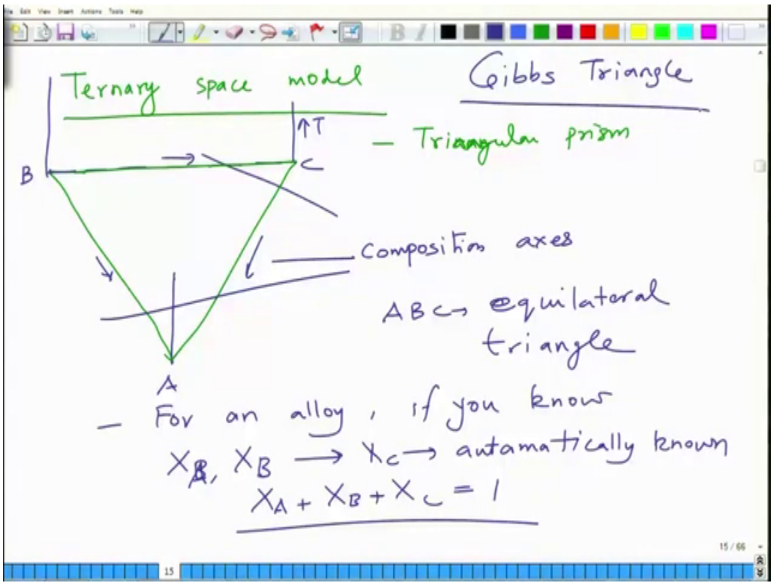

So, we take vertical sections, we take horizontal sections and then we evaluate the composition versus in within the composition and temperature landscape identify various phases. So, since it is a very complex phase diagram, there are certain things that we need to know. So, the ternary space is defined as.

So, we call it ternary first we begin with a ternary space model ok. So, ternary space model is essentially, we draw for the sake of convenience, a equilateral triangle. So, this does not look like a equilateral as such ok. So, this is you can say, it is a triangular, triangular prism like structure. So, when you draw the vertical boundaries, the vertical boundaries will go like this. So, these are temperature axis.

So, and this is the line on the back, it is actually not visible in the front A, B and C. So, it is a triangular prism on y on the on the sides of on the base along the sides of the triangle, you have composition axis and the vertical axis is temperature. So, this is temperature and these 3 are composition axis. So, ABC happens to be a for the sake of convenience equilateral triangle, all right and so for an alloy, if you know X A and X B then X C is already automatically known for a fixed temperature ok. So, because XA plus XB plus XC is equal to 1.

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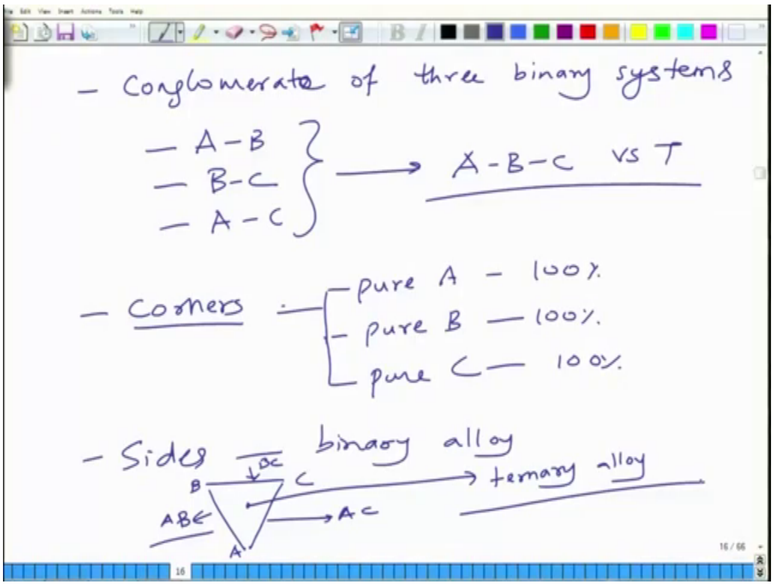

So, law of mass conservation applies. So, you have 2 variables in composition here and the third variable is temperature.

So, basically a ternary system is conglomerate of 3 binary systems. So, the first one is AB, second one is BC and third one is AC and these 3 together give you a phase diagram between A, B and C versus temperature ok. So, 3 binary systems are put together to construct a ternary phase diagram, the corners of this phase diagram, corners of this triangle. So, this is called as a Gibbs triangle ok. So, this triangle is called as Gibbs triangle. So, corners are pure A, pure B and pure C. So, 100 percent A, 100 percent B and 100 percent C and sides basically are binary alloys.

So, if you look at the sides ABC. So, this is AC, this is BC side and this is AB side. So, these are 3 binary systems that you have and within this triangle, what you have is that ternary alloy. So, when you have some compositions within this, this is the ternary alloy, anywhere with within this within this triangle is the ternary alloy.

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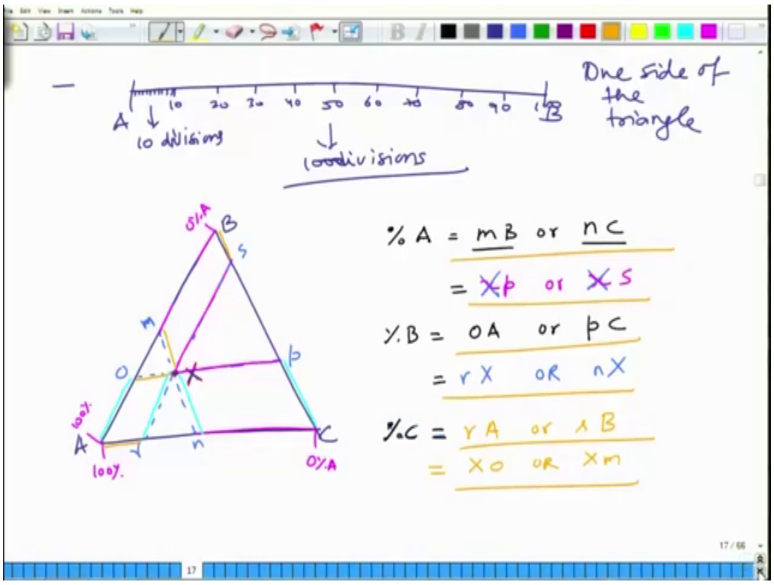

So generally, what you do is that, you take length of each triangle and divide that into 100 parts. So, this is let us say A. So, this is one side of A. So, you divide that in 100 parts. So, you this is 50 and then divide each of these. So, this is 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 and then divide these into 10.

So, this is 10 divisions. So, total you will have about 100 divisions. This is the typical way of doing things; you can have 1000 as well if you if you if you get down to resolution of 0.01, but in most cases it is good enough to draw 10. Now coming to what does it how do you? So, let us say these are triangle ABC. A, B and C within this triangle, let us say you have an alloy whose composition is X ok. So, X composition. So, if you want to determine how much? ABC, it has you draw these horizontal lines with respect to AB, BC and AC. So, in this case OP is the horizontal line with respect to AC parallel to AC, then you have another horizontal line rs, which is parallel to AB and then you have another line, which is mn, this is parallel to BC and at that intersection of these you have alloy X ok.

All right, this is the intersection. So, this line. So, percentage A is given as percentage A is depicted by either mB or nC because, they are equilateral triangle, which is equal to. So, this is let me now use a different color. So, I say this is mB or you can have nC and this is the apex A ok. So basically, you are looking at the intersection of the line nm, which is parallel to BC on the AB and AC axis and the intersection points are mn. So, the length mB or nC are equal and as you move from C towards A or B towards B, B towards A, you measure the composition of. So, A. So, this would be 0 percent A and, this would be 100 percent A, similarly along this line, it would be 0 percent A and here, it would be 100 percent A. So, this is equal to mB or Nc, what else is it equal to? By the equivalence of equivalent, equilateral triangle nC is also equal to px So, it is XP or it is also equal to SX So, X S. So, percentage is equal to mB or Nc, which is also equal to XP, which is this line and it is also equal to this line, they are all equal line.

Similarly, if you take percentage B, percentage B is equal to either OA or PC which is equal to now. So, OA is equal to this line, which is this line and PC is equal to this line. So, I can draw this is equal to I have made. So, this should be XP and XS. So, this is equal to rX or it is equal to nX all right. Similarly, you can have percentage C is now equal to. So, let me just identify, this one this is for B ok, let us use a different color for C. So, percentage C is now determined using the line, which is horizontal to AB axis. So, this is the line rs. So, this length or sorry I am not this length. So, one second. This length is essentially, your percentage C or this length is. So, basically we are saying r A or s B, these are the 2 lengths.

These are equal to XO, this length and this length. So, this is equal to XO or X m, these are the lines, these are the positions, these are the intersections or line lengths, which give you the composition of A, B and C for a given alloy.

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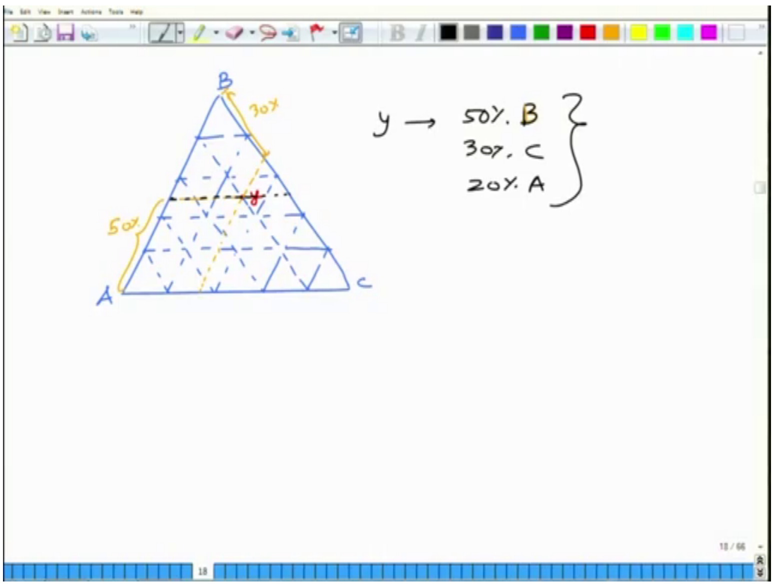

So, first thing first all right. So, let us say, you have an alloy, which is something like this. So let us say, this is A, B and C and I draw this. So, I have here, similarly now you can connect these lines. So, these are basically small, triangles that you have drawn in between let us say, I have an alloy somewhere here. Let us say, I have an alloy somewhere here this alloy let us say is y.

So, to determine the composition of this alloy, I draw parallel lines here. So, I can see that this alloy has what is this length? So, this is 100, we have intervals that a, we have division at every 20 degree. So, this is about 50 ok. So, this alloy has 50 percent B, because I am looking at the line, which is this line and then I look at another line, which is this line. So, this can give me a composition of which is parallel to AB axis, this can give me the C. So if I start from this point to this point, this is about 30 percent. So, I have 50 percent of B, 30 percent of C and what it means is that the alloy has 20 percent of A. So, this is how you determine the composition of alloy in a ternary phase diagram.

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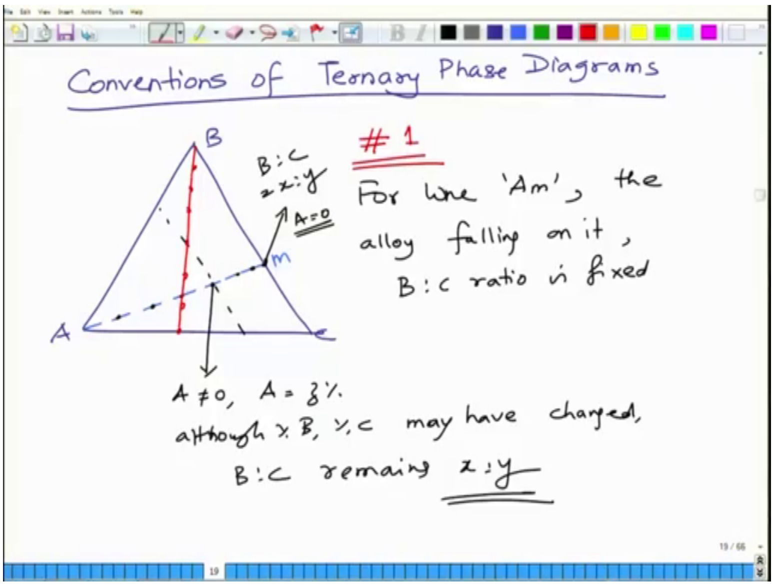

Now where there are let us learn about certain rules in ternary phase diagrams or conventions rather than rules. So, the first thing is, let us say we draw a triangle, we are going to be need drawing a lot of triangles. So, ABC ok. So, when I draw a line from point A to point on a line BC is let us say, this is a point m. So, the first convention that we define is therefore, this line Am for line A m the ratio of alloy. So this for any alloy that falls on this line all right. So, as you move away from A of course, the A content increasing so, but a line Am the alloy is falling on it B to C ratio is fixed. So for example, at this point you will have I do not know x percentage of B with respect to y percentage of BC ok, but since you are at this line there is no A. So, A is equal to 0 at this point.

So, but A is equal to 0 ok. So, the ratio of the 2 is equal to. So, let me just say that A to B ratio is equal to x is to y all right ok, when you are at this point then A is not equal to 0. So, let us say A is equal to z percent ok, but so you would be, now at this point if you draw a horizontal line, you will get the A percentage, but the B and C although the percentages of B and C have changed. So, this is sorry B and C.

So although, the percentages of absolute percentage of BC may have changed the ratio B is to C remains x is to y. The ratio remains the same the percentages might have changed, but ratio remains the same. So, this is the first rule, that if you have an alloy that falls on a line Am, where m is up you start from one vertex of the equilateral triangle and when the line ends at A point on the line in front of that vertex, then any alloy composition that falls on this line will have fixed composition of B and C; in this case B and C, if we drew a line from for example, from here to here.

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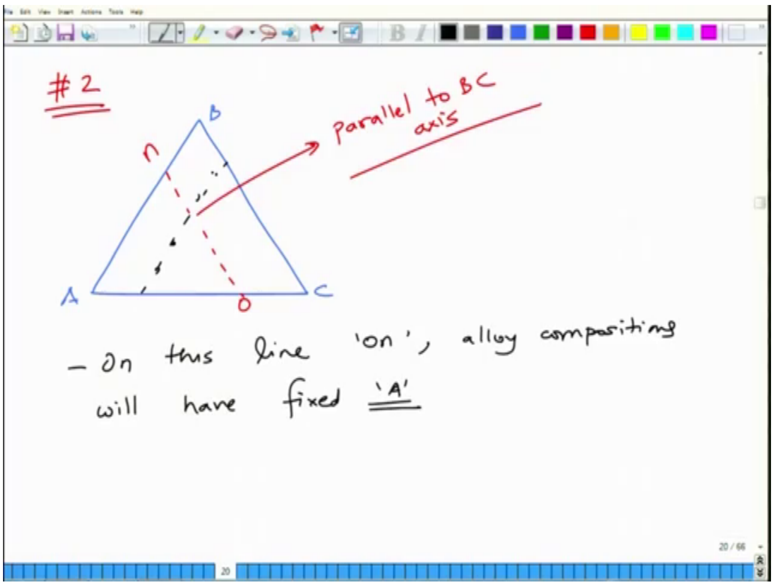

Then any alloy whose composition falls on this line will have a fixed ratio of A and C. So, this is how it. So, this is the first concept of ternary phase diagram the second concept of ternary phase diagram is, if I draw a line o n that is parallel to BC axis. So, line o n which is parallel to BC axis then all the alloy since, this is a line which is parallel to BC axis, which means on this line o n alloys (Refer Time: 26:15) compositions will have fixed A. So, A content will not change for this line ok. So, similarly if you have a line which is parallel to AB, any alloy composition. So, if you draw a line here and you take many composition here, here all of them will have fixed C content ok. So, this is another rule and the third rule that we have is, you have a alloy ABC.

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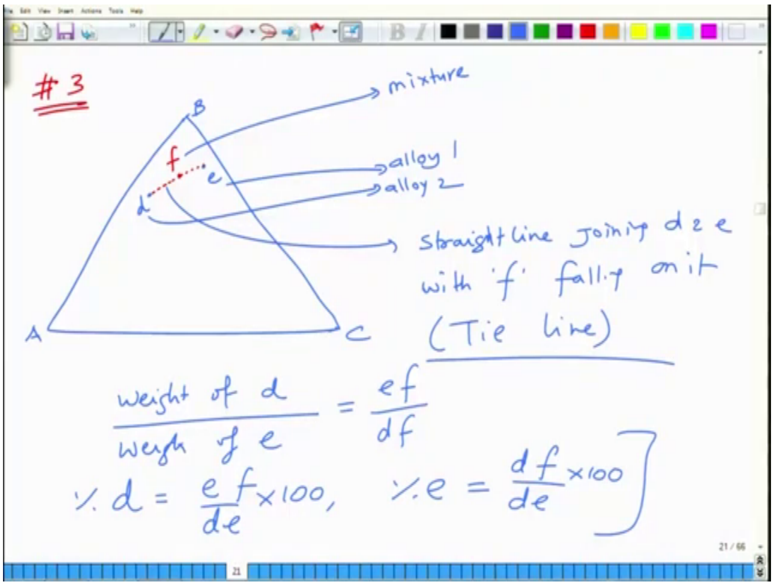

If you have 2 alloys, let us say one whose composition is d another whose composition is e then, the resultant alloy composition will fall on a straight line joining d and e and the alloy will have a composition f. So. So, A and B d and e are alloy 1, this is alloy 2 and this is mixture and this is the straight line that is drawn between point. So, this is straight line joining d and e with f falling on it and this is called as A, this line is called as tie line and accordingly the weight of d divided by weight of e it is given as. So, weight of d is given at as ef and weight of e is given as a df.

So, percentage d in this case is ef divided by de into 100 and percentage e would be equal to de sorry df divided by de into 100, this is basically a lever rule that we are stating that alloy 1 has a percentage. This much ef divided by de in the final alloy and alloy e has a percentage df divided by de in the final alloy. So, this is what this is a few this is are of these are a few rules of ternary phase diagram that, we can discuss in this lecture.

There are few more which are remaining; that we will see in the next class, what we have discussed basically is the ternary diagram landscape in which we have learned how to construct a ternary phase diagram? How to read the phase diagram in terms of composition? And then, what is the meaning of various lines that you can draw in the ternary phase diagrams which allow you to determine the composition of the alloy so let us look at in more detail in the next lecture.

Thank you very much.