Phase Diagrams in Material Science Engineering
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Lecture - 07
Binary Phase Diagram-Isomorphous Diagram

Welcome, today we are going to start a new topic; that is a binary phase diagrams. In the last few lectures, I have discussed about the single component phase diagrams, or what is known as unary phase diagrams.

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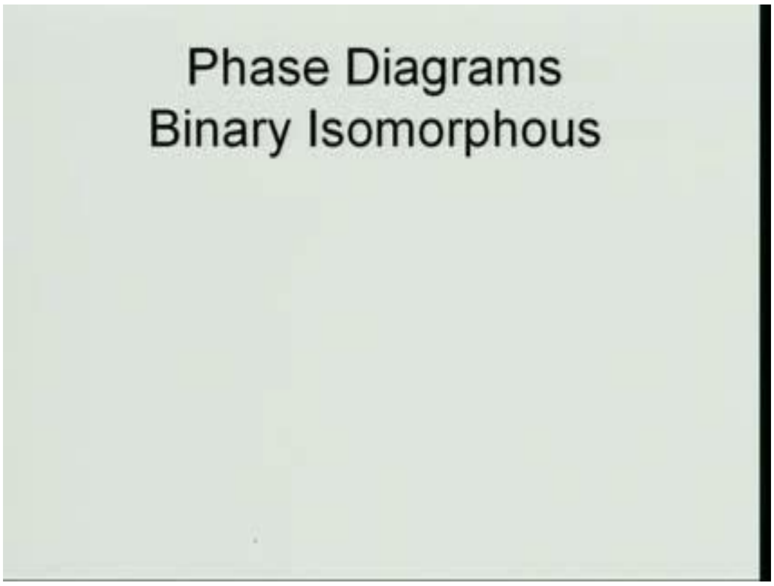

Unary means single component. As a part of that I discussed different phase diagrams, like water, carbon, iron, sulphur or it with carbon dioxide, and we have probably seen that phase diagrams of single component system, consists of two excess pressure and temperature. So, pressure and temperatures are varied, and the different phases for any system are plotted on the diagram. Like let us take consider iron, I know that iron is a very classic system, because iron is the bulk component of steels. So, iron has basically three different phases, at you need one atmospheric pressure, depending on temperature.

The lowest, the room temperature phase is, alpha phase, because a bcc structure with the largest parameter of 2.864 (Refer Time: 01:32) sheet about 912 degree Celsius temperature. These low temperature phase, alpha phase transforms to gamma, and again the gamma phase transforms to another bcc phase with the largest parameter of 2.94

(Refer Time: 01:47) at about 1394 degree Celsius temperature. So, as you know that these phase diagrams, basically has two excess pressure and temperature, because in pure component system, there is no composition variables, but when we talk about binary phase diagrams, there are three variables presents a (Refer Time: 02:12) pressure temperature we have another variables known as composition, and this compositions can be represented in many ways; that we will discuss very neatly, but let us suppose there are three variables pressure temperature and composition, in a binary phase diagram. The first we will see how we can actually generate such a kind of phase diagrams, and we can use them. So, if there are three axis's which are mutually perpendicular to each other pressure, temperature, and composition, then the diagram will be a three dimensional one. Like the one I have seen you here, in this picture, you have z axis is basically pressure, and x axis is the composition, and another y axis is the temperature.

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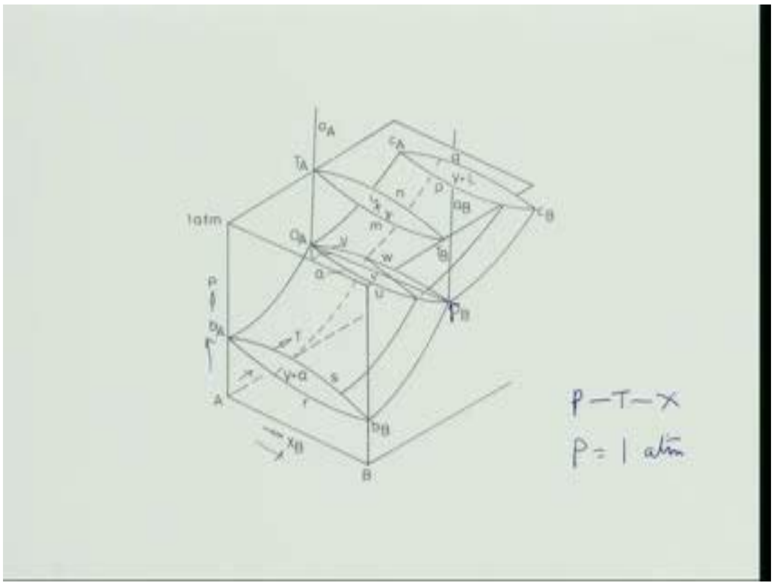

So, as you can see if we plot for the very simple system like a and b, where a and b are the two components, still the phase diagram is very complex. So, first let us discuss that how we can plot the three different complete variables in a system. So, I showed you the pressure, where is along z axis composition along x axis temperature one and y axis. And this diagram shows different regions like vapor solid equilibria, solid liquid equilibria, vapor liquid equilibria. This is solid liquid equilibria, this is solid liquid equilibria, it is solid and liquid, this is vapor liquid and vapor solid. So, all these three equilibria, are represented in the pressure, temperature, composition plot, and if you know, notice very carefully you meteorologist are not good at three dimensional plots; like mathematicians or others. So, we always like to have two dimensional plots; like two axis, how to do that. before I go about it, let me just tell you what is this diagram is about. as I said him here, if you see oa the point oa is basically corresponding to the univariant point of a; that means, this is either melting temperature, or vaporizing temperature of pure a.

Similarly point o b correspond to this point here, correspond to the univariant point of b. it can be anything, melting temperature or vaporizing temperature. and the two phase equilibrias are exist; two phase equilibria means two phase is coexist in this lenticular separations like vapor plusalpha, v plus alpha are l plus alpha or v plus l, where v is the vapor, l is the liquid, alpha is solid phase, we can represent, and then we can connect them to different curves; like here you see b a to o a, and then a it goes above like that. Similarly for along the b p o b b b to o b goes up. So, that is what we actually, we can represent the different phase equilibria in the three dimensional plot, but as you know, such a thing is very cumbersive and complex. So, that is why we can use a very clever approach. What is that? We can always assume very simply, pressure to be constant. If I assume pressure is constant and pressure is one atm one atmospheric pressure, then I can take a section along these. I can take a section at one atmospheric pressure on thesediagram. How do you look like, very simple.

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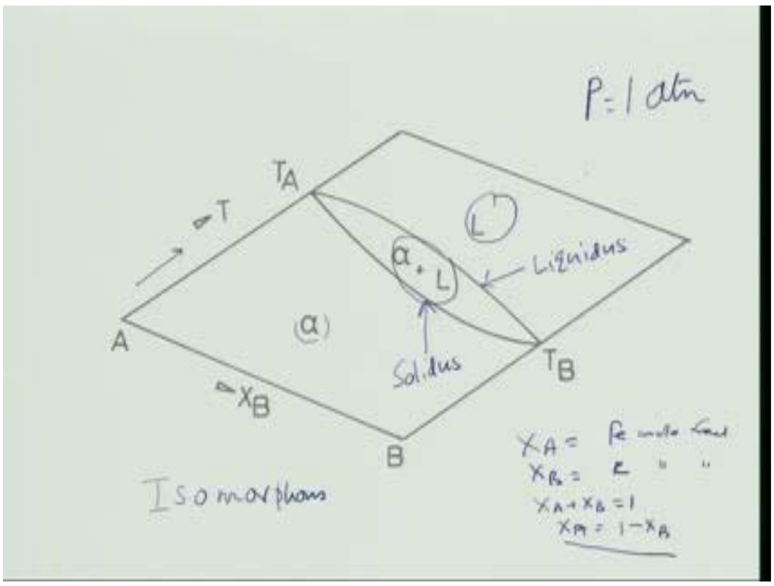

If I take a section at a pressure is equal to one atmospheric pressure atm, then it will look like this; very simple, it will look like a this is temperature axis on the vertical, and horizontal axis is a composition, and there are two components a and b. So, therefore, one composition axis is enough, because if I know one composition other composition can be easily obtained. Before I discuss what is this inside this diagram, let me first do a little bit about composition. How we can different composition of two different components in a system let us first (Refer Time: 06:44).

Let us suppose there are two components a and b, for the simplicity suppose two components are iron and carbon, very simple thing, let us assume that although this will not follow this diagram, but still. So, if I have two components iron and carbon, and if I know that a binary alloy, basically an alloy means mixture of two components together. Suppose binary component binary alloy of iron carbon consisting of x a mole fraction of x a mole fraction of iron, x a mole fraction is iron, Fe mole fraction and x b is this carbon mole fraction. Then I know very simple this is mole fraction therefore, x a plus x b equal to one.

So, if I plot one of these two either xa or xb I can get the other one, how. Suppose if I use x b as a plot, as a independent variable. So, then I can obtain x a is equal to one minus x b. So, that is why I in a binary phase diagram we have one composition axis, because the other one is easily obtainable by this relationship. Now one can actually use more fractions, one can use weight percentage, one can use adding percentage as different units of composition.

How we can actually convert all of these to each other. Let us assume that first time is that, I take different weights of mass of iron carbon, suppose in this case. Suppose I take about eighty percent iron weight percentage, and twenty weight percent of carbon. So, I can actually easily convert this weight percent of iron and weight percent of carbon to atom percentage, or mole percentage by using their atomic weights .how we do it; that is going to easily done. I will show you in the in the board very easily. Suppose I have a component a with 88 percent in alloy, and component b twenty eight percent in a alloy.

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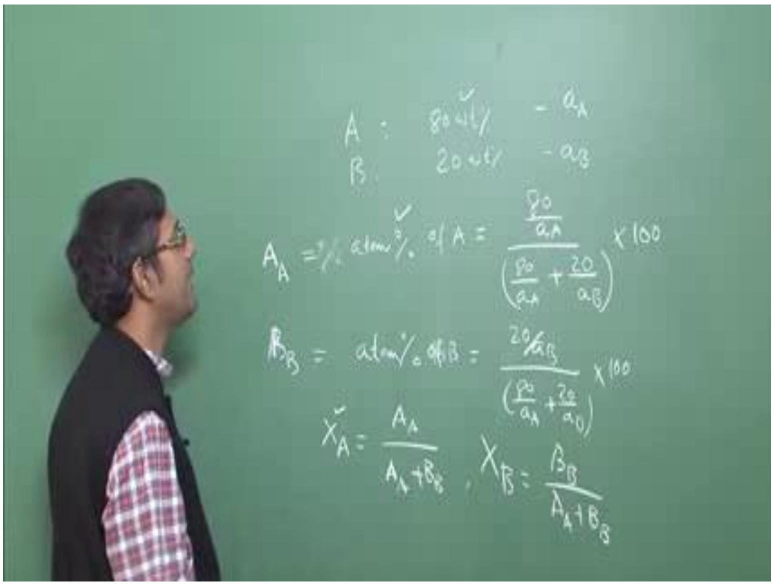

See if I know the atomic weight of a; suppose atomic weight a is aa, atomic weight of b is ab, then I can easily calculate what will be the atomic percentage, percentage atomic or atomic percentage, easily calculate of a is equal to, very easily the weight percent divide by the atomic weight. So, eighty divide by atomic weight of a divide by eighty divide by the atomic weight plus twenty divide by the atomic weight into hundred; that is all.

It will give you a atomic percent of a. similarly atomic percent of b can easily obtained is equal to 20 a b divide by 8 by a a plus 20 by ab into 100; that is how we can be obtained, but we can convert from weight percent to atom percent, and basically if I know the atom percentage, I can convert this to atom percent, suppose this is equal to atom percent of a is equal to a a, atom percent of b is equal to bb. In mole fraction of a is equal to aa divide by aa plus bb please follow my symbols. Similarly, mole fraction of b is equal to bb divide by aa plus bb that. So, we can convert one to others; see if I have weight percent of the different components known to me. I can convert this to atom percentage and from there I can convert into mole fraction very easily.

On the other hand if you know the atom percentage, and if you know the atomic weights, you can convert to weight percentage. This is the very simple rules, a simple mathematical terms. So, in three ways we represent compositions; one is in weight percentage, other one is atom percentage, and third is the mole fraction, or atomic fraction which we are very defined. So, your problems which you will see in your exams can be of, data can be represented any of these three units. So, you have to convert them from one to other, and basically we can solve a simple problem here, which I will tell you.

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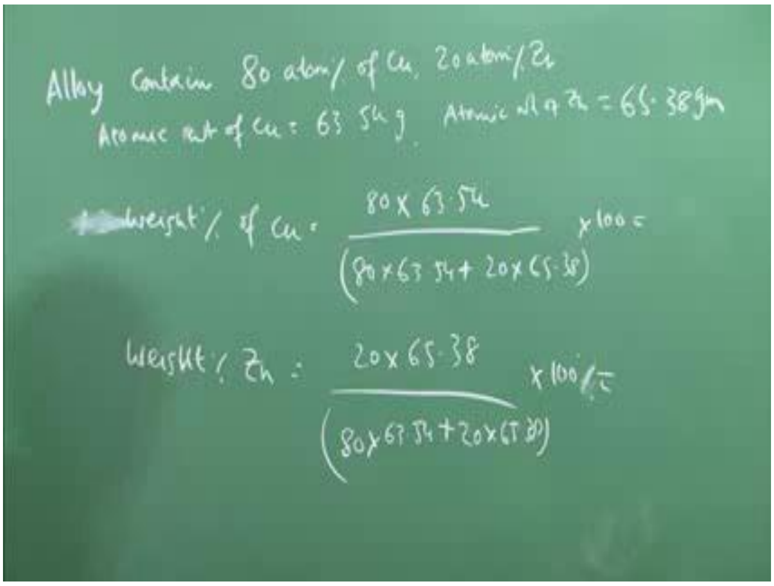

Suppose a alloy, if alloy contains about 80 atom percent of copper, and 20 atom percent of zinc, and you have been asked to convert this data to weight percentage, how did I do. And now we know that the atomic weight of copper is 63.54 grams, and atomic weight of zinc is about 65.38, they are similar. So, how do I convert, from atom percent to weight percentage very simple? So, I simply write weight percent of, these we have to convert into weight percentage from these atomic percent of copper, is equal to eighty into atomic weight of copper, atomic weight of copper is 63.54 divide by 8 into 63.54 plus 20 into 65.38 into 100. Similarly weight percent of zinc is very easy to do, is twenty into atomic weight of zinc 65.38 divide by again the same thing which denominator we have 80 into 63.54 plus 20 into 65.38. You can solve this problem yourself I will give the answer in the next class, that is very easy. Steps are all done; you can solve your problem yourself.

So, you have understood that composition can represented in three ways; atom percentage, weight percentage, or mole fraction. phase diagrams can be of different types; like iron carbon phase diagram carbon (Refer Time: 14:12) in terms of weight percentage, but copper zinc phase diagram you will see this the mole fraction of or the, sorry the composition is spelt in terms of atom percentage, and there are phase diagrams we will see the composition represent as a mole fraction, but thing which I am trying to stress you upon here is that, you must know how to convert one unit to other. If the data are given in weight percentage, you can convert easily to atom percentage by using atomic weights. You have to divide the weight percentage by atomic weight to get the atomic percentage, and from atomic weight, atomic percentage you can convert to mole fraction very easily. So, I hope it is clear.

Now, let us get back to these diagram which is a section of this three dimension diagram at one atmospheric pressure, and these diagram is shown here in this in this slide, where you see there are three zones one is known as l, l it correspond to liquid other one is known alpha, alpha correspond solid phase, and there is a zone lenticular or lens separate zone, known as alpha plus liquid.

There are three zones, before I go into this diagram in detail I like to tell you that binary phase diagrams can be of different types, and we are going to do well, a lot of time on these different types of binary phase diagrams. starting with Isomorphous system the eutectic peritectic phonotactic and others, but. So, in all these binary phase diagrams, whether it is a isomorphous system, eutectic system peritectic system any other the axis will remain same; that is what I want to spend time on that; x axis will be always composition like (Refer Time: 16:06) depended by either of these three units, and y axis will be always temperature axis. what is going to change is the thing which is inside, thing which is plotted and this is what you should get into a mind very clearly, then binary phase diagram is easy to digest, very easy to digest.

Once you know that what is there inside and how to read it, then seventy percent of your job is done, as a scientist, as a engineer, as a software engineer wherever you are working. So, that is what we are going to discuss in detail. Now let us consider system which is known as isomorphous, what is known as isomorphous I will explain to you. Isomorphous, because the first binary phase diagram which I am going to discuss is known as isomorphous phase diagram.

Isomorphous means; iso means same, morphous means same morphology; obviously, this different phase diagrams will depend uponinteraction between a and b a two components there. suppose the two components as such that they are miscible in any proportion, in both in solid and liquid then the phase diagram which forms is known as isomorphous phase diagram. What is the meaning of miscible in all proportions both in solid and liquid state? Suppose if I take water and sugar. I add sugar into water it will get mixed up, but it to you cannot keep on adding sugar into water and mix it up, beyond the saturation limit, sugar will not get mixed into water. So, therefore, that is not completely miscible in system in all proportions

Similarly if I take a solid, solid; obviously, tends to the metal. Suppose if I take iron, which element if I add into iron will be miscible all throughout, very difficult answer, very difficult to answer this question. So, that means, that if I take two elements a and b and if they are miscible in all proportions, both in solid and liquid you call as isomorphous system; that means, if I take 90 percent iron, 10 percent of suppose something else, 10 percent of say manganese, because iron manganese is very interesting phase diagram.

If I take that will be miscible nicely, if I take 80 percent manganese 20 percent iron actually miscible. Similarly if I take 50 percentage 50 percentage of iron and 50 percentage of manganese it is also miscible in both solid and liquid. So, if they are miscible in all proportions, all proportion means, starting from one percent of iron to 100 percent iron, or vice versa weight for the manganese 90 percent 99 percent iron to 1 percent manganese, in all proportion they are miscible then we form, what is known as isomorphous system.

We will later discuss which are the systems which will form isomorphous system later on is in (Refer Time: 19:21) rules, but let us for the time sake, let us assume that we have a system, binary system with two components a b, which are miscible in all proportion both in solid and liquid state, then only you will have these phase diagram, phase (Refer Time: 19:36) diagram means we have a region of solid alpha, region of liquid which are separated by region of alpha plus liquid. The boundaries between alpha plus liquid with the alpha.

There are two boundaries you see here; one is the lower boundary one is the upper boundary. The boundary here this one is known as solidus, on the other hand the upper boundary, the boundary between liquid and the alpha plus liquid in known as liquidus. Please remember these words, these are very sacrosanct, you cannot change. So, the lower boundary is solidus, upper boundary is liquidus so; that means, what is the meaning of that, physically it means you have if you are below the temperature, any temperature below the solidus, you will have all this fully solid, no liquid will be present. And if you are sitting any where above this liqudus, then you will have all the liquid, in between these two only you have solid plus liquid coexist.

So, this is what is the basically the prime features of isomorphous phase diagrams, and the region of solid plus liquid, is looks like a lens, any lens if you take it looks like a lens. So, therefore, we have three regions solid liquid and solid plus liquid, and these three regions are bounded by two curves solidus and liquidus.

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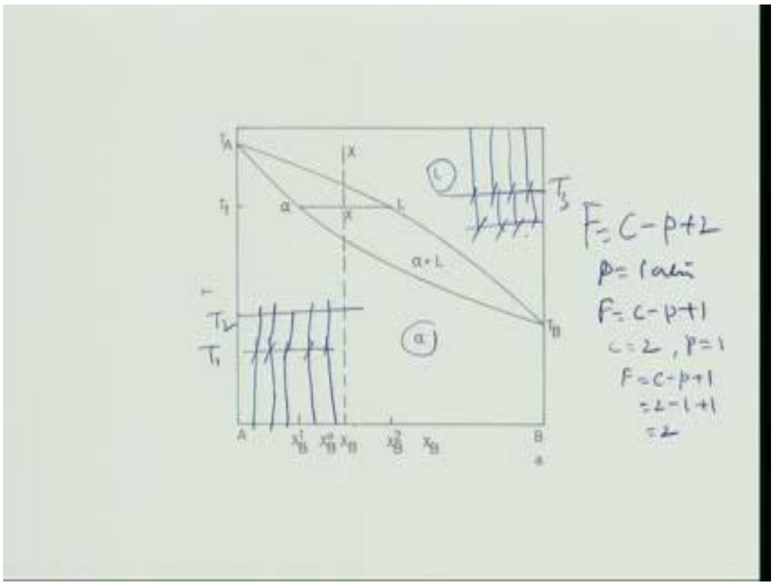

This is again plotted here nicely and I am going to discuss little bit more in details. It will be more in details. As you see here again we have liquid solid alpha, why do we use alpha here for solid. You know in all solid phases in phase diagrams, I told you earlier also and represented by Greek letters, and Greek letters starts with alpha, it goes on beta gamma delta many others. So, as the number of phase solid phase will increase, we have to use different symbols; Greek symbols, only Greek symbols are utilized no other symbols. This is very well defined, you cannot change that.

So, you if you see here again the same phase diagram temperature versus composition axis plotted, and we have three regions liquid alpha and alpha plus liquid now. So, when we have a single co region alpha or whenever single (Refer Time: 22:31) region liquid, it is very easy to apply the phase do. Let us do that first we know phase rule is given as c minus p plus two where f is the degrees of freedom. So, here pressure is constant we have kept P is pressure is one atmosphere. So, that way f will be equal to c minus p plus one, because two corresponding temperature and pressure, pressure is not varying here. So, this is the case.

Now, I will just explain in this class how to apply the phase rule in the single phase (Refer Time: 23:07) region like liquid and alpha. So, let us first do that, a single (Refer Time: 23:13) region, here c is the component is two because they are two components a and b, and in a single pressure is p p is 1, because your (Refer Time: 23:21) is 1. So, f is equal to c minus p plus 1; that is equal to 2 minus 1 plus 1 is equal to 2. so; that means, there is a freedom equal to 2. What is the meaning of that? Let us select the temperature in a single pressure t 1. Now I can have many compositions, you can draw this composition, what is this many such that, where alpha is stable. Similarly if I take a different temperature t 2 alpha is also stable at many compositions.

So; that means, I can have vary both temperature and the composition simultaneously, still alpha will be remaining alpha stable, no change. similarly if I take a liquid, if I consider temperature t t 3 here, forget about these t 1 t a, t 3 here, and I can have different compositions where liquid is stable if I change the temperature, even our liquid stable at different compositions.

So that means, I can have a both temperature and composition simultaneously, still I will not change the liquid phase liquid phase will remain stable. this is the meaning of f equal to 2; that means, I have 2 degrees of freedom I have 2 handles again change them simultaneously, but I will not change the phase, phase will remain either liquid or alpha whatever or whichever single region you are in. I hope this is very clear, because this is what very important, very important things to apply phase rule, this is the way we have to apply. in the books also they will describe you very nicely. So, please read the books.

In the next class I will discuss how to apply it in the 2 phase region alpha plus liquid, and how to use other diagrams other things to discuss about that.