Experimental Physics-I

Prof. Amal Kumar Das
Department of Physics
Indian Institute of Technology, Kharagpur

Lecture – 13
Basic Analysis (Contd.)

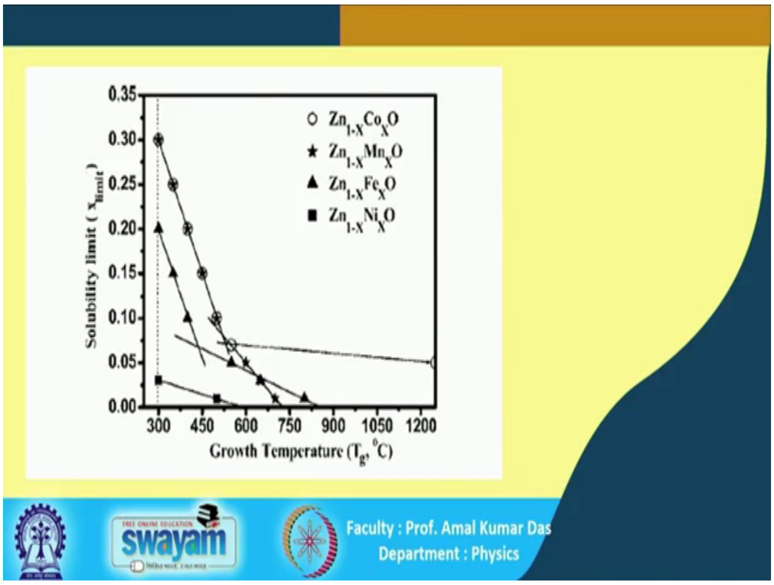
So, I will continue discussion on graph plotting.

(Refer Slide Time: 00:27)

As well as today I will discuss about the calibration. So, graph plotting I have discussed that how to plot graph and a graph paper. So, this is the basically number one plotting and same way actually we use the graphics to plot the graph. So, today I will discuss what is the advantage we can get from graph plotting as well as how we can extract the information from the from the graph.

So, actually this on the same graph sometimes will plot few sets of data. So, from that one can compare with one with the other and directly we can see this change of how they are different. So, just I will show I have one plot from my left I will show you this basically for comparison this type of graph we plot.

(Refer Slide Time: 01:50)



So, here you forget what is this zinc, cobalt, oxide etcetera this you forget this is just one experiment we did on this and I plot it. So, just I copied it and taken here to show you. So, basically just here we can see this axis is x axis is growth temperature and y axis is solubility limit.

So, this is similar as say what is the solubility limit of sugar in water. Now, that if you want to study at different temperature. So, solubility of sugar in water it will be different at different temperatures ok. So, if we take this example so, this whatever here I am showing this similar to that. So, this growth temperature whatever this say it is a water temperature and this whatever here am showing this four types of sample.

So, one you can take as a so this four type of sample I have taken so, you can take one is salt, another is sugar etcetera. So, four types of solid you can take and put in water. And this water you are keeping at different temperature finding out the solubility of different solids. So, here these four types of solids we have taken and we are finding out the solubility limit at different temperature.

So, solubility will maximum how much the solid can be resolved in the in the liquid so, that we have plot it. So, this is say there are four plots and in this type of graph basically we use separate different regions different symbols. So, one symbol we are using this circle, then this star, then triangle, this then square ok. So, if you want to compare similar type of similar type of data ok.

So, then we put them in we plot them in same graph and for that you have to use the different symbol. So, that one can understand; one can understand this that this which this which lines or this sets of data for which sample and that also you have to mention here which we have mentioned this circle for this zinc cobalt oxide then star for zinc manganese oxide. So, in your case whatever example I gave you. So, that we have to write this circle for sugar circle star for say salt etcetera ok.

So, this graph as I showed this. So, graph paper is used or plotting graph is used to compare the single sets of data and how the solubility limit here is changing for different samples and directly you can compare. You can compare that these are solubility limit of this solubility limit of this one this here zinc nickel oxide. So, basically in zinc oxide we have put in different transition methods so, cobalt manganese, iron and nickel.

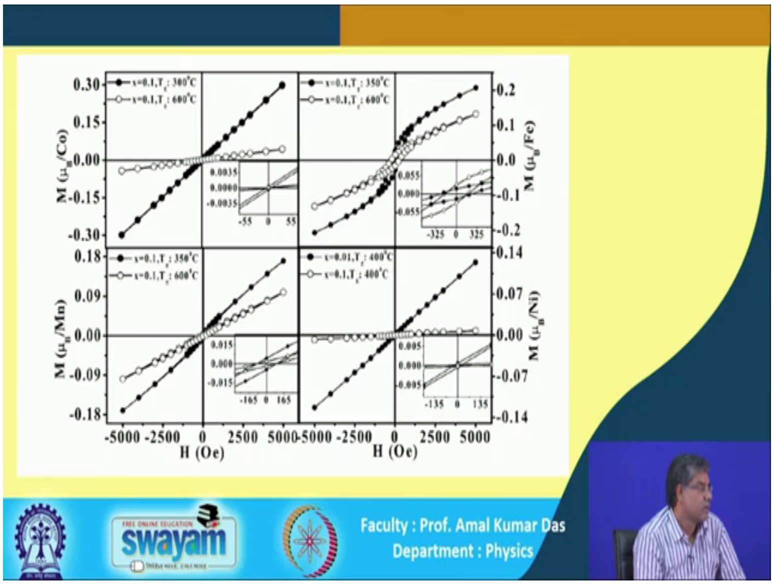
So, how much cup of cobalt can be dissolved in zinc oxide. It is a zinc oxide you can you can think that it is a it is the water and cobalt, manganese, irons etcetera you can think as a sugar of these the salt etcetera. So, this your solubility limit of this elements should be we are trying to find out at different temperatures ok.

So, from here directly we can compare of a solubility limit of mutual is the minimum and then this is I think about this is 3 percent and this one is for this one is for iron. So, it is a 20 percent and star one is manganese star one is manganese.

So, this both manganese and this cobalt both sorry definitely this is 30 percent and with temperature half its solubility limit is changing for different elements that directly one can compare. Now, this four sets of data you have four sets of data on a table. So, from table it is difficult to interpret, but if you plot them so, it is very easy to compare. So, this is the advantage of this plotting graph and how and one has to decide that how many issues represent this data or a graph.

So, if you plot again you will define four graph paper for four sets of data so, they will again it will be difficult to compare. So, if you put those on a same graph using different symbols ok. So, easily one can follow this four sets of data and this is the this difference among them is very is visible and is very clear. So, this is the way we can interpret data using graph paper of plotting graph.

(Refer Slide Time: 08:30)



So, next I will show this another type of plots here again I have basically four plots; this is one plots then this is another plots so, this third one and this is fourth one ok. Here what we have plotted here you can see we have plotted basically magnetization as a function of magnetic field. Magnetization as a function of magnetic field so, this also again data from our lab and that just we have taken from our paper.

So, this we have measured in our laboratory. So, magnetic material so, basically this material was I think it was I think it is a ferrite metal what about the metal forget it. But, we have measured the magnetization of the magnetic material as a function of magnetic field. And here two plots you are seeing that is basically same sample, but this sample was prepared at different temperature what was at 300 degree centigrade and other is 600 degree centigrade where other you say here 350 degree centigrade 650.

So, two types of sample same sample, but it is annealed it prepared it was prepared in to two temperature. Now, we want to see the difference what is the difference in magnetic property of this two both temperature. So, here we have plotted these two sets of data. So, you can see one is close this one is solids circular another is open circle. So, here in all this cases you can see there is a difference. So, here direct again you are plotting these two sets of data in same graph.

Here basically you can think that this is a this is a one graph this is second third fourth graph, but again we have we have plotted on same graph paper and this graph paper was divided into four parts. So, each part is used for a for a plotting of two sets of data. So, here also another advantage that all of them you are putting on a same graph, but this time it is slight different that instead of the paper you have used one graph paper.

And that in that so, in that graph paper you have you have taken this four regions for plotting four different samples and for each samples again two sets of data. So, that is what that is what you have present lot of data in a same graph paper. So, here one is that for comparison how many sets of data we are plotting on the same graph this is one information second information is that in each graph you see we have another small portion this another graph you can see another plot you can see this basically we tell is the inset we tell this is the inset here basically from this graph.

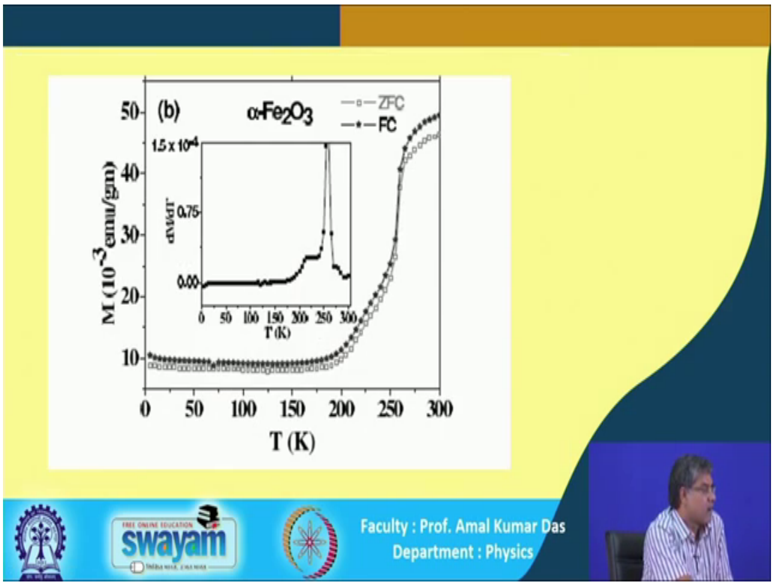
So, ferromagnetic material generally ferromagnetic material you get MH loop hysteresis loop hysteresis loop from hysteresis loop what you want to know? You want to know what is the coercivity what is the remanent magnetization what is the saturation magnetization. So, this information we want to know from this graph, but in all cases problem is it loops it is not a hysteresis loop just a line.

So, that is because of this scale you know this range of this field is huge and because of that this these are these all data's squeezed. So, basically now you have to expand you have to magnify it to see whether they are passing through the 0 or they have some their they have they are cutting x axis and y axis at different points rather than the 0. So, that points is basically will tell you about the coercivity and the remanent magnetization.

So, for so, you have to magnify this portion ok. So, that is what we have done in here. So, here range is minus 5000 to plus 5000 more than 5000. So, here just minus 55 to plus 55 means, very small portion this portion here magnified. So, this magnified portion here you have plotted here magnified portion you have plot it here and you can see clearly no it is not single line it is not a line passing through the 0, it is not a line passing through the 0, but they are crossing they are cutting this y axis at this point and x axis at this point. So, this is the coercivity. So, and this is the remanent magnetization. So, you can find out the value of this coercivity or remanent magnetization.

So, it is not here important this how to find out coercivity or remanent magnetization, but this just for example, I have taken. So, this is the way to find out the information from the from the plotting graph and just plotting graph is not enough. So, you have to you have to know how to extract the information and for that what you have to do. So, this is another type of use of the graph paper to extract the information.

(Refer Slide Time: 15:37)



So, next another example I have taken here so, here what we have plot it? So, here basically this is again from our lab this data we have measured the magnetization of a magnetic material as a function of temperature it will vary that temperature and measure the magnetization and then we have plot it here. So, so, here what we have seen this curve this is like this.

We will change of magnetization with temperature if we start from higher temperature 300 Kelvin is basically the room temperature. So, then this magnetization is around 45 unit per gram whatever that value. So, now, it is it is changing suddenly drops you know then suddenly drops then it changes like this changes like this then again it is become flat ok. So, this type of change so, this magnetization as a function of temperature this is accelerating due to find out the transition temperature you know.

Generally in biotic material there is the transition temperature, below the transition temperature it may be the ferromagnetic or anti ferromagnetic and above the transition temperature it is ferromagnetic. So, what is the transition temperature if you want to find out.

So, you know this ferromagnetic material this it has in paramagnetic p phase it is the higher magnetization and this magnetization changes with temperature it decreases and then its suddenly drops towards the towards the 0 ok. So, then when this it so, this so, this basically what is happening the ferromagnetic phase it is getting changed to the paramagnetic phase. So, at what temperature this basically this change occurs of this change is completed. So, that if you can find out from the change of curvature of the curve.

So, is so, there is a inflection point inflection point where basically this curvature changes. So, here you can see this is one curvature and this is the another other side curvature. So, this curvature here like this ok. So, radius of curvature is this and here this another curvature this another curvature here another curvature here is another curvature. So, here it seems as so, there is basically slope there is a certain points it is called inflection points and there this slope changes sudden change of slopes from positive slopes to negative slopes.

So, so, this point is taken as a this inflection point is taken as a transition temperature ok. So, so, one can guess that here there is a transition here and there is a small some other kind of phenomena here. So, so, how to find out this transition temperature? So, generally from here you can tell this is the point this is the point 250 around 250 or 260 is the transition temperature.

So, from here also generally we take this middle point and tell this is corresponding this temperature is the transition temperature but if you want to find out accurately and you know that this that will be of transition temperature where the slope is suddenly changing.

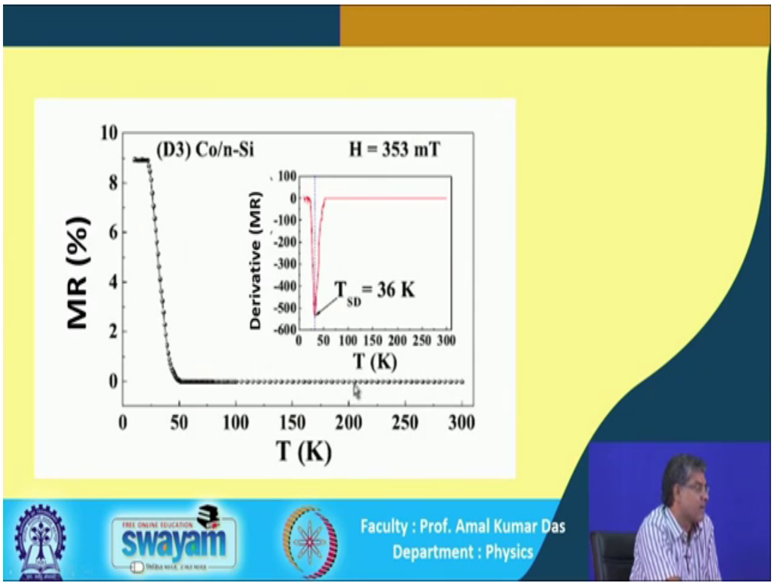
So, slope means see this dM by dT right that differentiation of magnetization with respect to temperature. So, dM by dT. So, that is slope. So, now, if I plot dM by dT versus T then basically I am plotting change of plotting slope as a function of temperature. So, how slope is changing as a function of temperature so, this we have plotted here. So, dM by dT as a function of temperature. Now, here you can see this is the change of slope is see this as I have told from positive to negative or negative to positive this change sudden change that the inflection point at the graph size and paper.

So, here this change slope change is prominent here it is difficult to tell the exact point where this slope changes means sign of the slope changes, but from here clearly you can see this is the here these changes. And this temperature it is the around accurately you can find out is this 250 or 255 or 252 accurately you can find out ok.

So, this is another tricks we apply to find out the information. So, in this case we want to find out the transition temperature and we know we know if this which point would be the transition temperature not the inflection point and inflection points where this just sign of the slope changes.

So, it is better to plot this slope as a function of temperature. So, that you can find out from this your original data and from the from this plot you can find out the transition temperature accurately, but from this curve it is difficult to find out the exact accurate transition temperature ok. So, this is another use of the graph plotting of the graph plotting of your data on a graph paper. So, and similar another example I have.

(Refer Slide Time: 22:30)



Here we have another data is the because they are slightly complicated to transition kind of things are there, but now aim is not there to discuss the physics, but I am discussing about the integrity of the graph. So, here it is clear you see this just this is this slope is 0 here also slope is 0. So, in between this in between this slope changing so; that means, this type of variation is tells.

So, here it is basically this radius of curvature is this side and here radius of curvature is this side. So, there is a change of curvature. So, exactly what is the inflection point here so, it is very difficult to find out the exact inflection point.

But generally we take this middle point of this, but so, that is a it may not be accurate. So, again if you take this the derivative of this y axis as a function of x axis then here. So, that derivative we have taken of this curve and here you can see that this change of slopes change of sign of the slope is you can find out here. So, from this plot accurately you can take what is the temperature it is the 36 in accuracy of one Kelvin you can.

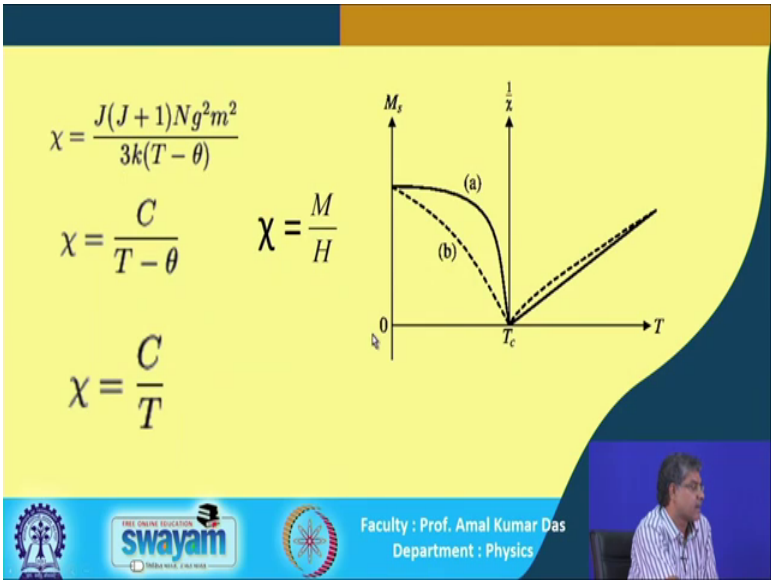
So, but here it is it from this graph what is the slope what is the what is the transition temperature it will be it will be it will be accuracy will not be as we find out from this derivative. So, here the uncertainty will be more and here is very precisely telling this exactly what is which temperature is inflection point and there is the transition temperature. So, here basically if you had measured magneto resistance we have measured magneto resistance as a function of temperature.

So, if we apply magnetic field this on a material and if we measure the resistance. So, resistance of the my resistance of this material changes with the; changes with the magnetic field. Now, if you use a particular magnetic field at that magnetic field what about the magneto resistance now that magneto resistance how it is changing with temperature that is what we have measured. So, this is one of our sample from that on that sample we have taken we have measured this is again from our lab and we have plotted and got the information from this.

So, this again some transition here basically this so, this is a higher resistance lower resistance. So, insulator to metal transition so, electrical transition is there. So, they are similar to magnetic material ferromagnetic to paramagnetic transition in this case insulator or metal to insulator transition when you are coming down from room temperature to lower temperature ok.

So, this is the example of utilization of the graph to find out your parameter whatever your purpose of doing the experiment. So, that you can you can get from the plotting graph and basically for a analyzing the graph analyzing. So, this is the only way to analyze the data in a graph paper.

(Refer Slide Time: 26:49)



So, I think there are there are many examples I can give and same graph can be used for two ways you see here this two axis basically again magnetization as a function of temperature ok.

So, this part is plotted as a magnetization as a function of temperature, but other part is plotted as a this 1 by chi versus temperature. So, what is the reason that I will not tell now, but this is the this relation you know this is the relation for (Refer Time: 27:36) this is the (Refer Time: 27:42) it is called I think (Refer Time: 27:51) law or this (Refer Time: 27:52) law (Refer Time: 27:54) law is basically is what for paramagnetic and (Refer Time: 27:57) law is for ferromagnetic material. But this theta here basically this is also for paramagnetic phase, but that is this equation is valid only above theta T minus theta. So, this theta is basically some transition temperature this so, it is you can tell it is TC T minus TC. So, this expression is valid otherwise it will be negative because if T is less than TC then it will be negative so, then it is not valid.

So, this expression is valid only above TC only above TC. So, above TC it is ferromagnetic if paramagnetic phase below TC below theta it is ferromagnetic phase. So, since this equation is valid only for paramagnetic phase and I have opportunity here you see if I plot chi versus T and chi is nothing, but M by H ok. So, measurement we have done M versus H.

Now, M versus T apply a particular field now you divide this M by this that magnetic field then it is chi this chi is inversely proportional to the temperature ok. So, it is the if you plot here it will be I think hyperbola this curve will be hyperbola.

But if we plot one by chi versus T so, they will be linear their relation will be linear. So, and always when we plot if you have opportunity. So, we try to get linear curve. So, instead of plotting chi versus T if you plot 1 chi versus T then you will get a linear curve and then it will easy to interpret it because, in this case if you just it is easy to find out the slope of this line slope of this line.

If you find out the slope of this line then you can get this value of this constant C this fully constant. So, but if we plot chi versus T then it will be hyperbola curve and from hyperbola curve it will be difficult to find out this C. So, to extract information so, you have to (Refer Time: 30:40) important. So, you have to decide whether I should plot chi versus T or 1 by chi versus T.

And in this case here this that magnetic metal we have taken and doing experiment measuring magnetization as a function of temperature. So, some portion it is below Tc it is ferromagnetic phase and in ferromagnetic phase this 1 by this relation is not valid ok.

So, but in this case representation magnetization versus temperature is good enough because, this variation in this like this (Refer Time: 31:20) changes and it goes towards 0 that; that means, there is the transition temperature it is going towards the ferromagnetic phase or paramagnetic phase. And in paramagnetic phase this if we plot 1 by chi versus T then it should be straight line. So, directly you can also if you know the nature of the curve for your from theory.

So, then plotting your you should plot your data accordingly and then directly for seeing the curve we can we can tell our about the nature of the magnetization. Also we can find out the some parameters as here is one can find out the C ok. So, these are few examples I showed you, how to plot what information you will get and how to extract the information ok? These are the in general I discussed about the utility of the graphs how to plot graph and how to get the information?

So, I think that is enough for a for you to do your experiment in lab and get the information. So, I think I will stop here and I will discuss calibration in next class.

Thank you.