Experimental Physics - II
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Lecture - 53
Polarimeter

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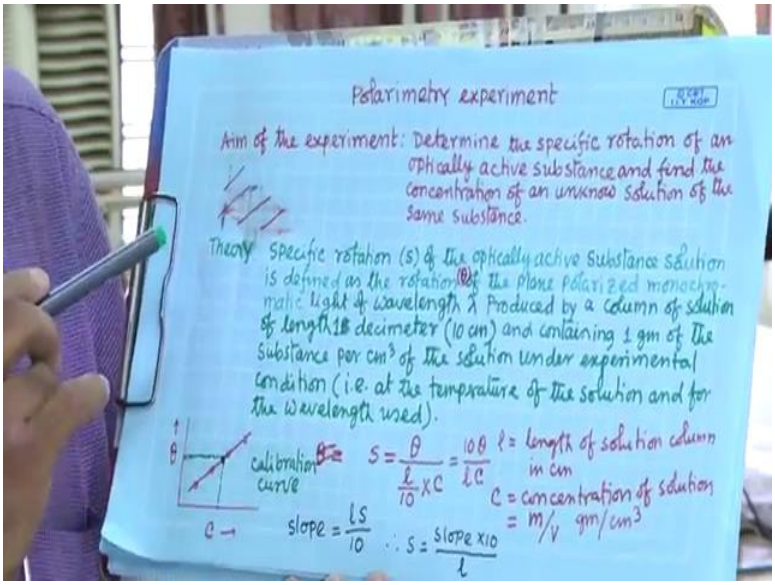

today I will demonstrate polarimetry experiment. Say aim of this experiment is: determine the specific rotation of an optically active substance and find the concentration of an unknown solution of the same substance. that means, the specific rotation of optically active substance that we have to find out and we can also find out the unknown concentration of the solution of that active, optically active substance.

theory for this experiment is very simple. if we know the definition of specific rotation, then it is working formula easily we can derive. definition of the specific rotation is the specific rotation of the optically active substance solution is defined as the rotation theta of the plane polarized monochromatic light of wavelength lambda produced by a column of solution of length 1 decimeter; means, 10 centimeter and, containing 1 gram of the substance per cube centimeter, per cc of the solution under experimental conditions; means, at the temperature of the solution and for the wavelength used for this experiment.

if this is the definition, so then S equal to; angle of rotation of the plane polarized light, when it is passing through the length; passing through the length of the solution column if that is l. If that is l centimeter so per decimeter means, l divide by 10 that is the decimeter theta divide by this l divide by 10 and then per unit concentration, ok; means, 1 gram of the substance per cm cube; that is the nothing, but the concentration so divide by concentration C S equal to 10 theta by lC, it is not least count lC; l is the length of the water column in centimeter and C is the concentration of the solution,

And, concentration of the solution is m by V, m is the mass of the solute, ok here, we have we will take sugar and then divide by volume say it will take some volume. generally, we can take 100 cm cube cc; so, then for 20 percent concentration m has to be 20 gram. for different concentration of the solution if we can measure the rotation of the plane polarization light; that means, concentration versus the rotation that angle theta. we can plot a graph that for different concentration, what are the rotations

theta by C, that we can get that is nothing, but the slope of this graph ok you will get straight line and slope of this graph is theta by C, theta by C that slope of the graph will be l S by 10; l S by 10 that is the slope, so that slope we can find out from this graph. Now, that S will be slope into 10 divide by l ok, l length of the solution column in centimeters, we have to remember that is there in the centimeters we can calculate the S. And for you can do the experiment for unknown concentration of the same salute ok; in our case it will be sugar, so that unknown concentration of that solution you can find out,

we will put this solution in the tube for containing the solution it is length is known to us, Now, all conditions are same for that solution we will measure the angle theta, experimentally you will measure the angle theta and if you put this theta in graph So for that theta from this graph itself, what will be the C concentration, you can find out from the graph itself or you can if from this graph slope is calculated, using this not slope yeah, slope is calculated and then from there you are finding out the specific rotation. using this experiment or result of specific rotation you can find out the concentration of unknown solution.

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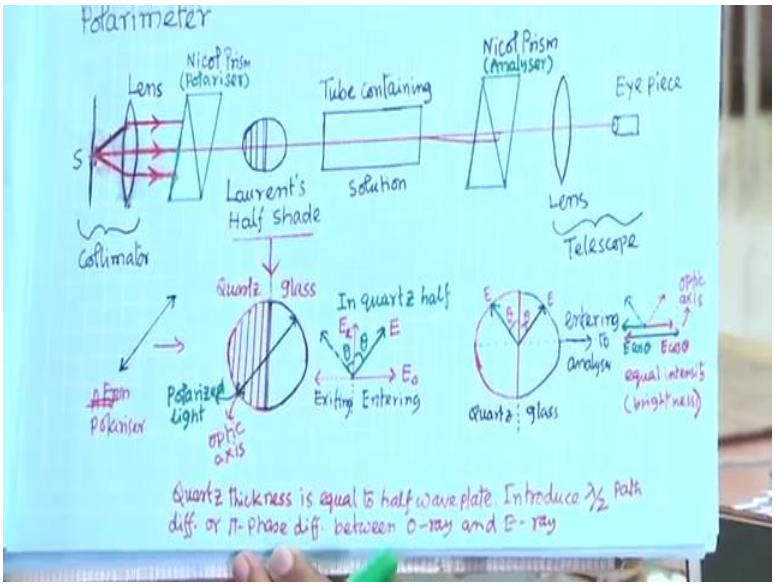

this is the theoretical part of this experiment; now, we will use polarimeter. this polarimeter is it was used by Laurent's you know, Laurent's not (Refer Time: 07:22), Laurent's, in polarimeter what things are there, ok? In polarimeter you have collimator; you have collimator; that means, slit source and then lens ok it is producing parallel rays then we have a polarizer. that is nothing, but the Nicol Prism that is nothing, but the Nicol Prism; what is Nicol Prism? I described earlier. it produce the what is light plane polarized light. now, when this light it is unpolarized light, when so we will take sodium light. it is a nearly monochromatic light, when it will pass through this Nicol Prism it is a polarizer. light will be we will get plane polarized.

that means, electric component will be in a particular direction; now it will pass through a it is called Laurent's half shade, Laurent's half shade, so it will pass through this Laurent's half shade. What is Laurent's half shade? I will explain; so, then this light this polarized light it will pass through the tube containing solution. it will pass through this solution, then whatever the angle of the plane polarized light was, here due to passing to the solution of the optically active solute; so, this electric component it will rotate, that means, plane polarization that it will rotate by angle say theta.

now it will rotate by angle theta then it will another Nicol Prism will use as analyzer. it will pass through this analyzer if initially this polarizer and Nicol Prism, another Nicol Prism analyzer, if they put parallel their optics axis are parallel then what will happen? if

there is no rotation here; if there is no rotation here, so we could get light intense light; we could get intense light.

Now, if we rotate this analyzer by 90 degree so then it would be first position, then we should not see any light; we should not see any light, but if any rotation is there then in first position you will not see the dark; there will be some brightness to make it dark you have rotate more. how much you have rotate to get it completely dark or completely b that will be the rotation of the plane polarized light that we will measure,

now question is, then using only this polarizer analyzer we could do the experiment. why we need this Laurent's half shade? Laurent's half shade is it makes more sensitive this detection without this also one can do this experiment, but it is to get this complete dark or complete brightness is since we are seeing through the solution, ok; it is become (Refer Time: 11:52), it is a difficult to identify you know this dark complete that position and complete b position, so it is difficult.

if we use this type of Laurent's half shade this changing of the its sensitivity; its sensitivity of detection of this distinction of this color not color if the in intensity, It is a much more easier and that is why we tell is more much more sensitive, it is make this system is more sensitive and that was discovered by Laurent's. that is why it's a we tell this Laurent's Polarimeter and this (Refer Time: 12:40) Laurent's half shade.

Now, what is Laurent's half shade? Laurent's half shade; it is half of this circle. half of the circle or semicircle is made of quartz and it is optics axis, quartz and calcite you know these are uniaxial crystal and it has optics axis. optic axes are parallel to the surface, it cut in such a way. these optics axes are parallel to the surface. And, other half other semicircle is made of simple glass. It does not this light is polarization does the traffic by this glass, ok in general.

now if you use this half shade; here this quartz thickness, here quartz thickness one is the condition is that this optics axis will be parallel to the surface, another thickness of this plate is such that it is half wave plate, half wave plate. Half wave plate I described half wave plate is when O-ray and E-ray will pass through it, it will introduce lambda by 2 path difference or phase difference pi between E-ray and O-ray. that is the half wave quarter plate half wave plate. another plate quarter wave plates lambda by 2 it half depends introduced another full wave plate means, lambda path difference is introduced.

from this polarizer, when polarized light plane polarized light; so, it is electric component say this ok; so, it will fall on this; it will fall on this half shade Laurent's half shade this way, so yeah, this way. when it is falling here. it is a falling on the glass plate as well as falling on the quartz. it will pass through this plate. when it will pass to this plate, so this electric component through that galas it will not change anything. it will be equal in intensity when it will go other side ok, but this part, the part which is falling on the quartz side, if electric component direction is this one, electric component this direction and optic axis is this direction,

now when this light plane polarized light falls on the quartz ok; so, it divided into two rays, O-rays and E-rays ok; O-rays and E-rays you know this one is sigma polarized light, another is pi polarized light. this this component, this will be divided into two component perpendicular mutually perpendicular two component. E component along this direction, so it is the normal to the optic axis it will be E-ray oh sorry O-ray and, another component is this.

it will be parallel to the optic axis, so it will be E-ray, this ray plane polarized light ray when it will fall on the quartz part, ok it will break into two parts, E-ray and O-ray, so it is the entering during entering this is a situation; when it will exit to the thickness of the plane. other side exiting part what will happen? There will be phase difference between E-ray and O-ray by pi; that means, if I keep this one with respect to this, if this one change phase pi. this direction will be in opposite direction so these dotted lines. this will change the direction after going out when it will come out from this plate,

now one component E-ray is this component when it is coming out another component will be this, resultant one you will get this one; now you see, but for glass part there will not be changed it will be in this direction. you will get in glass part, so when it will come out; so electric component will be in this direction and this quartz part the electric component will be in this direction. And, this is this direction is normal to this to this direction, original direction

these two are normal, so if it makes angle theta; so other are also making angle theta with the optic axis, now this is the situation when it is coming out, when it is coming out from the Laurent's half shade. Now, here say this tube containing solution. initially do not take solution just take simple water ok, no optically active solute. what will happen? when it

will pass to it, there will not be any rotation, there will not be any rotation of the electric component or plane of polarization ok, plane polarized light so there will not be any rotation. then it will come to the analyzer.

Now, this is the analyzer part, what we will do? when it is coming out falling on the polarizer falling say polarizer this sorry this is the polarizer this is analyzer same thing Nicol Prism; so if it is optic axis say initially this direction ok, if it is this direction so what will happen? For this direction optic axis; that means, component of this electric component along this direction that will pass through. component will be from glass part that component will be E cos theta and for the other half quartz part, so it is this direction so this direction that also component will be E-cos theta.

from both halves; so when will see through the telescope, we will see this image of this half shade; image of this half shade from both half equal amplitude is coming out so; that means, it will be looks; it looks equally b it looks b if this is a starting point, now if I rotate this analyzer it is optics axis will rotate. now I am at this situation, so this situation is of equal intensity, this situation is equal in intensity, why equal intensity? Because this component is this angle are same.

Now, when I am rotating for this position ok, now you see component from this half and component from another half they are not equal. you will see the variation of the intensity of these two half. when I will come this position then what will happen? optic axis will be parallel to the electric this vectors in the quartz part, that means, this part will completely exit will go, come out and this other part is perpendicular to the optic axis you will not get this component pass through this analyzer.

that means, this half glass half looks dark and this quartz part will looks b from equal in intensity now next stage I got this one half is b, one half is dark then if I continue the rotation, I will get this position optic axis; in this position also you will see this is equal angle of this electric component in both half, from both half this E cos theta in this case I think it will be sin theta, so E cos theta have written it should be E sin theta and in this position it will be E cos theta.

that means, main thing is the both are equal, competent are equal from both half. again, at this position I will get the uniformly b of this both half. Now, again I am continuing the change, so this it will change in intensity will not be uniform, so it will change when

I am in this direction is 90 degree with this where we got this both half equally this both half, one half was dark and one half b

now it will be just one half will be dark, one half will be b so it is the opposite direction, Because now glass part that electric component will pass through, because optic axis along this and this compound is perpendicular to the optic axis; so this component will not pass through this quartz half will be dark and this half will be b,

Now, so that means, uniform and then that b, then uniform then that b, if I continue; if I continue is initial position to it is now I am at to 180 degree again I will get uniform, because at this position I will get uniform situation, then it will continue then again I will get; again I will get this situation 180 degree opposite to the dark b situation, I will get again dark b situation again I am continue then I will get uniform ok, again I am continuing I will get this position dark b situation,

I so one; I will come back to this again this 360 degree, so this means, 0 position. in one complete rotation I am getting 4 times uniform; 4 times uniform, one is this and then second is this, then third is this, then forth is this from uniform situation in both half. So, and dark b, b dark so this also will be get 4 times 2, 3, 4, I will demonstrate what I explained ok, what these half shade is doing. in our case so what will do, we will actually see the uniform for detecting the rotation measuring the angle we will actually see the uniform situation both half are uniformly b

if we take that standard; if we take that standard, so what we will do? Always you will do this 360 degree rotation then we will take 4 reading radian ok, wherever we will get this uniform situation we will get this 4, for what are that will do we will note down the reading, Now, we will put the solution, first we will put this solution of highest confrontation and then will do this, because now this will be rotated, this will be rotated, that rotation actually; so that will change this electric component will rotate,

now our uniform situation to get it, so we have to also rotate the polarizer (Refer Time: 27:32) analyzer by this angle to get the uniform brightness on both half, that way we will find out the concentration versus the angle of rotation for different concentration at least 4, 5 concentration will do. Then, that is the experiment we have to do and for that procedures, so we have to one procedure we have to follow to prepare the solution.

Initially as I told highest solution, highest solution of highest concentration we will prepare set 20 percent or 15 percent say 20 percent,

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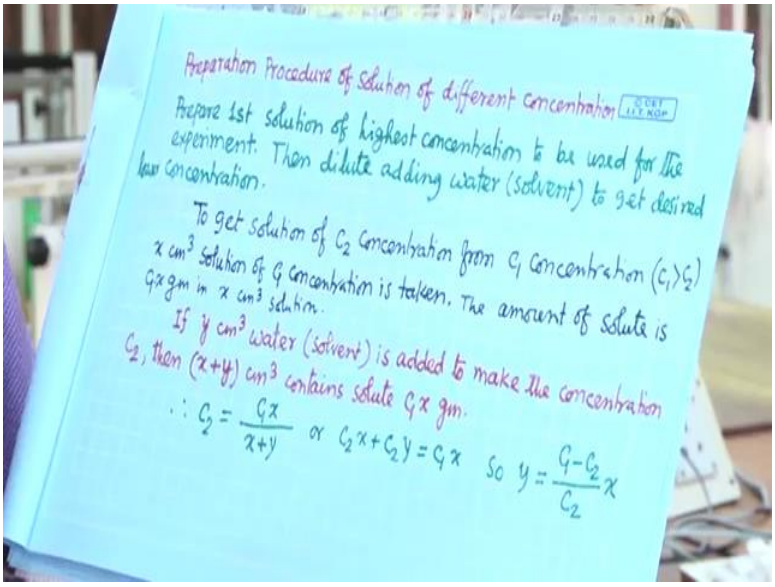

now we will dilute the solution to get the lower concentration. that is the calculation I have shown here ok, if C 1 is the initial solution concentration of solution of the solution, now I want to make C 2 that concentration; C 1 is greater than C 2 means, C2 is less than C 1. Then if I take x, if I take this volume of the solution of concentration C 1 if that is x; if that is x ok then how much water distilled water have to put in the solution to make the concentration C 2. that amount of water which amount of water I have to add. that is here details I have I have written. that will come C 1 minus C 2 divided by C 2 into x

using this formula, we can prepare solution of different concentration. from C 1 to C2, then C 2 to C 3, where C3 is less than C2; that way we can go for lower and lower concentration of the solution and for each solution will do the experiment and then finally, you can just pour water arbitrarily and make the solution or you can pour some more sugar to make the unknown solution and do the again measurement. you will find out the theta for that unknown solution and knowing the theta you can find out the concentration for the graph or calculate from the using the experimental value of specific rotation.

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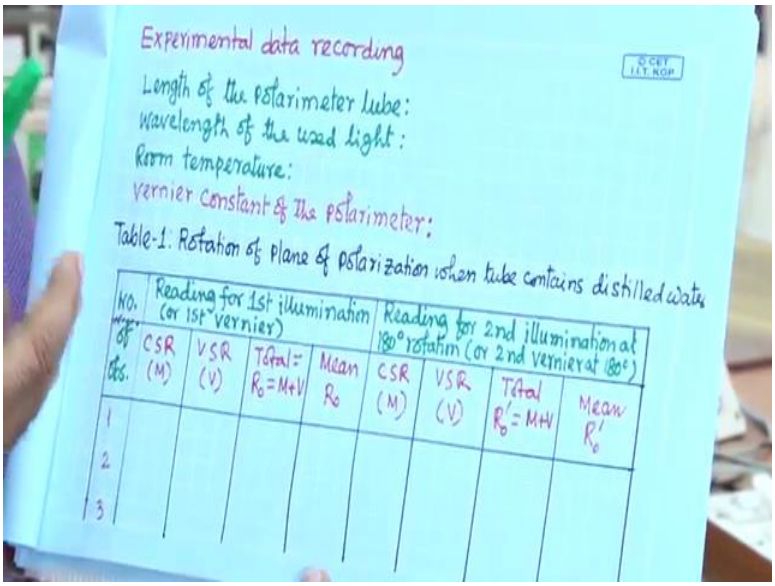

here are this experimental data recording length of the polarimeter tube that is given, or you can measure using the scale. whatever so that you should write, wavelength whatever you are used. we will you sodium light 5, 8, 9, 3 angstrom wavelength, room temperature you should note down of the S. we expect that solution temperature room temperature will be same, if you do not cool or heat it; so, then Vernier constant of the polarimeter.

there will be circular scale and there will be Vernier, ok; Vernier constant of the polarimeter you have to find out and write. then table rotation of the plane of polarization when tube contains distilled water as I told distilled water, reading for first illumination in some polarimeter there are two Vernier, in some polarimeter one Vernier. as I told there will be 4; there will be 4 uniform illumination, but you can take reading for 4 you can take reading for 2 here I have written for 2.

2 you remember one whenever first one you are taking this second illumination, we are that meaning is that 180 degree, after 180 degree rotation whatever the reading you are getting there is the second, generally this first this actually 4 uniform illumination we will get. 2 of them are weak in intensity and 2 of them will be have b in intensity highest in intensity ok, but in our case, it is the difficult to distinguish that in intensity. anyway, so we will take 2 180 degree apart from each other,

you note down this reading take the observation 1, 2, 3 ok for first elimination uniform illumination and for second uniform elimination take the reading, these mean reading for this distilled water R 0 and this R 0 dash,

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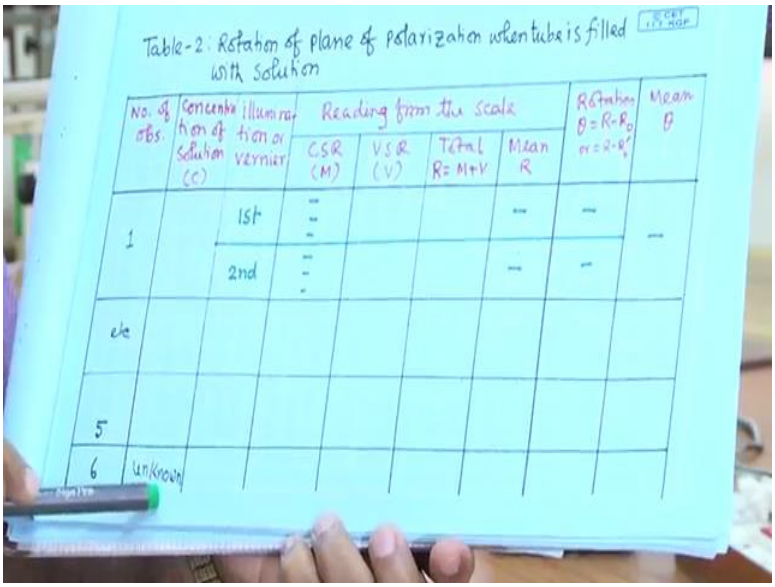

then you do the experiment for different concentration. For different concentration, now for first illumination second illumination take 2 3 reading and then find out the mean value of this, mean value of the of R. R is the for first illumination and second illumination. R and R 0, there R 0 and R 0 dash we have consider, here we can also you can consider this R and R dash,

now, rotation theta will be R minus R 0; theta will be R minus R 0 and, for other case R dash minus R 0 dash, they are 180 degree apart from each other. whatever angle you will get that should be same ok, it will so average of these two will be the mean theta for one concentration then start with the second concentration repeat the experiment, so if I know the mean theta for at least 4, 5, 5 concentration and then sixth one you should know, you should do this experiment for unknown concentration and find out the theta.

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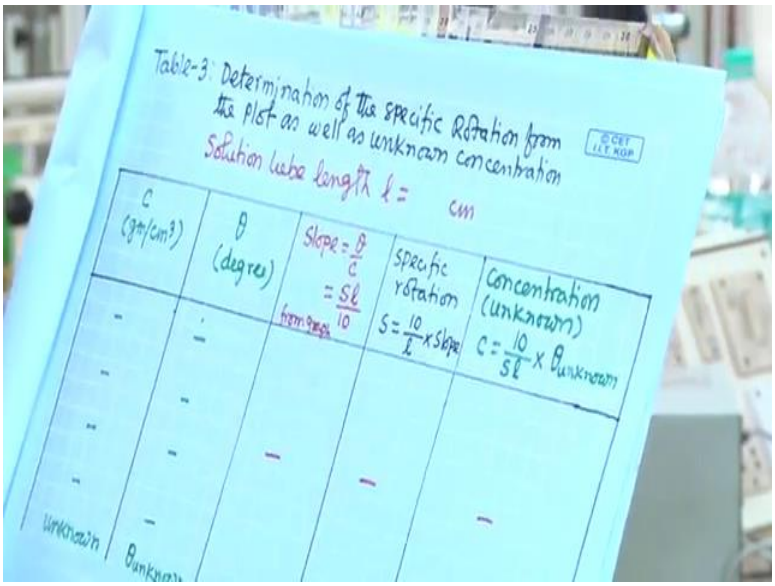

that is the explain the I have to do. now for determining the specific rotation from the plot as well as unknown concentration, so you just make table concentration versus the theta you plot graph from graph is find out the slope, Now, this slope we used for calculating the specific rotation and using the specific rotation we can calculate the concentration of unknown solution, where experimentally you have measure theta for this unknown solution. you can find out the concentration of unknown solution,

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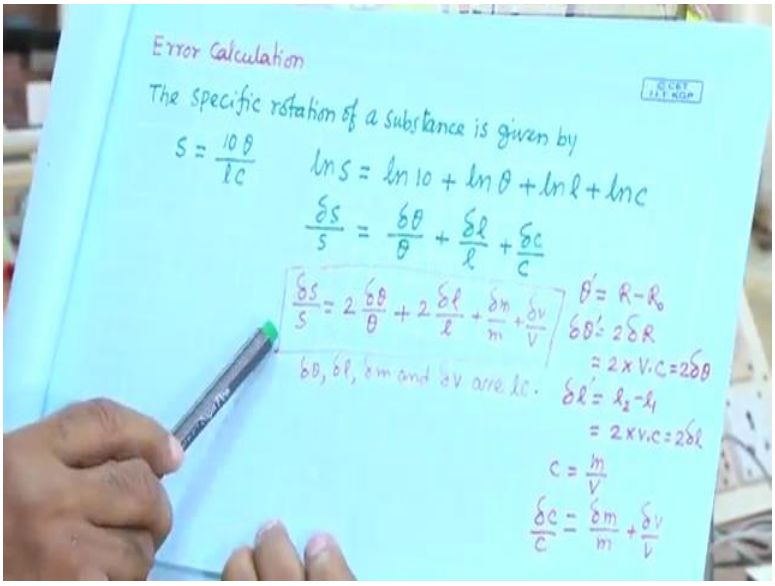

Then you have to calculate the error. this the S equal to the 10 theta by l C del S by S equal to 2 del theta by theta plus 2 del l by l plus 2 del m by m plus del V by [vocalized-noise],

that is the formula for l calculation, how It has come have shown clearly, because C equal to me by V. you are measuring mass and the volume. you have to so always error you have to convert in the parameter which you have you are measuring and 2 is coming, because we are taking the difference of 2 reading. that is the 2 is coming. using this formula, you can find out error, now I will show you the experimental setup and demonstrate the experiment.

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this is the experimental setup of polarimeter. whatever I told I think again I have said the camera, here so this the polarimeter, ok in polarimeter what things there are I explain, you have collimator you have telescope in between you have polarizer and then half shade. that is inside you cannot see, ok and, then I have put the you see this is the tube continuing solution. it is a water is there but here the same thing we have put with a solution of sugar of 20 percent in intensity.

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now, then we have analyzer; then we have analyzer and after analyzer we have telescope. through telescope whatever here from mobile camera what about this here you are seeing. that you are seeing the image of the, you are seeing this half shade plate.

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Now, here there is a scale circular scale there is a Vernier. here it is the I can see this how many there are, I think 10 or 10 divisions are there and, here the circular scale it's the 1 yes; it is a total 360 degree, 10 it is a 1 degree. 1 degree and it is the 1 degree and this one it is the telling that 0 to 60. It is 0 to 60, but I can see how many it was in

between this is telling is 1 division, I think this 10 division is there; 10 division is there one has to find out the Vernier constant from this ok, Vernier constant it is so 1 by 1 degree by 10, Because Vernier total division is 10, so it is a point 1 degree. it will be point 1 degree.

this polarizer not polarizer that is analyzer that is attached to with this scale ok with is Vernier If I am rotating this Vernier you see I am rotating this Vernier so; that means, this I am rotating the analyzer, I am rotating the analyzer now what here this spot you are seeing camera. there is the half shade one it is half shade plate you are seeing; I have to trying to make slightly bigger yes; slightly bigger,

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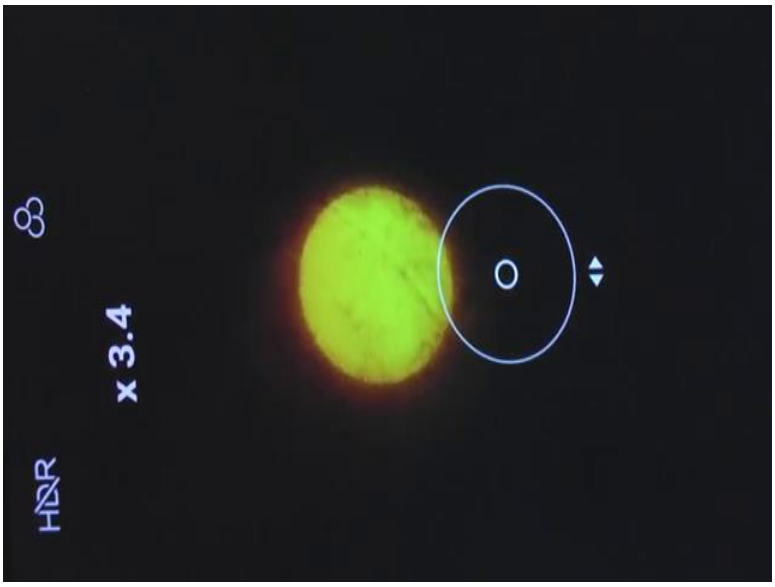

now whatever for this half plate I told you. I will try to demonstrate I am starting from here this reading it is a 0 you know. now, I am rotating, I am rotating in say this direction you start to count and see now let me see what I am going to get ok, first at this position I am getting see half is b and half is dark, this is one, it is the must be parallel this optics axis must be parallel to one or either one of the electric component, two electric component will come on from the glass from the of, one from the quartz and they are mutually 90 degree this angle is 90 degree between these two. I got this one and, this I am getting around 27 degree

Now, I will continue and then you see I will get a position where both half are uniform. Now, this I can tell this uniform position, this angle is around I am seeing the 60, Now,

I am continuing you see I am getting another position where you are getting this half is this now, next half is dark and other half is b, this is the second position I am getting where is the electric component one electric component is parallel to the optic axis other one is perpendicular So I will continue then I should get one uniform position; one uniform position this I can take yes; this I can take uniform position yes, uniform position I can take, Then I will continue and then I should get the half is b and half is dark, yes.

I lost it, no; I think this is the position of this half is dark and this half is b this third time I got Now, third time I should got get the uniform one yes; this is the uniform one this third time I got, Then so yeah, it is disturbed got disturbed, but I will try to yes, uniform one then I am continuing, then yes I think I needs that one or contrast is not good. Yes, here contrast is not good it seems I think I have to yes; I think here one position I am getting yes contrast is yeah now probably, it is yes. I think I have to just no; I lost the contrast I think we have to set it, of this now I am in original position it seems 0,

This other half other half I got the dark and b anyway, so I think just quickly I will rotate, so this is I think quickly if I just rotate and see the variation of this uniform, then no I think this something. So, I will show you that; I was showing that 4 uniform leave b both half and, 4 half is b, half is dark ago, that collusion should arrive. if I start from here it is a 330 degree it is a uniform vision.

if I continue the rotation so I am getting this position where you can see this half is dark and this half is b Then again, yeah it is I think more is becoming more prominent let me check it; whether I am getting another uniform yes, here I am getting another uniform. if I continue, I am getting the dark this other side and this side b then I am continuing then I am getting the uniform is uniform, ok then I am getting the another position where one half is I think this the find out this half is dark and other half is b

if I continue another uniform position, I got no this I think this is the inform better informed. if I continue I will get one another position why this half is dark and this half is b, this way there will be 4 times of uniform vision and this 4 times of half is dark and half is b condition, that is the important for concept for the half shade plate Laurent half shade, so now, I will remove this camera, ok and, I will just explain the experiment.

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first what we have to do actually will measure the let us say length of this tube using the scale. I think this is not the difficult part I think this I have to measures between these two end. it is the I think if I put 0. it is in this case I am getting to read 18, but water is up to this. Yeah, so I think one has to before putting water, one has to open it and see the, I think here I can see yes,

Another solution is there, so this generally it is a 20 centimeter either you can measure or here it is given this yes; generally, 20 centimeter this length or you measure and find out this it is a difficult to measure this way, I do not think this is the length, it is the length should be something yes. length from here to I think water is from starting from here to here at this to ensure that is 20, I can see this is 20.

this you have to measure, or it is supplied and then so here this similar tube. here this 20 percent concentration of solution we have put here and using that one I was showing you to this 4 region. first you have to this same tube ok, first you have to take this water. For water you have to find out; you have to find out this uniform shaded region, I cannot see. I think this is the position to put. Yes, now, I can see, what? No; no, I have to put it properly. I am not able to ok; I think this is the flat edge we have to put down. then only you can it will be centers column will be axis centers yes, I can see.

from here then will not be any rotation of there to answer all the time so here only one electric no rotation, but I think this same way you will get this 4 uniform and, but at

some angle I will set at a yes. I will find out the first illumination say uniform one, I think this the position I will note down in a another reading I will take this just 180 degree opposite yeah, this is the another position I am getting, I am no; I am getting a uniform illumination I will I have to take this reading. this is the R 0reading you know, ok for illumination one and illumination two.

Now, this is done as per this one because noting down the reading is not difficult one, is not difficult one so this table one just as a showed this put water and then do it,

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And, then I have to so if you use the same tube remove this water and solution you have to prepare. Generally, you take this you see there is a scale here of cm cube cc. it is a 100 cc and now 20 gram sugar you can put in 100 cc or 10 gram sugar you can put 50 cc make 20 percent solution this is the solution as I told, yes I think which one is solution I confused, but hopefully this one have taken in my hand. you put this solution close it and now try to find the uniform, but it is look the uniform the same place. I think it cannot be the sugar one, I think this could be the sugar one anyway I, yes, it is change probably.

Yes, anyway if you are being this go to this first illumination and see this final of the first illumination, I think this would be the first illumination then note down go at 180 degree approximately and there for second illumination you take the reading. this reading takes few times; at this position you can take few times or rotate, rotate and rotate and take 2 3 time and take an average of that one, Now, you take out the solution if you have more

solutions here I have more solutions I will put the distilled water I have to calculate what percentage I want. I will; from after calculation I will make it, I add water into the solution, first I have to I think this is the solution and you if it is 20 percent solution.

you take this solution of say some 100 ml or 50 ml of the solution and calculate that to make it 15 percent what is the water I have to add you put water, make it solution, uniform solution and then you change this previous solution and put this solution and repeat the experiment. You repeat the experiment for 5, 6, 5 solution of known concentration and then you do the sixth one same way.

taking reading is this very easy, if you identify the uniform vision and only here in this experiment main part I discuss and demonstrate that what is the function of Laurent's half shade. And how we can explain that uniform illumination or half is uniformly illuminated, and half is dark ok, we are getting fourth times uniform one and fourth time this dark b, b dark this just exchanging the one.

how we are getting that one so that I explain theoretically, and I have demonstrated that one. that is the main part to understand that one and other rest of the things is easy also repairing solution also one has to from higher concentration of solutions, how to get the lower concentration of solutions that also I describe. I think this is the simple experiment, but it is very nice experiment to find out the specific rotation as well as the concentration of unknown solution, I think I will stop here.

Thank you.