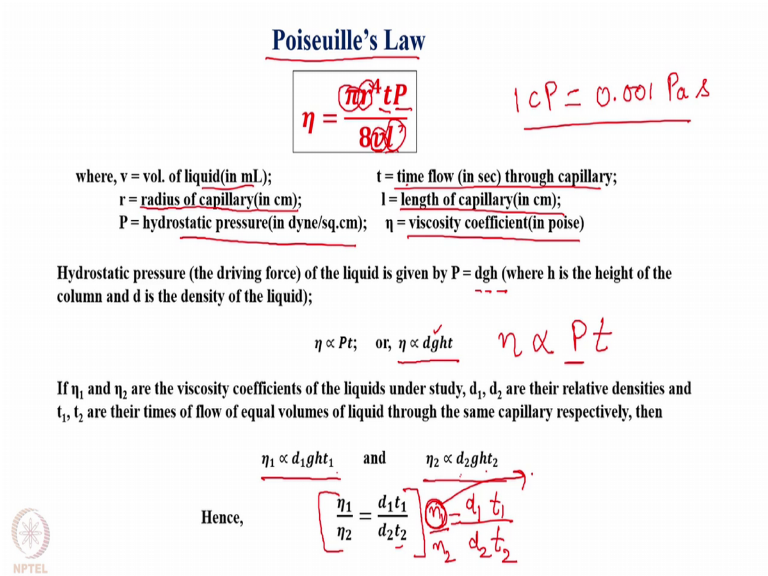
Advanced Chemical Thermodynamics and Kinetics

Prof. Arijit Kumar De
Department of Chemical Sciences
Indian Institutes of Science Education and Research, Mohali

Lecture - 42
Transport Phenomena: Coefficient of viscosity

Today we will be demonstrating how to determine the viscosity of an unknown liquid with respect to water at room temperature using Ostwald viscometer. Basically viscosity is their resistance which is offered by a liquid while flowing to other part of the liquid. This method that we are going to use to determine the viscosity of an unknown liquid is based on Poiseuille's law.

(Refer Slide Time: 00:39)



The experiment that we are performing today which is to determine the viscosity and then the concentration of the given unknown liquid is based on a law which is known as Poiseuille's law; which is given by this equation. Eta is equal to pi r to the power 4 into t into P divided by 8 v l; where r is the radius of the capillary through which the liquid is flowing; t is the time of flow which is taken by the liquid to flow from one edged mark to the other edged mark.

P is given as P is the value of hydrostatic pressure. Eta is the value of viscosity coefficient and which has a unit of poise; v is the volume of the liquid in mL and l is the length of capillary which is there in Ostwald viscometer. All these parameters give the value of viscosity coefficient in poise. And 1 centipoise is equal to 0.001 Pascal second.

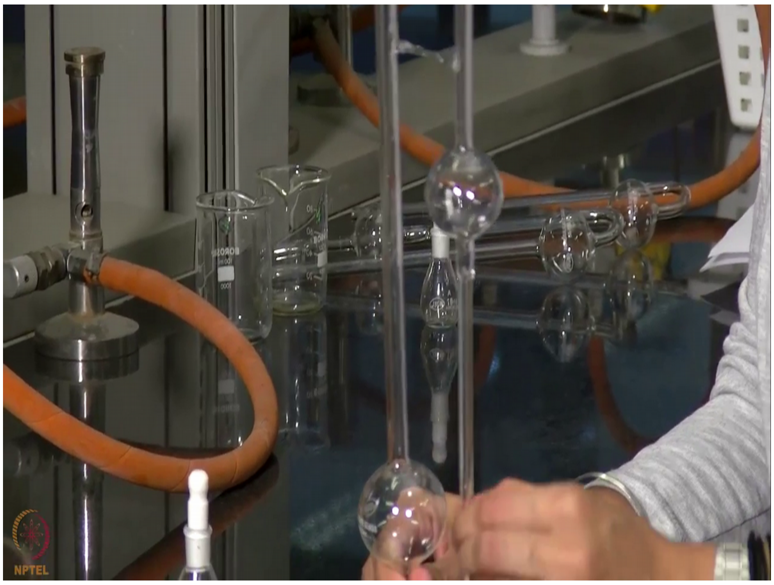
Since we are using a Ostwald viscometer, and the liquids one is the reference liquid and the other liquid under observation are flowing through the same capillary. Therefore, the values of r which is the radius of the capillary, the value of l which is the length of the capillary and the value of pi and the volume are constant. Therefore, eta is directly proportional to value of P which is the pressure and the value of time of flow.

So, the value of P can be substituted in terms of d g and h; where h is the height of the column, d is the density of the liquid and g is the acceleration due to gravity. So, eta becomes directly proportional to d g h and t. Since the value of g is also constant if we are comparing 2 liquids. So, eta 1 is directly proportional to d 1 g h and t 1, suppose there is another liquid which has a density v 2 a time of flow t 2. So, eta 2 becomes directly proportional to d 2 g h and t 2.

So now if we divide these 2 values and take the ratio of eta 1 and eta 2 it becomes directly proportional to d 1 t 1 and divided by d 2 t 2. So, using this experiment, will be determining the densities and also the times of flow in order to calculate the ratio of eta 1 and eta 2, and then we will be considering one as a reference so that we can get the value of eta for the liquid under observation.

Basically we will be using water as a reference whose viscosity at different temperatures is already known. In order to proceed with the experiment, I will be showing you what all things will be using.

(Refer Slide Time: 04:01)

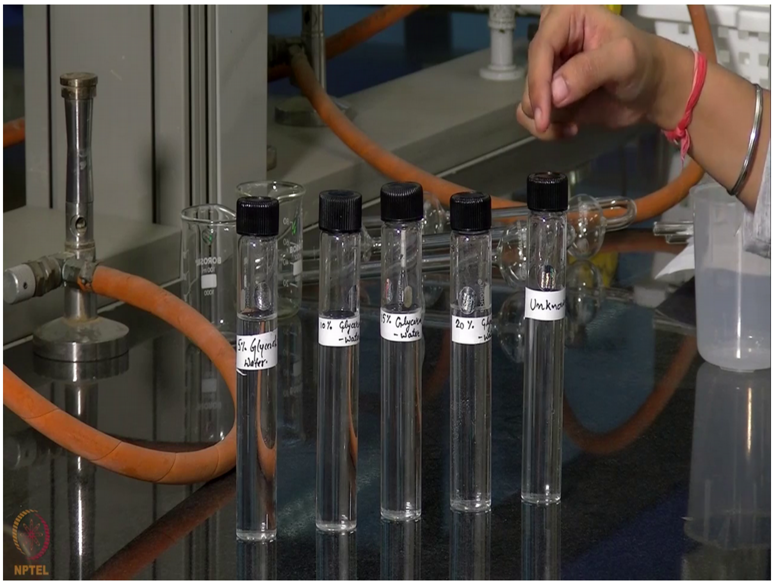


So, the 2 main things that we will be using is this U shaped Ostwald viscometer; which has 2 glass bulbs and a thin capillary and there are 2 edged marks here. And the other thing that we will be using is a specific gravity bottle which has a volume of 10 milliliters.

(Refer Slide Time: 04:15)

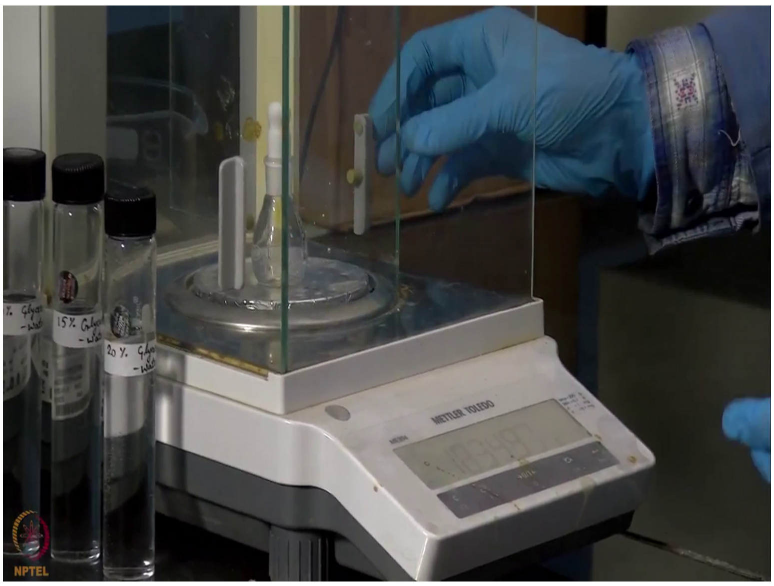
And we will be filling it with first of all with the reference liquid which is water here and then with the other solutions that we have.

(Refer Slide Time: 04:27)



So, the solutions that we will be using today are 5, 10, 15 and 20 percent solutions of glycerol water. And there is an unknown solution which we will be using and will be determining it is concentration. So, for our viscosity calculation, we will be requiring density of each of our solution. So, for calculating the density we have the specific gravity bottle which you can see here. Now this specific gravity bottle has a volume of 10 mL. So, what we will do that we will first measure the weight of this empty specific gravity bottle which you can see here.

(Refer Slide Time: 05:07)



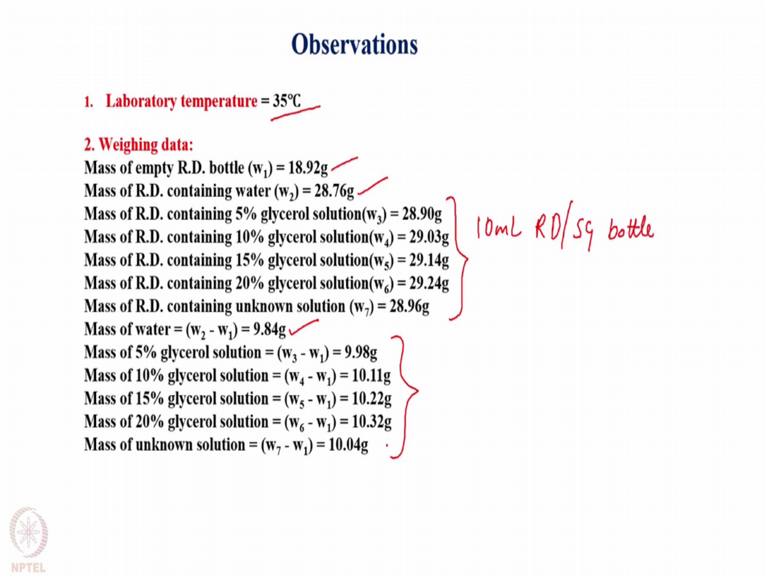
Now, what we need to do is we have to fill this specific gravity bottle with water.

(Refer Slide Time: 05:17)

And we will then close the lid of this specific gravity bottle. So, water which is in excess from 10 mL will be out from the bottle and we will have to wipe this bottle. So, we are just wiping this, the excess water which we had. So, this needs to be done properly so that we do not get the weight of any excess water present. We will now take the weight of this specific gravity bottle filled with 10 mL water. So, that now we have the weight of both our empty specific gravity bottle and the specific gravity bottle filled with water. So, what we need to do is the is that we have to subtract the weight of empty a specific gravity bottle from that filled with water. We from that we will get the weight of 10 mL of our water present in the specific gravity bottle.

So, we will fill the specific gravity bottle with 10 mL of our samples of different concentration of glycerol present, and we will then weigh them and subtract the mass of empty specific gravity bottle from each of the mass. From that we can get the mass of all different samples of different concentration of glycerol which we made. So, these are the different solutions of glycerol which we made. We had 5 percent, 10 percent, 15 percent and 20 percent volume by volume solutions of glycerol, and then unknown solution of glycerol; whose concentration we will be determining.

(Refer Slide Time: 07:05)

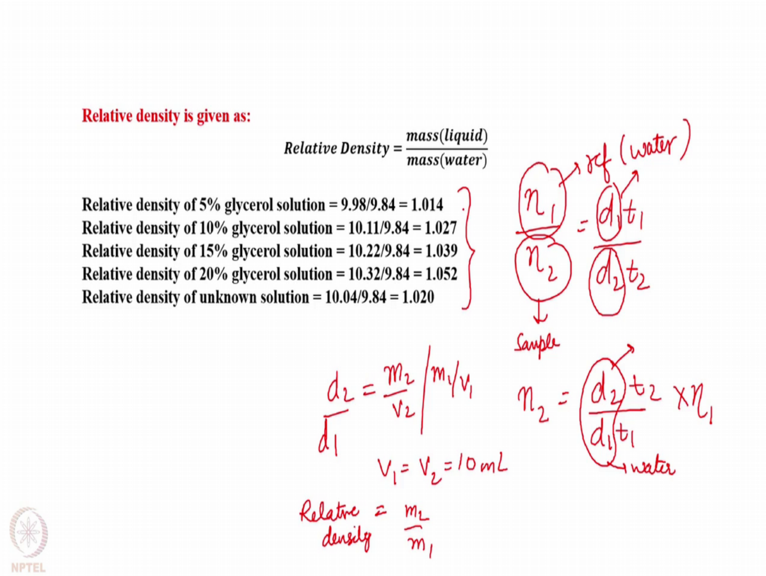


So, after weighing the mass of different samples or different volume by volume solutions of glucose and water this is the observations which we obtain. So, first of all to measure the viscosity, we need to know the viscosity of the reference at the particular temperature. So, we need to know the laboratory temperature in which the experiment in being done.

So, the laboratory temperature for this condition was 35 degree centigrade. So, the laboratory temperature in which this experiment was done was 35 degree centigrade. Now the mass of empty R D bottle or a specific gravity bottle obtained was 18.92 grams. And the mass of R D bottle, R D here is relative density which we are we also call it a specific gravity bottle has a mass of 28.76 gram.

Now, these are the masses of different volume by volume solutions of glycerol, which were added to a 10 mL R D bottle. Now what we did was we subtracted the mass of R D bottle containing water with that of empty R D bottle, and we obtained the mass of 10 mL water as 9.8 per gram. Similarly, we obtain the masses for different glycerol solutions as indicated here.

(Refer Slide Time: 08:15)



Now we already told that the ratio of viscosity of 2 different liquids can be written as eta 1 by eta 2 is equal to d 1 t 1 by d 2 t 2; where eta 1 is the viscosity of our reference liquid which is water air, and eta 2 is the viscosity of our sample which we want to obtain. Now, d 1 here is the density of water and d 2 here is the density of the unknown sample or the sample, whose viscosity we want to determine. Now t 1 t 2 are the respective flow times. So, from this equation we can obtain eta 2 as d 2 t 2 upon d 1 e t 1 into eta 1. Now this d 2 t 2 is the ratio of densities of unknown liquid or the liquid under a study with that of water. We call this ratio as relative density.

So, density is mass per unit volume so, it can be written as m 2 v 2, and d 1 can be written as m 1 by v 1. Now since our specific gravity bottle has a volume of 10 mL. So, v 1 here is equal to v 2 is equal to 10 mL. So, we can see that our relative density is m 2 by m 1. So, since we had the masses for different glycerol solutions and the mass of water, we will divide each of the masses of different glycerol solution with water to obtain the value of relative density for different solutions. So, we have the relative densities for different solutions. We will now use these relative densities to calculate the viscosity of these different solutions.

(Refer Slide Time: 10:07)

So now, we have clamped our viscometer into a stand. So, we can see that this viscometer consists of 2 bulbs and the capillary. Also we can see that this upper bulb has a 2 marks on it is 2 sides. So, for calculating the viscosity of our sample, we need to fill the viscometer through this portion, and we will then suck the liquid through this suction pump, and we need to raise the liquid above this mark. We will then allow the liquid to flow through this bulb and we will start our stopwatch when the liquid reaches this point, and we will stop our stopwatch when the liquid reaches these points.

So, we will take the reading for each of our sample the time taken between these 2 edges, and we will do this 3 times for each of our sample. And we will then average the readings and then we will use these readings for our further calculations. So, we will now start with first filling this viscometer with water.

(Refer Slide Time: 11:07)

Now, since we have this bulb filled, what we will now do it we will now suck the liquid to the other bulb through this suction pump. So, we can see that when we suck it through this, the liquid level in this bulb is raising.

Now, that we have rosen our liquid level above this mark, we will now allow it to fall through this bulb and we will note start our stopwatch, when the liquid level reaches this point, and will stop our stopwatch when the liquid reaches this point.

(Refer Slide Time: 12:41)

We now have a stopwatch with us; we will now allow the liquid to fall through this bulb. You so now that we can see that our liquid has flown between these 2 edges. So, we will now do it again for the same sample and we will repeat this thing 2 times more. We will then take the average of all these 3 readings, and use these readings for all further calculations.

So, like we did for it for water, we will now repeat the experiment with our 5 percent glycerol water solution. Now we will similarly fill the viscometer with this 5 percent glycerol solution, and will now note that note the time taken by this glycerol solution to flow between these 2 edges. And then we will do this experiment again 3 times and take the average of these readings.

So now that we have taken the readings for our different concentration of glycerol, we will now proceed with the unknown glycerol solution. So, in the similar way we will fill our viscometer with this no glycerol solution. We will now suck it through this bulb, and now that we are above this mark, we will now allow it to pass through the capillary between these 2 edges. And we will note the time as the similar way we did for other samples. Now I will remove this section and allow it to fall through that 2 marks.

So, we can see that the liquid now has flown between these 2 marks. And we have noted the time for this flow; we will now repeat this experiment 2 more time. And in the similar way take the reading and average them. Now that we have found out the time of flow for different solutions which were volume by volume solutions of glycerol water, we can use these values to determine the viscosities of these solutions which can be plotted versus the concentration of these solutions, and the concentration for the unknown solution can then be determined.

(Refer Slide Time: 16:51)

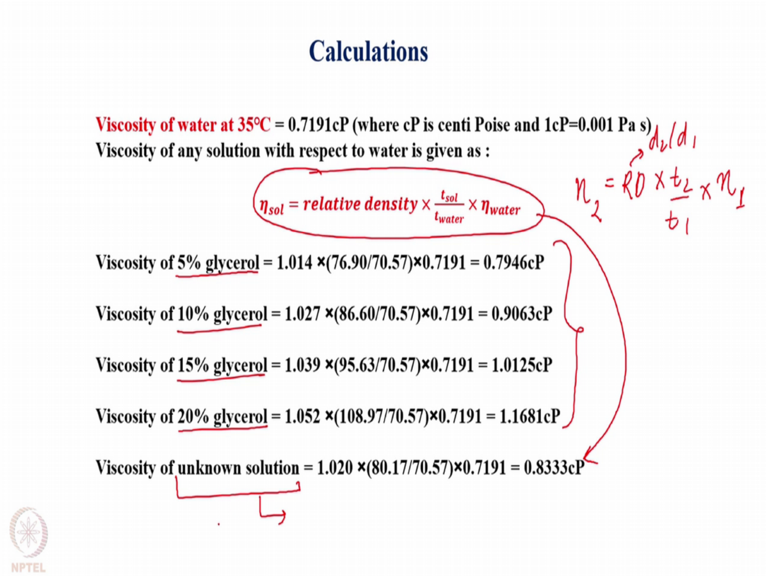
Flow time for different % v/v glycerol-water solutions

S.No.	Solution	Flow time (sec)			
		t_1	t_2	t_3	Mean
1	Water	70.8	71.1	69.8	70.57
2	5% glycerol	76.8	76.9	77	76.90
3	10% glycerol	87.6	86.4	85.8	86.60
4	15% glycerol	96.5	95.8	94.6	95.63
5	20% glycerol	108.3	110.1	108.5	108.97
6	Unknown Solution	80.1	80.3	80.1	80.17

So, to calculate the viscosity of the different solution apart from relative density we also need their flow times. So, this is the flow time obtained for water and we took 3 readings for them; which were obtained as 70.8, 71.1 and 69.8, and then we took the average of these readings which was 70.75.

We did this for all other liquids, that is 5 percent glycerol 10 percent glycerol 15 percent glycerol and 20 percent glycerol. We also did this for the unknown liquid or unknown solution of glycerol, and we obtained the readings as 80.1, 80.3 and 80.1. So, we took their average and it was obtained as 80.17. So, all the readings are here in are in seconds. So now, we will use these flow times to calculate the viscosity of our unknown sample or the viscosity of different glycerol solutions.

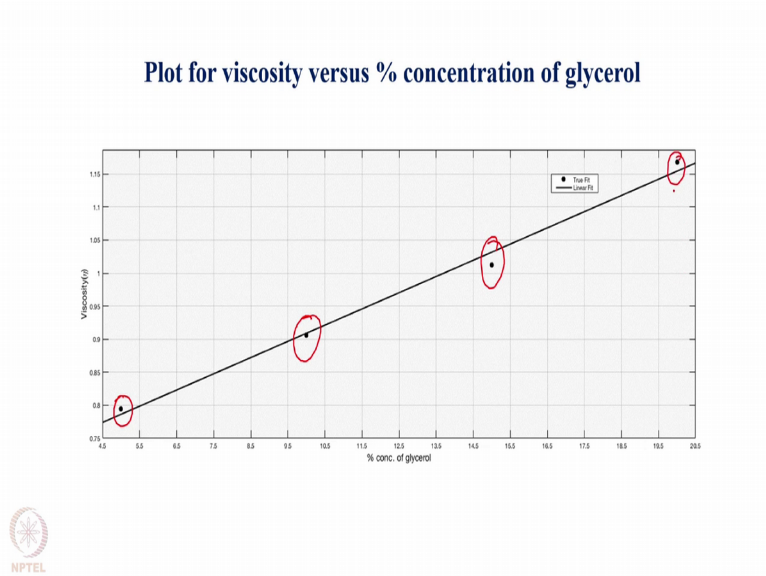
(Refer Slide Time: 17:45)



So now we all that we previously told then eta 2 or eta of the solution under study is the relative density; that is, d 2 by d 1 into the ratio of their time of flow, that is t 2 by t 1 into the viscosity of the reference eta 1, that is air water. So, relative density we obtained from this and flow times for different solutions we have in this column. So, we can substitute all the values for 5 percent glycerol, 10 percent glycerol, 15 percent glycerol and 20 percent glycerol. So, we obtain their viscosities as indicated here.

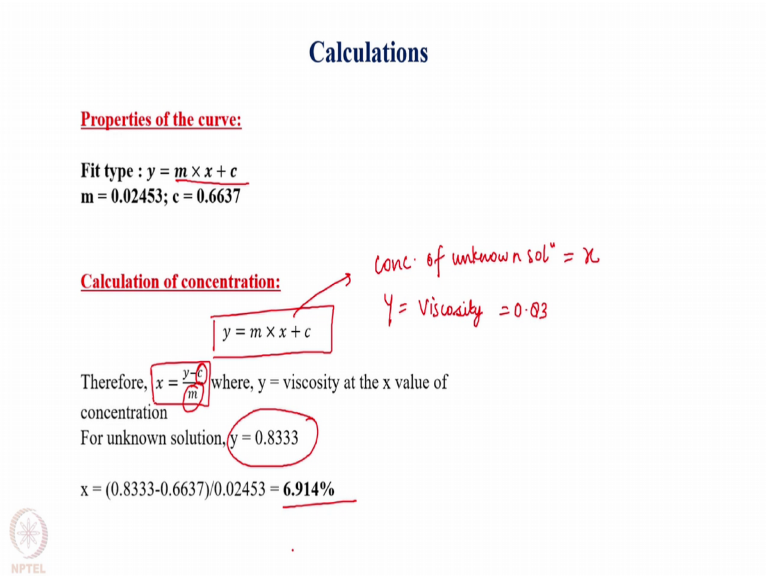
Also we did the same thing for unknown glycerol solution, because we have the flow time for the known glycerol solution. And we also have its relative density with respect to water as 1.0 to 0. So, we substituted all this value in this equation, and obtained the viscosity of unknown glycerol solution as 0.83 centipoise. Now, what we want to do next is to determine the concentration of this unknown solution. So, what we need to do to determine the concentration of this unknown solution is to draw a plot between viscosity of the solution versus the concentration of solution.

(Refer Slide Time: 19:05)



So, for different solutions which we can see here that 5 percent glycerol solution is here, whose viscosity is marked here. The concentration, the viscosity of 10 percent glycerol solution is mark here. The viscosity of 15 percent glycerol solution is marked here, and the viscosity of 20 percent glycerol solution is mark here.

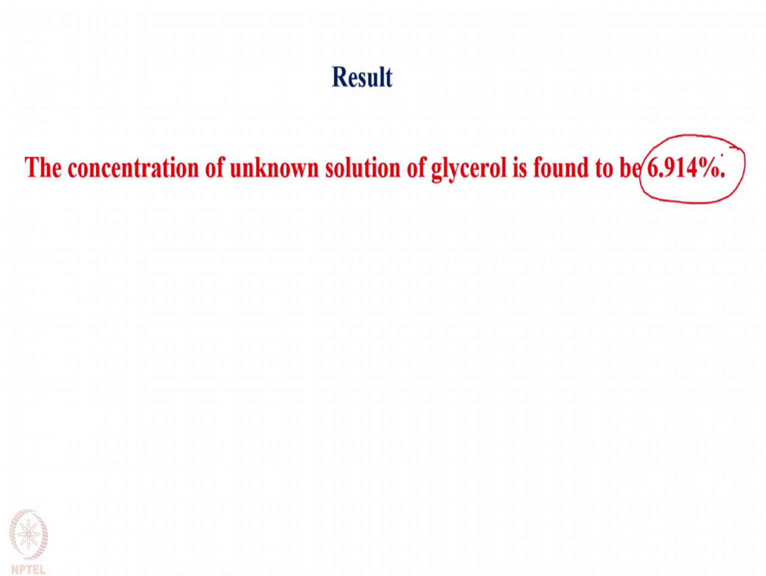
(Refer Slide Time: 19:27)



Now, these points are fitted in a linear equation of type y is equal to m x plus c. So, here m is the slope of this curve and c is the y intercept. So, we obtain this equation y is equal to m x plus c. So, here y we which is the viscosity of unknown liquid which we obtained as 0.83 which we will substitute here so, we need to determine the value of x.

So, x here is the concentration of the unknown solution or concentration of any solution. So, y is the viscosity of our unknown which is obtained as 0.83. So, we will substitute all this value in this equation. Since, we have our y we have our y intercept as c and we have the slope of this curve. So, after substituting all this value we obtained x as 6.9 percent so, which is the concentration of our unknown glycerol solution.

(Refer Slide Time: 20:31)



So, we can see that the concentration of unknown solution of glycerol is found to be 6.91 percent.