Quantitative Methods in Chemistry
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Module No # 05
Lecture No # 23
Using Spreadsheet Software to Perform data Analysis towards Calibrating a Burette

Welcome to the next lecture in quantitative methods in chemistry. We are into the sixth week where we have started to understand what is data? What is error? What is uncertainty associated with them? How to fit data and concepts of that sort? As we are moving forward to this week we will be trying to learn how to use different software in order to document a data and perform even the analysis within this software.

The reason why we would like to do this is because as the science has becomes enormous one starts acquire a quite a amount of data before they start writing their observations. So rather performing inference are there in the observation. So it does help to have all the data put with an a given concise format such that it can be easily transported across and at the same time one is able to analyze the data anywhere everywhere at the disposal of the computer.

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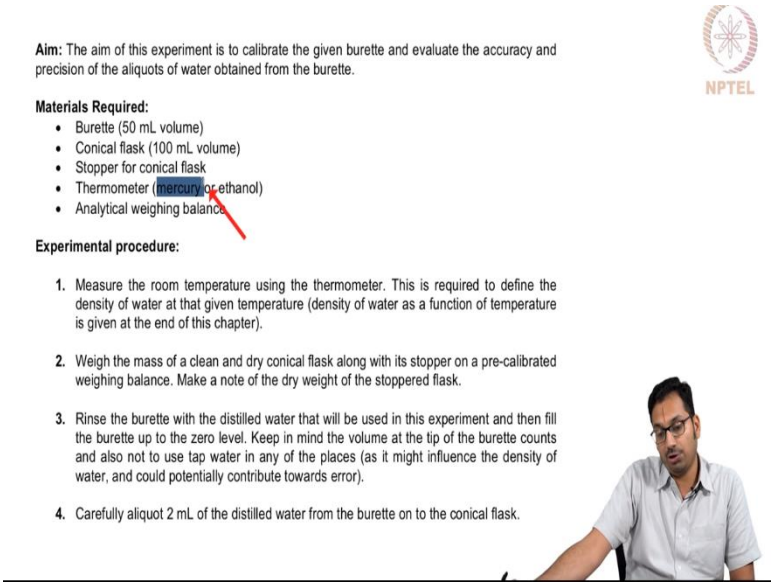

So in order to do the same we will be taking an example like we are done in one of the earlier lecture where we will be taken an example of how a burette can be calibrated. And as always we

should be also taking a look at the different steps that are required in order to do such an experiment. While doing so we were also be taking a look at where all systematic errors could come up and how this data can be looked upon to see whether your systematic errors that are popped up.

In order to for you to repeat the experiment if possible so in order to do that the first thing is going to be to understand the aim where the aim of this experiment is to calibrate the given burette as we all use burette in many different experiment this I will hope will be able to make connect with the students who are listening to this lecture. And we will try to analyze what is the accuracy and precision for that given burette.

As you might remember we define accuracy is the agreement between the sample mean that you have got an in within the true value. And precision is how far do this measurement deviate from the sample mean. If you are able to do infinite measurements meaning that if you are able to have lots of measurements which sample's the entire population then you go close to the population mean and the standard deviation will be the standard deviation of the population itself.

As always we try to start by asking what are the materials required? As we have started by trying to see we were going to be calibrating a burette we need the burette and this case we are taking 50 mL burette and assume it remember all burettes have a certain listing at a given temperature. So this is a burette let say we take it that room temperature where it is listed to have the minimum error that comes up.

We would also need a conical flask which we would end up by collecting the liquid that aliquot of the burette. Conical flask is better than a beaker because even if water starts to splash it does not end up leaving the conical flask. If in case of a beaker you could have where a droplet goes out that results in systematic error that could come up so therefore, most often for any titration for being abusing conical flask for this reason.

And of course we also would like to stopper the conical flask where you realize if you are making other measurements no contamination end up coming up in such a flask. Thermometer as always so as to remember or at least make a note of the temperature at which you are making a

measurement. In addition for this experiment this is also going to play a role and one could end up using a mercury thermometer or an ethanol thermometer.

If you are doing at room temperature ethanol will be safer because incase the thermometer breaks there are no issues. Of course if you are doing experiment at much higher temperature let say at 80 degree Celsius then ethanol thermometer will not work and then you might have to using a mercury thermometer. You are able to realize that depending upon the setup that you are going to end up having the apparatus also could slightly change and the judicious choice of the same has to be done while you about setup the experiment. Last but not least one of the important equipment that one might needing in this is the analytical balance which would help us determine the amount of aliquots that we end up adding.

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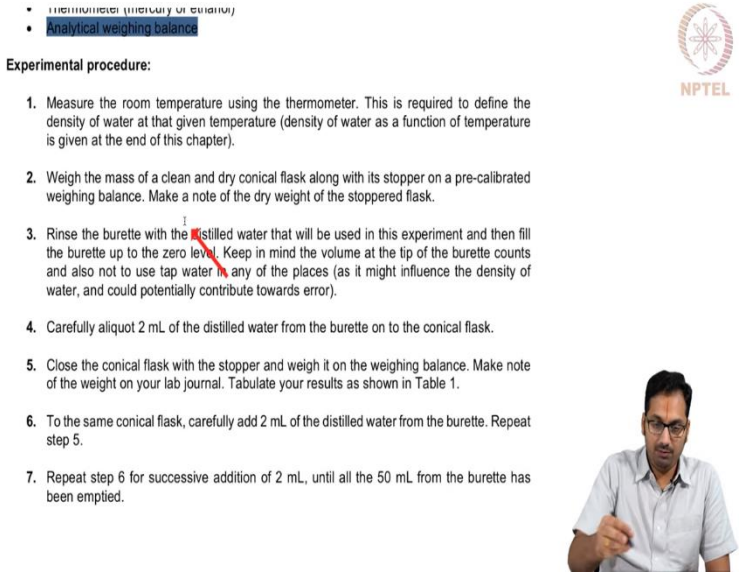

So now let us (()) (04:41) into the experimental procedure it is a relatively a simple procedure the first step is to measure room temperature with the thermometer. This is required because you are going to be having a water in your burette. And this water is going to be in aliquoted out into the conical flask. If you add a known amount of water and if you able to measure how much you added this would help you understand how much is the accuracy that comes out of the burette.

Remember it just not the accuracy of the burette it also depend upon how you end up aliquoting. If you start making a few mistakes here let say a certain systematic error that comes up this is going to end up not just the calibration of burette it is also ending up calibrating your own

standards of how much you end up adding. Ok the next step would be you weigh mass of the dry conical flask.

This is done because using this flask is where you going to be adding different volumes of water to measure how much comes out. So this help you understand the aliquoting a certain volume v from the burette and if you are able to measure the same volume by getting the mass and taking a product from mass to density you will be able to agree that you are doing whatever you are anticipating to be doing ok.

Before you start the experiment rinse the burette with distilled water that you are using remember the emphasis and distilled water is need here this is to ensure that the density that has measured of the range of temperatures of this water is very well know. If you are using tap water at different location it might have difference salts which will end up changing the density of water therefore our estimate could be wrong and result in systematic error due the water that you end up using.

So it is always a good idea to be using distilled water for this experiment so as to accurately determine the calibration of the burette and the procedure. Remember to fill the burette up to the zero level. This is the mistake many students end up doing where they do not fill up the bottom part of the burette where the solution comes from and this results in a systematic error of about 1 to 2 mL depending upon the make of the burette that is the same point it is written here.

So generally protocol as you able to realize well also have the information of do's and do not in order to minimize an influence of the error that might end up coming ok. Now starts the experiment you carefully aliquot 2 mL of the distilled water from the burette to the conical flask. After having done that close the conical flask and then weigh it again in the weighing balance since you have weighed empty conical flask.

And now you are weighing it with 2 mL addition you will be able to understand how much of mass and what you have added is in the density you will be able to convert the mass into volume and determine how much volume we expected to add and how much volume we ended up adding therefore helping you how to calibrate the burette. So repeat this task by adding 2 mL of water again and again until you have certain number of measurements so that you can understand

whether you are able to repeatedly add carefully or if there are any mistakes that end up coming if you might remember a constant error or proportional error could be determine from the experiment that you are doing.

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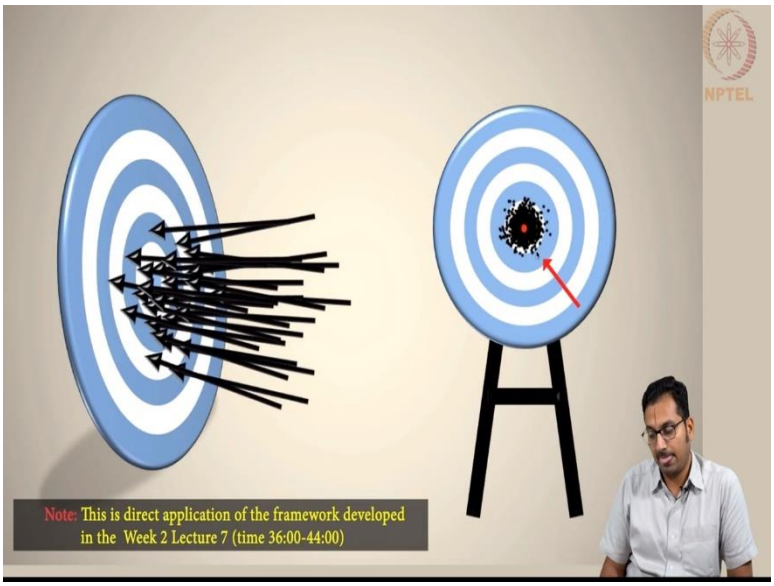

We will now take a look at an animation of the same so as to understand what is that we are trying to do. Let us assume that we are trying to make a measurement such that you are going to determine how good the accuracy and precision is.

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As you might have remembered earlier will be taking an example of arrows hitting a dart board. Let say you want to hit the right of the center of the dart board however you going to achieve this. And in order to this of all the dart if you might remember the represented in 2D surface as you might end up seeing here coming up as dots in the measurement. And the average and the standard deviation will help us understand accuracy could be given as a dot that goes in the center with darts that help you to understand what is this standard deviation that end up coming?

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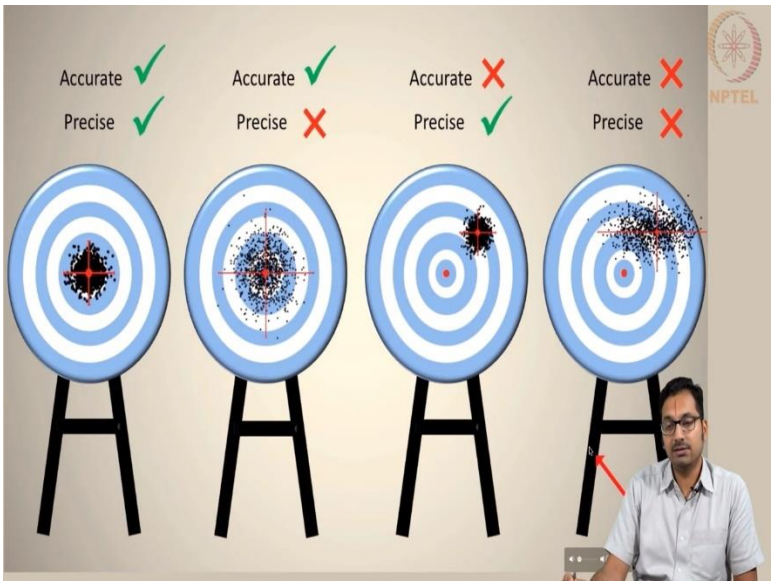

And let say these are the 4 different measurements that we end up having. We have already seen this during the lecture which give you better accuracy and which gives you better precision. As a scientist if you are calibrating the burette you want ensure that if you are adding 2 mL it exactly want to add only 2 mL not more or less. As you are able to realize these are 4 difference characters one ends of having a in just to exemplify the point that we are trying to understand who gives you better precision? Who that gives to accuracy at whom neither gives to accuracy or precision?

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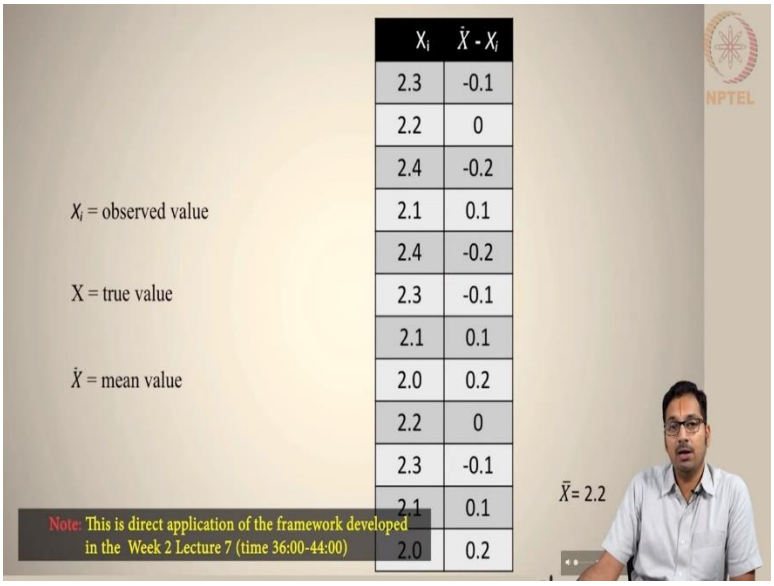

So let say Xi is observed value meaning that you are trying to make measurement and x is the true value capital X is the true value meaning that is where you want to be as close as possible

after you measurement and X bar is the mean value which is trying to pick up what is the true value. Then what we end up doing is that these are all the measured or the observed value you determine.

What is the mean that comes out of this measurement and take a difference between this mean to that of the every observed value so that you even understanding of how much residual comes in to place? Meaning that how far each measurement from the sample mean itself having done that the next part would be to a determine how the sample mean and the standard deviation parameter would help you access accuracy and precision.

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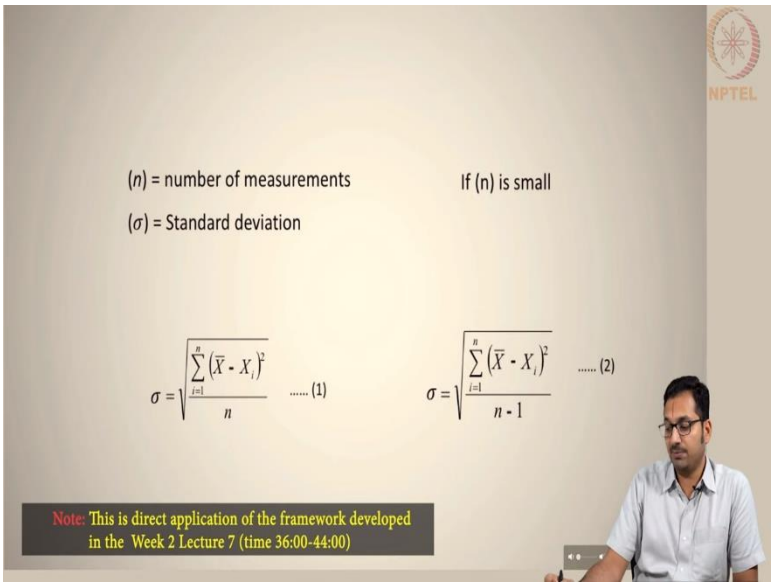

So you want to ensure that you have a certain number of measure n that goes through an sigma that is the sample standard deviation as given here. In this case of population standard deviation assuming a have a good number of measurements. And in the case that n is small this ends up being given as the square root of sums up a squares between difference between the sample mean and observed value divided by n - 1 for n number of measurement where n is small number.

Now having done that let us try to look at how can we distinguish the dart boards that we saw a little while back. Watch you end up seeing is that if you want to hit the middle of the dart board the average nicely comes up to the middle in the standard deviations is fairly with in the first circle. On the other hand, in the second case what ends up having is happening is that all the average comes up nicely at the center the spread of the points are quite a bit.

And you are able to realize some of the points are even falling beyond the 3 standard deviation which does make sense because you are looking at 0.3% of values which may end up falling out. And on the other hand in this case what you are able to realize true value of center the average value of all of this which is the sample mean comes up quite far away although you have very good precision that end up coming up.

So this is the one of the case where one has to be careful although you have a poor accuracy of very high precision and not always or never in any given scenario this is a good reason because this ends up giving resulting in a biased analysis. Now going to the next case if you see the true value that is here the average values for these measurement are far away and the spread is bad which results in a imprecise and an inaccurate measurement. This is a very bad scenario to be existing or working in.

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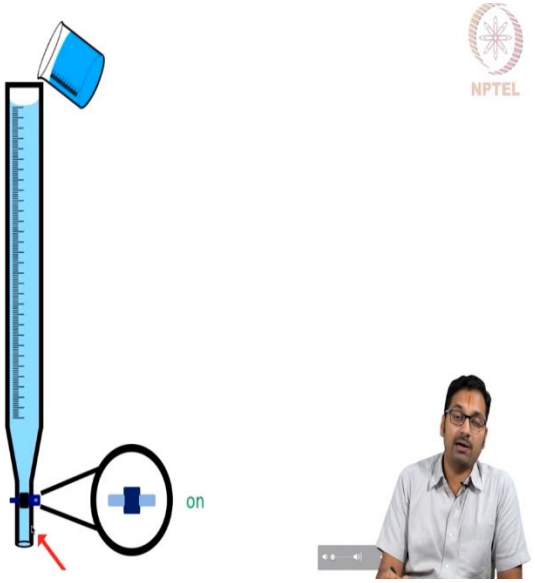

Ok so now let us take a quick look at how this experiment will be performed. You are looking at the burette here where the distilled water that you end up adding is carefully added on to the burette. Ensure that the burette is opens so as to fill the bottom portion of it which will ensure that no systematic errors come into place. If you are not filling this part you are definitely going to introduce a certain constant error across each of our measurement.

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Now having done that trying to use your schematic ok you measure the weight of a (()) (12:15) conical flask and once you have gotten that the next step would be take the conical flask and carefully add a few mL of water into it and repeat the measurement in the weighing balance the difference in this would help you understand how much mass of the water has been added.

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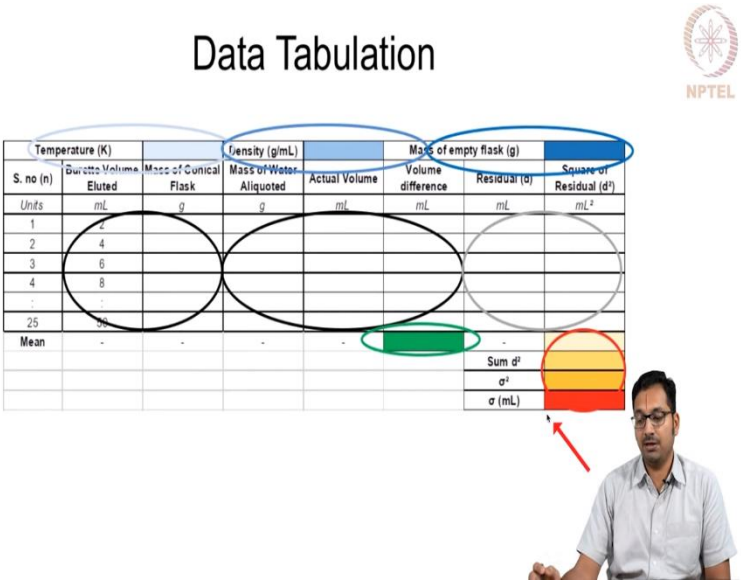

And then this is where we are coming into this week topic of how the data can be entered into a software. If you are able to realize a good scientist would end up making a table that is comprehensive as you are able to realize these are the measurements that are being done. And these are the different volume we end up adding in this case we are trying to say let say you do 25 experiments where n = 22 adding 2 mL where expected the finally finish it off in 50 mL.

So the next step while we are doing this would be measuring the mass of the conical flask with water which means that you should also had the empty weight of the conical. Remember the density of the water is going to play a role because of the function of temperature density also changes. So it is a good idea of temperature to start with.

Now that once you measure the empty weight after as you keep adding the aliquots to be able to measure what weight it has come through and therefore you can determine what mass is added and what is the actual volume difference that comes up having done that you will able to find the differences for each of the aliquot and get the mean. The mean from the distance are the

difference of the mean from actually every addition will give you the residual from which we will be calculating the standard deviation.

Of course first step would be to get the differences from each of the measure to mean as given in the residual square of the residual sum of the square of the residuals then you use a formula of standard deviation and finally get the samples standard deviation in terms of sigma.

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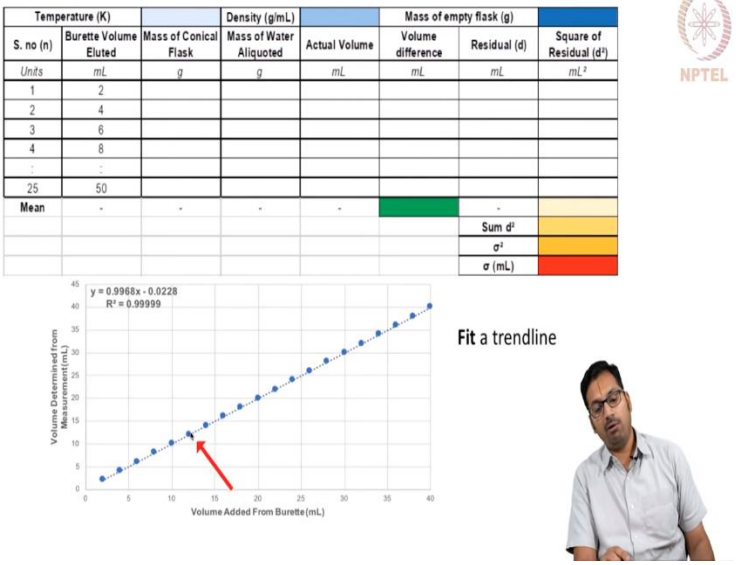

Temperature (K)			Density (g/mL)		Mass of empty flask (g)		
S. no (n)	Burette Volume Eluted	Mass of Conical Flask	Mass of Water Aliquoted	Actual Volume	Volume difference	Residual (d)	Square of Residual (d^2)
Units	*mL*	*g*	*g*	*mL*	*mL*	*mL*	*mL²*
1	2						
2	4						
3	6						
4	8						
:	:						
25	50						
Mean	-	-	-	-		-	
						Sum d^2	
						σ^2	
						σ (mL)	

So once you get this you can actually plot as a function of volume that you ended up adding in the burette for those actual volume that came up which will help you to fit and determine whether your accuracy is good which will be seeing in the moment. And how off you from each of the measurement that ended up happening. So now let us start to go ahead and pick up some of the skills that you might end up needing for the software analysis.

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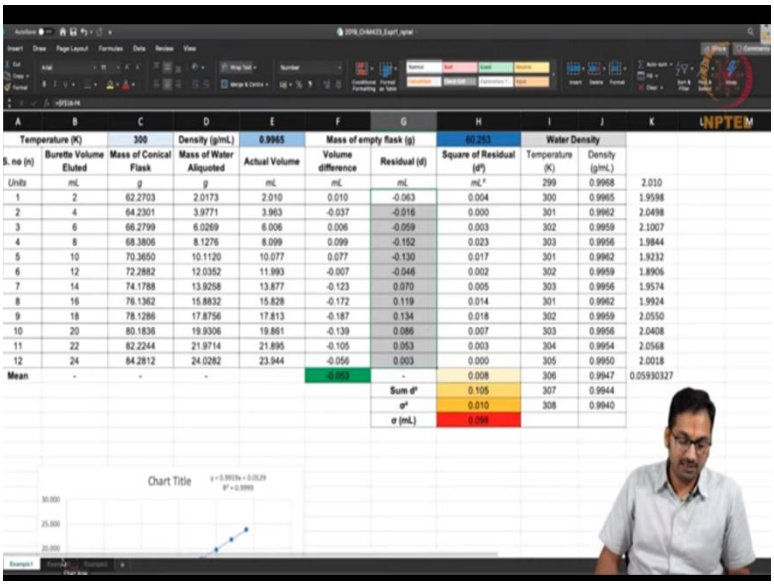

Ok so now we are moving on to how this experiment can be nicely documented with the use of a software. So here as you are able to see this experiment is done at 300 degree kelvin so as to get the density of water. If you realize the density of the water a 300 kelvin is 0.9965 which we end up writing here. Many of the software spreadsheet software in particular end up having their own bias and how many decimal points to indicate.

So it is always a good idea to indicate and good for you to carefully change whatever number of significance figure make sense. And let us assume that for this measurement the scientist measures a total mass of 60.253 grams where the uncertainty exist the third the last the decimal. Basically in 1 milligram for each of this measurement and let say that the following measurements were made let say that after the scientist as carefully determine the empty weight of the conical he ends up adding the 2 mL of aliquots each time to perform 12 such experiments here the case n = 12 and he is also able to measure the mass of the conical as a function of this volume that has been added. As you are able to realize this comes up with the mass of the conical.

So the first step that would end up happening here is to take the difference in each of the step so as to understand how much volume has been added. So we have been looking at how spreadsheet has been used for different analysis. We are going to be ending up doing the same thing where we carefully add formulated in order to get whatever we want. So in this case you want to understand what is the mass of the 2 mL aliquot addition to that of the mass of the conical itself.

So this is going to be in the cells C4 as in most of the spreadsheet you are going to have alphabetical sorting at the top and numerical sorting on the left. So given cell can be tribute to a certain alphabet and a number. And in this case you want to take a difference between the mass of the conical which has entered in the cell C4 to that of the mass of the empty conical which is in H1. So what ends up happening here is that you write a formula C4 - H1.

So if you are able to realize the C4 is highlighted while the blue and H1 is highlighted with the red which helps you to understand which 2 parameters are you taking a difference between in this measurement. Once you enter you are able to realize that this is carefully calculated the difference between this value and that of the empty conical flask. Of course, one can repeat the same process by typing it where you take the difference between C5 and that of H1 and so on.

Although this appears a little automated this is indeed the boring and laborious process and there are better ways of writing such a formula where you actually say it is C4- dollar H dollar 1 which indicates if I am copy pasting this set of formula on to this on to these cells what is end up happening is that you will carefully notice is that as you copy paste C4 becomes C5 while the H1 does not change.

So this helps you because if you are having many different values one it takes a lot of time for to take the difference carefully with this otherwise if you copy paste this formula this will be erroneous without the dollar because it will end up taking differences not from this but also from other cells that go here ok. So for instance why do not we take an example of what happens if we do not have the dollar here.

Well the first value will come up fine the remaining values will not make sense. As you are able to realize it is not able to understand the value here because it is trying to take the difference pretend 64.2301 to that of the square of the residual so which does not make strength it is a string as you forward you able to realize that this value is the difference between C7 and H4 which is not the difference that you want to end up taking.

So one has to be very careful where you in include this dollar such that for every value end up measuring the dollar one does not move at all. So this help you understand how to use spread

sheet in order to make the difference across different cell and keeping once cell constant where other cell increments based on the value that you want to measure. So now that you know what is the mass of the water that has been aliquoted one has to remember to get the volume because you are adding volume and you would like to see what is the response that comes from a given volume?

So the volume is going to be given by the product of mass to its density. Once again in this case I am using another formula that goes is D4 Asterisk E1. This asterisk is the symbol for multiplication that we end up using in all this software and division is we plainly given by a backslash. So here one is able to realize that D4 star E1 is what you want and similar to previous example if you copy paste this all of the cells it is going to end up having a problem because you while you want an increment the D you do not want the increment E because it is a single value. So what you end up doing is to give it as a dollar E dollar 1 in the formula.

Now if you copy paste it would make total sense where carefully the volume that has been added in each of the aliquot that nicely come up. Now what you are able to realize is that for every 2 ml increment you were able to see the amount of volume that you have added. So the first step here would be to take the difference between how much you have added to that of how much you expected yourself to add.

So what you end up getting in this row this can be happily copy pasted largely because all this formula end up going as a cereal increment. So you can also copy paste this. So now what you see is that for 12 different measurements you have been fairly accurate enough where the mistakes happen in most of the cases in the second decimal. If you carefully pay attention for these measurements the mistake happens in the first decimal itself.

This helps you to understand the facts that there are measurements where one end up adding a little more or a little less. One way of determining where do you fall is to take the average of this differences that end up coming by having the average formula. So this is once again were the software helps where the average is nothing but the ratio of the sum of each of this value to the total number of measurements in this case you would end up summing all of them in F dividing by the total number which is 12.

So but instead of doing that you end up getting average in a single shot. You are able to realize the average nicely represents values across meaning that you have some values that deviate by -0.19 ml well others end up deviating with -0.10. So the average of all of this including values that go away and in some cases positive deviations to finally come up with average of -0.05.

So this is what once again indicates that you are probably erroneous in the second decimal but thinking over the 3 standard deviation that comes you probably looking in -0.15 also exist in a value it nicely thus happen in this data that you are trying to look at. Now that you have gotten the average of all of this measurement the next step that you like to do is to take the difference between the sample mean and that of each measurement.

Once again if you realize you want to keep make sure the sample mean is kept constant so you want to make it as dollar F dollar 16 and you start making the differences and what we end up getting is that these are the residuals for each of the measurement that you end up making. So just before going ahead let us see whether how good has our aliquots been. So I am trying to plot the aliquots that you ended up adding this case the column B with that of column G carefully selecting only the values that we would like to plot.

So if you go to insert and plot a scatter plot what here able to realize is that in the X axis you have the different values rather the volumes that you aliquoted and in the y axis the residual meaning that how far from the average that you deviated and you are nicely able to see good amount of points less than the average and more than the average. Of course, in this measurement it is quite interesting to see that the initial first values are less than the average and the final values are above than the average.

This could also indicates the biased or the systematic error that comes up but for now lets not worry about it. Let us go ahead and try to understand what is the standard deviation? In order to do that we would like to take up this square of it which is given by that cell charact 2 charact indicates to the power often 2 indicates the square if you want to take the cube you would do the character 3.

So now you end up getting the square of the residuals because if you remember the standard deviation is nothing but the square root of sum of the square root of the residuals to the total number of measurement or total number of measurement -1. In this case since we have only 12 measurements we have to do square root divided by n - 1. So what are we going to get here so let us try to take this sum of all the residuals and you can also try to get the average of the residual.

You see in this case the average of the residual nicely falls very close to 0. This indicates that almost every measurement from the average measurement that you end up getting you nicely have equal number of points above the average and below the average and the magnitude of this value being small indicates that you do not have large errors that are come up ok. Now thus you have taken out some you want get the following measurement this is going to be this values divided by total numbers of counts that you end up having luckily this kind of software nicely have the kind of count that you end up having.

Meaning that it can itself count how many values you have. So in this case the count is going to be obtain by using the formula or the library function called count and selecting the values that you forgotten it. And since n - 1 I am taking H17 which is the sum of the residual square divided by the count -1. So what you end up getting if this is the variance and this standard deviation is going to be the square root of this variants ok. So now that we have understood this is representation of the precision of measurement. What is my average? You should be able to understand what is the average that comes up by having eternal cell that we can define here.

The average on the other hand can also be obtained by a quick fit I hope you have learnt what is fit in the previous classes. So let us try to do a fit of the variable that you ended up changing that is the independent variable to that of the dependent variable that you ended up getting from the measurement. And if you get a scatter plot you are nicely get the linear curve and this should be helping us to understand what is the accuracy that comes up that’s try to added to the trend line.

Trend line helps you to get a fit now this software will help you to get all this in a single click. And you are able to remember that for these kind of measurement if you added a no volume of water suppose you get no volume of water. So therefore you can set the intercept to 0. Meaning that at when you have added no volume of water you expect no mass of the water to be dis

obtain. You also display the equation on the chart to start with let us also see what happens when you do not have the intercepts 0.

And you can also have a reasonable way of determining what is indeed the fit? Whether the fit is good enough or not? Basically the linear regression fits helps you get a parameter called R square. In this case R square is very close to one. You might remember R square of 0 means it is poor fit and R square of one means it is an excellent fit. And what you are able to see here while x is the variable that you are varying this is the slope that you end up getting this is your intercepts that you end up getting.

The intercepts says what is the constant offset that you end up getting well the slope give you an indication of how much proportionality comes in to place. Let us say that you wanted to add 2 mL every time and you precisely and accurately added only 2 mL. This curve is going to be fitted with an equation which says Y = X meaning that for every 2 ml that you added you are able to measure 2mL correctly.

But you are able to realize there are deviation that come up largely because there are being difference that have come due to various different thing. Of course due to systematic error that would come from the weighing or the aliquots that you ended up doing where you adding 1 drop more or less. On the other hand maybe your temperature was fluctuating during this measurement which once again ends up having errors that might increase the temperature that kept on changing fluctuating during this measurements.

And the standard offset could have come from the basic fact that the burette or the weighing balance for mis calibrated meaning that which is why prefer starting any experiment calibrating the instrument become important. And of course the fit makes you happy in this case because of fit seems to be quite reasonable where all the points are in fact contained within the fitted line which I shown as a dotted line in this case.

So you are able to see that the dotted line nicely passes over a each of the fitted value or each of the measured value which indicates that you gotten a reasonable fit ok. Now having understood that what we are trying to see what is the average value that come up for the each of the

measurement? In order to get that what we will end up doing right now is to take the difference between the values that you obtain.

So the first one you already got 2 mL. So the next aliquot measurement you can try to ask what is the difference between the subsequent measurements. And then you copy paste this carefully to understand what you end up getting. Now what you are able to realize is that for every 2mL that you try to add you are having subtle deviation that come up. Meaning that in this case you ended up adding 10 microliters more, in this case you ended up adding 40 mic above 40 microliters less.

In this case about 50 microliters more and so on. And here about 100 mic sorry not microliters about 10 about 10 microliters more ok I think and then about 100 microliters more here. So let us try to take the average that comes up here and then average will help you to understand how accurate you were. You wanted to add 2 mL and you are actually add 2 mL and you should be able to even get a standard deviational this measurement let try to say how different from the standard deviation and that you have measured.

If you will able to see the fitted value gives the 0.0529 and that is somewhere close to what you are getting here. So you are able to realize the same analysis that could be done in certainly different ways which will give you certainly different values. But overall what you are able to understand here you will had a 2 mL that you wanted aliquot and you are only getting the average around 2 but your standard deviation is about 0.06 mL right.

So basically you have a variation of 60 microliter in each of the aliquot that you ended up getting. And you are also able to remember the fact that the residual that that came for each of the measurement are above and below the average which makes you happy.

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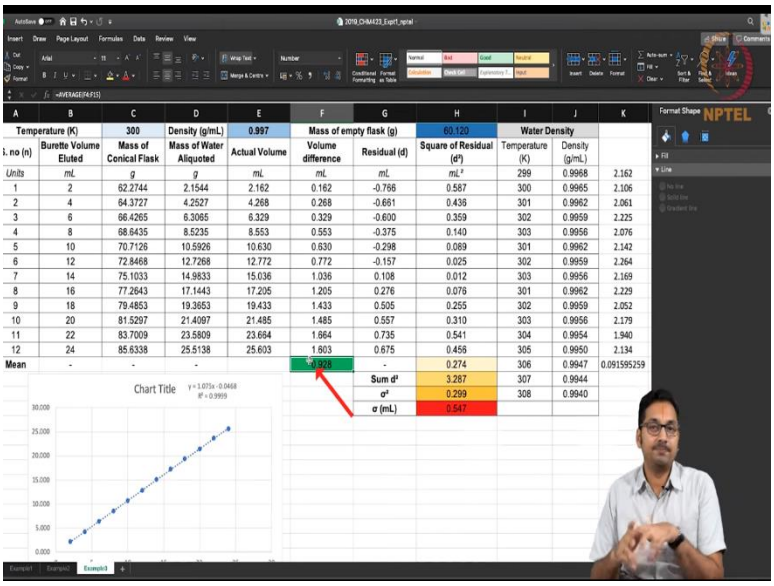

Let us take another example in a similar case and in this case I have already done all the necessary math using the similar type of formula that we saw in the previous slide. So what we are able to see here the experimentalist ended up measuring all these values again and determine what is the mass for aliquot that ended up coming and converts it to the volume based on the density.

After having done that finds what is the difference between what aliquot has been added and what was expected to be added. And this is been done for each of this step and you are able to realize that average volume difference comes upto -0.26. In the previous case you had very close to 0 which indicated that you had a very reliable basically a precise way of adding aliquots. But in this case you are able to realize that quite far away that indicates that your measurement is erroneous.

And one important thing to remember is that in this case you had quite number of values that go above and below the average for instance let plotted again and take a look at it. You are able to realize that the good number of values go above and below so that makes you feel good. But on the other hand in this case you are already able to observe the fact almost all of this value are negative. So why do not you plot and take a look what is happening?

When you plot what you are able to realize all the deviations are below the 0 line. You want to be as close to its possible 0 line. And you are able to realize all this point are below the 0 line this

clearly indicates that either one measurement completely offset all the other measurement such that although it is random its around this value is quite far away. It is randomized around the mean value of -0.25 however you are trying to make sure the average goes to 0.

So this clearly indicate your shifted from where ever you suppose to be. So this clearly indicates the systematic error that has come up in the researcher's analysis. Of course repeating the analysis here you end up getting standard deviation that is very close. You got 0.1 earlier you are getting same 0.1 here. But let try to see what is the accuracy that comes up for this measurements. Once again that we do by taking the difference between these values.

And you are able to realize here is that the researcher has had an initial measurement which was about 0.15 away and there are some measurements are once again keep on repeating to a similar magnitude. So now let us quickly figure out what is the average. You are able to realize that coming close to 1.97 98 actually and the standard deviation is about 0.1. Now if you see this similar analysis done for this researcher got 2 plus minus 2.00 rather 2.01 plus minus 0.06 and this case this researcher gets 1.98 plus minus 0.1.

So this once again indicates that the second researcher has about twice the amount of error or lack of precision that comes in measurement how are the average value works out? Let us quickly take eternal example int his case what ends up having this being done wantedly where the average is quite far away. In this case you are able to see a certain number that comes. But in this case it is much farther away this probably once again indicates something let us quickly take a look that how much far away is the researcher in each of the measurement.

You are able to realize that this researcher has the same level of precision as the example 2 which gives 0.1 however the average is clearly shifted away. You are expecting an average of 2 mL but you are getting something like 2.13 mL. So in the previous case you got 1.98 plus minus 0.10 and at this case you are getting 2.13 plus minus 0.10 or 0.09. So although within 2 standard deviations these 2 measurements agree with each other even within one standard deviation there are just barely close to each other.

But definitely within 2 standard deviation they agree with the each other you are able to realize that in comparison to the first researcher who got 2 plus minus 0.06. These 2 people are less

accurate and less precise. Accuracy cannot be tool for the second guy where the accuracy is still good but the precision is poor. But in this case you are able to realize that the accuracy is poor so as the precision. So you would want to mimic the scenario as the first researcher by making sure either the experimental set up is done in such a way that no systematic error pop up.

Ok in this experiment what we saw so far is how to use a software in this case the simple spread sheet in order to make your analysis and try to see whether you do get systematic error. So what do you mean by systematic errors? When you are trying to measure 2 mL in this case if you keep getting an average that is farther away which is 2.13 there is probably some error that you are consistently making.

And in this case if you are able to realize when you want to aliquot 2 mL except for this measurement all the other measurement are above the 2 ml. This once again indicates the systematic bias that comes into the data. On the other hand if you are able to see the first researcher when you want to measure 2 mL you have values that are above and below 2 mL within the small error that comes up with equal of value of above and 2 above and below 2 mL that helps you get a fairly accurate measurement as well.

This is a simple example but as you start doing bigger experiments larger number of data sets come up and you would have to do data analysis at every step which ends up also propagating different errors that come up. If you remember we learnt about what is the error propagation and those things stop also start coming up. In this case where are all you could have a error. Probably propagation is the density measurement is assumed that it is correct until the fourth decimal.

It could be a case where your thermometer was some good enough to give you plus minus 1 kelvin or your density measurement is little erroneous, or you ended up using water that has some contaminants. And at the same time the weighing balance that you end up using need not be calibrated or it has a constant or proportional error that ends up coming. Therefore, it is always a good idea to calibrate the instruments before you start.

And each of the measurement that you end up getting the actual volume is obtain from the density so therefore the error gets propagated from their as well. And finally what could end up happening is that researcher as you are copy pasting you might end up making some mistakes

which results in erroneous measurements. Luckily that is personal error and that would end up giving a gross mistake from the measurement that you end up making.

So you would be able to pickup what is the gross error. And on the other hand systematic errors would come up if you are having all the values above or below a certain value that you are trying to measure. Calibration errors have to be taken care before you start and let say that all of these have been taken care and you still end up getting standard deviation of about 0.06.

This indicates these are indeed random errors and the only way for us to find is to repeat this measurement several number of times and see how much the standard deviation changes and trying to get the histogram plot. Once again the histogram if you are able to get a nice normal distribution that kind of indicates that this is indeed a random error and you probably cannot reduce it any further due to whatever inherently exist in the system.

And I hope this has given you example of how to use software and in this week you would be given data so as to students to analyze using a simple spreadsheet software and to start with this is an example where it is a linear regression that we ended up fitting to understand how the data can be analyzed. And to finish up same way we ended up doing the linear fit for the first one you can do it for this one as well just to see how far does the measurement deviate from the average value.

You will you might still end up getting good fits here you still end up getting R square of 0. 9999 which indicates the good fit. But unlike the first example where do you had value very close to 1. So you had something like 0.9919 in this case you are having 1. 075 which means about 8% off meaning that each of the measurement you are adding about 8% higher or lower. And the standard deviation in this case a negative of -0.05 which means that it could also have started with slight shift that ends up coming.

So one is able to understand that the same analysis could be done in certainly different ways to have an idea how far is your measurement and how to be careful when you are making such measurements. In the next class we will be trying to take a look at how to remain enthalpy of dissolution of a solid solute in water and use some similar software to get what is enthalpy of a dissolution. Thank you very much.