Quantitative Methods in Chemistry

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Lecture-02

Defining Molality and Normality, relationship with Molarity

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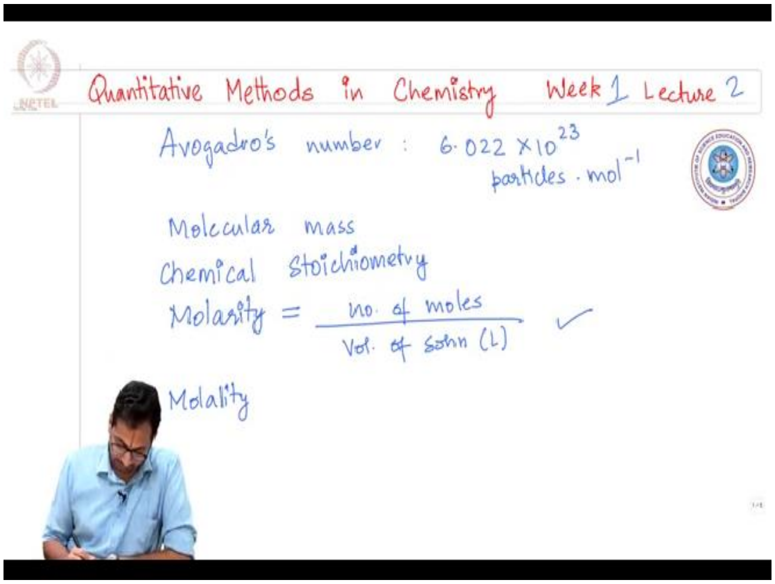

We are moving a Hcl with the second lecture in the first week of our classes, the first point being the Avogadro number. This number helps us understand how many particles are present in 1 mole of any chemical which is 6.022 into 10 to the power of 23 particles per mole. And then we moved on to understand that the molecular mass determination, molecular weight for different types of chemicals, we try to look at sodium carbonate, water and sucrose.

In addition to understanding how to determine the molecular mass, we also defined what this chemical stoichiometry having different chemical stoichiometry, we understood what is the limiting reagent and how to determine stoichiometry of different reactions that engage in a chemical reaction, the finished of the lecture by defining the concentration term called molarity. How did we define molarity, molarity is defined as the number of moles divided by volume of solution in liters.

To continue from where we left off, the next unit of concentration that we will be trying to look at today is molality. Let us ask a first question. Since we have already learned what is molarity. What is the need for learning what is molality.

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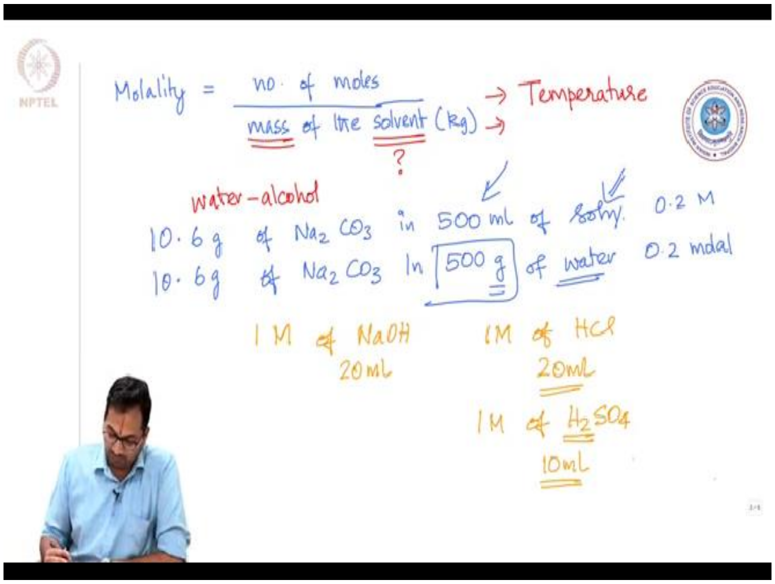

First thing molarity is dependent on the volume of the solution. So, one has to remember how do we make such solutions, you would end up adding let us say solid on liquid to a volumetric flask and make up the volume to given mark in that given volumetric flask, let us say we want 100 ml, we take 100 ml volumetric flask and make it up to that given mark looking at the lower meniscus or upper meniscus depending upon the solution.

However, one has to understand that making up solution in terms of volume has a major limitation in the fact that small variations in temperature could result in differences in volume of the same liquid. It could be that the vapor pressure of a given liquid is different and you could also have other problems that are associated with it. Therefore, the term molality was introduced, where molality is given by the number of moles present in 1 kg of the solving meaning mass of the solving in kilograms.

The major differences that come here is that it is not the volume of the solution. And other thing of course I just mentioned it is not the solution we are looking at we are looking at the solvent, as we know that the mass is going to be almost invariant with respect to temperature, this is a measurement that would be easy to do. The reason why we are choosing this is to ensure that small variations in temperature did not result in variation in the concentration in unit that you are looking at okay.

So what are the advantages of it as I mentioned temperature is one advantage. And the second advantage here is that let us say you have multiple solutes. So what will end up happening is that when you have multiple solutes, it does not matter how does the volume of the solvent change. So basically you are adding the same mass of the solvent here. Therefore, when you are determining molality of a given chemical, it is invariant to other solutes that are present.

However, there is a slight disadvantage here. What do we decide as a solvent. For instance, if you are taking a water alcohol mixture, and you are dissolving a given salute into it you pick the alcohol as a solvent, or the water is the solvent. These are things that clawed a little bit of how to use this parameter. So it has not been used much. But let us take a look at an example as we did yesterday.

So, yesterday we took an example of 10.6 grams of sodium carbonate in 500 ml of solution. Remember, I had mentioned it as water, which is a slight mistake we had assume there that dissolving 10.6 grams of sodium carbonate does not change the volume, which may not be right. And these are the other things that come as an advantage of molality it does not matter how the volumes change, you are adding a certain mass, which ensures that your determination of concentration is fairly accurate.

So now going on the same thing if you are trying to understand, let us see what happens when you dissolve 10.6 grams of sodium carbonate in 500 grams of water. You realize that this is as we calculated yesterday 0.2 molar on this case is be 0.2 molal. So, that is the main difference that comes up between these 2. But remember, this is a measurement that goes with the mass of the solvent, rather than the volume of the solution.

So that is the major difference that comes up between molarity and molality okay, as we move further, why do not we take a look at a simple reaction. What do I mean by simple reaction is that let us say you have 1 mole of NaOH and you would like to neutralize it with an acid. So let us take 1 molar of Hcl, if you are going to take a certain volume here, let us say you take 20 ml here, you will need about 20 ml or rather you would exactly need 20 ml of Hcl that is 1 molar to standardize or rather to neutralize the sodium hydroxide base.

On the other hand, let us say we are trying to neutralize it with sulfuric acid. A simple question that would come up here is that how much volume would be required. And if we are able to see, since there are 2 protons that are present in this acid, you would only need about half of this. So this results in a little bit of tricky understanding of molarity. Basically, when you have 1 molar NaOH, you have equal volume of Hcl with 1 molar that neutralizes it, while half of the same concentration of H 2 SO 4 tends to neutralize it.

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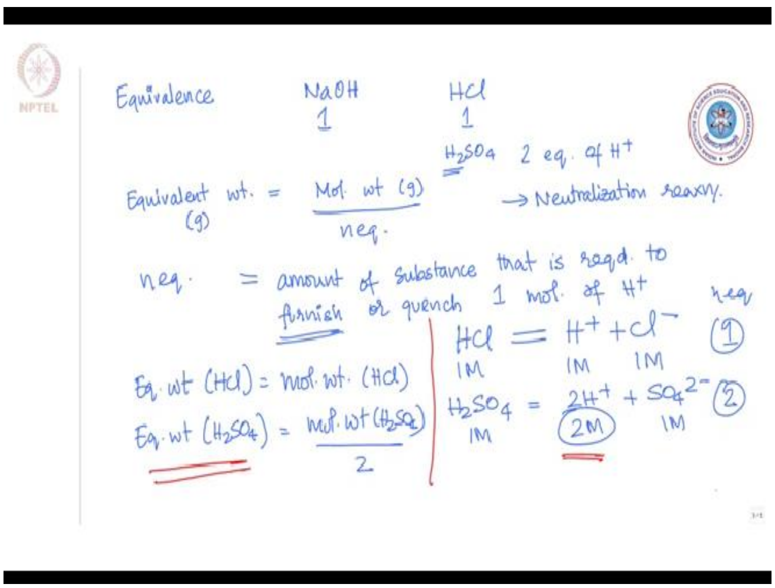

So this brings us to the concept of equivalence. So, basically for NaOH and Hcl the equivalence here is 1 : 1, on the other hand H 2 SO 4 which tends to have 2 such basically provides 2 equivalents of H +. So, this is where is the definition of equivalent weight comes into picture. So the equivalent weight is given by the molecular weight, of course, in grams equivalent weight is also defined in grams divided by the number of equivalents.

Here unlike molarity, which does not matter what kind of reaction you are using a chemical, this definition of equivalent weight requires what you are going to be using the chemical towards, for instance, let us say you have a chemical that could be used in this case, let us say NaOH for a neutralization reaction. In case of the neutralization reaction, the number of equivalence is defined as the amount of substance that is required to furnish or quench 1 mole of H +.

So, what do we mean by this is that the number of equivalence in case of H 2 SO 4 it can furnish 2 moles of H +. On the other hand when you are looking at Hcl 1 mole of Hcl 1 molar solution of Hcl ends up providing 1 mole of 2 H + ions. So this is where the excellence comes from what you are able to realize is that your Hcl the number of equivalents is 1. On the other hand, the number of equivalents for H 2 SO 4 is 2.

So therefore what ends up happening the equivalent weight for Hcl is equal to its molecular weight in this reaction, but on the other hand the equal weight of H 2 SO 4 sulfuric acid will be half of its molecular weight. This is important to understand because this gives us a perspective of what is equals. Once again, going back to the example that we started with. If you have 1 molar solution of NaOH.

If you had 1 molar solution of Hcl of equal volume, you tend to neutralize it. On the other hand, if you are having 1 molar solution of NaOH you just need half the volume that comes up from the equivalent weight of H 2 SO 4 as it financials twice the amount of H + ions.

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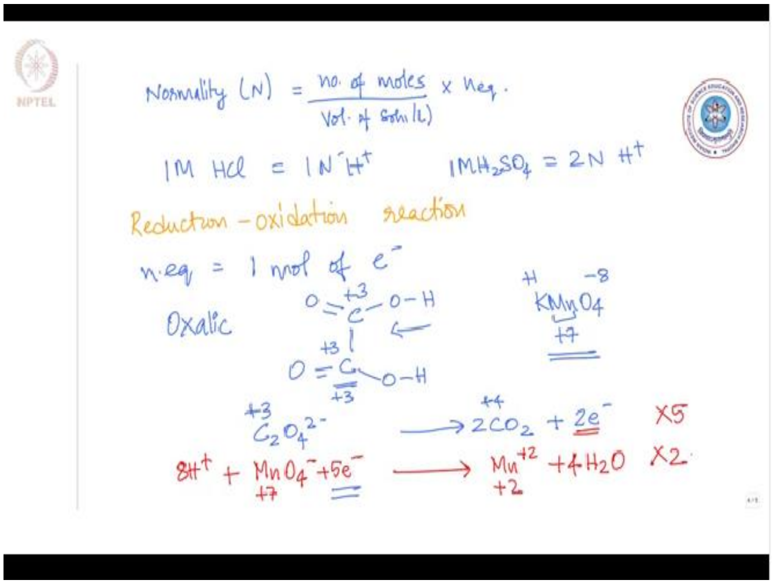

Now, we have defined equivalent weight, the next definition that we will be looking forward is to understand what is normality give another unit n is defined as number of moles present in given volume of solution in liters times the number of equivalents. So the major difference that you are able to see here is that unlike molarity, you are actually having yet another term, which comes up in the denominator, which is a number of equivalents.

As we just saw in a moment back for Hcl and H 2 SO 4 the number of equivalents are different from each other. So for instance for such a neutralization reaction a 1 molar Hcl solution is 1 normal Hcl. On the other hand, a 1 molar H 2 SO 4 solution is 2 normal H + ions okay. We have just seen that number of equivalents has been defined for a neutralization reaction. Let us quickly ponder how this gets defined for a reduction oxidation that is a redox reaction okay.

For reductively action, the number of equivalents will be equal to the amount of substance that furnishes or quenches that is consumes or produces 1 mole of electrons. Why do not we take a little moment to understand how this is defined for a simple redox reaction. I am sure from your school days you have been doing that iteration of oxalic acid with potassium permanganate. What is oxalic acid. Oxalic acid is a diprotic acid where the oxidation state of carbon is + 3.

And then you are titrating it against potassium permanganate, where the oxidation state of manganese is + 7. So now when you are using an oxidizing agent against oxalic acid, what is going to end up happening is that the carbon is going to get oxidized. So let us take a look at the reaction of oxalic acid getting oxidized by potassium permanganate. Oxalic acid can be written as C 2 O 4 2 -, and it is becoming carbon dioxide.

Here, carbon is a + 4 state here carbon is in + 3 state. So when you are having something like this, what is going to end up happening is that you are losing electrons that go on the other side and what also ends up happening here is that you have to balance the reaction on either side okay. On the other hand let us change the color Mn O 4 - is oxidizing agent, that means it gets reduced, it goes to M n + 2 state.

And what you are able to realize here is that it goes from + 7 to + 2, this indicates it has taken 5 electrons. So in addition to taking this, what you are able to see here appreciate here is that you have 6 negative charges on the left side, but + 2 charge on the right side. So this indicates that you got to be adding acid in these places. Of course, the other part that is going to end up coming is H 2 O. So here what is going to end up happening is that to introduce neutrality, one is able to understand that you have 6 negative charges and your + 2 you have to add 8 H +.

And in order to balance this you have a 4 H 2 O that makes it 8 hydrogens on both sides and 4 oxygens and the neutrality is balanced. What you are able to see here is that the oxalic acid loses 2 electrons, while the permanganate gains 5 electrons. So what is going to end up happening similar to LCM and GCD you got multiply this by 5, but you got multiply this by 2.

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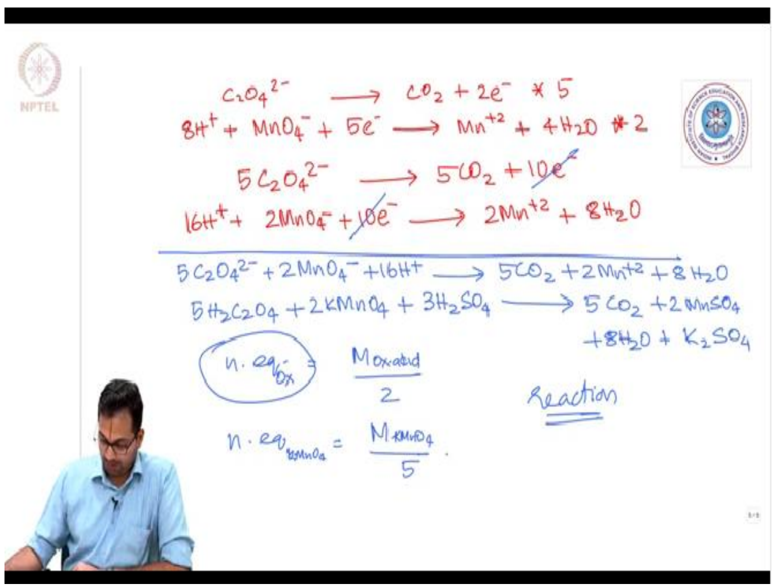

So let us rewrite the reactions C 2 O 4. This results in mutual cancellation of electrons on both sides, which gives us an overall balanced reaction of 5 C 2 O 4 2 -, + 2 Mn O 4 - + 16 H + giving 5 CO 2 + 2 mn + 2 + 8 H 2 O. Of course, you are able to see the fact that you need about 10 protons here as oxalic acid has the protons. So if you move the 10 here, what is going to end up happening is that you are going to have 5 H 2 C 2 O 4 + 2 KMnO 4 +, so how many protons you have left, you have 6 protons left.

So 6 can be written as 3 H 2 SO 4, you need an acid for this redox reaction to happen. That is going to result in 5 CO 2 + 2 MnSO 4 + 8 H 2 O, remember there is potassium is K 2 SO 4. So, you have 3 sulfate on the left hand 3 on the right side. So, now that we have done this what we are able to realize the equivalence of oxalic acid is going to be given by molecular weight of oxalic acid divided by 2.

While the equivalence of KMnO 4 is going to be given by molecular weight of KMnO 4 by 5. So, this helps you understand the concept of equivalence is dependent upon the reaction that you are putting the chemical through. So, without the idea of understanding what reaction you are going to be using the chemical for you cannot be defining what are the number of equivalents. So far we have seen examples of number of equal determine for a neutralization and a redox reaction.

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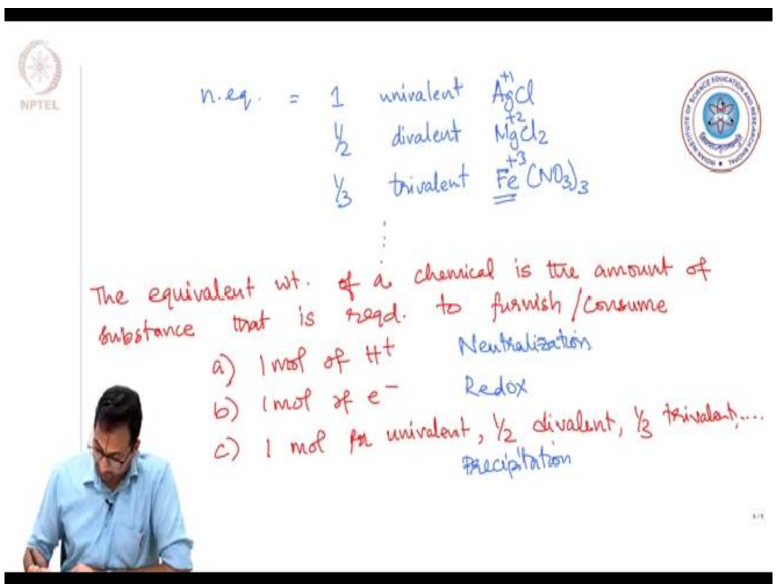

Let us go and repeat the same process of understanding number of equivalence for a precipitation reaction. For instance, if the number of equivalence for a precipitation reaction is going to be 1 for a univalent cation or anion 1 by 2 for a divalent anion or cation and 1 by 3 for a trivalent anion or cation and so on. So, for instance univalent, what do we mean by univalent and something like any NaCl or silver nitrate or other.

So, what do we mean by univalent. Let me give some examples of univalent something like silver chloride divalent one can think of magnesium chloride, 5 valent one can think of ferric nitrate. So, here the equivalence of iron is going to be one third because it is going to be plus enter presenters + 3 + 2 and + 1 okay. So now let us try to generalize overall what is the equivalent weight.

The equivalent weight of a chemical is the amount of substance that is required to furnish or consume 1 mole of H + ions 1 mole of electrons 1 mole for univalent one half for divalent and one third for trivalent and this is defined depending upon the condition of reaction. So this is a neutralization reaction. Well, this is a redox reaction. The last case it is a precipitation reaction okay.

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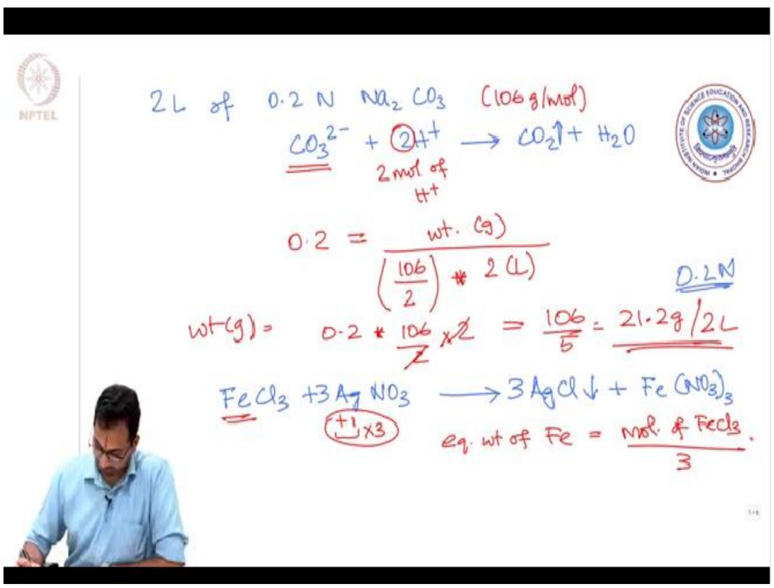

So why do not we solve some examples. So let us say you have to prepare 2 liters of 0.2 normal Na 2 CO 3. The same example as we have been seeing so far, that the sodium carbonate where this carbonate gets converted to carbon dioxide. This is very common reaction that has been I am sure you guys have all performed in your lab practicals where you determine where the carbonate is your anionic by adding a little bit of acid and you get effervescence.

Effervescence comes because of the fact your carbon dioxide that escapes to solution + H 2 O alright. So it is already balanced to start with. So now the question is how do you prepare 0.2

normal of 2 liters, one is able to understand quite clearly since carbonate is taking 2 equivalents, the number of equivalents of the carbonate is going to be given by 1 over 2. The normality is already given as 0.2 which is going to be equal to the weight that is n gram.

So we need to understand how much of sodium carbonate to add. I am sure from the last lecture, we remember, the molecular weight of sodium carbonate is 106 grams per mole then divided by the molecular weight number of equivalence. So basically you had the definition on the equivalent weight and here you are putting the 2 product, the number of liters in solution. So you are going to have weight in grams is going to be given by 0.2 times 106 by 2 times 2, which is going to be 106 by 5 21.2 grams for 2 liters to make overall concentration of 0.2 normal in this reaction.

So now that we have seen an example of this, we can also try to understand what will be the equivalent weight in case of a precipitation reaction. So let us take an example of ferric chloride that reacts with silver nitrate to give our favorite silver meratus AgCl which precipitates and forms a beautiful mirror in your test tube plus ferric nitrate. So we need to balance this really quickly. So what is going to end up happening in you need to add 3 here.

So that the chorine gets balanced and this automatically balances it. In this case, what you are able to realize is that the iron atom is going to be engaging itself or rather will be using 3 equivalents of a univalent silver ion. So therefore, the equivalent weight of ion in this case, is going to given by molecular of FeCl with FeCl 3 divided by 3.

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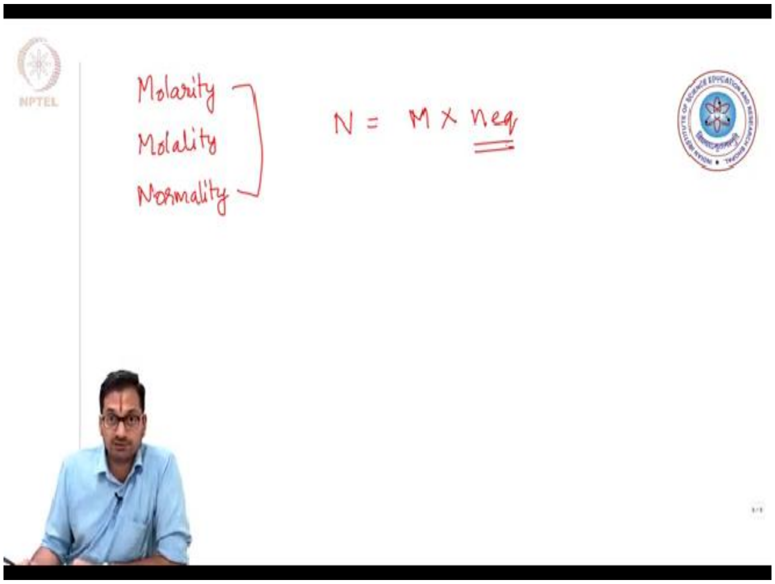

To sum it up in today's class, we have seen 2 more definitions of concentration that can be attributed to chemicals, we start with the molarity yesterday. And then the understood what is molality and the need for it largely because he wanted to have a temperature independent measurement and you have normality that brings us to the concept of equivalence which helps us understand how much to add, even before you get started with.

How are molarity and normality related, normality is going to be given by the product of molarity to the number of equivalents and we just defined in this entire class, how the definition of equivalence goes.