Bio-electrochemistry

Prof. Mainak Das

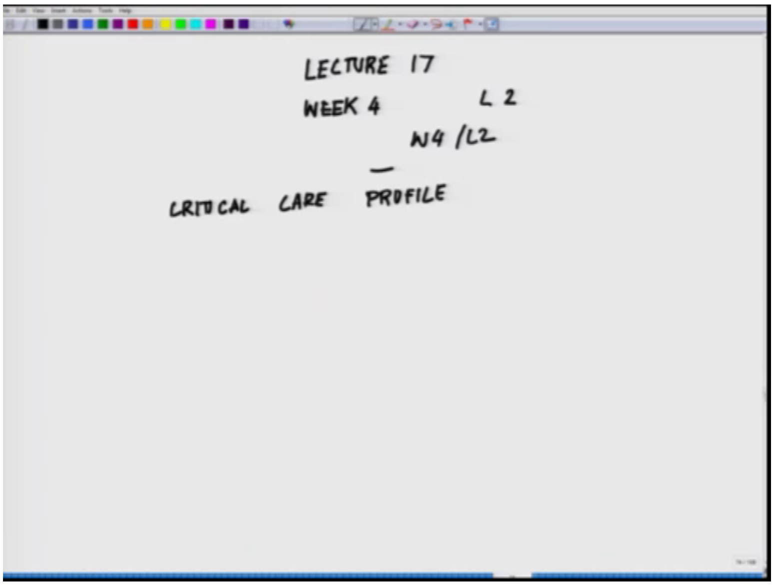
Department of Biological Science and Bioengineering and Design Programme
Indian Institute of Technology, Kanpur

Lecture – 17

Critical Care Profile & Metal Electrode

Welcome back to the lecture series in by electrochemistry. So, in the last class, we were talking about the different kind of electrodes, and I mention about metal electrodes and ion selective electrodes. So, what I thought let us think of a situation where there really the biological component of electrochemistry comes very handy. So, if you see a critical care profile in a hospital, there is something very interesting you will observe. So, let us start the lecture today.

(Refer Slide Time: 00:46)



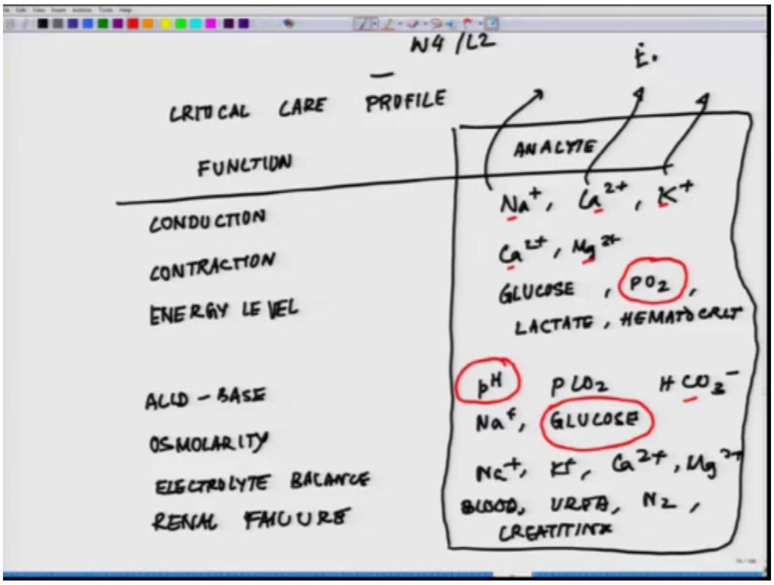
LECTURE 17
WEEK 4 L 2
W4 /L2

CRITICAL CARE PROFILE

So, this is our lecture 17, 19, 20 and this is our week 4 lecture 2. So, W 4 slash L 2.

So, now if you see a critical care profile in an hospital. So, you will observe something very interesting, and we will come back to the electrode concept from there, exactly the application part of it.

(Refer Slide Time: 01:23).



W4 /L2

E.

CRITICAL CARE PROFILE

FUNCTION	ANALYTE
CONDUCTION	Na^+, Ca^{2+}, K^+
CONTRACTION	Ca^{2+}, Mg^{2+}
ENERGY LEVEL	GLUCOSE, PO_2, LACTATE, HEMATOCRIT
ACID - BASE	pH PCO_2 HCO_3^-
OSMOLARITY	Na^+, GLUCOSE
ELECTROLYTE BALANCE	Na^+, K^+, Ca^{2+}, Mg^{2+}
RENAL FAILURE	BLOOD, UREA, N_2, CREATITINE

So, the function and analyte. So, function say for example, conduction; if we talk about nerve conduction. So, when we nerve talk about nerve conduction, there are nerve conduction or you know connection of a cardiac conduction. So, we talk about Ca plus and K plus.

Now, if we look at the muscle contraction or nerve contraction, sorry cardiac muscle contraction. So, we talk about Ca 2 plus some time magnesium. Now we talk about energy, metabolism or energy level, when you look at energy level, we look at glucose, we talk about oxygen, we talk about lactate, and we take out talk about haematocrit then whenever we talk about acid and base.

So, what is the level of acidity in the body, and we talk about p H talk about P Co 2 partial pressure of carbon dioxide, when we talk about osmolarity of the blood which is by the way osmolarity of the blood is around 328 milli OS mole, osmolarity we talked about sodium plus glucose. So, if the glucose level goes up the osmolarity will go up.

Then electrolyte balance if, we talk about electrolyte balance, then we are looking forward to Na plus potassium, calcium, magnesium, then when we talk about the renal failure, we look for blood, urea, nitrogen, creatinine.

A doctor needs to look at all these parameters as soon as a person comes in critical care unit, or even on a day to day like you know, whole body checkup these are the things they look forward to. What is interesting for an bio electrochemistry if you look at it.

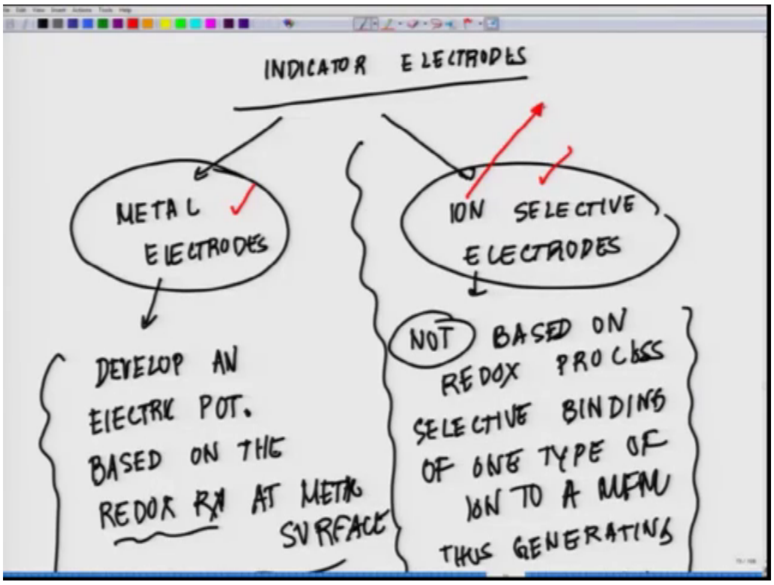
Interesting part for the bio electrochemistry why you should study this subject. So, we are almost closing in, and I needed to share this very clearly with you, why you really needed to look at it. Because if you look at all these things the chart, what I have just now prepared for you. These are could you recollect something, these are the simple ions, which either by accepting an electron, or by donating an electron there is an E 0 value which can be created.

Now, if you just put your imagination because, we would not be able to cover all of them, but I wanted to you to imagine, if these analytes can accept an electron, and change its gets reduced or donate an electron gets oxidized. So, essentially using that analyte, if I have a standard I can calibrate a standard than any further addition, will lead to a change in either the potential or a current. Either the voltage or the current keep that in mind that is the most important part.

So say for example, I say that suppose what we will be dealing. So, in this rest of the course what will be we will talk about so, I am just underlining just a little bit of we will underline how a glucose electrochemical sensor works, how a oxygen electrode works, we will definitely talk about these two, how the p H electrode works, we will talk about the third one.

So, we will pick up some of them of course, there is huge amount of body of work all over the place, but if I give you some of these examples that will kind of give you an idea how to look for the other ones. Now the previous class, when I told you that you know you have 2 different kind of electrodes.

(Refer Slide Time: 06:02)



INDICATOR ELECTRODES

METAL ✓ ELECTRODES

DEVELOP AN ELECTRIC POT. BASED ON THE REDOX RX AT METAL SURFACE

ION SELECTIVE ✓ ELECTRODES

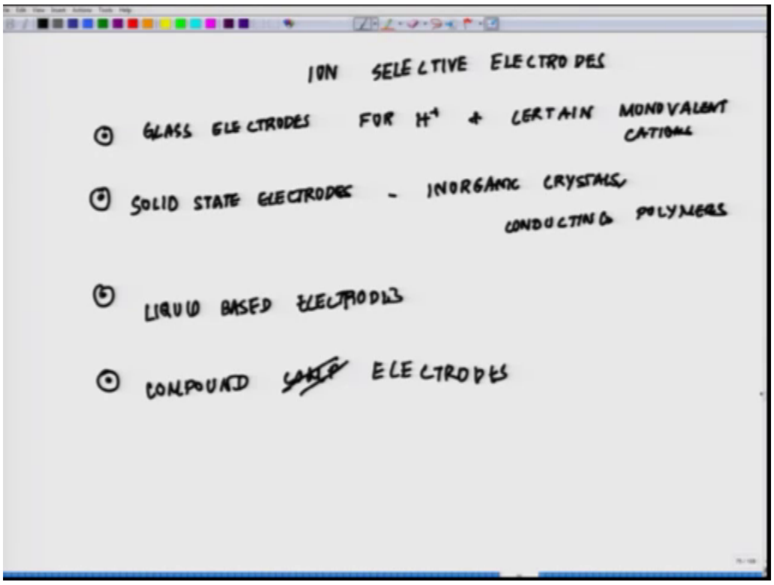
NOT BASED ON REDOX PROCESS

SELECTIVE BINDING OF ONE TYPE OF ION TO A MEM

THUS GENERATING

You could have a metal electrode, or you could have a ion selective electrode. When I say ion selective electrode, then I am talking about these kind of ions analyte, sodium, calcium, potassium magnesium HCO 3. Now if you have a sensor which could sense that particular binding of that ion, and it gets reduced and change the potential it should be able to determine its quantity with respect to an known quantity. So, keep this in mind, and in terms of the ion selective electrode.

(Refer Slide Time: 06:50).



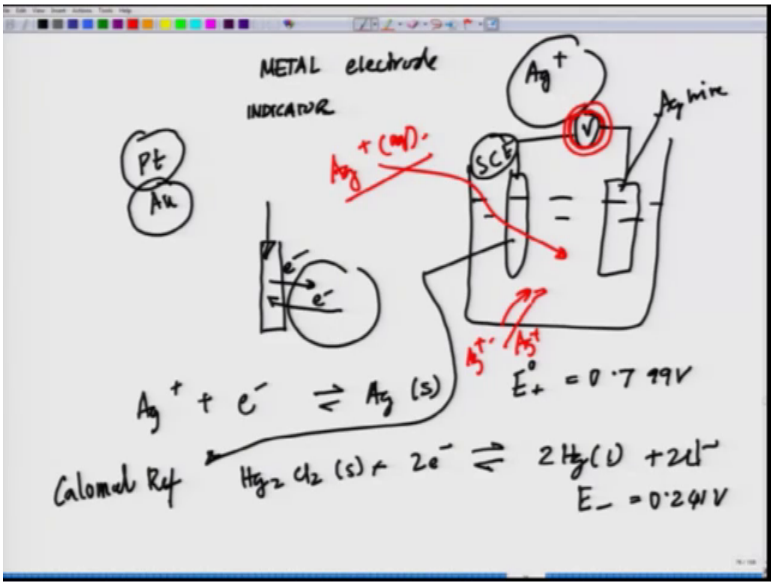
ION SELECTIVE ELECTRODES

- GLASS ELECTRODES FOR H^+ + CERTAIN MONOVALENT CATIONS
- SOLID STATE ELECTRODES - INORGANIC CRYSTALS, CONDUCTING POLYMERS
- LIQUID BASED ELECTRODES
- COMPOUND ~~[illegible]~~ ELECTRODES

If we talk about, what are the different ion selective electrode which are there currently with the technology, they are of this kind ion selective electrode are of these different types say for example, one of them is the glass electrodes, which are used for H plus, and certain monovalent cations for H plus, and certain we will talk about it that is essentially the p H certain monovalent cation, then you have solid state electrodes solid state electrodes. These solid state electrodes are based on inorganic crystal or recently conductive polymers.

We may not have a scope really to go through this, but just have an idea inorganic crystals, or you have conducting polymers, then you have liquid based electrodes, then you have compound electrodes. I am not getting into the details of it, but just I wish you have an idea compound sorry compound electrodes. These are the different kind of ion selective electrodes, what out of them 1 or 2 will be dealing with. Now let us talk about a metal electrode, where we started in the last class.

(Refer Slide Time: 08:51)



So, one of the metal electrode we will talk about today. Metal electrode is the one which is used for measuring Ag plus ion concentration. So, the most common metal indicator electrode. So, we have already talked about the reference electrode and the indicator electrodes. So, now we will be only concentrating on the indicator electrode of course, with respect to our 3 different kind of references either hydrogen or Ag AgCl, or calomel.

These are the 3 reference we have already talked about. So, we are not going to get into that any more.

So, now we are talking only about the indicator electrode metal. So, one of the major indicator electrodes, which are being used most common metal indicator electrodes is platinum, and then you have gold these are relatively inert and, basically it does not participate in any chemical reaction. It is purpose is simply to transmit electrons to or from species in solution to, it is suppose you the have the platinum indicated electrode either it will pass the electron like this. To the solution or from the solution it will pick up the electron and it will pass it on. So, on the other hand, if you look at it selectively binding happens in the ion selective electrode.

Now, these are basically relatively fairly inert and do not participate in chemical reactions, its purpose is simply to transmit electron to or from species in solution. Either to the solution or pulling the electron out of it, gold electrode are even more inert than platinum.

Various type of carbon are used as indicator electrode, because the rate of many redox reaction on the carbon side of surface are very fast, and you see a lot of work is currently happening on graphene oxide, reduce graphene oxide based carbon electrodes you know carbon quantum dots.

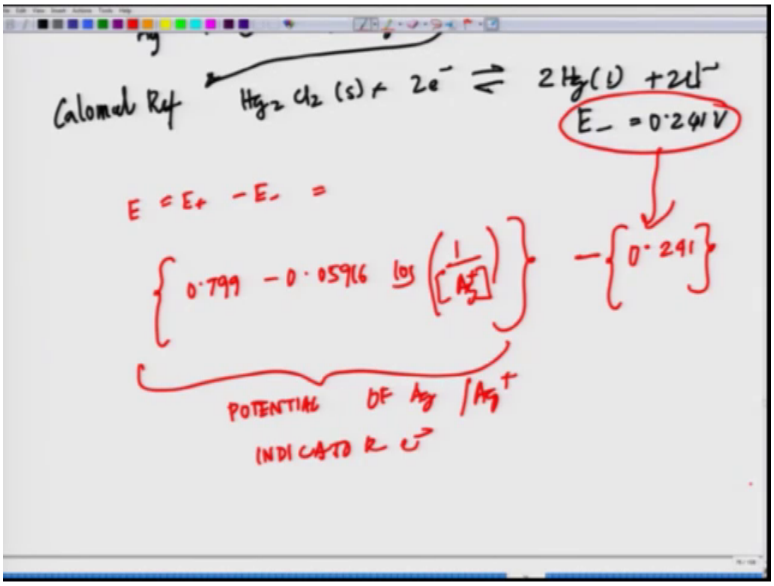
Because the electron really moves through in a very rapid pace that increases the sensitivity as well as the efficiency of the system. So, this is what an electrode out here, does a metal electrode works best. When its surface is large and clean again, there are several techniques to clean it.

So, what we will be talking about a silver electrode that can be used with a reference electrode to measure Ag plus ion concentration the reaction. At the Ag indicator electrode is Ag plus. So, you always have to have a practice of writing these reactions Ag solid, where E 0 plus is equal to 0 sorry 0.799 volt, and with reference to an calomel electrode.

We have already talked about calomel electrode calomel reference electrode, which is Ag 2 cl 2 solid plus 2 electron leading to 2 Ag liquid plus 2 c l minus, and here E minus is equal to 0.241 volt. And if you have to picture it will be something like this here, you have the reference electrode sitting there double junction saturated calomel electrode C E calomel standard what we have talked about. Here at the voltmeter you are measuring the voltage, and here you have the Ag wire, and the solution has analyte is Ag plus aqueous. Now if you know under a known condition the voltage.

Now, if you change the concentration, if you add more of a g plus into the solution, then the voltage is going to change and that is exactly what you are going to measure.

(Refer Slide Time: 13:14)



Calomel Ref $Hg_2Cl_2(s) + 2e^- \rightleftharpoons 2Hg(l) + 2Cl^-$

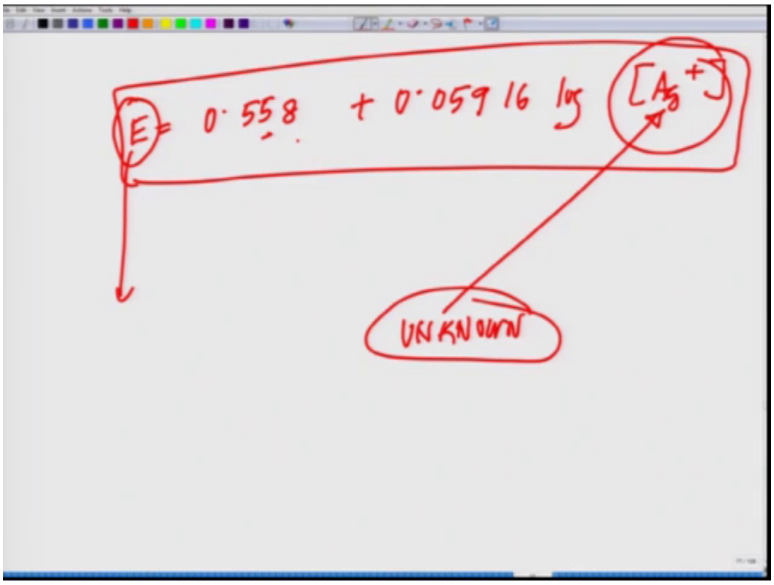
$\boxed{E_- = 0.241 V}$

$E = E_+ - E_- =$

$$\underbrace{\left\{0.799 - 0.05916 \log\left(\frac{1}{[Ag^+]}\right)\right\}}_{\text{POTENTIAL OF } Ag/Ag^+ \text{ INDICATOR E}} - \{0.241\}$$

So, now, if you look at it the way the equation will pan out will be E is equal to E plus minus equals to we have already talked about the values right 799. Now, let me plug in the values the values will look like something like this, 0.799 minus 0.0596, its log 1 upon Ag plus which is your analyte you are trying to look forward to, what you have to find out minus 0.241, which is this value which is potential of the standard calomel reference electrode, and this is essentially your potential of Ag, Ag plus indicator electrode.

(Refer Slide Time: 14:20).



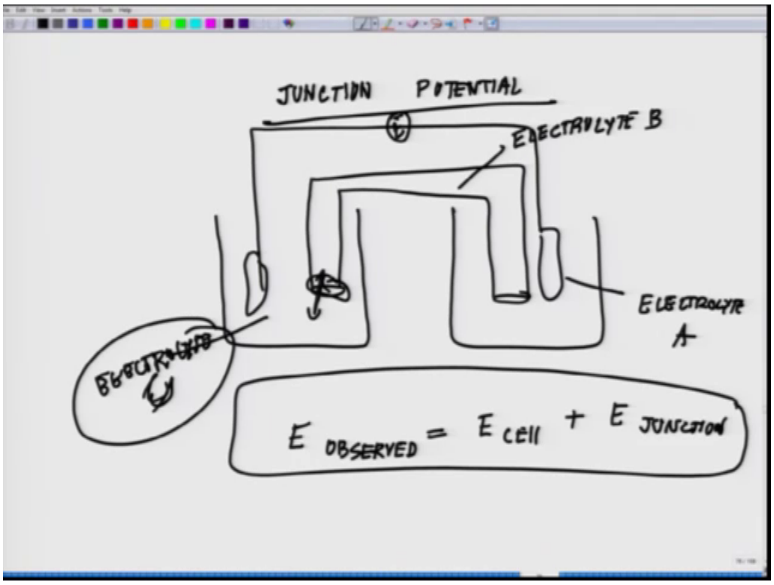
$$E = 0.558 + 0.05916 \log [Ag^+]$$

UNKNOWN

So, now if you calculate E, E is equal to 0.558 plus 0.05916 log Ag plus. Now this is your unknown. Now if you know this value which will be shown by a voltmeter, you can tell how much analyte is added into the system. So, if you know the known amount then you can always back calculate and figure it out. So, this is how a metal electrode works, and as long as you have this reaction straightened up in your brain, you can always calculate. What is the voltage? What is being obtained?

So, this is one example what I wanted to show you from here, I will move on to another example of ion selective electrodes. Now let us talk about the ion selective electrode, but before I move on to the ion selective electrode.

(Refer Slide Time: 15:37)

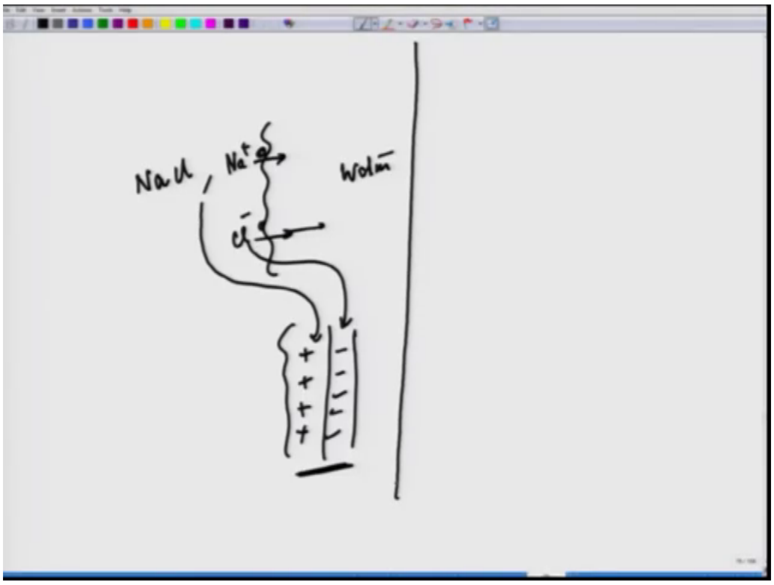


There is a concept which I wanted to introduce is called junction potential. What is junction potential? Junction potential is essentially, when dissimilar electrolyte solution are in contact. When dissimilar electrolyte solution are in contact a voltage difference called junction potential develop at their interface, this is a situation you will observe when you have a salt bridge, which has a different electrolyte, electrolyte B, and you have an electrolyte A, you have a electrolyte C.

Now, whenever dissimilar electrolyte solutions are in contact a voltage difference is created across this, which is called a junction potential. This is small voltage you usually few millivolt is found at each end of the salt bridge connecting the half cells. The junction potential puts fundamental limitations on the accuracy of direct potentiometric measurements, because we usually do not know the contribution of the junction to the measured voltage.

So, E observed is equal to whatever the E whatever you have the 2 electrode, you have the E which we are measuring here, E observed is equal to E cell plus E junction. So, you will always have a junction potential, because the junction potential is usually unknown and E cell is slightly uncertain. So, essentially why junction potential occurs, if you consider an NaCl in contact with distilled water, an NaCl ions begin to diffuse from NaCl solution into the water.

(Refer Slide Time: 17:54)



Say for example, you have this is the situation say for example, NaCl solution here, you have the water solution, and both Na ions and Cl ions are diffusing out both Na and the Cl ion begins to diffuse from NaCl solution into water.

However Cl ion has higher mobility than sodium ions that is chloride ion will diffuse faster than sodium. So, as a result a region rich in chloride with excessive negative charge developed at the front. So, what will be the next picture will be something like this, you will have negative, negative, negative, negative at the front, and positive, positive, positive at the back the positive are coming from the sodium, and the negatives are coming from the chloride ions.

Behind it is a positively charge region depleted of chloride. This result in an electric potential difference at the junction of NaCl, and water phases. So, this kind of situation lead to a junction potential. The result is an electric potential difference at the junction of NaCl, and water phases the junction potential opposes the movement of chloride, and accelerates a movement of sodium.

The steady state junction potential represent the balance between unequal mobilities. So, there is an unequal mobility, what is being highlighted here that creates a charge imbalance, and the tendency of the resulting charge imbalance retards the movement of chloride ions. So, this is a classic case of junction potential, what I wanted to highlight and these kind of junction potential problems, will come time and again as you will be doing practical experiment in this area. So, having said this now we will move on to our next class onto the ion selective electrode with one example of ion selective electrode, then as we promised. We will talk about oxygen electrodes, we will talk about the p H electrode, and we will talk about the glucose electrode.

Thank you.