

in this video we're going to talk about electrochemistry and in particular the two types of electrochemical cells there's the galvanic or voltaic cell and then the electrolytic cell so you might think what does chemistry have to do with electricity well what these cells do is they convert between chemical energy and electrical energy and you might think how does that happen well remember when we learned about redox reactions and how they transfer electrons that's all electricity is it's the transfer or movement of electrons so if we have a redox reaction we have the potential to harness electricity from it so this is actually really cool because this is how batteries work so starting with the galvanic or voltaic cell the most important thing you need to know about this is that it is a spontaneous process and it produces electrical energy and we can harness this electrical energy and where is the electrical energy coming from it's coming from the chemical energy from the redox reaction that's occurring here so the redox reaction is occurring between iron and copper and the setup here looks fairly complicated but the good news is there's just a few important things you have to know about it so over here we have a molten solution of iron and then a solid block of iron and then over here we have a molten solution of copper and then a solid block of copper and these blocks are connected by a wire here along which electrons can travel and this battery here is facilitating the transfer of electrons another important thing you should know is that these solutions are connected by what's known as a salt bridge and this essentially completes the electrical circuit so you should remember from redox reactions oxidation is losing electrons and reduction is gaining electrons and that should remind you that over here since we're losing electrons from this solution the iron solution is being oxidized and then over here since we're gaining electrons in the copper solution the copper solution is being reduced another cool thing you can remember is an ox red cat and this reminds you that where oxidation is occurring this is always where the anode is and where reduction is occurring that's always the cathode is so how did we know that this was going to be spontaneous well it turns out each element has a natural tendency to want to either gain electrons or donate electrons and we can quantify that with what's called the standard reduction potential or E° with the little degree symbol or sometimes known as Enoch so you can see here that I've written out the standard reduction potentials for copper and iron and they have a certain voltage associated with them and you can see here that I wrote when a naught is positive ΔG is negative and when we know ΔG is negative we know it must be a spontaneous reaction so since the E° not for copper is positive that means copper must spontaneously want to accept electrons and get reduced but since the E° not for iron is negative that means this is a non spontaneous reaction ΔG would be greater than zero so iron does not want to gain electrons it does not want to become reduced it actually wants to do the opposite and wants to get oxidized it wants to give off electrons so in this case when the iron gets to give off electrons like it wants and the copper gets to accept electrons like it wants then everyone's happy the reaction is spontaneous it happens without any intervention and it actually produces energy so again this converts chemical energy into electrical energy in other words it collects electrical energy from a spontaneous chemical reaction and this is like using a battery to power a device like having your phone in your pocket a mobile phone that has a mobile battery that powers your phone wherever you go so the important thing you need to know about these calculations is that E° not is always the standard reduction so notice even though I've written out an oxidation reaction here because that's what's

happening you have to use the E° for ions reduction and similarly we use the E° for coppers reduction and that's actually what happens copper is getting reduced so the equation to determine E_{cell} or the overall reduction potential of this entire system is right here E_{cell} equals the E° of the cathode minus the E° of the anode so here the cathode was 0.34 volts positive 0.34 volts and you can just find this on a standard reduction table and the E° for iron was negative point four volts and again you can find that on a table so the cathode minus the anode minus a negative means this is going to be plus point four four we get the overall E_{cell} is positive 0.78 volts and again when E_{cell} is positive or greater than zero it is spontaneous ΔG is less than zero okay moving on to the electrolytic cell so this is a non spontaneous process it needs electrical energy to occur so this redox reaction doesn't naturally want to happen we have to power it this is analogous to charging up a rechargeable battery from a wall outlet you know your phone is not going to charge itself you have to plug it in and obtain the electrical energy to drive this non spontaneous chemical reaction so notice how we have the same setup we had before except there's one important difference the flow of electrons is reversed now it's going from the copper to the iron and remember iron has a natural tendency to not want to be reduced it wants to be oxidized it wants to go in the opposite direction because it has a negative E° copper on the other hand has a positive voltage associated with its reduction so it loves to get electrons it loves to be reduced this is positive that means it's negative ΔG and thus it's spontaneous so naturally the electrons want to go to the copper iron wants to give them up and the copper wants to accept them that's why this is non spontaneous so notice how reduction is still at the cathode and oxidation is still at the anode that's never going to change but now the copper is the anode and the iron is the cathode so using the same process we did to obtain this E_{cell} we can do that over here so again E° iron is going to be negative 0.44 volts because we always use the standard reduction potential table to find that negative 0.44 volts and again the E° for copper even though it's being oxidized this time we still use its reduction potential standard reduction potential for its anode and we get positive 0.34 volts so for our E_{cell} equation $E_{\text{cathode}} - E_{\text{anode}}$ this time our cathode is 0.44 volts and negative 0.44 and then we subtract E_{anode} so minus 0.34 and we get negative 0.78 volts that means E_{cell} is negative it's not greater than 0 it's negative therefore ΔG is greater than zero so this is non spontaneous this does not want to happen that's why now this battery is doing work it's actually powering this entire process so this process converts electrical energy into chemical energy in other words it uses electrical energy to drive a non spontaneous chemical reaction to occur ok since I talked a little bit about standard reduction potentials I want to go through this chart a little bit because it can be confusing so this is an abbreviated chart I don't have all of the elements written up here but I just want to illustrate the concepts and how you read this chart so standard reduction potentials essentially tell you the E° or the voltage that's given off when a certain element is reduced at 25 degrees Celsius and this entire chart is based around the reduction of H^+ or protons chemists arbitrarily chose the reduction of H^+ to have a voltage of zero or an E° of zero and this is in particular a 1 molar solution of H^+ and of course that means the pH is zero so everything is based around this benchmark we know that the reduction of protons is associated with a zero E° or zero voltage and then everything is built off of that so as you go higher you can see that the E° gets higher it becomes more positive and that means it becomes more favorable

remember ΔG not greater than zero means ΔG less than 0 which means it's spontaneous this means the reaction is spontaneous as written in the forward direction and if these reactions are spontaneous these are all reduction potentials so that means these things are very good at getting reduced so I wrote that here they're better at being reduced as you go higher and that means they're better oxidizing agents or stronger oxidants remember an oxidant is an oxidizing agent it accepts electrons in other words it gets reduced and it oxidizes something else oxidation is losing so it takes the electrons from something else and uses it to become reduced so as you go down the E° gets negative and it becomes more and more negative the further you go down so this means that ΔG is less than zero the reaction is spontaneous in the reverse direction so when E° is less than zero ΔG is greater than zero in other words this stuff is non spontaneous this doesn't want to happen iron doesn't like to accept electrons lithium doesn't like to accept electrons they would rather go the reverse direction in the spontaneous direction and become oxidized or lose electrons so that's why I wrote that here these are better at being oxidized the lower you go because they want to go the reverse direction and thus they are weaker oxidants they're weaker oxidizing agents they don't want to accept electrons and get reduced they would rather be reductants they're stronger reductants because they're better at donating their electrons to something else they donate their electrons and want to become oxidized so as you go higher up here again these are weaker reductants these are up here above the hydrogen these are better at accepting electrons these are better at donating electrons and these definitions here are sort of confusing but just try to keep in mind if something gets oxidized it's a reducing agent if something gets reduced it's an oxidizing agent an oxidant means oxidizing agent reductant means reducing agent and there's also rare case we're not equals zero the reaction is at equilibrium at standard conditions and this is exactly the case with hydrogen and remember our equation here in order to find the E° or the standard reduction potential of an entire electrochemical cell you do a cathode minus an anode so another important thing you should know is that voltage is in units joules per Coulomb and a Coulomb is amps times seconds which is essentially a measure of how much charge is going through a wire okay so let me ask you a question what's a better reductant lithium solid or H_2 gas well of course lithium right because as we go down the reductants gets stronger we get better at donating our electrons remember this is negative so it's non spontaneous in the forward direction but it is spontaneous in the reverse direction thus lithium loves to donate electrons it loves to become oxidized and reduce something else thus it's a strong reductant okay what's a better oxidant F_2 gas or H^+ plus $2H^+$ well of course the F_2 right it's a stronger oxidant because of this positive E° on it it is spontaneous in the forward direction it loves to become reduced and to gain electrons and thus to oxidize something else it's taking the electrons from something else and oxidizing it so it can become reduced so it's confusing but I promise if you go through it enough times in your head it'll eventually sink in please keep looking at this chart and memorize these definitions down here and really make sure you've got it straight so I really hope this video helped you guys out and I'll see you in the next one