Welding Processes

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Fundamentals of Ionisation in welding arc

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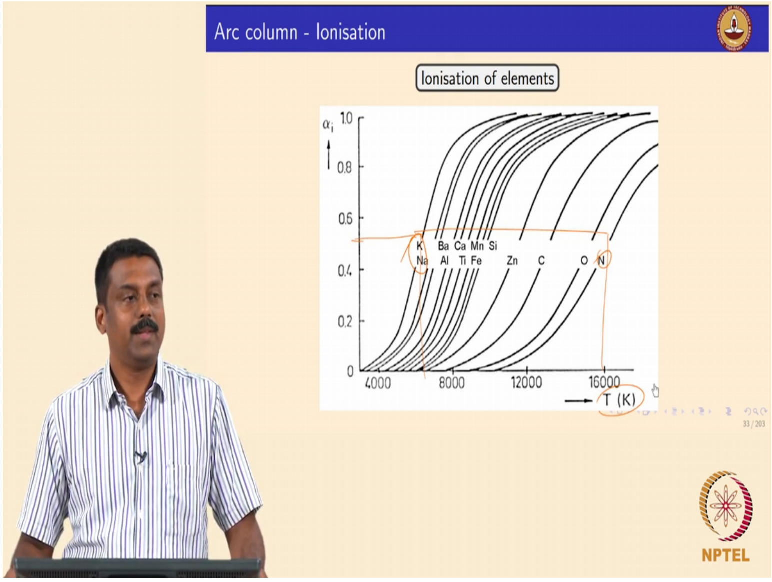

So I just listed some of the ionisation curves, so here obviously this can be replaced with energy but then the natural curve will change it become x model TK, now if you put the temperature, in this curve nitrogen has the very highest ionisation potential, sodium, potassium they are very low ionisation potential, so that is why you always create the sodium ions and the potassium ions much easily whereas if you want to create N plus the temperature has to go much higher because of the very high ionisation potential, ionisation energy needed to ionise the nitrogen oxygen for example in this case okay similar the same is for 0.5 on 50 percent ionisation it can never happen for nitrogen at temperatures of about 7000 Kelvin.

So system temperature should be increased close to 16,000 Kelvin, yes then only you can ionise, then only you can have sustained discharge, is not it otherwise your arc will extinguish, nice, is it clear? So there is how we need to heat it up to such of temperature in arc otherwise you will never have sustained discharge, yes clear? So these are shielding gases we use nitrogen, okay oxygen, cilium, argon and each shielding gas has its own unique ionisation values potential, right? So obviously the temperature of the arc will also change as a function of the shielding gases okay so the selection of shielding gas will also influence definitely your heat generation because of these very specific reason okay so you can choose whatever chilling gas you want but obviously you will also change the arc temperature okay.

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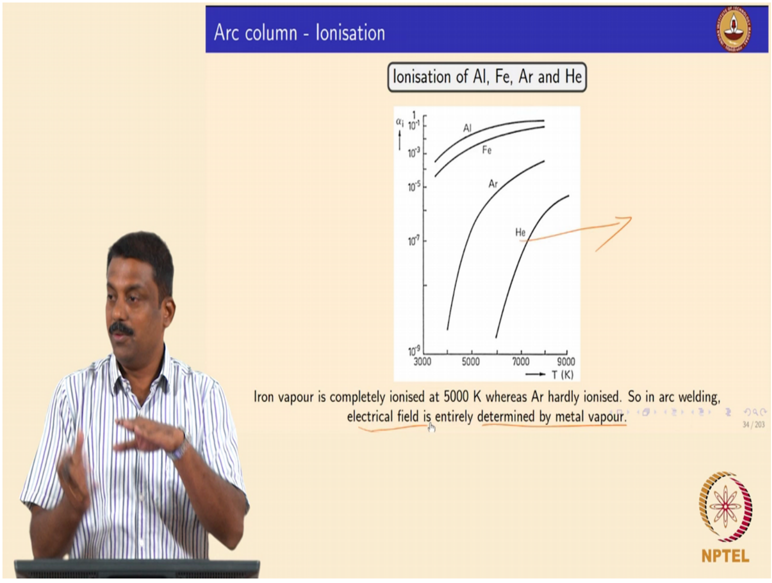

And before going to look at shielding gas, so moment you strike and arc using a shielding gas for example use a helium as a shielding gas okay you have for example a simple tungsten electrode which supplies energy for initial ionisation, thermionic emission is happening electrons are released from the cathode okay and they are going the arc column and arc column in this case for example you make it with helium, the moment electron reach helium regions obviously once the electrons which are actually emitted from the cathode gains the ionisation energy required for knocking electrons from helium, electrons will be knocked out from helium, right?

And then the space charges will be conducted because of the subsequent alavance of these ionisation from the tip of the cathode to anode then what will happen you strike and arc, right? So then discharge can be sustained because of this ionisation process okay the ignition is by thermionic emission. The moment ignition happens the electrons reach the gas medium upon gaining the energy Ei the ionisation energy the electrons are knocked out creating helium ions and this process create an avalanche of this reaction, the moment you have enough charge carriers developed you will have conduction of this charge carriers from cathode to anode then you strike an arc okay so the moment you strike and arc so obviously you also melted, is not it?

The anode, so if you keep tungsten electrodes as a cathode you will start melting the anode and if the anode is superheated the molten anode would also vaporises, right? Then it formed metal vapours, metal vapours are also gas subsequently they will also ionise, is not it? Because ion vapour is ion gas it also ionise but if you look at an ionised energy of these metal vapours they are much lower than the inert gases you use, is not it? For example you are welding an ion steel, the iron vapours the ionised energy of ion vapour is much lower than the shielding either helium or argon.

So the moment you create the ion vapour okay and then they ion vapour would start sequentially ionised would carry forward this discharge okay because ion is easy to vaporises, is not it? Similarly if you are doing welding in aluminium, the moment you create aluminium vapour aluminium word ionise much easily at much lower temperature than helium and argon, so aluminium vapour can supply the electrons needed for these stained discharge okay that is what I showed in this graph say for example if you have an helium and argon shielding and that is actually used for arc ignition, the moment you create arc, you ignite an arc you start vaporising the metal and then subsequently these metal vapours would ionise and the ionisation of metal vapour would be the rate controlling okay.

So that is what when you are doing welding, when they arc ignition is happening the arc is really hotter when the arc is ignited okay because when the… at the ignition point you are ionising the shielding gas which should be argon or helium. Now point ignition once you start creating enough supply of metal vapour okay and then your metal vapour would determine the arc temperature, is it clear? Is it clear or not? So if you look at in a real welding case the metal vapour would dictate the electrical field therefore the temperature, so during ignition your shielding gas would ionise and then arc is ignited.

The moment you have… enough vapour is generated metal vapour generated because of the ionisation energy of the metal vapour are much lower than the inert gases, the metal vapour would supply the electrons needed to carry forward the electrical field in the arc, so that is what when you are doing welding of steel or aluminium, they arc temperature is much lower when you have plasma state okay so by say for example you are creating with argon because argon is inert the ionisation energy is so high the temperature of arc by pure argon will be much higher than when you are welding with the shielding gas of argon okay you may use the shielding gas of an argon but ultimately the arc is sustained by the ionisation of the metal vapour okay, so in argon case when you have shielding gas and the anode is not molten.

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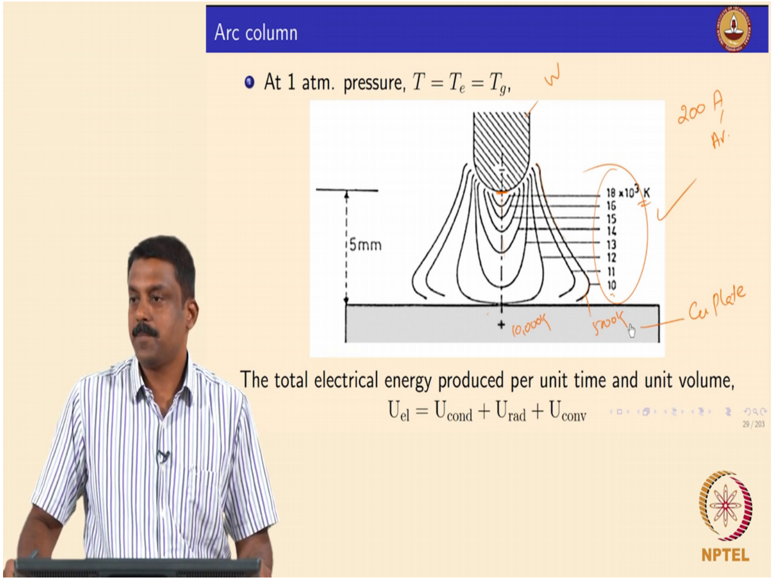

The figure I showed you so in this case and this is the experiment was carried out water cooled copper plate that means that you not vaporising copper here okay that means that the arc here is fully created by the ionisation of argon okay, so if you are not melting the anode in vaporising then you can know that exactly the temperature of the arc only by argon, so that is how the temperatures are much higher okay suppose if you start vaporising these anode the temperature would drastically come down, so the arc column temperature will be not more than 10,000 Kelvin and envelope will be close to 5000 Kelvin.

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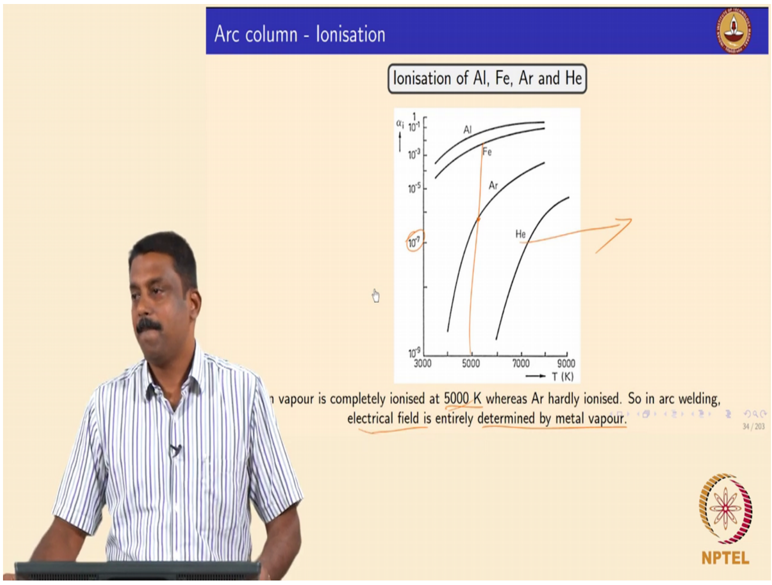

In a real welding case where you are welding metal or alloy okay because in that case the metal vapour would determining your arc temperature, is it clear? So the lesson here is so when you have gases very high-ionised energy the arc temperature will also will be very high, right? Because obviously if you want to ionise inert gases you need to supply more energy and that can happen only at high temperatures compared to gas which have lower ionisation energy okay so this is extremely important in welding case because that will determining your choice of shielding gas plus the arc temperature would also be determining by the metal vapour in generate, right, is it clear?

So that is what I want to tell you with this line that look at 5000 Kelvin you will see that ion vapour would completely ionise okay whereas in argon (())(10:43) hardly ionised okay 10 power minus 7 very few atoms are ionised, so what is the rate controlling here? Metal vapour, iron vapour, is not it? Is it clear? So once ion ionises, the ion vapour ionises obviously you have sustained discharge the electrons got what it needed electrons and ions, whatever it be if they charge carriers are transported from one cathode to anode, so you strike an arc, arc is sustained does not matter you need create me with argon or helium as long as you have a gas in this case it is metal gas, metal vapour, yes, is it clear? Good.

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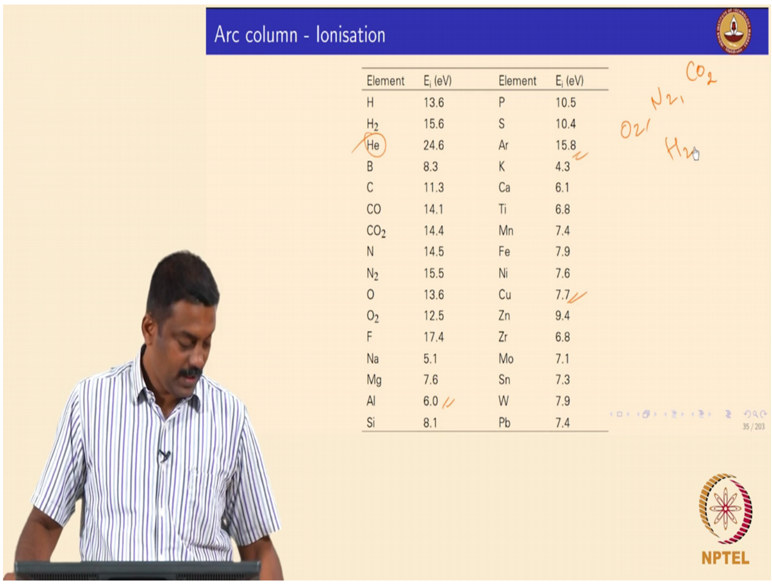

So I just table it at ionisation energy of various elements and if you look at helium the electron volt is maximum 24.6 and if you look at helium it is 24.6 and argon okay we have argon here yes 50.8 and if you look at metals there very low copper for example 7.7 okay one third of helium close to one third, right? And if you look at the aluminium it is much lower as well therefore when you have metal vapour, so obviously you can ionise them easily at low temperatures, yes, is it clear?

So the fundamentals of choosing a shielding gas is derived from these physics it is not like randomly you can go and weld with argon or helium okay because you have argon you can just like that go and choose argon and weld because your arc temperature would also determining by the ionisation. So the principle of choosing shielding gas is all determining by the physics governed in this sustained discharge okay. Similarly if you mix it with 2 gases obviously that will also affect the temperature of the arc because the ionisation will be changed, right, is it clear? So apart from the atomic ionisation sometimes you may also have a diatomic gases or molecular gases okay that also you can use sometimes doing welding, is not it? For example O2 or N2 or even CO2 For example okay sometimes you also use diatomic hydrogen, hydrogen molecule, so then if you use such gases the first reaction that will happen is not the ionisation but the dissociation, right?

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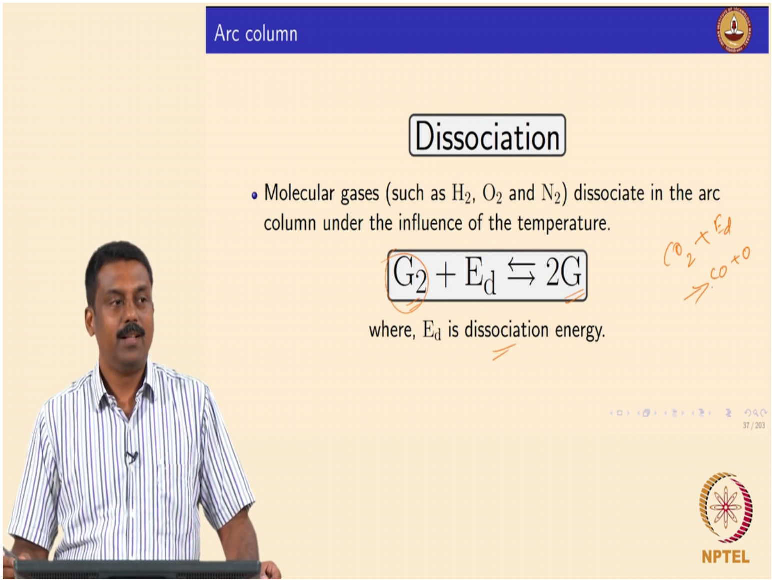

So dissociation is nothing but again when the molecule gases are used and they 1st dissociate before even being ionised, so they would 1st dissociate in arc column again the heat is supplied, unless you supply heat we would not give the energy for dissociation okay so Ed is dissociation energy, it is nothing but the same as ionisation. When the molecule gas is supplied energy becomes atomic gas, so when diatomic gas becomes an atomic gas okay so CO2 becomes, when CO2 dissociates what will happen?

Student: C plus (())(14:49)

Prof: C plus 2, really? This will be called monoxide and oxygen okay so you create an atomic carbon monoxide okay and then no action at all. Subsequently this carbon monoxide oxygen atom will ionise okay.

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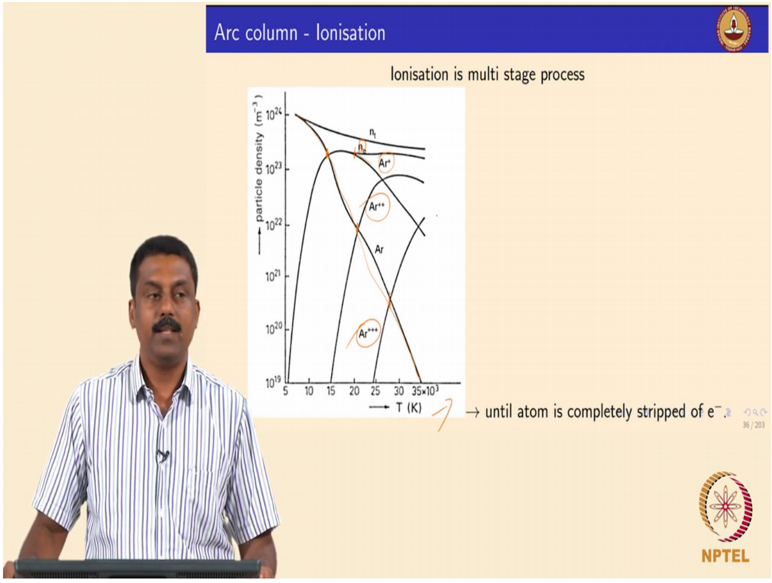

So again the ionisation is also not a single step process whether you have an atomic gas diatomic gas, diatomic gas first will disintegrate into an atomic gas and then the ionisation would progress into multistage process okay, so first reaction obviously…so suppose the graph shows the number density of various ions you have has function of temperature okay so for example this graph, this line shows the number density of argon atoms as function of temperature, okay.

So upon reaching sufficient temperature then the ionisation, the first ionisation, basic ionisation is to create argon plus, so the argon plus will be created and in this process we also create an electron okay so argon plus will create but if temperature increase subsequently, the argon plus would also subsequently further ionise into argon 2 plus okay and then argon 3 plus okay subsequently once all the electrons are stepped off it leave with an empty shell okay so this process would be continuing until the atom is completely stripped off of electrons, right? Is it clear?

So it is consumed by the process but energy is balanced okay so whatever energy supply it also gain somewhere, right? And of course they will also collide, mutual collision can lead to generation of subsequently an enormous amount of heat and this process would continue by this alavance of reactions of ionisation collision and generates now heat and heat is used to ionise again and then again collision to generate heat, so the chain reaction would continue until all the electrons are completely stripped off. So if the supply of gas is topped, what will happens then? It will not have any more gas atoms to ionise so you cannot strike an arc, right?

So shielding gas if it is stopped you turn off the bottle, what will happen to the arc? Arc extinguishes because it is all consumed, right? Because you ionised the gas such an extent that all the electrons are completely stripped of and it is extremely rapid process okay, so you need to supply continuously the shielding gas okay, so if you stop it then the arc will not be stable and subsequently arc would also extinguish.

In an atmospheric conditions you may continue because you still further have the gas atoms in the atmospheric conditions but then it is not enough for sustained discharge unless you supply shielding gas continuously, is it clear? Yes.

Student: Why with the increasing temperature the decrease in particle density in case of argon?

Prof: In case of argon?

Student: Yes.

Prof: Yes argon is converted into argon plus 2 plus argon 3 plus also this is the neutral argon atom okay so electron density is increasing upon this temperature for example argon plus goes down because you start create argon 2 plus. Upon this temperature it will also come down because you start creating argon 3 plus.

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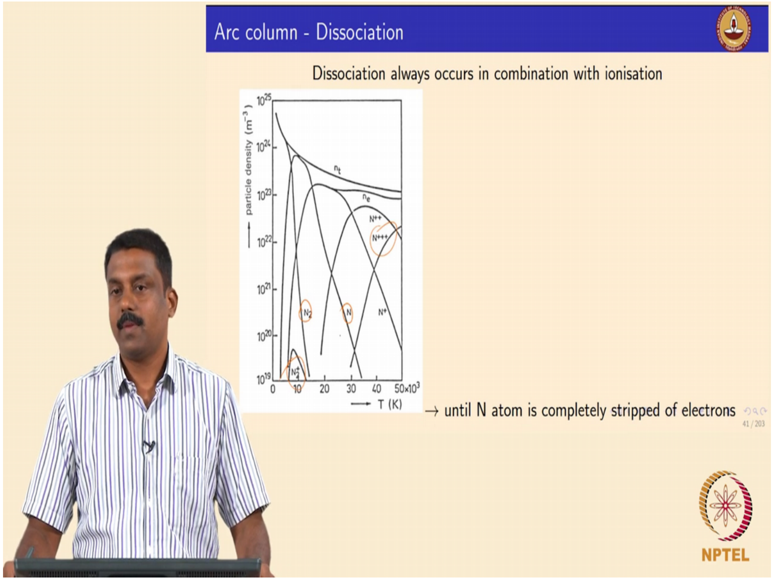

The same thing is applicable if you have a diatomic gas okay so in diatomic gas the first reaction is dissociation okay dissociation is nothing but when you have N2 nitrogen it will first become N okay but then the atomic gas once it becomes atomised the diatomic gas once it becomes atomised then you will start ionise see N becomes N plus subsequently N2 plus and N3 plus and it can go up to so N plus and yes sometimes it can also be N2 plus but it is very rare okay so the first reaction should happen is the dissociation of N. Dissociation of N2 becomes N and once it becomes N obviously the electrons would generate by ionising the N and becomes N plus and N2 plus and N3 plus okay.

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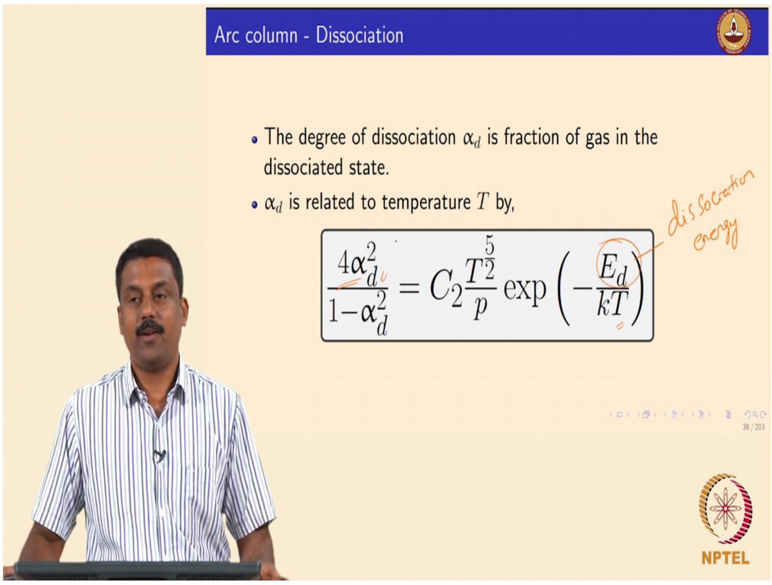

So the dissociation can also be calculated, the fraction dissociation the same as you calculate a degree of ionisation. The only difference here is 2 times there each (())(20:35) gives one electron whereas in this case the fraction gives 2 products okay. So when N_2 dissociate it becomes 2N, so you put 2 over there and the same Sara equation okay (())(20:55) Sara equation. It can be used and Ed is not an ionise energy in this case is dissociation energy. Again it is all related temperature same by the Sara equation, right? So this is again it will follow the same curve of ionisation, yes clear? The Ed so once you know that no temperature obviously no pipe calculated Ed where Ed is a material parameter, gas parameter.

You can calculate what is the fraction dissociator? And this is important creation in arc perspective because the heat conduction by this process dissociation is very effective, so in subsequent slides when we calculate the heat transfer by conduction this equation is very important okay because the dissociation and subsequently the ionisation of dissociation gas would have the heat conductor from one point to other point okay, so when you look at the heat conduction and this phenomena the dissociation is extremely critical okay. So that is why when you use a diatomic gas as a shielding as For example N_2 or CO_2, the arc temperature is much lower compared to when you use atomic gas, why because you need to supply energy for this process.

The second is endothermic reaction okay, so when you use carbon dioxide as a shielding gas, the heat generated in the arc is much lower okay and because dissociation also needs energy and sometimes dissociation can also conduct heat effectively from 1 point to another point, okay. So we look at in subsequent classes how it is actually going to affect the temperature distribution of an arc. So now you can assume that because the dissociation is endothermic obviously the heat in the arc is also contained or reduced, so when you use diatomic CO_2 carbon dioxide shielding out temperature can decrease significantly okay. So that is what when you want to control the heat input when you are welding some cases we do not use up your atomic gas, we use argon plus CO_2 okay. So we use an additional diatomic gas, so that we can control or we can reduce the heat okay it is not only by this process but it also affect your conduction, okay, is it clear? Is it clear or not? So is very basic, right?

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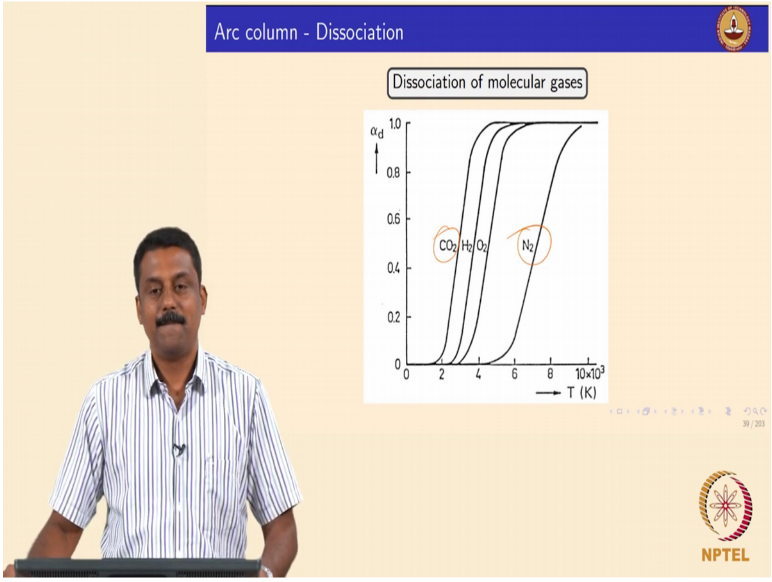

So again the same principle applies to the dissociation action as well, so obviously N2 has a very high dissociation energy okay whereas CO2 has very low dissociation energy, so obviously when you CO2 what will happen? It can associate at low temperature. In ionisation of carbon monoxide is much lower than atomic nitrogen that means that when you CO2 the arc temperatures will be much lower, right? Is it clear? Okay the same principle goes when you use CO2 and argon, argon is atomic gas ionisation is very high, the out temperature will be very high whereas CO2 can be dissociated at low temperature and ionised at low temperature obviously the system temperature can be lower, right, is it clear? Good.

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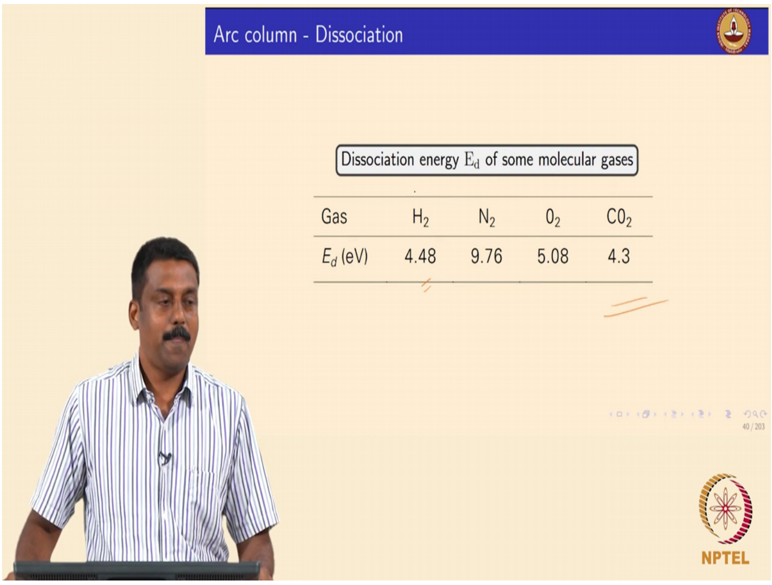

So some of the table you can note it down so nitrogen as dissociation energy of 9.76, CO2 4.3 and hydrogen 4.48 so sometimes note to (())(25:27) is hydrogen, so hydrogen cannot be used for ferritic steel, right? What will happen then? We will have hydrogen diffusion okay some cases we can use hydrogen. To control the diatomic gases are mixed with atomic gases during welding to control the heat okay we can balance it. If we use pure helium the heat is enormous okay because helium can be ionised at the temperatures of 15000 Kelvin okay then arc temperature is enormous okay. So you mix some sea water with that so that the entire system temperature can be decreased.

Student: Can we just directly use CO2.

Prof: You can use CO2 as well but then the arc stability we will see in subsequent classes why PuCO2, PuCO2 you are using it already, so when you use flux code arc welding self-shielded, what they mean by self-shielded?

Student: (())(26:29)

Prof: Yes, so flux burns generates CO2 okay so these are all subsequent chapters okay, so you can also use PuCO2 but the arc stability may not be good because of the various reactions I am going to show you in the conduction conduction radiation okay, is it clear? The arc temperature is affected by the presence of diatomic gases because of the dissociation from an arc and we will also see in subsequent slides how the heat is conducted from one place to the other place by conduction, convection and radiation yes, good.

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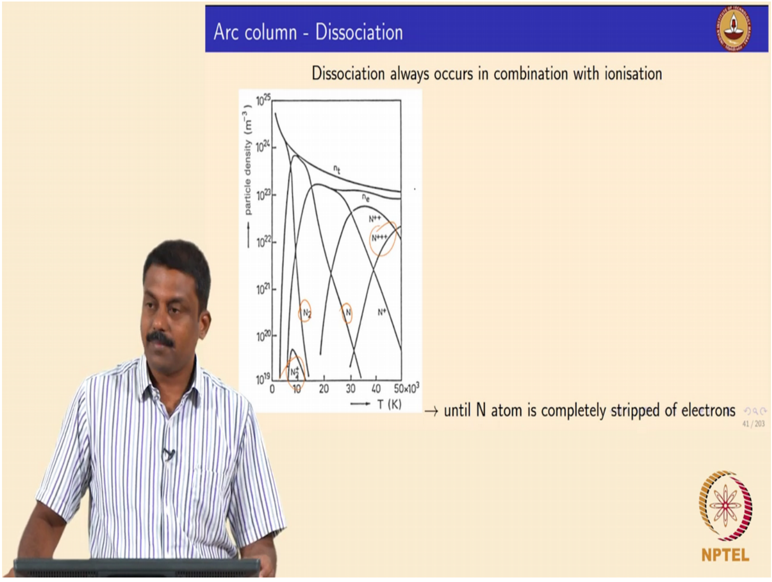

So this is clear so we completely stripped of the electrons from the atomic equation and then until you consume the entire gas, reaction would continue then you need to supply the fresh gas to make it sustained, yes is it clear? Good.