Atomic and Molecular Physics
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Lecture - 10
Atomic structure of an atom (Contd.)

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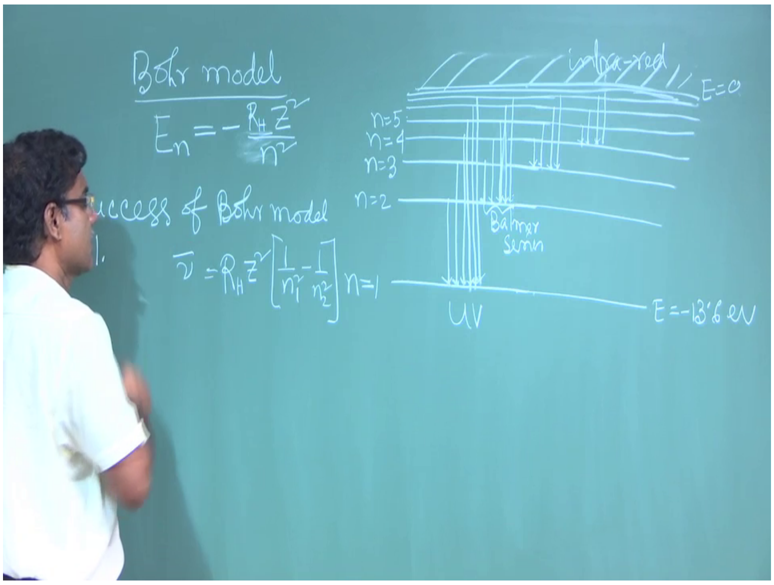

So, we have learned so far this basically Bohr model. From Bohr model, we have seen that energy of an atom; it is a quantized. So, this that we have seen that it is basically R by R H, I can write for hydrogen atom R H by Z square, no R H Z square by n square right; that we have seen. So, energy levels they are the energy total energy of electron in a mean an atom is quantized. So, energy level we have seen for n equal to 1 n equal to 2 n equal to 3 n equal to 4, right and this transition n equal to 5, n equal to 6, n equal to 6, n equal to 7 etcetera.

So, it can be. So, then I think I should make it longer then this type of transition also possible. So, it is a basically after that is basically there are; so continue. So, this energy level E equal to basically 0 and here E equal to minus 13.6 ev. So, Bohr what is the success of Bohr model success of Bohr model first one is; it was able to it was able to explain the atomic spectra specially this atomic spectra of hydrogen it was able to exactly find out the wavelength of each spectra lines and before Bohr model only Ballmer series was discovered because it was in visible range ok.

So, this wavelength is between 400 to 700. So, these; the for visible light. So, that is it a; it was easy to see in spectrometer, but later on, but Bohr model. So, this basically these series was observed. So, this Ballmer series; so, you see it is in visible range. So, wavelength below this visible range. This smaller wavelength higher frequency so that is basically u v range, this side u v range ultraviolet range and higher to Ballmer series; so, this say infrared region.

So, that stuff that is; so, that is why this series and the other series was not visible, but later on, it was found it was found that there are other series, but that series that the indication from that existence of the other series was caught from the Ballmer model Bohr model and which was able to explain or reproduce not reproduce which was able to able to tell about the root of the empirical formula a Ballmer that we have seen. So, these 2 series these the ultraviolet range and this side is it is this called infrared region this side is infrared region infrared region this side is infrared region.

So, Ballmer this Bohr from Bohr model is we have seen that this Rydberg constant generally, we tell this the term value generally we tell that term value term. So, this Z square and these are 1 by n 1 square minus 1 by n 2 square. So, that was the basically nu bar it is the nu bar. So, for hydrogen Z 1 has to take Z equal to 1. So, for Ballmer series, it was for n equal to for Ballmer series, it was n 1 equal to 2 and then n 2 equal to higher t higher energy 3, 4, 5, etcetera, right.

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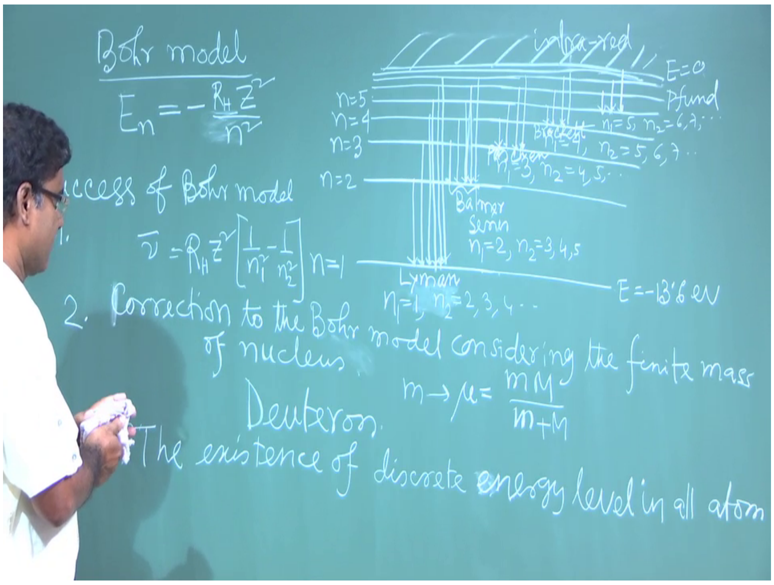

So, from these Bohr model one can easily think about that when n 1 equal to n 1 equal to 1 and then n 2 equal to 2, 3, 4, 5, etcetera. So, then this type of transition should be possible and we should be able to see this another series and later on it was discovered it was found and that series is called Lyman series.

Similarly, when n equal to n 1 equal to 3 and n 2 equal to 4 5 etcetera; so, then there should be another series and that is called Paschen series; Paschen series P A S C H E N; Paschen series. So, this n equal to 4 and then n 2 equal to 5, 6, 7, 8, etcetera. So, these series is called bracket series bracket; bracket series and there also another series. So, this for n equal to n 1 equal to 5 n 2 equal to 6, 7, etcetera. So, this series is called Pfund Pfund series Pfund series. So, these actually this initially one series was observed that is called Ballmer series empirical with empirical formula it was explained.

Now, Bohr model was able to explain that empirical formula basically; what is the root of this empirical formula. So, that was Bohr model was able to explain that one not only that it predicts the existence of other series and it was discovered later on. So, that is the that is the one can say this the success of Bohr model second due to correction this correction to the Bohr model to the Bohr model or Bohr that energy model due to considering the finite mass of nucleus considering the finite mass considering the finite mass of nucleus mass of nucleus ok.

So, that I have we have seen this m we replaced by mu. Mu is basically m M by m plus M right and from after this correction, it was possible to discover the deuteron. So, it is basically like isotope of hydrogen isotope of hydrogen deuteron that we have discussed. So, these are the basically success of this Bohr model and the third one also, one can claim that this Bohr model is basically for one electron system, but for many electron system we cannot apply this one directly to many electron system, but it, but it indicates it tells that that in many electron system in many electron system this theory may not be applicable directly, but the existence of the quantized energy level. So, that should be should be found it in any atom of having many electrons ok.

So, this from this work; so, one can tell that the existence of one can assume the existence of discrete energy levels or quantization of energy in all atoms whether it is single electron system or it is main electron system. So, these things this things was taken has a success of Bohr model another aspect also one can discuss that.

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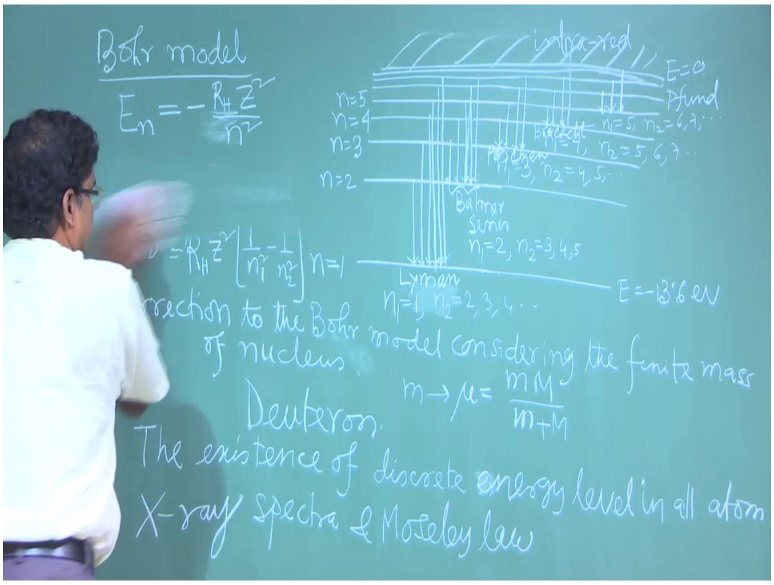

About the Moseley law, X-ray; X-ray spectra; X-ray spectra and Moseley law. So, what about Moseley law it was able to explain the it was able to explain the X-ray spectra and this Bohr model that whatever the expression we have got. So, that was able to explain this Moseley law so that I can just discuss. So, one has to know how X-ray is produced how X-ray is generated how X-ray is generated.

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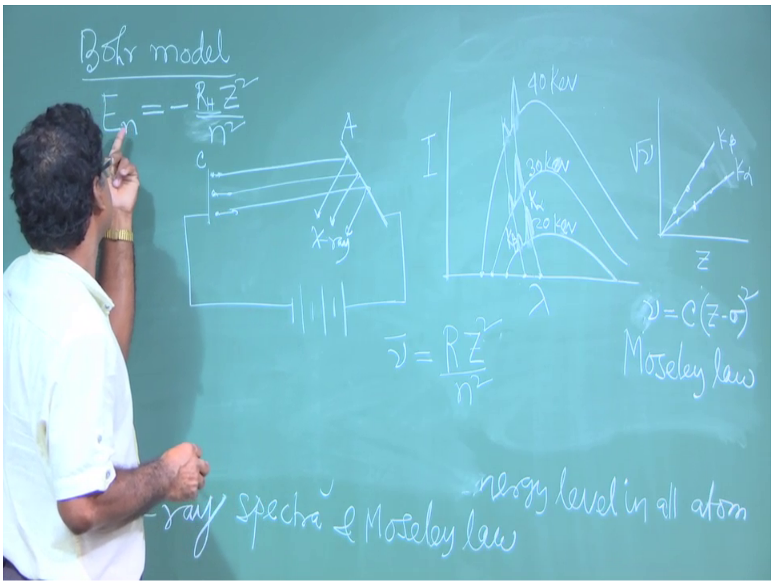

So, X-ray is generated basically from cathode from cathode electrons emits electron emits and there is anode there is anode. So, basically high voltage is applied between cathode or anode then this emitted electron it will be oscillated and it will hit the anode with generally a little target; it is made of generally molybdenum copper or cobalt this type metal is used for this target and then from here X-ray come out from here radiation come out and that is wavelength is in the range of one angstrom or 0.1 to 10 angstrom in that range. So, that is X-ray if you see in spectroscopy this X-ray, then we will see the spectrum distribution intensity distribution of this X-ray as a function of wavelength.

So, it is like this; this different curve, I have drawn for different applied voltage see to generally in kilo volt range is kilo volt 20 kilo volt of this, we say 30 kilo volt, this 40 kilo volt. So, one can write also kilo electron volt that is the energy of electron kilo electron volt one can write. So, this type of X-ray. So, this here what can see this is the continuous X-ray all sorts of wavelength are there, but its intensity depends on the depends on the wavelength ok.

Now, apart from that what happens at higher at higher voltage. So, sometimes or in other voltage also, but intensity depends. So, it is a superimpose of some peak superimpose some peak. So, resultant intensities distributions like this. So, one is continuous X-ray like this and another is some peak appears some peaks appears also, this minimum wavelength of this continuous X-ray depends on the it depends on the wavelength sorry it depends on the on the voltage applied between the cathode or anode. So, that was not understood that was not understood why it should depend it should depend on the on the voltage why this smaller than this wavelength for this twenty k kilo electron volt why smaller than this wavelength is not observed is not it seems is not possible ok.

So, this issue was not understood also; so, these peaks from where they are coming from where they are coming. So, that is also not understood, but for a, but this wavelength of all this peaks wavelength of some all these peaks is same. So, the drawing is not perfect so, but wavelength for all these peaks. So, so it does not this wavelength does not depend on this voltage this peak. So, this is same peak this is also same peak. So, these 2 peak whatever here the wavelength for other voltage also this wavelength are same. So, is the voltage in dependent where as this one voltage dependent.

So, origin of this now it is fine it is understood. So, what Mosley law did? So, this peak name was given k meter and this say k alpha k beta k alpha also these are k beta line these are these are k alpha line. So, wavelength each region miss what can one can get from here corresponding frequency one can find out and he used different target different material anode material and found that this k alpha k beta. So, they are wavelength depends on the on the material it depends on the material. So, it depends on the Z value. So, he plot it he plot it this Z and this square root of nu frequency square root of nu and found that is the straight line one for k. So, one has to see. So, frequency. So, this is higher wavelength k alpha that is higher wavelength. So, it will be lower frequency it will be lower frequency for same Z, it will be lower frequency.

So, it will be for k alpha and it should be for k beta and it is straight line. So, for different material when he calculated and plot it the data and he found they are following the straight line. So, and he gave the empirical formula. So, that is nu we found this empirical formula that mu equal to nu equal to some constant some constant nu equal to some constant Z minus some that sigma it is it is also sigma is constant, but this material dependent. So, that later on I will discuss. So, sigma it is a square ok.

So, this type of empirical formula was able to fit this data and of course, the square root of this basically this square will not be there. So, it is; this expression is basically for straight line. So, that is called the basically Moseley law this is called Moseley law. So, this was the picture and that now after this Bohr model. So, it was understood this formula that our nu was; what was that nu bar was basically Rydberg constant by Z square Rydberg constant, it was Z square now Z square multiplied by n square this term right, when I will write, when I write E n, then I should not write R H because yeah that I should not write R H because I will miss one should not write here.

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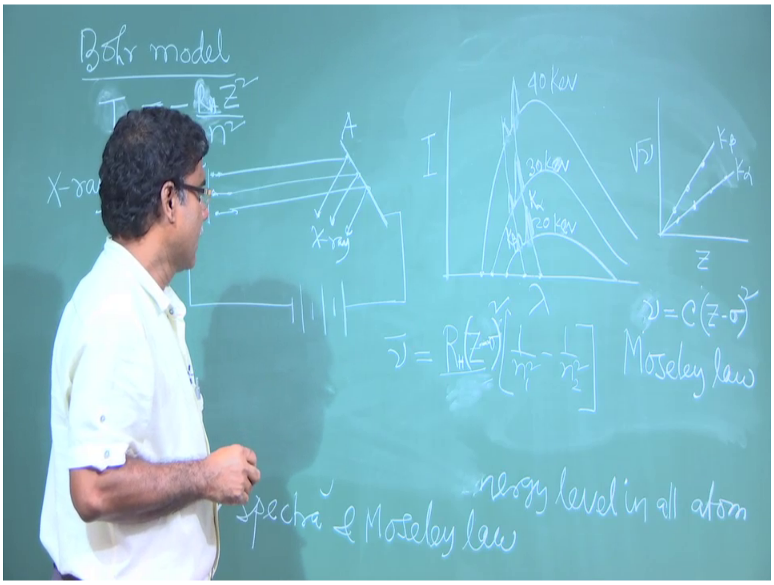

If I write R H, then I have to write basically. So, it is not n people write as a term value t its write as a t term value. So, I cannot write n if I write R H.

So, nu bar equal to this; for say R is constant for hydrogen, then it is not n square now it is one by n 1 square minus one by n 2 square. So, this is constant this is constant and now these was explained. So, this peak; this peak these are line at a particular wavelength. So, these are coming it is a metal dependent Z dependence. So, it is coming from the atom, it is coming from the atom and it is basically coming from the atomic transition this radiation is coming from atomic transition.

So, this in atoms its separation of the energy levels it will depend on the on the Z value it will depend on the Z value. So, basically transition it happens for the out routes outer electron. So, only difference is that only difference is that this in case of hydrogen only one electron. So, these electrons can see the whole charge full charge of nucleus if you have many electrons. So, outer electron it cannot see the full charge of nucleus because other electrons are there surrounding that nucleus. So, as if this negative charge spinned the nucleus nuclear charge positive charge. So, this outer electron it will see less positive charge it will see less positive charge.

So, that is why the Z for multi electron the Z one can write is it is less than Z. So, Z minus from spinning constant Z minus sigma Z minus sigma some spinning constant and now here for one lines, if we consider k alpha line. So, if it is for n 1 equal to 1 and n 2 equal to it say 2.

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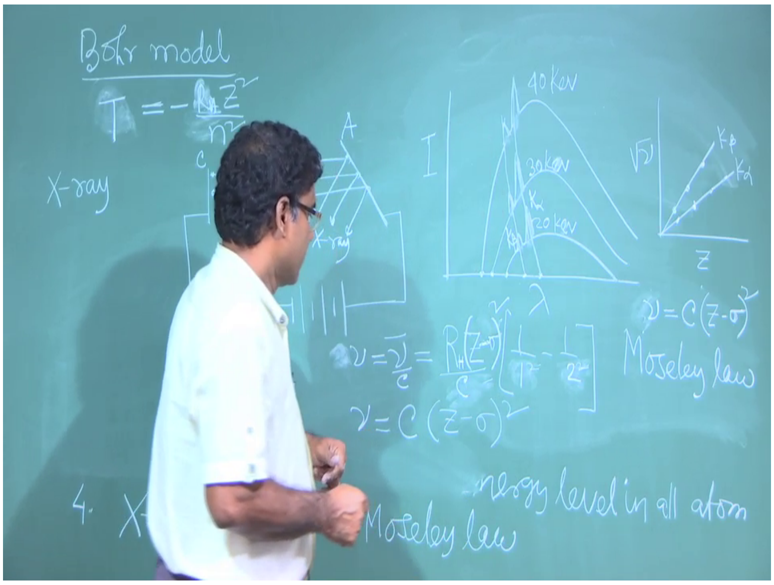

So, n 1 squares n 2 square. So, this also constant it will give some value. So, your nu bar. So, nu bar equal to basically is C nu, nu bar equal to C nu. So, nu equal to basically one. So, write divide by C divide by C. Remember this C here, this is the same is the light velocity and these are some constant. So, nu; so, from here one can say this nu equal to R H this constant this one this also constant. So, nu is equal to some constant C this is velocity C like velocity Z minus sigma whole square. So, this peak is basically coming from the transition from one energy level to the other energy level.

So, for other one, if it is for k alpha; if it is for k alpha then for k beta; it is basically this transition from n 1 equal to 2 n equal to n 1 n 2 equal to 3.

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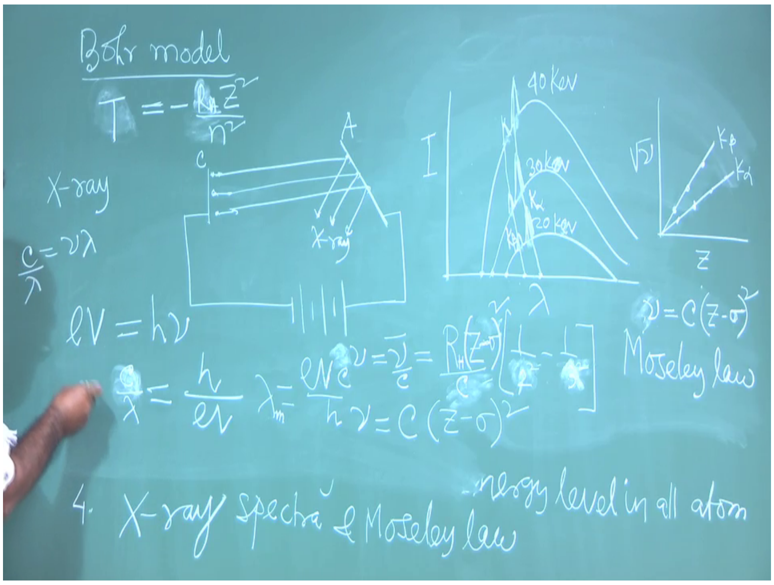

So, again it is constant some value. So, this C will be different than the earlier c. So, it is basically showing the slope. So, slope will be different slope will be different. So, this is also is taken as a success of Bohr model success of Bohr model that it can explain the fixed this Moseley law. So, and just I will tell you what is the reason for this one its. So, when this excess electron is coming and hitting this material; so, it try to create it inside the material and de it de-accelerated. So, it lose energy is lose energy and that energy come out as a radiation ok.

Because de-accelerated charged particle it radiates. So, that is why it is the this we get this continuous X-ray and when it is following and it is de-accelerated and also what happens it excites some electrons from ground state to the higher energy state and due to this excitation again within very short time this electrons come back to the again ground state and this energy difference whatever electron observed or got from this the accelerated electron.

Now, again this it release as a radiation and. So, that transition it material dependent it is the energy level dependent an energy level depends on the material. So, so this we get. So, that is the origin for this k alpha k beta k gamma some other l alpha l beta. So, dependent lecture is there. So, that we generally get. So, that is the reason for getting these. So, that is why this X-ray is called the characteristic X-ray characteristics X-ray and what happens for this one. So, sometimes it happen this if this pool energy. So, electron accelerated electron it is it falls on the target material it is trying to paint it inside, but sometimes what happens is atoms absorb this pool energy hole energy and it emits there will be transition and it emits radiation ok.

So, hole energy basically that is e v right whatever voltage and this electron this 2 hole energy if it is converted to the radiation. So, what will be the wavelength this energy now this will get radiation. So, wavelength is h nu wavelength is not wavelength this energy will be a energy of the radiation will be h nu so that 2 should be equal. So, you will get nu equal to h by e v. So, nu equal to basically C by lambda C equal to nu lambda C equal to C equal to nu lambda. So, I will get new equal to C by lambda, yes, I will get C by lambda. So, lambda equal to I will get lambda equal to e v lambda equal to e v C by h e v C by h. So, e c b h a constant. So, b is voltage applied voltage.

So, you cannot get lower value than this because these are whatever value of voltage. So, whole energy converted to the converter to the radiation; so, corresponding wavelength. So, that will be the minimum wavelength that will be the minimum wavelength minimum wavelength means maximum frequency maximum frequencies maximum energy. So, you will get minimum wavelength for a particular voltage. So, that is what happened and voltage is higher and higher this lambda m will be higher and higher lambda m will be voltage is higher and higher lambda m will be lambda minimum that is the minimum value will be higher and higher, it seems have I did any mistake yes.

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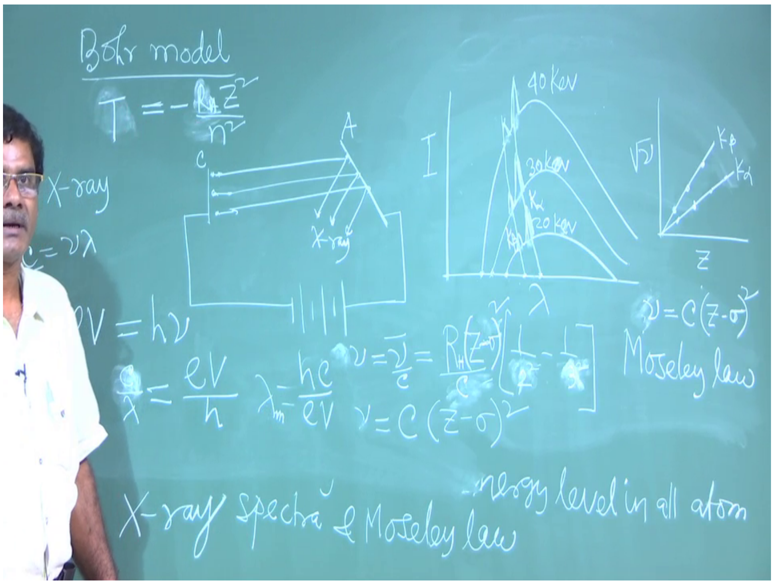

So, that is the problem I did mistake it has to be it is not that it is just opposite e v by that is why mean explanation was getting stuck. So, e v by h. So, now, this C by lambda now lambda minimum will be h c by e v yes is basically H C by yes now if voltage is higher. So, this lambda will be lower. So, that is why a voltage is higher lambda minimum lambda; lambda minimum will be lower yeah. So, that is the things. So, I will stop here.

Thank you.