good morning

so in the last class we concluded our discussion on deep roller waves the

so called matter waves and we pointed out that in spite of the experimental evidence there are a few loose ends which we have to settle it is not that they have been settled but i encourage you to think about the fact that if you apply the usual formula that velocity is the product of frequency and wavelength then you get contradiction between the particle velocity and the wave velocity we then went on to introduce the topic of the

so called fundamental constituents of matter were called atoms in the ancient days in our country they were called anus and i gave a sort of brief historical introduction as to how different civilizations and different scientists conceived of atoms

so as i told you the major philip came actually from chemistry and thermodynamics

so we said that periodic table had a very very great importance in actually solidifying the concept of an atom because it introduced the important concept of an element what i then started to discuss was the famous experiment conducted by rutherford

so i believe that i stopped at that particular point i showed you the apparatus which i will show you again today i will describe what the apparatus is for the sake of continuity and then we will see what the results are

so these were the things that we discussed and this is the apparatus

so this illustration this is of course not a photograph of the operators or a drawing

so you have this lead shield which contains the radioactive source bismuth 83 that is it has 83 protons the way we understand today and it emits alpha particles alpha particles carry an energy of 5.

5 million electron volt

so they are highly energetic then there is another lead shield here some kind of a plate which has a thin hole and therefore it acts as a collimator led is a very good absorber otherwise and then this golden looking plate is the foil very very thin foil on which the alpha particles impinge that is what we have and then they get scattered all around and it is schematically shown through these scintillation plates which are made of zinc sulphide which were actually moved around it is known that the gold foil carries a whole lot of charge close to 100 let us say and my alpha particle itself carries 4 units of charge 2 units of charge and that is something that we have to remember in the analysis

so this experiment was a crucial experiment to decide whether the thomson model of the atom was correct or not and the thomson model itself was illustrated in this figure the second sphere that you see here that is what you have

so you have a kind of semi solid sphere let us say which is in which the positive charge is continuously distributed and these yellow dots actually show us that electrons are probably spent around in this solid charge in other words we are assuming that the positive charge is not a particle in that sense it is an extended object we only want to assume that electrons are really much much smaller than the positive charge and we know today that it is not completely correct okay

so this is the experimental apparatus and these are the details as i told you source was bismuth energy was 5.

5 mb and the target was really very very thin

so we have to remember that it is

so thin that it has only a few layers of the atomic charge atomic distribution that means there was also an assumption or an understanding that the atomic size is of the order of let us say 10 to the power of 8 meters or maybe 10 to the

power of 9 or 10 to the power of minus 8 meters therefore the crucial question to be settled by the experiment is whether the positive charge is distributed over a region of something like 10 to the power of minus 9 to 10 to the power of minus 8 meters that is a very very important thing if you do not remember this then the result cannot be easily appreciated

so this is where we had stopped and we will now continue to look at what we are going to get i do not have a curve for rutherford's experimental result itself but here are some curves for scattering of proton on gold proton and platinum and proton on boron and you see that they all show a universal feature

so we do not have go gold is common to both of them

so if you look at the green line there if you look at the green line here what we find is that we have simply replace the alpha particle by the proton and the energy is a little bit smaller about 2 muv instead of being a 5.

5 muv alpha particle it does not matter but you see that all these scattering cross sections have a universal feature namely they are quite large in the forward scattering

so this is the recoil angle

so theta equal to 0 is like forward scattering the particle simply goes unscattered let us say and as you keep on increasing the value of theta then it starts getting scattered more and more i will illustrate that in a minute but the most important thing is that even when you come to very very large angles

so we are speaking of something like 180 degrees even when you look at the back scattering 180 is what the particle goes and then turns back even when you do that what you find is that the scattering cross section is not equal to zero

so what is the picture that we have and let us show that

so the main understanding here is that all the scattering is taking place because of the positive charge and not because of the negative charge there is a good reason to make this assumption that is something that we have to know the thing is that the atom is very very heavy compared to an electron remember an electron has a mass of about 0.

5 mmv by c squared whereas an atom is 2000 times heavier than that and our alpha particle is coming with an energy of 5.

5 muv

so if a projectile which is 10 000 times heavier then the target were to hit the target the target would be ripped off means the electrons would all be flying all over the place that is not what is happening in the rutherford cross section the projectile the 5 muv alpha particle is getting scattered and we do not see too many electrons in fact we do not see any electron therefore it is to be assumed that the projectile is hitting a target which is of comparable mass in fact it is of larger mass because as we saw if you assume gold has let us say about atomic mass of about 150 i don't know what the mass is it is certainly about 50 60 times larger than at least 40 times larger than the alpha particle

so if you look at it from that particular viewpoint what we find is that this scattering is essentially against a stationary target and a very heavy target

so we are interested in the scattering of what the a relatively light particle by a relatively heavy particle we have to remember that now if i come back to this particular figure

so this is my positive charge distribution

so maybe i will use another sheet to illustrate that

so i have my positive charge distribution sitting here i am not assuming that there are

so many plus particles it simply says that this region is filled with a positive charge now even if you do not know how to solve the problem a good question that we can ask is what is it that we expect of this scattering that is

something that we can ask now imagine the projectiles are coming like this the area over which the beam is spread is much much larger than that of a single atom obviously now the field produced by this let us take it to be a spherically charged distribution is 1 over r squared outside the sphere one hour outside outside the sphere that means it drops off very very rapidly

so if my beam is very far away it virtually passes unscattered that is the statement that we are making all of them have the same energy

so essentially scattering is characterized by the impact parameter the strength of scattering is characterized by the impact parameter and remember impact parameter is the approach of the shortest distance now if i look at a alpha look at an alpha particle a projectile particle which is relatively close this of course will be repelled by this star distribution

so what will happen it will come here and because of the repulsion it will go in this direction and now from this center we can calculate what the impact parameter is this is a completely symmetric situation the particle here will be repelled by this and the particle far away here will go straight away and that is what we are saying since the field is rapidly falling away most of the particles are not scattered and you see that in that particular in this slide where you have a very very large number of alpha particles which are coming in the forward direction close to theta equal to zero

so the scattering angle is obviously with respect to the incoming angle and this is the theta that we have in mind how far it goes an exceptional situation or the important situation is when the particle is coming head on

so this is the center of my charge distribution and my particle is coming now depending on the energy of the particle if the energy is not very large enough at some point the potential energy matches exactly the kinetic energy it is very easy to work out half v square is equal to q 1 q 2 over 4 pi epsilon naught d where d is the distance of the shortest approach q 1 and q 2 are the charges that are carried at this point the particle comes to rest and it recoils that is what is going to happen now when it recoils that is the cross section corresponding to 180 degrees but then if the energy is large enough to penetrate this charge distribution and that is very easy to work out

so if the radius of this start distribution is r what we are going to do is to replace d by r

so if my kinetic energy is larger than this threshold energy then what happens the charge particle alpha particle would penetrate the start distribution now once you penetrate the start distribution things change because here the electric field will actually start decreasing as you approach the center that is what is going to happen

so here the electric field was increasing here the electric field will start decreasing as you approach the centre because you have the great figure which depicts how the electric field behaves inside a sphere please take this to be a sphere

so inside it is linearly raising because it is like a harmonic oscillator potential and outside it falls off like 1 over r square

so this is 1 over r square and it is linearly raising

so as it enters the electric field actually decreases the repulsive force decreases at the origin exactly at the origin there is no electric force at all it comes here and it moves and we should be able to see that in other words the whole question of the

so called back scattering whether the particle comes and gets rebounded here or the particle continues to move here depends on two aspects one is whether the energy is enough to penetrate this charge distribution and that is tied with what this r is what the radius is

so if i draw another line what the radius is if the radius becomes smaller and smaller the energy required to penetrate it becomes larger and larger and in fact if r goes to zero if all the charge is concentrated at one particular point then there is no way that my alpha particle will be able to pass by the point charge because there is always an r for which what are we saying half m v square is equal to q one q two over 4 pi epsilon naught d if i write there is always a d which will satisfy this because d can be made sufficiently small therefore this quantity can be made sufficiently large therefore whether the plum pudding model is correct or not depends on what the energies are depends on what the chart distribution radius is and what kind of scattering we are looking at this is the way we should understand rutherford experiment now there is an exp although i have given this kind of an analysis you can do a very simple calculation

so let us say that is of the order of 100 without any loss of generality gold probably has a much lesser number of charges your energy is something like projectile is 5.

5 muv

so if you did that you can ask what is the shortest distance my gold particle my alpha particle can approach the gold foil that is a question that we can ask if you work it out you will find it please take it as an exercise it will be a tiny fraction of an angstrom it will be the tiny fraction of an angstrom

so if your analysis were based on just the recoil then we are not going to really get much information about the distribution of charge inside an atom is that ok except that it tells you that if the charge distribution is there it is occupying a much much smaller space in the atom

so this problem is not difficult to work out

so what we are saying is that my atom has a size of something like one angstrom and we are saying that if you work out this problem my chart distribution is actually of the size of what probably a fraction of an angstrom that is what we are saying that means there is no uniform charge distribution throughout the atom but it does not tell you exactly what the size of the chart distribution is because suppose you got something like a 0.

1 angstroms or some such thing which is 5 times smaller than the size of the hydrogen atom for the care in the case of gold it is a little bit more complicated but if you got a number like this it is not going to tell me much about the size of the nucleus but in spite of that you should perform this calculation it is not a difficult calculation to perform

so please ask given the set of the gold how close these back scattered alpha particles could have approached that puts some kind of an upper limit on the size of the charge distribution but the real input or the real answer comes not simply from the black back scattering but from something different and this is a very very important result

so we should not only look at the number of electrons or the alpha particles that are scattered backwards we should actually look at the complete angular distribution normally your books tell you that rather for found that most of the electrons were not scattered and a significant number of them were actually coming back of this scattered electrons a significant number of them were coming back because of the 100 percent recoil that is what we showed at 180 degrees that is not enough for us to draw a quantitative conclusion we should actually look at the complete angular distribution and rutherford indeed did that experiment in this figure for example we showed that the detector was moving all around the circle and it was collecting the scattered alpha particles that is something that we have to remember okay i cannot work out the theory for the scattering of an electron or of an alpha particle in the field of a nucleus but

one thing all of us know is that coulomb interaction is uncannily close to gravitational interaction

so let me write that here

so my gravitation is g m by r square my coulomb is q one q two one over four pi epsilon naught by r square both of them are inverse square loss

so purely numerically if i were to make a mapping q one q twos are like the two masses one over four pi epsilon naught is like your g in some units the s units and you have an r squared and we know when newton propounded his gravitational law he solved the problem of not only the bound planets but also comets which we never return what is it that we learnt what newton taught us was that in general this is very very important for us

so in an inverse square field what do i mean by that force goes like one over r squared most general trajectory the path is either one ellipse in special cases this ellipse can become a sphere at one end and a straight line in the other end that is what you have and secondly the second you say hyperbola

so essentially conic sections which can actually become a parabola this is what we find if it is attractive if it is repulsive there is no question of being an ellipse because we are looking at a repulsive scattering

so all trajectories are hyperbolas that is what we have

so if i were to write the scattering again

so this is the scattering center my positive charge is coming this is also positive q one this is some small q then when it goes and gets scattered like this this is actually a section of a hyperbola this is a section of a hyperbola

so that is what we have

so now we are going to ask what is the probability that this particle is going to get scattered at this angle theta there is a question that we are asking and newton actually solved a problem

so in the case of planetary orbit of course you have hyperbolas if the energy is greater than zero and we know some comets return that means they are in highly elliptical orbits some comets never return and they are in this hyperbolic orbits newton had already worked it out there is a very very important thing for us therefore we know if you start looking at the scattering cross section the number of alpha particles that come at different angles here is an illustration this is not exactly rutherford scattering but it is some other scattering but never mind about that if your charge distribution was over a reasonable volume of the atom then your cross section should look like this it comes here there is a bump it comes down there is a bump it comes down there is a bump

so on and

so forth

so it is as if there is a continuously falling curve as i keep on increasing my scattering angle but suddenly there is some kind of a trigonometric function which is superposed over that for example you can imagine remember your lcr circuit where you have a damping you know it oscillates and falls down oscillates and falls down that is what is happening there is something similar to that and this is a hallmark of a scattering from a extended chart distribution this is something and this is an experimental result and is confirmed by theory ok but if you look at this which i showed for scattering of hydrogen on gold you do not see any bumps it is a very very smoothly following function and therefore from this we can conclude that if at all my positive charge has a certain distribution it is very very small compared to the size of the atom that is a very important result this is a illustrative result but actually i have one result coming from geiger and mars then geiger and marsden were students of who students of rutherford they very carefully did the fitting

of rutherford results

so the circles are experimental points okay this is the scattered number of alpha particles that he is going to look at now the

so called rutherford formula is the theoretical expression assuming that all the charge is concentrated at one point and you see that the experimental numbers are in complete agreement you barely see any difference at all they are in complete agreement with the theoretical curve that means if at all my charge is distributed over a certain volume it should be a tiny tiny fraction of the atomic size in fact if you estimate that you find that the distance over which my positive charge is distributed is 10 000 times smaller than the size of the atom this is the most important result of the other first experiment

so what i mean to say is that a careful detailed quantitative analysis is a very very important factor in interpreting these results we cannot simply go by qualitative reasoning

so even though at this point you do not know how to derive this formula you should know that rutherford and his students geiger and mars then they did a fairly accurate and careful analysis before they drew the conclusion that the positive charge is concentrated in a very small region okay what is the natural consequence the natural consequence is the planetary model

so let us go back to the atom we have been looking at the scattering

so what we are saying is that my atom has a size of let us say a an angstrom one angstrom is 10 to the power of minus 8 centimeters which is 10 to the power of minus 10 meters or 0.

1 nanometer that is what i have it is of the size of an angstrom that is what i have and now i am saying this is the size of the atom now i am saying all the positive charge is sitting here in a very small region and this is probably something like 10 to the power of minus 13 centimeters or one femtometer 10 to the power of minus 15 is called femtometer that is what it is sitting and we know that in an atom we have discrete number of charges the total positive charge is equal to the total negative charge they are the electrons the force between the positive charge and the negative charge is of course attractive

so what do we do we go back and fall upon the newtonian result and what we have is essentially a planetary model if these orbits are bound these are probably moving in orbits like this this picture or this cartoon of course is made in more recent days when we know that that positive charge distribution itself is consisting of protons and neutrons even these discoveries were made by whom were made by a student of rutherford chadwick discovered the neutron protons are already known in the cathode rays that is what we have and we imagine that our electrons which are denoted by these red crosses they are all moving in orbits this is from encyclopedia britannica this of course is very schematic you should not assume that there are two electrons per particular orbit or you should not assume at this particular point that all orbits are circular because when we discussed or when you studied kepler's laws what did kepler tell us kepler told us that the planetary motion is all elliptic sometimes it can become circular

so even here the lesson that we have is that the orbits are elliptical and electrons are distributed over them and the center of attraction the center of the force the positive charge is in a very very small region this picture is of course not to scale there is the mandatory warning because this makes it appear that my protons and neutrons are occupying a large region in space that is not correct as we told you it is a very very small number ok

so this was a hallmark and at this point you see that we have all completely forgotten about photoelectric effect planck hypothesis deep broly waves everything i suddenly start started motivating you about what the ultimate structure of the matter ultimate fundamental constituents of matter by looking

at electrons and wave like behavior and
 so on and
 so forth but actually what we are going to do is quite tied up with the idea of a quantum and that is because although the planetary model where you imagine that all the electrons are going in circular or electrical orbits may be consistent with the results of rather fat scattering they are not consistent with other aspects of electromagnetic theory
 so what we have to now do is to go back and ask ourselves what we know from maxwell's equations or electromagnetic theory
 so i am going to summarize it very qualitatively
 so the first statement is that charge at rest what does it do it produces electrostatic field
 so you can think of a single point charge
 so it will produce one over r square field now if the chain charge is moving with a velocity v not only will it produce an electric field it will also produce a magnetic field because a moving charge constitutes a current that is what we have
 so this produces electric and magnetic fields this produces electric and magnetic fields that is what it produces the operative word here is this is uniform that means no acceleration
 so now the question that we are going to ask is what happens if i take a charged particle and it starts accelerating
 so this acceleration can be linear or it can be going in a circle or it can be odd the charge particle can be otherwise oscillating up and down
 so on and
 so forth
 so obviously when the particle is accelerating except perhaps at one or two instants it also has a velocity
 so you should be producing e and b electric field and magnetic field but now there is a difference it produces a special kind of electric and magnetic field which corresponds to electromagnetic wave
 so in your chapter on electricity magnetism and optics in your class 12 ncrt book you people studied or learned that what we call as light is nothing but an electromagnetic wave
 so what is happening if a wave is propagating in some direction then my electric field will be one direction and magnetic field will be in the other direction and d cross b will be the direction of the propagation
 so you have learnt quite a lot about polarization direction of the electric field linear polarization
 so on and
 so forth that is what you have learned
 so basically what is happening in a physical way is that when you want to accelerate a particle you start pumping in energy and when you start pumping in energy part of it will go to increase the energy of the particle part of it will get liberated and it will become electromagnetic radiation
 so what is happening is that if a particle is accelerating it also starts emitting radiation of course to accelerate a particle you do not have to pump in energy for example if the moon is going around the earth the earth is going around the sun nobody is supplying any energy but then it is accelerating because it is in a circular orbit and the fact that an accelerating particle emits radiation is valid for all kinds of acceleration that is the very very important thing and it is a uncontested consequence of maxwell's theory electromagnetic theory that you have read and now you see if you look at this picture the outer electron is going in one orbit the inner electrons are going

in another orbit they have all accelerations given by m v squared by r
 so what should happen the outer electron for example should gradually lose energy come into this orbit this should gradually lose energy come into this orbit
 so on and
 so forth and eventually all the electrons should lose their energy until the collapse inside the positive charge distribution the nucleus that is what should happen
 so in other words we have a serious problem with the notion of stability
 so what are we saying
 so initially the particle was in this orbit i am going to show that theoretically the available in other words if you wait for a sufficiently long time the size of the atom should be the size of the positive charge distribution which we know is something like 10 to the power of minus 15 meters the big question here is what is the time scale for the particle to continuously decelerate and fall into the nucleus we have to answer that question if it is of the order of the age of the universe we will say you cannot care it is hardly emitting at all but maxwell's equations also tell you what the time scales are and these time scales are all of nano seconds 10 to the power of minus 9 seconds but we know that our universe has been there according to the big bang theory for 10 to the power of 12 or 14 seconds and our earth has been there for a billion years 10 to the power of 9 years
 so on and
 so forth and atoms have been there that means there is something seriously wrong with this picture now you can see we are again at the crossroads of the contradiction of something that we observe with the classical laws prank saw a contradiction with the classical law with what he observed
 so he gave register he postulated the existence of a quantum of photon because he could not understand the black body radiation einstein saw a clash of uh consequence a clash of consequence of classical theory wave theory for example in photoelectric effect
 so he made use of the concept of the photon the quantum of energy again you see in the atom we are finding a conflict with a consequence of maxwell
 so at every point we are finding a conflict with the concept of a classical wave and a radiation from a charged particle
 so perhaps here also planck hypothesis or a quantum notion plays an important role and this is where bohr comes into picture and what he did was to bring in some of the ideas of einstein and planck and try to understand the results of rutherford now it is one thing to say that the charge particle radiates it is another thing to see good evidence for that unfortunately for us today we have great evidence starting from the laboratory scale to the astronomical scale
 so let me show you some pictures for example this is a radiation from a synchrotron
 so what is a synchrotron you produce a large magnetic field and you let in the electron and the electron keeps going ground and round in the magnetic field but at some point it passes through a tube where it will get accelerated
 so it comes with a higher energy then again it will go down again it gets a kick
 so on and
 so forth it is called a synchrotron because you have to synchronize the period over which it accelerates with the period of the orbit in relativity it is a little bit complicated never mind about that but if you believe mean maxwell consequences of maxwell's equation my charge is continuously accelerating therefore it should also continuously radiate

so this figure shows you the energy of the emitted photons and their number the number density against the unit this is a figure cake taken from one of the synchrotron results

so you can actually see it even in the visible region these of course are in very very high energy in the geb range is that ok you see that the radiation is emitted over the full spectrum is that ok its radiation is emitted over the full spectrum that means it is a very good evidence for the fact that accelerated charge particles radiate this is a another curve coming from a cosmological astrophysical object called active galactic nuclei active galactic nuclei support a very very large magnetic field in which the charged particles start getting accelerated and they start emitting radiation

so you see this is the intensity of the radiation against various wavelengths
so this is the characteristic synchrotron emission that is what is shown then of course lot of other things happen but the more important thing is that you see that it starts in the radio region and it comes to the infrared and almost borders on the visible and of course it will continue after that it is not the synchrotron lot of other processes take takeover but still there is acceleration it goes on to the visible region then it goes to the ultraviolet that is beyond the violet and then it goes to the x-ray region

so these have been observed and have been perfectly correlated with the consequences of maxwell's equation

so this is another particular example and here is actually a visible picture in the space where a jet is coming because of such an active galactic nucleus

so whether it is lab in your accelerators or whether it is the cosmic accelerators in outer space maxwell's equations are very well established

so we have to ask ourselves what is happening in the case of an atom why is it that my atom is not decaying why are my electrons not collapsing into the positive charge

so you see however you may look at it we are in continuous trouble the plum pudding model was first of all ruled out even if it were there it is difficult to explain the stability of such a system from electrostatics rutherford tells you that it is not plum pudding model probably it is a planetary model but then it is contradicting the classical law that accelerating charged particles must radiate it is a very very important question

so when we are speaking of the discrepancy between what is observed and what is predicted an atom should live for 10 to the power of minus 9 seconds whereas atoms have lived for 10 to the power of 12 or 10 to the power of 14

so there is a discrepancy of the order of 10 to the power of 20 that means there is something extraordinarily radical that is happening and that is where again the quantum hypothesis comes to be very very important

so this is something that we have to remember now does it mean that the atom does not radiate at all we did not say that we only said that the atom is stable that is what we said now however i can always excite an atom how do i exit an atom for example if i heat a material well enough my electrons will escape in photoelectric effect what happens radiation comes and hits the atom and the electrons will escape

so if you go back to the classical picture let us go back to the classical picture you can imagine that there is this nucleus here and there is an electron there is an electron let us say now what is going to happen is that the electron may be in this particular orbit i can supply energy and the electron can go to this orbit that is what can happen now what will happen is that of course classically speaking all orbits are allowed in between these two orbits

so depending on how much energy i supply it will go and sit in the orbit now there is nothing that tells me that the electron in the excited state in the

higher orbit should not come to the ground state
 so this is the minimum energy let us say
 so when i speak of the stability of an atom what i mean is that there is a minimum energy state of the atom and after that my atom will not by electron will not further fall down but if it is an excited state
 so it can go here it can go here this is an orbit this is another orbit these fellows can always come
 so how do they come when they come here classical theory will tell you that they should continuously emit radiation
 so let me go back to the previous picture in the previous picture you see the radiation is continuously emitted or look at this pitch the radiation is completely continuously limited
 so there are two aspects one is the stability and another is the nature of the radiation that is emitted when the atom is excited it is sent to a higher orbit that is what we are looking at and spectroscopists who have been studying atoms not only on the earth for that matter even in the sun very carefully they find the emitted radiation is not continuous but it comes in discrete lines only some of the wavelengths are allowed
 so in your course you will learn many many names lyman series bomber series bracket series and then you have fund series and then you have some other series it goes on and on and on and here is an example of what is called as a lyman series
 so you see it starts with a wavelength
 so actually we should start with the largest wavelength about 1200 this must be angstroms 1200 angstroms and goes all the way up to the up to 900 times comes that is what we see in the case of lyman series there are further classifications nine seventy two ten twenty six twelve sixteen etcetera etcetera never mind about that
 so in this region you have what is called as the lyman series we will come to that in a minute ok now there is another series called the bomber series is that okay lyman series is not in the visible region at all ok but bomber series is in the visible region because you see red you see blue you see violet is that ok here the wavelength is decreasing as i go in the other direction four zero one seven probably is almost already away from this one then you go to other regions these are all blue region after violet you get ultraviolet essentially
 so if i go back and look at the lyman series again the wavelengths are very very small
 so it is all in the ultraviolet or the x-ray region whereas here the wavelengths are larger and that is what you see and there is you see there is a very peculiar spacing between them what is the spacing that you see between these two there is a very large spacing it is smaller it is even smaller it is even smaller
 so the spacing becomes smaller and smaller as you move along the direction of what increasing wavelength now let me see decreasing wavelength or increasing wavelength decreasing wavelength and this is the same thing here also ok
 so you are starting with a wavelength of 1250 as you keep on decreasing it that is what we are doing in the come directly in this direction the spacing becomes smaller and smaller this is a unified picture of all kinds of series is that ok
 so you see there are very very nice groupings and there is very little overlap that is the most important thing all these are for hydrogen atom by the way
 so here is your lyman series
 so you see ultraviolet extends up to this point bomber series starts in the visible region and extends up to this point then you have what is called the ritz passion series which partly overlaps with the visible region it is almost

at the border of the visible region and then goes and then you have the
 so called bracket and the full
 so on and
 so forth there is one more and the fact is that they have no overlap and also similar structure as you go as you move along this particular direction the space between become smaller and smaller and smaller we have to understand why is the spectral distribution discrete and why are they grouped in this particular manner that is the question that we have to answer now there is a gentleman called rid burke who studied this in a very very careful way and he came up with a beautiful formula and that was the following he found that the wavelength emitted depends on a universal constant into 1 over n 1 square minus 1 over n 2 square that is what we found out where n 1 n 2 are integers
 so probably i should write it as n2 square minus n1 square that is what you found out now the interesting thing is if you put n1 equal to 1 and n2 equal to 2 3 etcetera etcetera this is what is called lyman if i put n 2 equal to 1 and take n 2 equal to sorry n 1 equal to one and n two equal to three four etcetera etcetera this becomes bomber in fact as you keep on shifting the value of n one by one unit then you will hit its passion bracket and
 so on and
 so forth r y is a number to which we have no clue and what is this called this is called the read per constant red bar constant and of course if my atom is sitting in the state corresponding to n one the orbit corresponding to n one i do not know what it means if my atom is sitting there there is no further decay there is no further emission that is what we find and this we have to understand
 so let us collect all the results that we have learnt
 so far from rutherford scattering the first one is that atom is mostly empty
 so what are we saying we are saying that there is a positive charge zte concentrated at the center and our electrons are moving in orbits and the size of this is of the order of 10 to the power of minus 15 meters whereas this distance is the order of 10 to the power of minus 10 meters that is the statement that we are making but then it also throws up a problem and that is this model is not in agreement with observations other observations what are the other observations number a spectral lines spectra of radiation are discrete as we saw but classical theory predicts it should be continuous
 so it is not continuous it is not continuous even more importantly and spectacularly the atoms that we are looking at are all stable whereas classical electromagnetic theory would predict that over a period of about 10 to the power of minus 9 seconds electrons should have collapsed electrons should have collapsed into the nucleus electrons do not collapse
 so what does it mean this means there must be a lowest orbit which is stable experiments predict the existence of a lowest orbit the lowest orbit which must be stable but this is not allowed by classical electromagnetic theory because classical electromagnetic theory tells me that every time there is acceleration there must be radiation and there is no known law that protects an atom
 so we have two tasks at hand two tasks understand discrete spectrum to understand stability and the solution to both these problems was given in one shot by bohr
 so in giving this solution he made assumptions which were apparently self-contradictory or certainly con in contradiction with known laws of physics
 so for this reason we do not call it as a theory but we call it as a model and today all these thing phenomena or all these developments are dubbed as world quantum theory the real quantum theory started only after schrodinger wrote his equation and heisenberg gave his uncertainty principle that is something that we have to remember

so what we shall now do in the next 10 minutes or

so that i have is to give an introduction to the bohr model i will explain what the model is and in the next lecture i will work out detailed consequences of this model

so what are the assumptions that bohr made

so let us start with the bohr model bohr was highly impressed by the work of planck and einstein and plank and einstein essentially had introduced a new fundamental constant h bar or h h bar is h by 2 pi we saw that in the next class and let us remember this has a dimension of energy into time but more importantly for us h has the dimension of angular momentum this is very important for us every time we think of h

so far we have been thinking of either energy or momentum e equal to h nu p equal to h by lambda but now if you look at the dimensional analysis this has the dimension of not only energy into time but also angular momentum and this is something that bohr exploited

so one thing is to exploit a new physics that might perhaps come from the invocation of planck's constant and the second thing that bohr did was to actually enunciate enunciator rule

so when i say that i initiate a rule it is like passing an order that means it is an ad hoc assumption and the rule emitted was that radiation emission of radiation by accelerating particles electrons in our case are also governed by by new physics that is to say mere maxwell's equations and a classical orbit are not enough to understand the nature of the atom

so that means we need new principles that is what board is but bohr still kept features of classical mechanics just as einstein kept features of classical mechanics and planck kept the features of quantum mechanics therefore bohr model is what we call today to be semi classical

so just as in the experiments of photoelectric effect or deep broly waves we find that the same object can be sometimes represented by a wave or a particle the same entity in a similar manner when we discuss a model like the bohr model for a moment we make use of the classical law at another moment we make use of a quantum law we do not try to reconcile the toe or we not try to understand how or where one law should play a role and another should not play a role there is a very important thing we do not do that we simply initiate the rules we compare with the experiments and if it agrees then we can try to build a more general theory that is the most important thing

so bohr model is a semi classical theory

so what is it that bohr did and i should remind you that what d brawley did was actually inspired by what board did that is something that we have to remember

so this is some kind of a brief introduction

so in the next lecture i will give you all the bohr postulates and then we will discuss the model tomorrow okay bye you