Atomic and Molecular Physics
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Lecture – 04
Experimental observations and theoretical development in discovery of constituents of an atom (Contd.)

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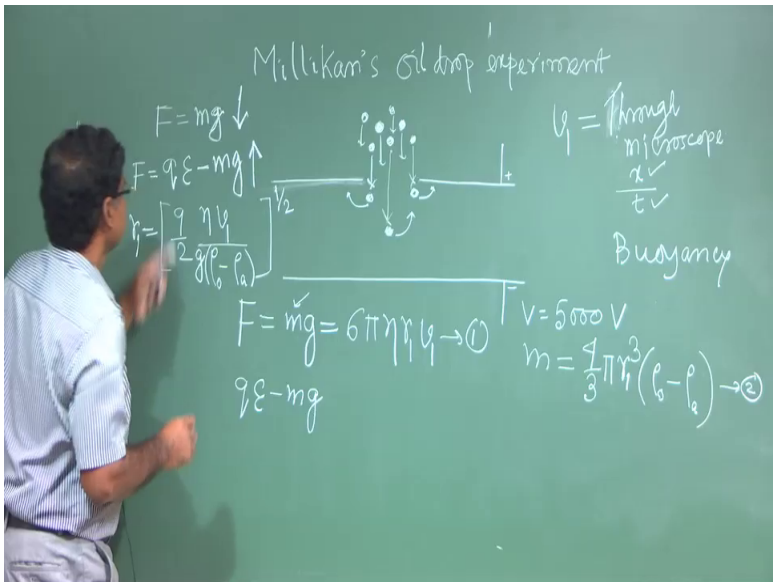

So, we will continue our discussion on the millikans oil drop experiment this is very famous experiment for measuring accurate charge of an electron. So, millikans oil drop experiment, so what was that experiment, so this basically this millikans what he did he used charge oil drop oil drops and now these charged oil drops it spread in space ok so it spray in space using spray or atomizer it is called a atomizer.

So, very small tiny oil drops was produced and thrown in space, now what will happen this oil drops will fall, there will be free fall of oil drops due to the gravitational force downward force gravitational force that is basically mass of the oil drop is m and gravitational force is g acceleration is g, so mg that will be the force acting on the on the oil drops.

So, now use atomizers to produce very small oil drops, it is not only one oil drops many oil drops and they fall they fall free fall these things fall see they are fall falling downwards so these all are falling. Now he used he used capacitor plate again to metal

plate keeping hole on top plate keeping hole on top plate. So, this must be parallel this must be parallel and then he applied voltage, he applied high voltage and it is a high voltage so this volt was around V equal to say 5000 volt it is very high volt, so our in that in our house what about electricity we are using this voltage you know this 220 volt single phase having 220 volt.

So, it is very high volt compared to that, now what will happen depending on the distance between these two capacitor plate now it will there will be electric field between these two capacitor plate. So, these way basically we generate electric field, so here electric field is applied on this on this oil drops. Then he found that if this top plate is positive and bottom plate is negative then what we found that these oil drops are moving up this oil drops are moving up ok.

So that means, this draw oil have our negatively charged, so electric field acting on this charge and it is this force will be apart and it will move, if their force is greater than the gravity gravitational force acting downwards, so net force then will be upwards so net force will be is if the charge of oil drops is q so the force will act upward force will act that q e, now resultant force will be q e minus mg acting upwards so that will be force when electric if it is so this is the force is downwards without applying electric field and when electric field is applied, so it will be upwards when this q e is greater than mg.

Otherwise it will remain downwards because of this higher force, gravitational force anyway. So, when there is no electric field so this is the force mg force is acting downwards and when and it is falling through a medium you know air medium it is falling through a air medium, so when any particle moves through a medium, so there is a viscosity of this medium and it leads to a terminal velocity it leads to a terminal velocity and this is basically it is the stokes law and that if well that velocity is V 1 this force is acting F mg equal to mg downwards and then stokes law is basically it is it tells that it is there will be resistive force acting in opposite direction due to the viscosity ok.

So, when downwards force and upwards force so there will be, so these two force one is resistive force and another is downwards gravitational force and due to these two force in viscous medium, so this particle reaches to the terminal velocity what is the terminal velocity, terminal velocity these two force as if they will raise the force and this

downward force there they will be balanced, there is no net force on the particle on the particle.

So, if there is no net force on the particle then there will not be any acceleration then there will not be any change of velocity, so whatever velocity it reach that is called terminal velocity now with that velocity it will move, so there is the terminal velocity. So, to get the terminal velocity condition is that this force will be balanced by this resistive force and what is the resistive force this 6 pi say it is the from stokes law it is 6 pi eta viscosity constant and the radius of these radius of this particle spherical say spherical particles here it is oil drop.

So, 6 pi eta r 1 V 1 say terminal velocity V 1 is terminal velocity. So, this is the situation will arise and so this will move downwards without acceleration, but with terminal velocity and this millikans what he did he measured this terminal velocity V 1, without when there is no electric field in that condition what is the terminal velocity V 1 he measured experimentally how he measured he used microscope he used microscope and in microscope there is a eye piece in microscope there is eye piece with scale ok.

Now, through microscope he sees the with time, with for a certain time what is the distance it is traversing, so distance and the for that time so on he found the velocity. So, experiment is not very so many times he has to measure many times he has to measure he has to reproduce the result ok so that were using microscope with scale in eye piece he found this value terminal velocity, so that is basically V 1 found through microscope.

What is the say for time t, what is the distance it is traversing, so he measured this x for a time t so he gets this V 1. So, when what is the this m here, m I have written that is basically effective mass of the oil drop why, so you know are given this principle. So, whenever this any particle it is in a medium easy to understand in liquid so it lose weight right it is because of buoyancy force it is upward basically ok. So, because of this buoyancy force of there is it in this case it is air, so this is effective mass effective mass m is basically these are what is mass, mass is basically the volume into density volume into density if density of this oil is rho of oil o and this effective mass will be then is minus rho density of air, so that will be the effective mass m right.

So, what we are getting then from 1 and 2 we can write from 1 and 2, so you can you can write r 1 because r 1 is not known to us. So, r 1 I can write r 1 equal to so if I replace so

if I replace this m by this, so I can see r cube in this side here r 1 so r square so basically r one square, so r 1 will be something in this bracket and then to the power half ok.

Now, this side 6 this side 4 by 3, then 9 by 2 it will be 9 by 2, then this side pi is there this side pi is there thus that will go now this side eta is there so eta will be there, V 1 will be there divide by this divided by rho 0 minus rho a 0 minus so and 1 g will be there, so this side g is there so I think I have to write here g. So, from here this is the expression of r 1 can find out because g is known rho 0 rho a is known eta is known ok.

If V is known V 1 is known so then one can find the r 1. So, experimentally he measured this V 1 so from here one can find out r 1. So, now if we apply electric field if you apply electric field and then what will happen as I told the direction is chosen in such a way this electric field that force will act upwards, so this will be the resultant force this will be the resultant force acting upwards. Now, due to these this force it will move this it will move upwards, so now net force is acting upwards due to this force again this mass this oil drop it will reach to the terminal velocity because it is moving through the viscous medium. So, there will be raise the force so I can write this the q E that force net force upward q E minus mg because so that force will be balanced by 6 pi eta r 1 now terminal velocity that will be different V 2.

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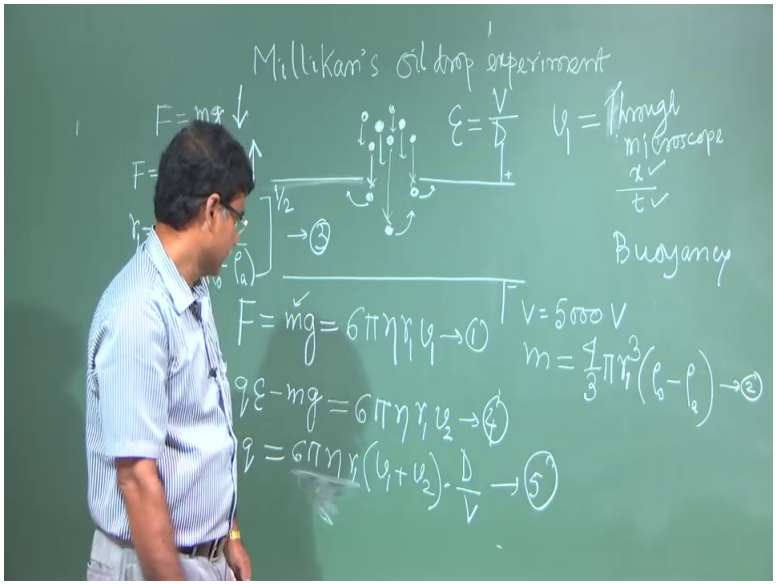
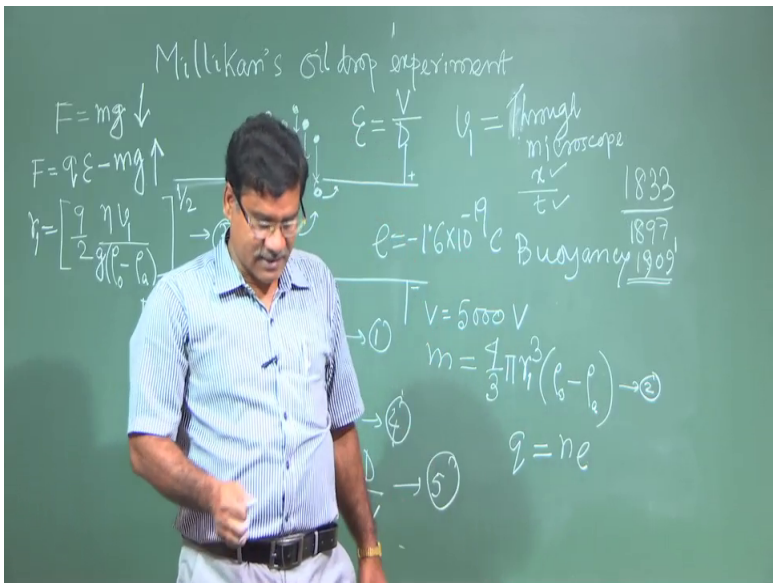


Now, terminal velocity will be different V 2, now from one end from this equation and this equation now if I tell this is the this is the equation 3 and this is the equation 4, now

from 1 and 4 you can you can because one I need here so I can get q E equal to this plus this is nothing but this, I will get q equal to I will get q equal to 6 pi eta r 1 into v 1 plus V 2 V 1 plus V 2 divided by e divided by electric field right. So, that will be the expression for q, and an electric field of course that that the electric field electric field of course, earlier I mentioned electric field will be V by D if this separation is D. So, one can get or you can write e is e can write into D by V there is this voltage and that the separation D by V ok.

So, now in this there is the final equation for charge in oil drop in this expression in this expression r 1 can in principle r 1 is this and here you can see everything is known except V 1 and V 2, if we know V 1 and v 2 right then you will get the charge q. (Refer Slide Time: 20:12)



We will get the charge q and he found the charge discharge from the measured the measured on many oil drops and he found the charge is always multiple of it is always multiple of some unit charge ok. So, this q are different for different oil drops or sometimes same whatever but it is always n e it is the interior integral multiple of e unit charge some charge and that he e found that he e found e equal to that value e equal to minus 1.6 into 10 to the power minus 19 coulomb. So, this second very beautiful experiment and from this experiment one can measure the charge of kept on very accurately and that is what the witness or famous that is why it is a very famous experiment and these experiment gave very exact value of electrons ok.

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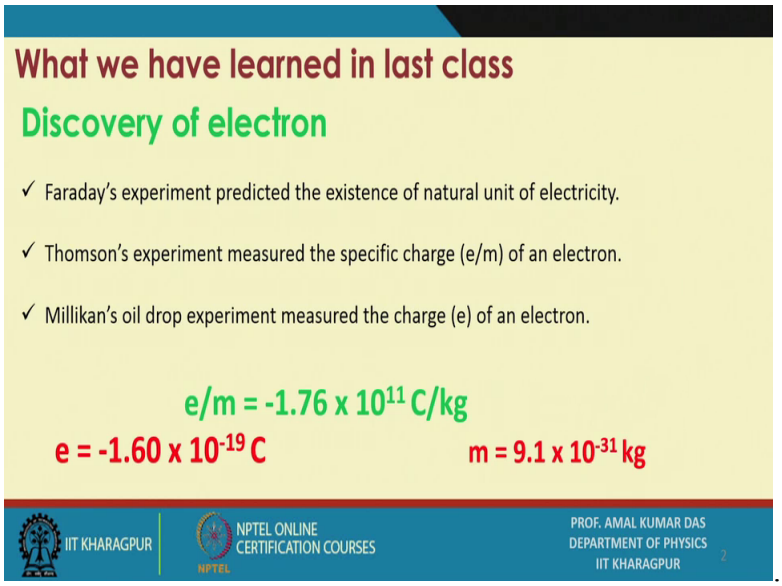

So, this is the oil drop method so what we learned from last class and this up to this so, we learned how the electron was discovered and what is the charge and mass of electron and this is the this is the and these took so long time you see faraday experiment that was in 1833 and just mentioned out the mentioned about the presence of or what is called this existence of the of the charge in nature in meter yeah and in 1897 and 1909 so only this time so it is almost 80 years time it took to find out the charge of electron and mass of the electron.

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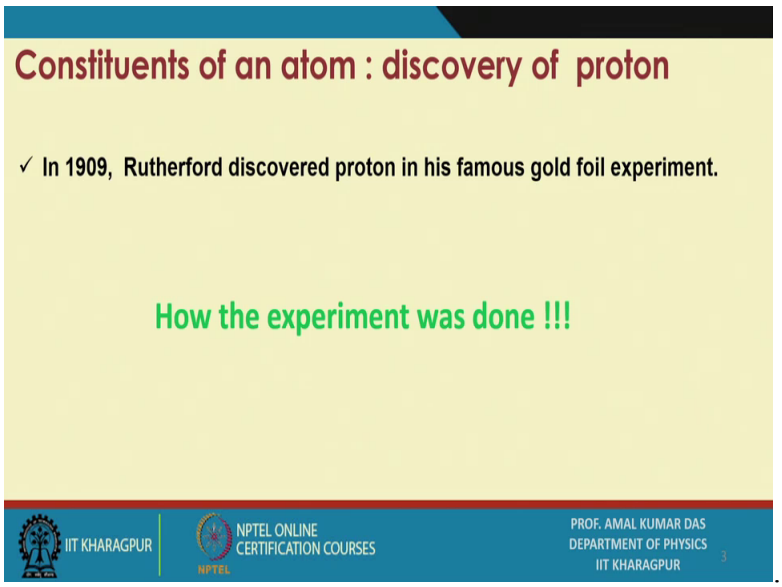

So, next I will go for how so this we want to know the constituents of an atom, so one is electron and how it is discovered that I have discussed, next discovery of proton another constituent of atom is proton so how it was discovered. So, in 1909 rutherford discovered proton in his famous gold foil experiment you know, so it is another famous experiment gold foil experiment and so how this explained is it is easily understood, so that I will explain what was that experiment and how he found how he discovered this proton in that experiment ok.

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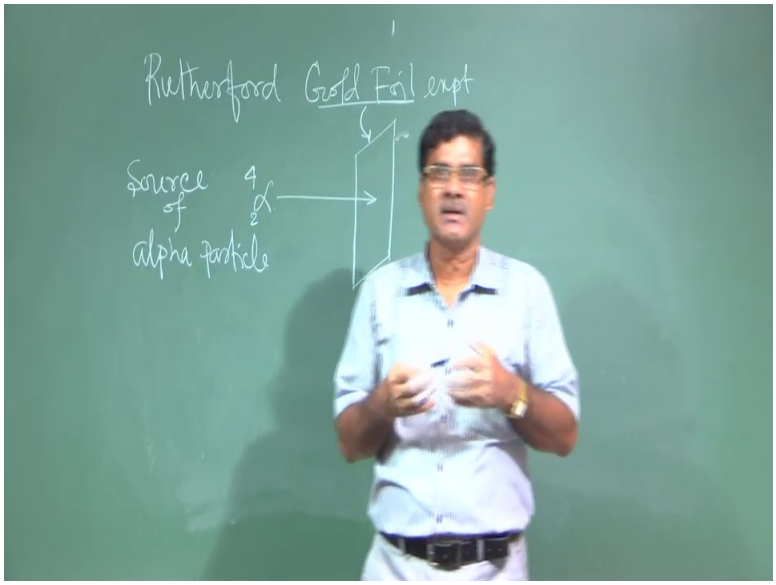

So, next experiment is rutherfords gold foil experiment, ok so rutherford gold foil experiment. So, foil is basically sheet very thin sheet it is called foil aluminum foil you know aluminum foil we used to pack our food so this very I think this file is maybe thinner than that one aluminum foil ok. So, what he did he alpha particle in a radioactive material it emits alpha particle, so alpha particle he took the source of alpha particle yeah it is basically this mass is 4 and he is charged positive charge is 2 alpha particle this how we write ok this charge is 2 positively charged, so this alpha particle he from a source he took and it is bombard a foil, it bombards a foil oh I think this is gold foil he put gold foil this alpha particle it is coming and hits this gold foil ok.

And then he study the scattering of this alpha particle after bombardment on this foil how that alpha particle are scattered so that is what he studied and he found that, so he put

basically he put basically I think he put a some fluorescent skin in a tape in a circular form, so let me try to draw but I do not know whether I can draw nicely.

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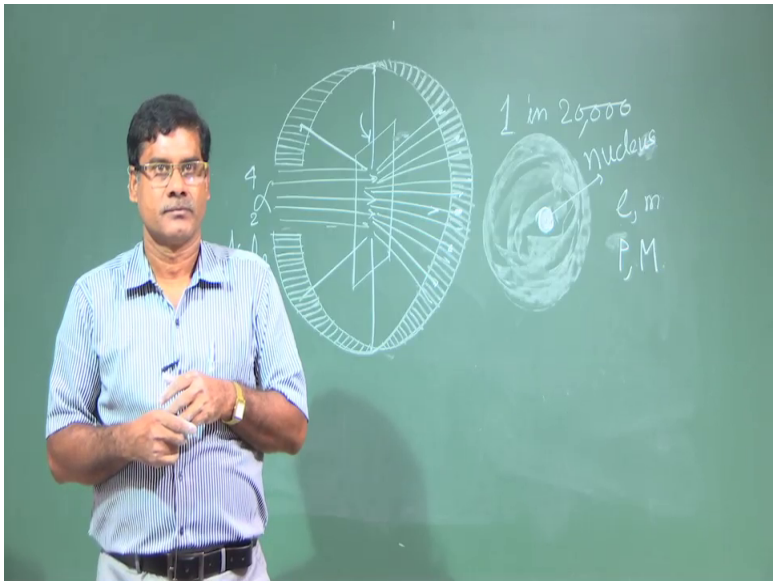

So, let us say that is the ok and then we will try to no I think this is basically foil is made of that tree, I think he use this foil it is not whole file it is the screen but it is a coated with zinc sulfide, it is the fluorescent material, (Refer Time: 29:51) so just it is the tape kind of things just suddenly it is put in circular form ok.

Now, this alpha particle bombard this file, now this it they are scattered so many alpha particle are hitting and he found that and their upper scattering from this file they are hitting this screen they are hitting this screen so one is so this seen, so there are many there are hitting and so it is scattered, so this is the so many alpha particles are coming and hitting this hitting power this gold foil and then they scattered and he found that most of them scattered without deviation, just as if it is there is no foil they are passing through the foil without scattering without deviation. But there are a very few very few alpha particle scattered in backward direction very few one in 20000 alpha particle scattered backward direction. So, as if you see this one foil you have taken so one particle alpha particle and gold foil it is atom gold atom have atom have a higher mass right nother particle have lighter.

So, it is not easy to pass through it through this foil right, so it was expected that most of them will be back scattered and very few will pass through it but result was just opposite,

most of them pass through it without deviation or deviated with very small angle and one in a 20000 alpha particle just get back scattered at nearly 180 ok.

So, these result was what it is telling it is telling that this so this foil is made up of atom it is a substance made up of atoms. So, atoms are arranged in this foil that is clear, now if atoms are solid if atoms are solid like a sphere solid sphere, then alpha particles should come back but it is not coming back opposite result we are saying they are passing through it so they have to pass through the atom right, so that is what rutherford conclude that atoms are it is atoms space in atoms are mostly back end it is free space.

So, all mass of the atom it is concentrated in a very small place in the atom, so most of the atom if this is the atomic size most of the atoms are free space and only this one only these it is mass because atom has mass atom has mass weight right that we know. Now, where how this mass is distributed, so from this experiment it is telling mass is not distributed over all this atom this mass whole mass is concentrated in a very small place, so that he called that this is the nucleus of atom and rest of the part of the atom are there is no mass in rest of the arrow. So, size of atom is bigger and compared to these size this whole mass is concentrated in a in a small space ok it is like the (Refer Time:35:56) this is the size of atom this mass is concerned so this part is called the nucleus.

Since atom have electron it has discovered and atom is neutral, so he then told that nucleus is nothing but the in nucleus is whatever the nurse it is nothing but the proton this is having positive charge. So, that is why this ah electrons are there electrons are there in atom and then mass it is the lighter atoms it is the lighter atom, now this whole mass is considering a place this called nucleus and this particle, another particle it will have the positive charge that mass higher mass and positive charge and higher mass and this particle he called the called the proton.

This positive charge was considered, because this atom has to be neutral and already electron is discovered thus this from this Rutherford experiment mainly it was found that this whole mass of the atom considered in a very small place that is called nucleus or this is a new particle and these new particle has to be positive charge because the overall atom is neutral and negative charged electrons are there ok.

So, exactly opposite charge of electron that is and higher mass, whole mass of the atom is considered in proton is nothing but the another particle that is the proton so that is why this proton was discovered so I will stop here.

Thank you for your attention.