Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) for Pollution Monitoring

Dr. J R Mudakavi
Department of Chemical Engineering
Indian Institute of Science, Bangalore

Lecture – 03
Course introduction and atomic structure – III

Greetings to you. We will start our module two today in the course of ICP – AES spectroscopy for pollution monitoring. In the last one hour, I had talked to you about the importance of spectroscopic methods and their relevance to the pollution control. So, I had also outlined to you the course programs that the first part and second part what would be the first module, second module etcetera and I we had also discussed about the basics of spectroscopy.

I had explained to you that; even though it is not necessary to know about the atomic structure and other things, I have made it a part of the course because many of the participants in this course are engineers; as well as people coming from other disciplines. And, because the atomic structure is the basis of all spectroscopic methods; I thought we will refresh your memory regarding the atomic and molecular structure.

It will be basically of the level of graduation and I think it will be a good revision for you. So, we will take about4 to 5 lectures for understanding of the atomic and molecular structure and then we will move on to the interaction of electromagnetic radiation with matter, that is, something to do with the spectroscope basics of spectroscopy. So, we will continue our discussion now on atomic and molecular structure. This is module two and the title of the module two is Atomic and Molecular Structure.

So, what is an atom? Do we know about atom? Since, how long and questions keep on as being asked, most of the physicists and chemists and every human being for that matter wants to know what are we made up of in the Christian mythology there is a concept of every human being is made from ashes from ashes to ashes and dust to dust that is the basics of Christianism and even in Hinduism we have known about the atoms since ancient times.

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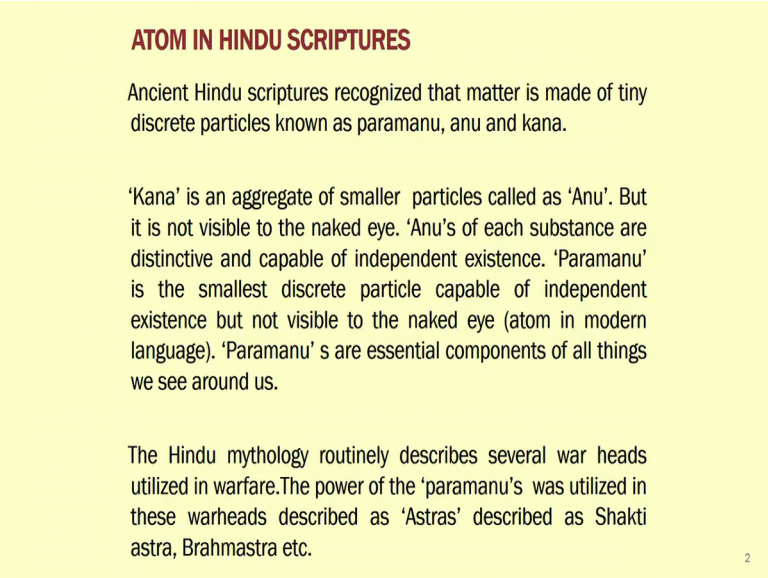

Ancient Hindu scriptures recognized that matter is made up of tiny discrete particles and they are known as [FL] and [FL]. So, [FL] is in sort of a molecule or an aggregate of these smaller particles called as [FL]. So, we are all familiar in India with [FL] we BARC – Baba Atomic Research Center is related to the generation of power and engaged in the utilization of nuclear energy and that is in Hindi translation it reads as a [FL].

So, [FL] is part of the fundamental particle. So, [FL] is the aggregate of smaller particle called as a [FL], but it is not visible to the naked eye and [FL] of each substances are distinctive and capable of independent existence; that means, whatever you see around different objects they are all made of power the basic structural unit called as [FL] which is having a separate existence.

For example; the spectacle what I am wearing is made of glass the [FL] of glass is made of glass only and our body hair is made up of fundamental particle called [FL] of the hair. A table will be made up of wood, like that if distinct particles what you see around you [FL] and [FL] is the smallest discrete particle capable of independent existence, but it is not visible to the naked eye; that means, each [FL] of different materials what we see around us are made up of [FL] and that is not visible to us as independent entity. So, it approximates to atom in a modern language.

In scientific terms we call it atoms. So, [FL] are the essential components of all things we see around us. So, now, we know three fundamental particles known to Hinduism;

one is [FL], another is [FL] and next is [FL] and [FL] is the aggregate matter what you see around you as distinctive object [FL] is the basic material which is capable of existence and [FL] is capable of independent existence, but it is not visible to the naked eye and [FL] is composed of different for discrete fundamental particles and that is not visible to our naked eye.

So, the Hindu mythology routinely describes several warheads it utilized in warfare and the interplanetary travel as you hear around you in the mythology for example, Narada used to travel from one planet to another planet and [FL] like that. So, these interplanetary travels must be requiring some sort of aero planes, they were now described as [FL] and the power required for that kind of travel must have been sort of nuclear power only. We can only guess about this at this time, because detailed the descriptions of the design and other things are not available right now or not accessible to human beings.

And, in the war Mahabharata war and several Ramayana war etcetera there are several warheads described and these are known as [FL] and so many other [FL]. So, many warheads have been described and those things must also have been some sort of nuclear warheads capable of causing great disasters which cannot, but be from the nuclear forces.

So, the idea is the concept of atoms and nuclear power is not new, but it was known to us and. So, with that basics we lost it somewhere in between and the modern era started as you all know in the Europe with renaissance and science was one of the earliest sign earliest disciplines that received a Philip with the number of scientists working on different aspects of atomic structure, molecular structure and things like that chemistry alchemy and several other medicine, several other aspects.

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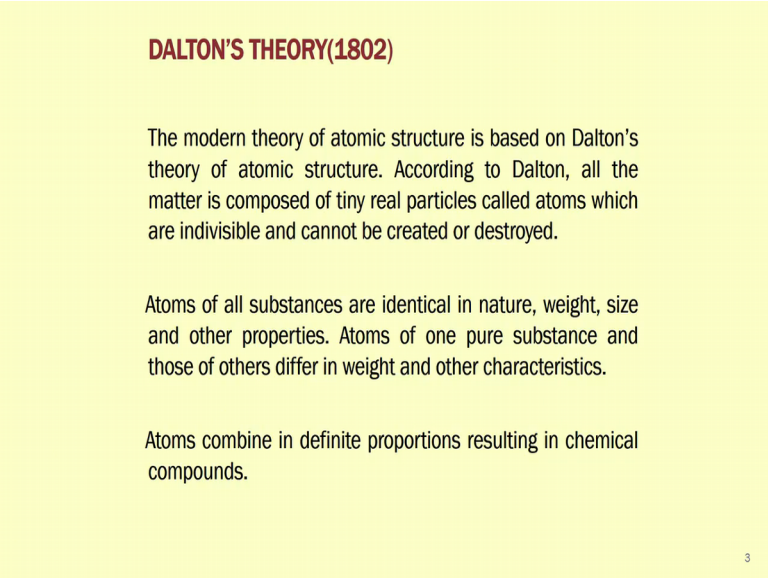

And, our current understanding of atomic structure is based on Dalton's theory, so that is somewhere around 1802. The modern theory of atomic structure as we understand today is based on Dalton's theory of atomic structure. According to Dalton all the matter is composed of tiny real particles called as atoms which are indivisible and cannot be created or destroyed. Two fundamental postulates he said; all particles are made up of atoms and you cannot create an atom or you cannot destroy an atom.

So, these re these two are the fundamental laws we all understand very easily there are no logic is required, but the interpretation is ascribed to Dalton's theory what he said is atoms of all structures are identical in nature, weight, size and other properties; that means, every material around you is made up of atoms which are identical in size, nature, weight, charge, etcetera.

So, atoms of one pure substance and those of other pure substances like elements what we call them they differ in their weight and other characteristics this also is pertaining to Dalton's theory and atoms another concept that he popularized is that the atoms combine in different definite proportions resulting in chemical compounds, that is, carbon will combine with oxygen 2 molecules of oxygen to give you carbon dioxide or it can combine with 1 molecule of oxygen to give you carbon monoxide and oxygen atom can combine with another oxygen atom to give you oxygen molecule like that different

compounds as we know all around us are all composed of atoms combining in definite proportions.

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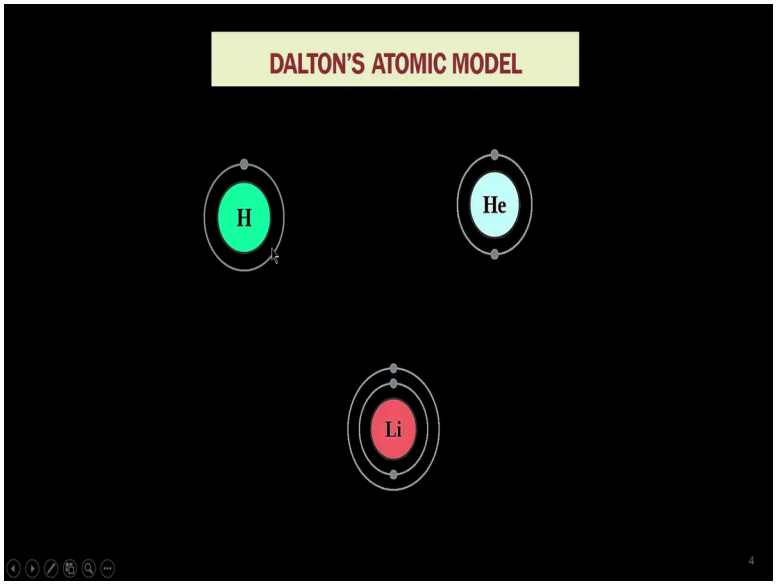

So, according to Dalton's atomic model this is how it should look. For example, we have hydrogen here and it has got a hydrogen atom is made up of 1 proton and 1 electron here. We have next is helium and this helium atom is distinct from hydrogen and it has got 2 electrons. This concept of electrons did not come from Dalton, but there is a representation here that is why I have not shown them in clear in distinctively.

But, what I am trying to show you here is every atom is different from the other. This is hydrogen, helium, lithium; our current understanding is it has got a hydrogen has got 1 electron helium, has got 2 lithium, has got 3 like that, but the atomic model basically is the fundamental particle of hydrogen, helium and lithium etcetera.

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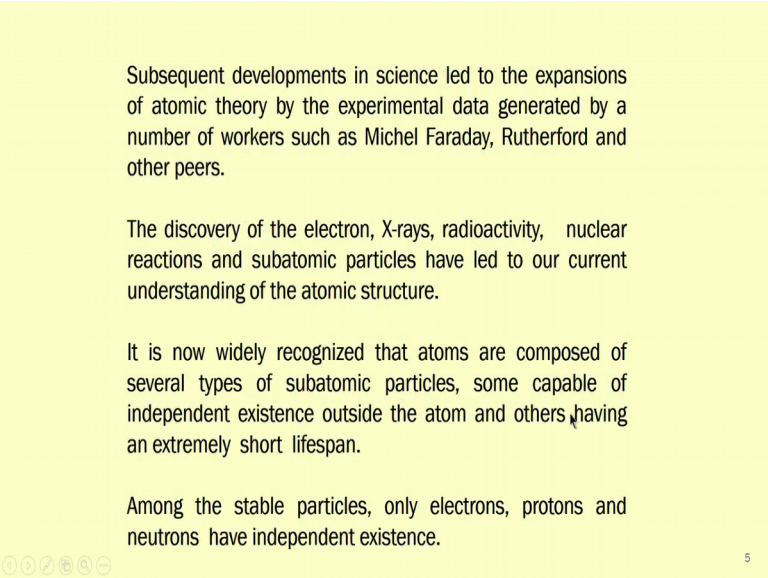

So, subsequent developments in science have led to the expansion of atomic theory. So, the basis for all this has come from the experimental data generated by number of workers such as Michael Faraday, Rutherford and then Millikan and Thompson and several other scientists engaged in the unraveling of the atomic structure over the years after John Dalton. So, what followed their discovering, their work is the discovery of electrons, X-rays, radioactivity, nuclear reactions and the discovery of sub atomic particles; these things have led to our current understanding of the atomic structure.

It is now widely recognized that atoms are composed of several types of air subatomic particles and some are capable of independent existence outside the atom and some others are having an extremely short lifespan. So, there are such that we do not see them around us. Our human senses are not capable of realizing the events happening at microseconds or nanoseconds. So, some are having independent existence, some do not have as far as our sensory perception is concerned.

So, among the stable particles, what do we know? We know that electrons, protons and neutrons have independent existence. All atoms are composed of electrons, protons and neutrons and they have independent existence, this every schoolboy knows. This is the result of the work of my several scientists undertaken somewhere around 1800s and thereafter.

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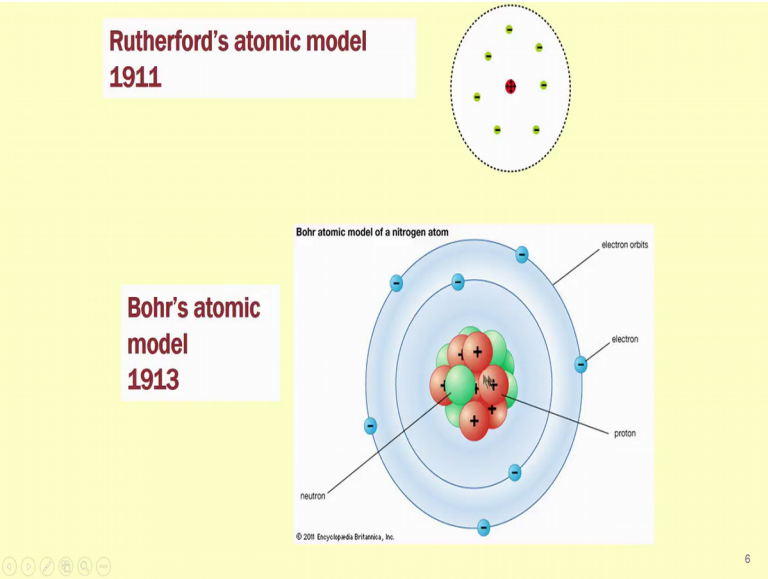

So, then came Rutherford's model, that is, somewhere around 1911 and imagine that we are talking of a research work of spanning about 100 years now. 1802 is Dalton's work and 1911 is Rutherford's model and then what Rutherford's model is based upon the discovery of all electrons, protons, neutrons, etcetera what he said is that the center of an atom, here you can say center of the atom, is a heavy and somewhat stable and electrons are there around it circulating the protons or nucleus and this is basically a simple model that states that the atom is a stable entity now.

Then came Bohr's model, somewhere around 1913 and what he said is there are protons described here with positive charge and there are neutrons described here which are shown in green color without any charge and that is the heaviest part of the atom it is at the center of the atomic structure and around it there are electrons described by this blue pieces, blue balls and that carry negative charge and these charges these electrons are going round and round the nucleus in fixed paths. The paths have been described here and there may be more than 1 electron in a particular path that is also understood and then there are a number of shells or energy levels at which all the electrons each electron moves in a particular orbit.

So, this is the Bohr's model and these are called as electron orbit and the round ones circles that are represented there and then all other things we have already described this I have taken from the encyclopedia Britannica for your easy reference.

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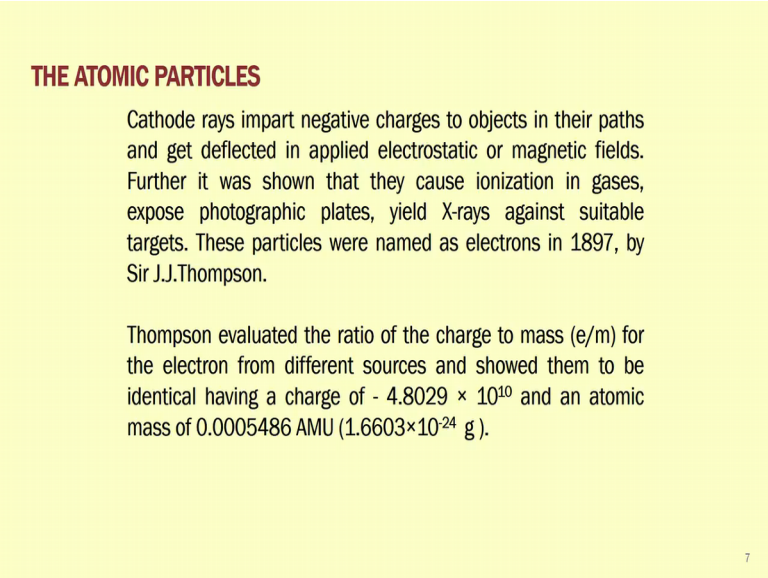

So, what are the atomic particles? The atomic particles are electrons, protons, neutrons etcetera and the cathode rays impart negative charges to the objects in their paths and they get deflected in applied electrostatic or magnetic field. So, J. J. Thompson showed that they cause ionization in gases. So, if you take cathode rays pass them through a container having a gas molecule you would pass the cathode rays; cathode rays means rays coming from a cathode electromagnetic radiation coming from a cathode if you take the pass them through a given gas molecule, gas container they cause ionization in the gases.

So, how do we know because if you put a photographic plate across the gas chamber you will see that they get darkened; that means, the rays are unable to pass through light and they get stopped they create a dark shade. So, the cathode rays also yield X-rays against suitable target. You take cathode ray and then pass the cathode ray to through on a metal piece they will come here hit it and bounce off and the bounced off rays are not same as what you have started with, that is, cathode rays they give X-rays.

So, what is X-rays? X-rays are cathode rays coming from the metal after bombarding the metal with the cathode rays. So, the wavelength of cathode ray should be smaller as larger than the X-rays that is why they are called X-rays also. So, these particles were named as electrons. So, in 1897 Sir J. J. Thompson did that experiment and then you know whatever rays were coming out he called them as electrons.

So, Thompson evaluated the ratio of the charge to mass you know that is e by m is the electrons carry electrical charge and it has got some mass for the electron from different sources and showed that all of them to be identical. They have a charge of minus 4.8029 into 10 raised to 10, a electrostatic unit esu and an atomic mass of 0.0005486 atomic mass units.

So, what is an atomic mass unit? It is 1 atomic mass unit is 1.6603 into 10 raise to minus 24 gram, that is, approximately hydrogen atom the weight of 1 hydrogen atom and each atomic mass of the electron is approximately 0.0005486. So, the X-rays coming from the cathode rays they were called electrons and the electron charge and mass has been described.

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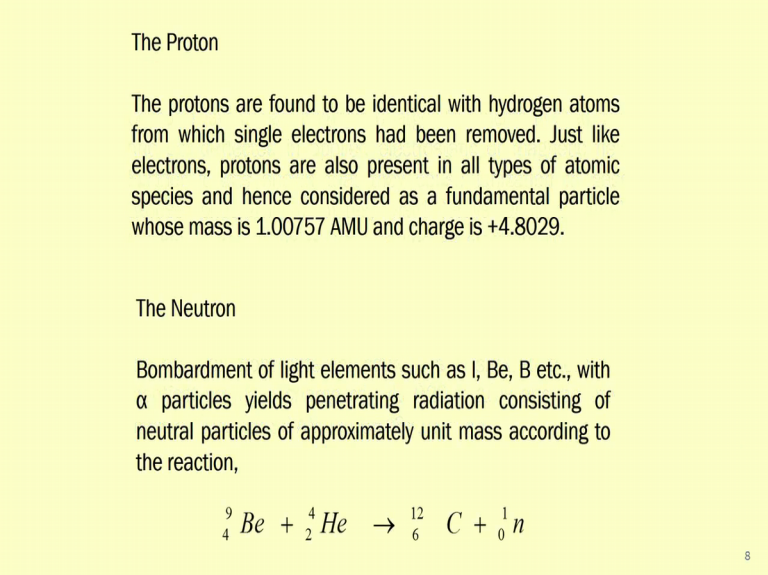

Now, what are the other particles atomic particles people are familiar with that is the proton the protons are found to be identical with hydrogen atoms from which single electrons have been removed. So, imagine go this hydrogen atom there is one electron here around it, if I remove this hydrogen atom then what I have is a hydrogen atom without an electron that is known as proton.

So, just like electrons protons are also present in all types of atomic species; that means, they are universal in nature every material around us is composed of protons and hence it is also considered as a fundamental particle whose mass is 1.00757 atomic mass units and charge is plus 4.8029. Now, we have described electron and proton. How we have

described? We have described the origin of the electrons and protons and we have described what the mass of each electron is and proton and what are the charges electrostatic charge is carried by electron and proton.

Now, then there were other discoveries which led to the postulation of neutrons. So, bombardment of light electron light elements such as beryllium, boron etcetera with alpha particles yields penetrating power radiation consisting of particles which are neutral in nature. So, the mass of each neutron is also approximately equal to the proton and the reaction can be represented like this that is if I take beryllium atom having a charge of 4 units and mass of 9 units that is how the reaction to is to be read. 4 beryllium 9 beryllium 4 9 are treated with 2 He 4, that is, 2 charge of helium is to mass is 4; that means, there are 2 protons and 2 neutrons that makes it 4 mass of the helium is 4 and mass of beryllium is 4 plus 5.

That means, it has 4 protons and 5 neutrons and that if I heat it with helium of 2 and 4 charge and mass what I get is a carbon atom having 6 charge positive charge and 12 mass followed by 1 neutron which comes out of the system as a single entity separately.

So, this entity does not have any charge, but it has got one unit mass that is 1.00757 atomic mass units.

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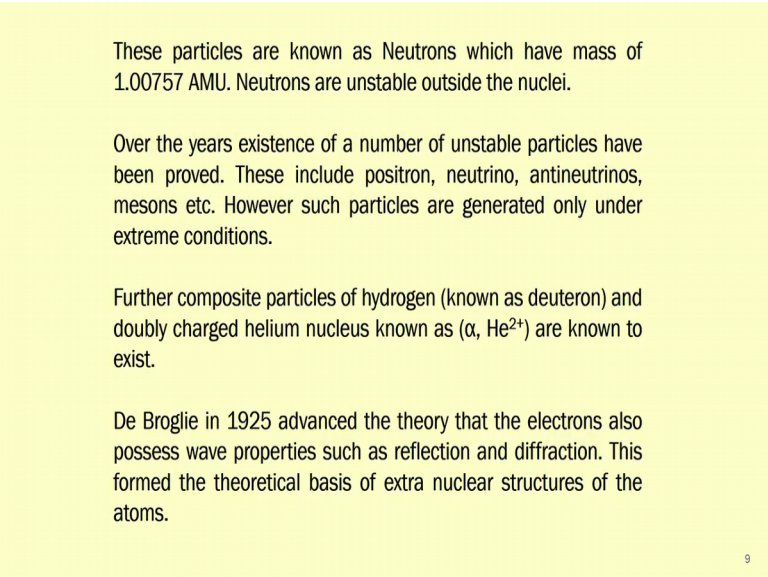

So, this is neutron. So, these particles are known as neutrons which have mass of 1.00757 AMU. Neutrons are unstable at outside the nuclei; that means, you let it out, let the neutron come out by the reaction with beryllium and helium, the neutron that comes out will not be having any separate exists it will go and hit something and then combine with some other element. So, these neutrons do not have a separate existence; that means, you do not see them flying around the neutral neutrons are flying around you.

So, over the years we have come across a number of unstable particles and they have been their existence has been proved and these include positron and neutrino, anti neutrinos, mesons etcetera. However such particles are generated only under extreme conditions of pressure temperature and then magnetic fields electric fields like that and most of them are chemical reactions nuclear reactions. So, further composite particles of hydrogen known as neutron and doubly charged helium nucleus, that is, alpha particles are known to exist for example, you take off the two electrons from helium we have helium two plus you look at this slide.

Now, I have written here that alpha and helium 2 plus and these are known to exist. So, our understanding that an atom is a simple system has been shattered. So, we do not know where these particles are in the located inside the atom, but we know that they are all there whenever there are extreme conditions of temperature, pressure and heat, electricity, nuclear reactions and then nuclear fusions, fissions and all those things they all these particles are generated these particles are known as there is some positron, neutrinos, antineutrinos, mesons etcetera.

And De Broglie, how are all these things what are all these things doing inside an atom. So, that is a question. Basically, if an atom is electrically stable; that means, the all the positive charge in a atom must be balanced by all the negative charge somehow or the other, but if the electrons are you know if one nucleus is heavy and positive electrons are around the nucleus going round and round; that means, there will be attraction and then subsequently all the electrons have to get stuck in along with them they have to hit the nucleus and all charge should go; that means, the whole universe should be neutral in nature. Unfortunately, it is not so. So there are systems inside the atoms which are slightly different than what we know the rules of physics.

So, there the electrons do not get attracted to the nucleus, they maintain a steady respectable distance from the nucleus and how these things are maintained is described by this Rutherford model, Bohr's model and all these things. What they say is in general, these things we keep on revolving around it and at force of attraction of the positive and negative charge is balanced by the force of repulsion generated by the centrifugal force and centripetal forces.

So, in nineteen twenty five De Broglie, he advanced through the theory that the electrons also possess wave properties such as reflection and diffraction. So, the wave properties mean what, the electrons move in ways not in straight line. So, the even though they go around the around the nucleus in a specific fashion regular circular orbits they would be moving like this round and round, but in a wave fashion. So, if the electron is moving in a wave fashion it must also show exhibit the properties of reflection and diffraction because that they are properties of all waves. So, this forms the theoretical basis of the extra nuclear structure of the atoms.

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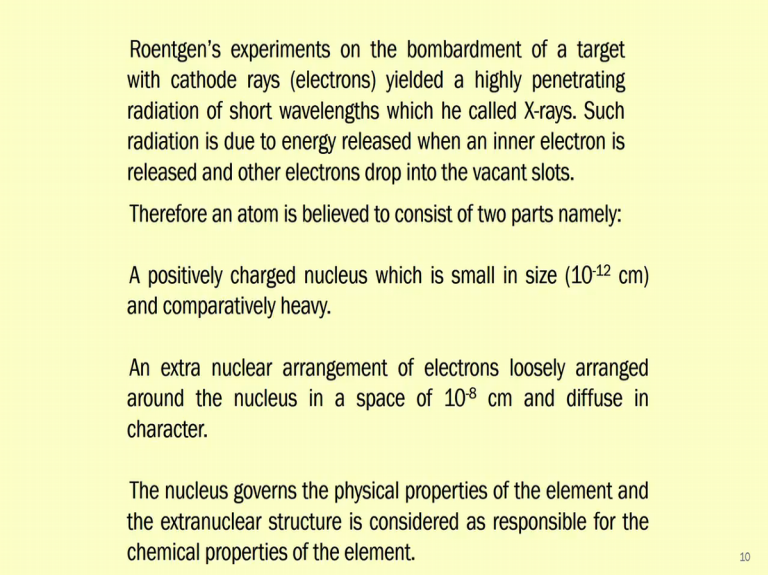

So, we will see what it is that extra nuclear structure of the atom what does it mean it accommodates all kinds of particles inside the atom to maintain it in a neutral conditions and the particle movement around a nucleus is what described by circular and wave nature of the electron movement.

So, Roentgen experiment that was the scientist Roentgen his experiments on the bombardment of a targeted cathode rays they yielded a highly penetrating radiation of wavelength which he called X-rays. Now, the X-rays are the cathode rays which are hitting a metal target and then coming off the metal target. So, these rays are called as x rays.

So, such radiation is due to the energy released when an inner electron is released and other electrons drop into the vacant slots; that means, when X-rays hit and when X-rays are coming out the electron from a higher orbit falls to lower orbit and then the energy difference comes out as x – ray. So, the conservation of mass and energy is always maintained and which is the fundamental rule of physics. So, that also is the same into another interpretation of Dalton's theory that is you cannot create energy nor destroy energy. You cannot create a molar atom nor destroy an atom, but you can change them around.

So, a positively charged nucleus which is therefore, the atomic structure current theories we believe that the atom consists of two parts; namely, a positively charged nucleus which is small in size approximately 10 raised to minus 12 centimeter and it is comparatively heavy with respect to the electrons. So, around the nucleus there is an extra nuclear arrangement of electrons loosely arranged around the nucleus in a space of about 10 raise to minus eight 8 and diffuse in character it is not very well defined.

So, for example, you can imagine the size the nuclear size is 10 raised to minus 12 and the electrons the size of the area of the electron moving around it is approximately 10 raised to minus 8 centimeter; that means, there is a difference of about 10 raise to 4. The space occupied by the electron is 10000 times more than the space occupied by the nucleus. There is an order of 4 difference you know 10 raise to minus 12 and 10 raise to minus 8.

So, 10 raise to minus 4 that is this is 10000 times bigger the area or volume occupied by the electrons compared to the nucleus. So, the nucleus governs the physical properties of the element and the extra nuclear structure is considered as responsible for the chemical properties of the element, that is, the electrons around it or the particles responsible for the chemical reactions and that is our understanding of the electro atomic structure.

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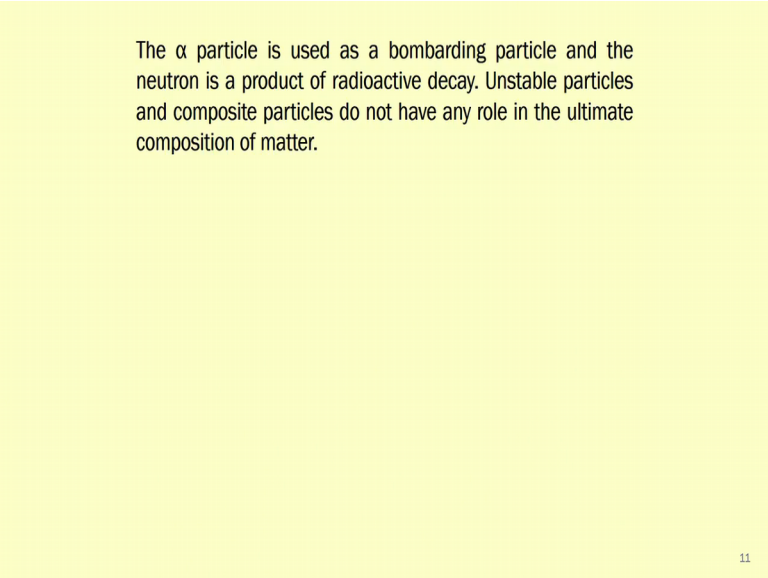

Now, the alpha particle is used as a bombarding particle and the neutron is a product of the radioactive decay and since these have been proved earlier. Unstable particles and composite particles which I mentioned as mesons and other things they do not have any role in the ultimate composition of the matter. Even though they are there the positrons mesons, neutrinos etcetera even though they are there they do not have any role in the day to day composition of the matter.

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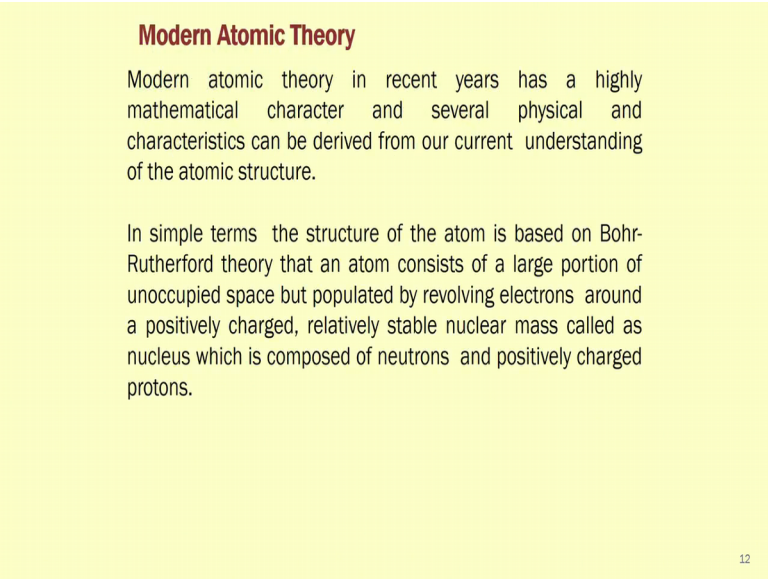

So, the modern atomic theory in recent years has been apart from these things it has to include wave nature of the electrons also and it has got a highly mathematical character and several physical and chemical characteristics can be derived from our current understanding of the atomic structure. We will continue our discussion in the next session.

Thank you.