Electrochemical Technology in Pollution Control

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Lecture – 02
Atomic structure – 1

We will continue our discussion on Electrochemical Technology in Pollution Monitoring course, starting from Atomic structure; because no it electro chemical technology works on a systems higher than molecules, mostly atomic level only. So, it is important for us to know about the atomic structure and for many of you, if you have a chemistry background it will be a good revision, for others it will be a good introduction. So, let us see how what you can do with this ok.

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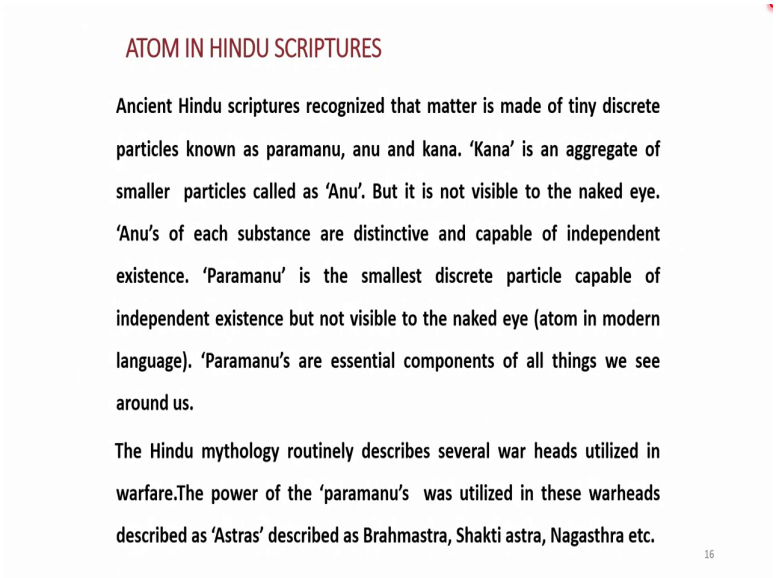

So, atom is not new to us at all, atom in Hindu scriptures I have put here first slide: ancient Hindu scriptures recognize that matter is made up of tiny discrete particles known as paramanu, anu and kana. ‘Kana’ is an aggregate of small particles called as ‘Anu’. Anu is equivalent to atom ok, but its not visible to the naked eye. Anu’s of each substance are distinctive and capable of independent existence, so also atoms. And, paramanu is the smallest discrete particle of anu that is also capable of independent existence, but not visible to the naked eye. So, paramanu’s are essential components of all things we see around us.

If I say electrons you will understand, but paramanu is definitely mean much more smaller than that. So, the Hindu mythology routinely describes several warheads utilized in warfare and the power of paramanu was utilized in these warheads, that is normally named as Astra, Brahmastra, Shakti astra, Nagastra; thousands of astra’s described in the Mahabharata war. Ramayana and Mahabharata war agni astra is there, several astras are there; most of them are based on the atomic power.

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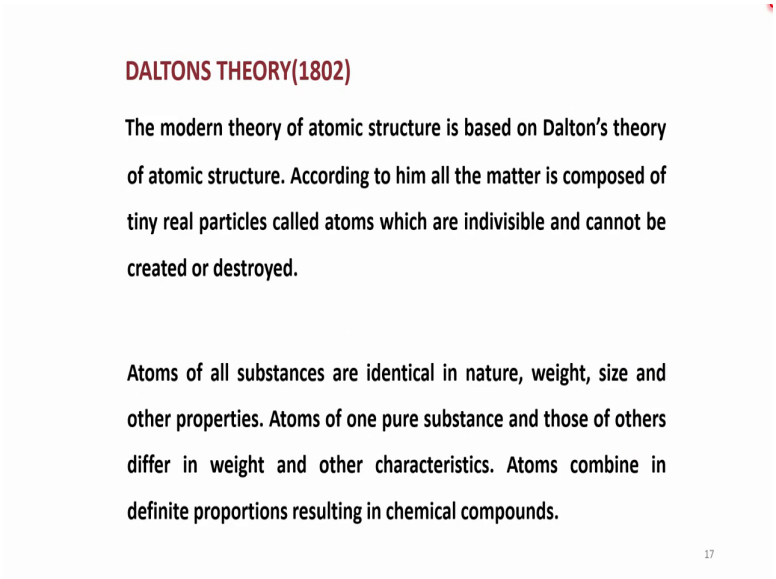

So, modern atomic theory started only in around 1802, when people in the west as usual took the lead in the development of science. So, the modern theory of atomic structure is based on the Daltons theory. And, what he said is all the matter is composed of tiny particles called as atoms which are indivisible. They cannot be created nor destroyed. Now, this is not acceptable to everyone, but it is not the atoms that are indivisible, but the smaller particles then the atoms are indivisible. So, atoms of all substances, but we are talking about the Daltons theory because it also holds some relevancy even now to some extent.

Especially, when we talk of aqueous solutions etcetera, we do talk of atoms as all atoms ions as indivisible only. So, it has got still some relevance, but not entirely scientifically true ok. So, the atoms of all substances according to Dalton are identical in nature, weight, size and other properties. Atoms of one pure substance and differs from other pure substances in

weight and other characteristics. So, atoms combined in definite proportions resulting in chemical compounds; I think this is all very fundamental, no need to this thing.

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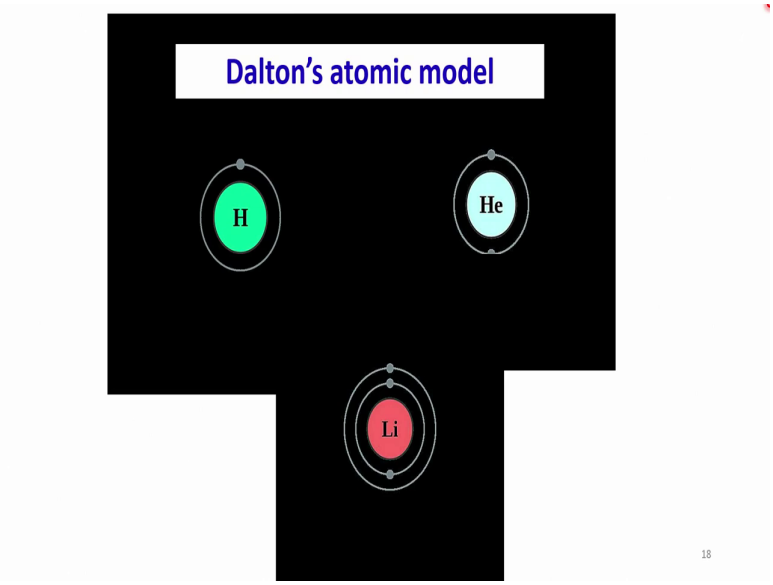

So, here we have a picture of hydrogen atom and helium atom and lithium atom, in the center I am showing a nucleus. Then the around that I in a circle I am showing 1 electron for hydrogen, 2 electron for helium and 3 electrons for lithium like that several atoms, elements can be built up.

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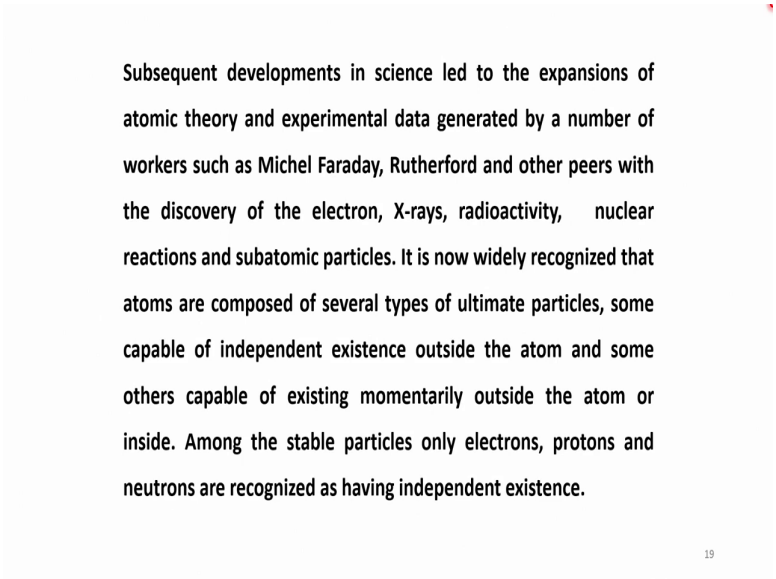

So, subsequent developments in science led to the expansion of atomic theory and experimental data generated by a number of workers. And, these workers are include fantastic scientists like Michael Faraday, Rutherford and other peers. And, with the discovery of electrons, X-rays, radioactivity, nuclear reactions and subatomic particles; all these things are have contributed to our understanding of our atomic structure.

Probably, in the previous slide I did not show you that the electrons are supposed to be moving around the hydrogen atom now. So, they are all moving in a circular motion even this the Dalton did not say that at that time ok. So, our modern understanding of the electro chemical atomic structure, we recognize that there are several kinds of subatomic particles. And, many of them are ultimate particles also, some of them are capable of independent existence, some of them are not.

So; that means, they may be in existence momentarily, but the outside the atom doubtful existence, inside the atom momentary existence. In cyclotrons and other nuclear reactors there could there could be the formation of such particles. And, among the stable particles we recognize electrons, protons and neutrons as having independent existence. They because they can be proved to be having independent existence not because you can see them or handle them individually.

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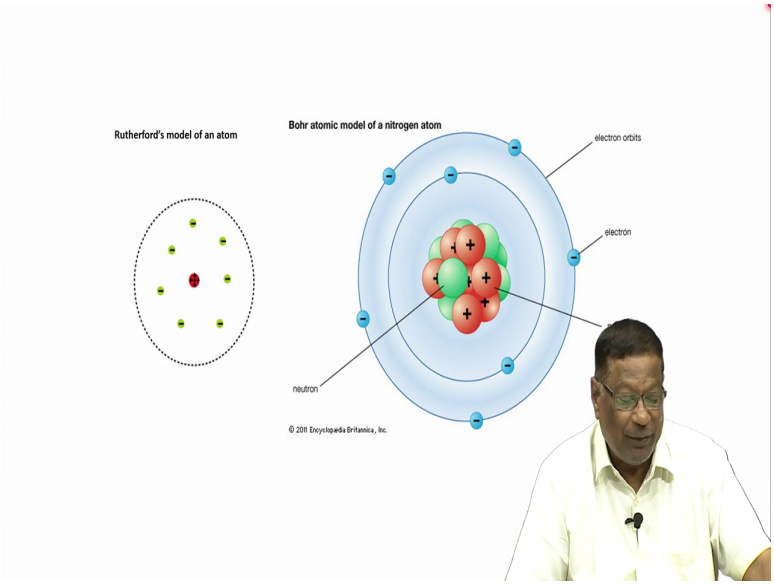

So, this is a Rutherford's atom on the left side. What I have here? I have a nucleus and then the electrons are around it and they are going round and round. This is the positive charge, electrons carry negative charge. So, this is one model and this is a Bohr atomic model, what Bohr said is all electrons and neutrons nucleus is composed of positive charged particles and neutral particles which are at the center of the atom. And, electrons are they are moving in

definite orbits around the nucleus, because these things carry a negative charge, this thing carries positive charge.

Theoretically they should attract each other and end up in a some sort of a union so, we will not say what your name it is. But, according to Bohr's theory these electrons are put in such a way that they do not their force is balanced attractive force is balanced by the by the rejecting force ok. And, these electrons remain traveling around the nucleus in fixed orbits that is known that this is stationary and these are known as stationary orbits. And, the electrons are arranged in different orbits for the same item, it may be 1 2 3 different orbits. Here I have an electron, these are the orbit, this is proton red one and the green one is neutron.

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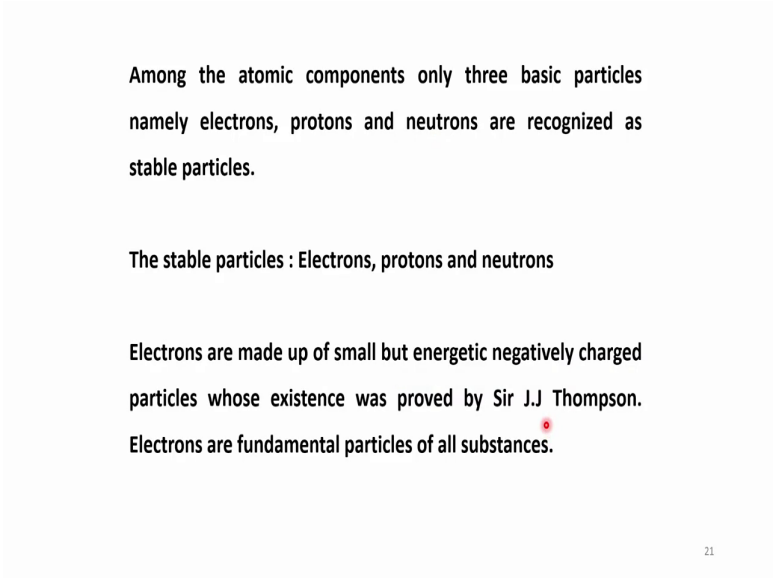

So, among the atomic components we have only three basic particles recognized as stable particles, electrons are made up of small, but energetic electrically charged particles. This

their existence was proved by Sir J. J Thompson and particle electrons are fundamental particles of all substances, basic theory high school chemistry. I am not teaching you more than that right now ok.

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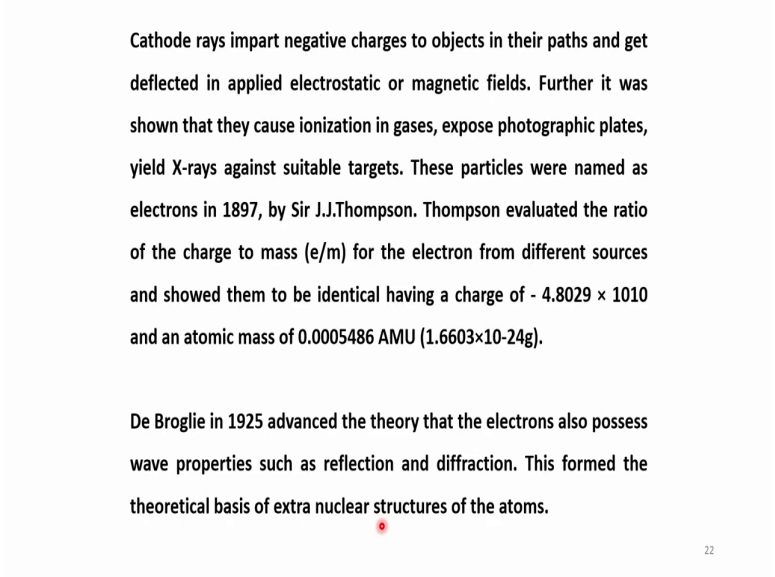

So, cathode rays impart negative charges to the objects in their paths and get deflected in applied electrostatic and magnetic field. This is how J. J Thompson was able to prove the existence of electrons. What he did was, he allowed the radiation to fall on the metals and then the photons generated will cause dent on the screen, phosphor. These particles we have named as electrons and Thompson evaluated the ratio of the charge to the mass ok, that is known as e by m; its a here I have put here for the electron from different sources of different metals.

The sources means different metals we put and he showed them to be identical having a charge of 4.8029 in to 10 raise to 10 and an atomic mass of 0.0005486 atomic mass units that is for the electron. So, De Broglie in 1928 advanced the theory that the electrons also possess wave properties such as electron can move like this, not go in a straight line. And, that is why that is how they were able to explain properties such as reflection and diffraction, this formed the theoretical basis of the extra nuclear structure of the atoms.

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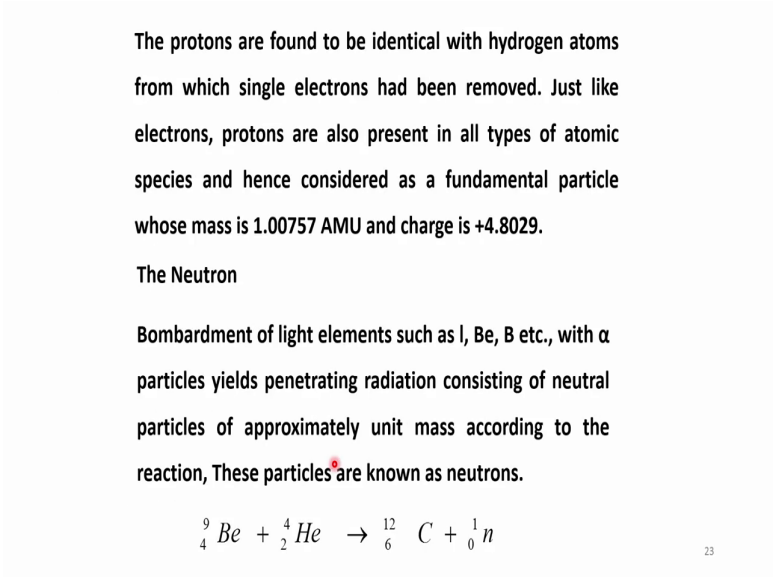

And, now come to the we talk about the protons little bit; the protons are found to be identical with hydrogen atoms in terms of weight from which hydrogen atom is nothing, but 1 proton and 1 electron. So, you remove the electron you have a proton ok; so, just like electrons protons are also present in all types of atomic species. And, there is no difference between

proton of one element into from another element. So, the it is also considered as fundamental particle, its charge is 1.00757 atomic mass charge is 4.8029 and the atomic mass is 1.00757.

So, bombardment of light elements such as the iodine, beryllium, boron etcetera with a with alpha particles yields penetrating radiation consisting of neutral particles of approximately unit mass according to the for this reaction. Here what is the reaction? Beryllium of 4 atomic charge and 9 atomic weight will react with helium atom that is alpha radiation of 2 atomic charge and 4 atomic mass to give you carbon of 6 atomic charge and 12 atomic mass plus 1 particle having no charge and 1 atomic mass ok, no charge and atomic mass.

So, theoretically as a chemist what do you we should see is 4 here, 2 here and 6 here. So, the there is one more particle it cannot carry anything more than what is on the left side left hand side it should match. So, if there are 6 here, it is 0 here, similarly atomic mass we can compare 9 plus 4 is 13 and 12 is here and 1 is neutron.

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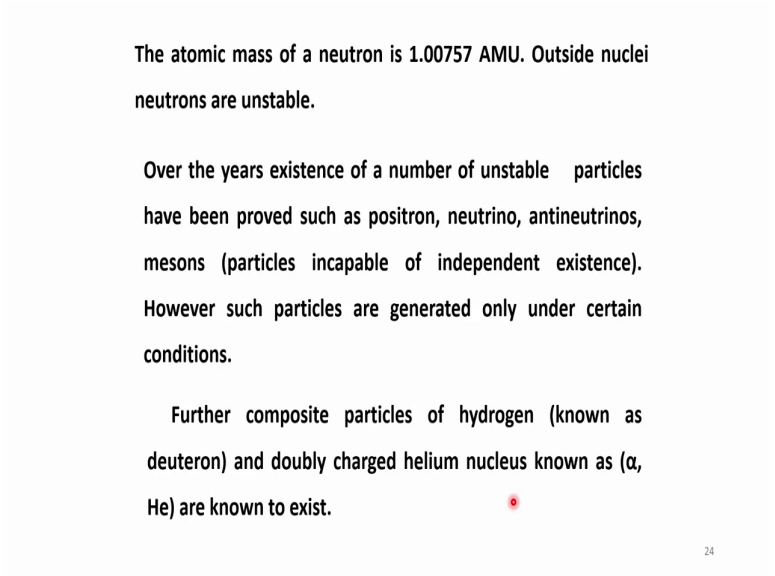

So, theoretically existence of neutron was proven by such reactions and the atomic mass of a neutron is 1.00757 atomic mass unit, but no charge, it has no charge. So, outside of the nuclei neutrons are unstable, inside of the nucleus yes, outside of the nucleus you cannot have it have a neutron hanging around here, around the in this room or any other room. So, over the year so, existence of number of unstable particles has been proved. We call them positron, neutrons, antineutrons, mesons and among these mesons are particles capable of independent existence.

However, such particles are generated only under certain conditions, they cannot be generated so easily. So, further composite particles of hydrogen known as deuteron it is a izotope. So, deuteron it has 2 neutrons and 1 proton, 1 proton and 1 neutron and a doubly charged helium

nucleus is known as alpha, alpha radiation. So, they are also known to exist, alpha radiation have are capable of having independent existence.

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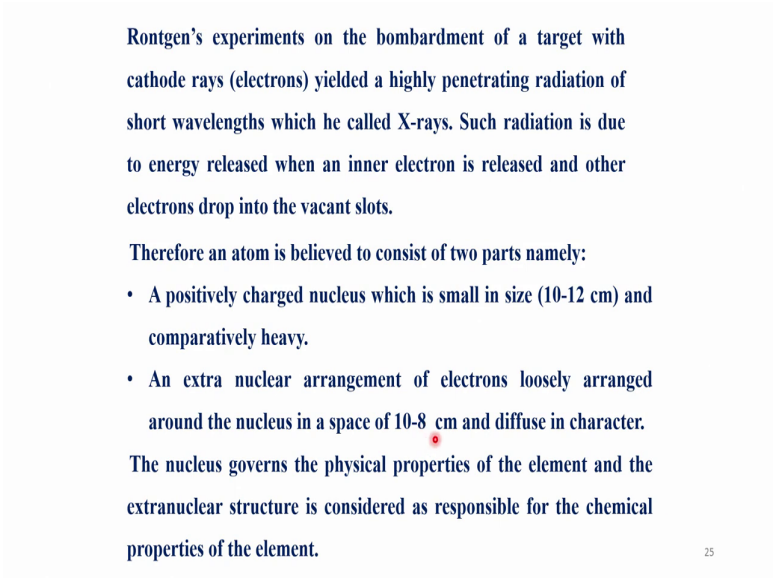

Then I want to talk to you about Rontgen's experiments on the bombardment of a target with cathode rays. What he did? He took a metal piece directed cathode rays that is electrons on their metal, he allowed them to come and hit the metal ion. So, the electron will either get deflected or something will happen. So, what will happen now? They yielded a radiation of shorter wavelength than what he had hit them with; that means, something happened. So, they are not the same as what went in, what came out was electromagnetic radiation of lower wavelength then what he had put in.

So, he called them X-rays such radiation is due to energy released when an electron from an inner electron is released and other electron drops into vacant splot vacant slot. Therefore, an

atom is believed to consist of two parts: namely a positively charged nucleus which is small in size. What is the size? Its about 10 raise to 12 10 raise to minus 12 centimeter and it is comparatively heavy.

And, an extra nuclear arrangement of electrons are there, loosely arranged around the nucleus in a space of about 10 raise to minus 8 centimeter ok. That means, the space in which electrons are organized around the nucleus is 10000 times; this is 10 raise to minus 8, this is 10 raise to minus 12.

So, 10000 times 10 raise to 3 10 raise to 4 ok. So, 10000 times extra space in which electrons are there around the nucleus of 10 raise to minus 12 centimeter size and the electrons are they are all over, all around so, they are diffusing character. 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. So, basically nucleus gives the physical properties and the electrons give the chemical properties.

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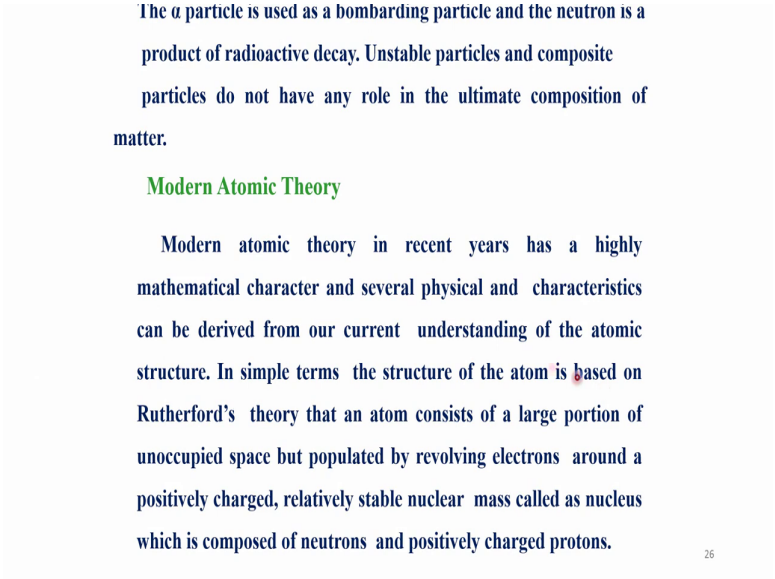

So, alpha particle is used as a bombarding particle because, it is easy; neutron is a product of radioactivity decay. Unstable particles and composite particles do not have any role in the ultimate composition of the matter that was all the history so far what I have told you. So, what is modern atomic theory? Modern atomic theory is not very different from what I have already told you and it says modern atomic theory has a slightly highly mathematical character and several physical and chemical characteristics that can be derived from their current understanding of the atomic structure.

In simplest terms the structure of the atom is based on the Rutherford's theory only, that atom consists of a large portion of a nucleus and that also has protons and neutrons and populated by electrons revolving around it. And, relatively stable nuclear mass is called as nucleus that is composed of neutrons and positively charged protons.

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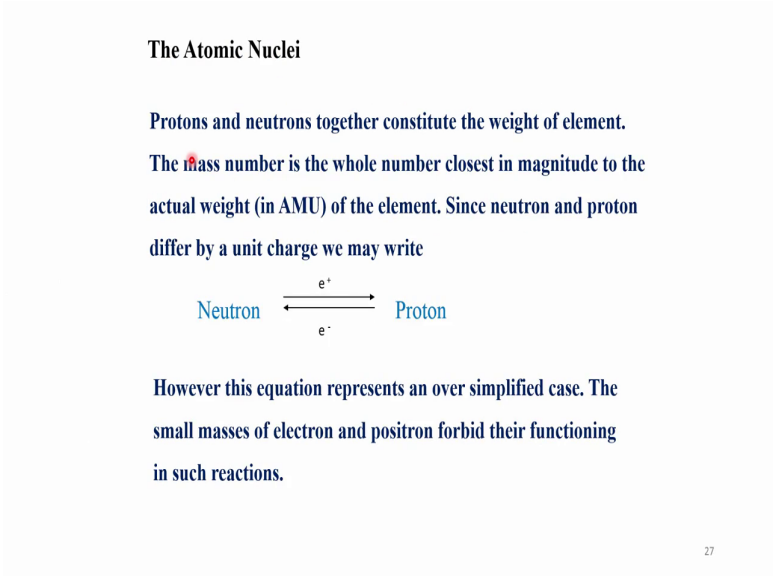

So, now we talk a little bit about the atomic nuclei. What is the atomic nuclei? So, protons and neutrons constitute the weight of the element, there that is the nucleus. So, the mass number is the whole number closest in magnitude to the actual weight of the element. So, that is what we call mass number, that is total number of protons and neutrons in any in any element. Since, neutrons and protons differ by a unit charge, proton is having plus 1, neutron is having 0.

So, the difference is 1 unit charge and we can write something like this a neutron, if I add 1 electron, if I remove 1 electron it becomes proton. If I add so, if I removed the electron from this thing, to the proton if I add 1 electron it becomes neutron. So, it says some sort of an equilibrium reaction; however, this equation represents a very simplified case. The small

masses of electrons and positrons forbid their functioning independently in such reactions. So, but still this represents what is known as atomic nuclei.

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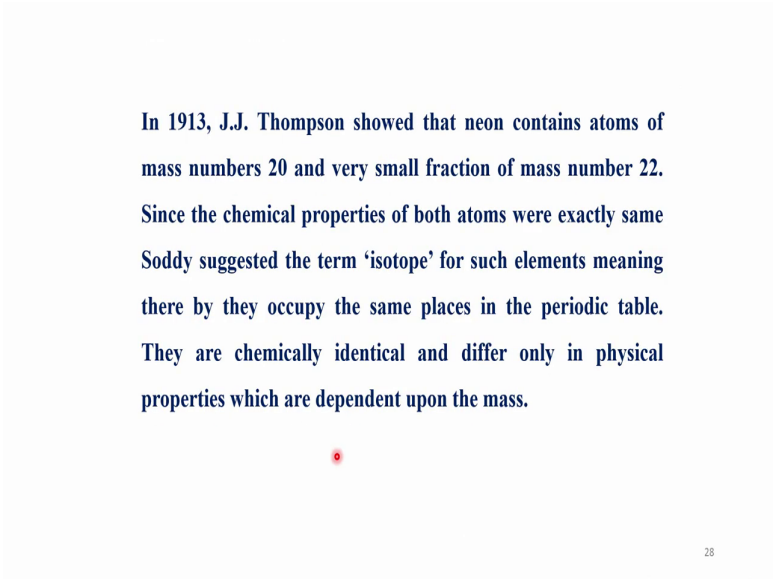

So, neon contains 20 mass number; that means, there are 20 numbers of protons and neutrons. Sometimes is if you take neon's you will also get a mass number of 22. Since, the chemical properties of both of them are exactly same then we call them isotopes. So, neutrons are more in neon sometimes.

So, there are some elements with 20 protons and some elements with 22 protons and neutron; sorry 20 protons and neutrons some elements with 22. They are isotopes; that means, they occupied the same place in the periodic table because, they are chemically they are same. They are identical, when they differ only in the physical properties which are dependent upon the mass.

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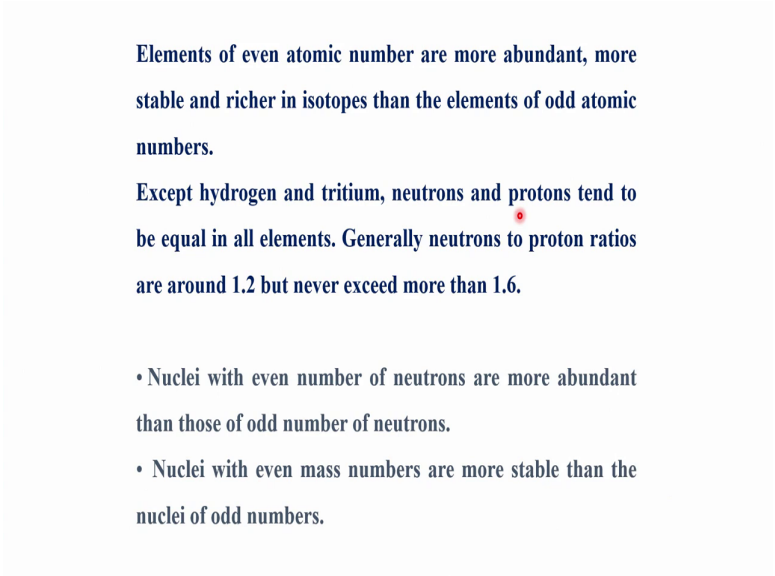

So, elements of even atomic number are more abundant. This is a little bit of a what do you call fact. So, if you look at their table, table of isotopes elements of even atomic number are more abundant and more stable, they are richer in isotopes than the elements of odd atomic numbers. So, except hydrogen and tritium neutrons and protons tend to be equal in all elements.

Generally, neutrons to proton ratios are around 1.2, but never exceed more than 1.6. So, nuclei with even number of neutrons are more abundant than those of the odd number of neutrons. So, nuclei with even mass numbers 2, 4, 6, 22, 26, like that they are more stable than the nuclei of odd numbers 3, 5 etcetera.

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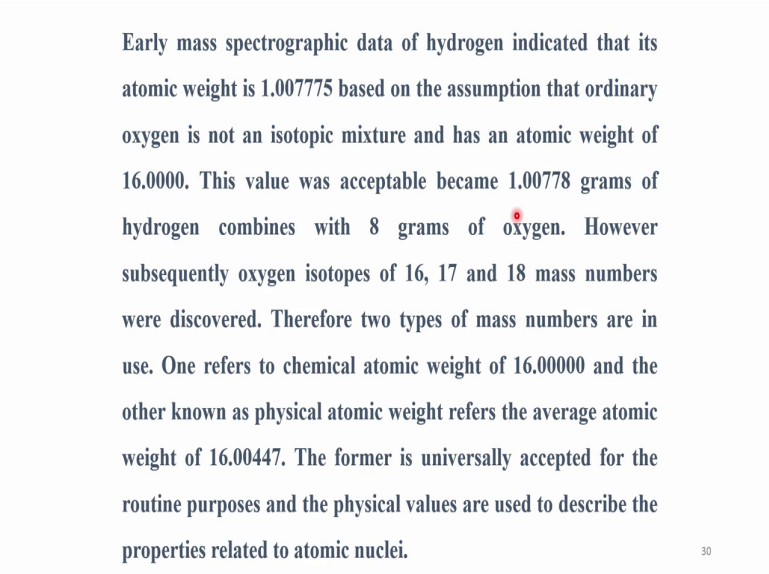

So, this is a general rule and early mass spectrographic data of hydrogen indicated that its atomic weight is 1.007775, it is based on the assumption that ordinary oxygen is having atomic weight of 16. And, nowadays we know that its not correct that the atomic weight of oxygen is 16, but we also know that atomic weight of oxygen may have some more isotopes also. So, it is not exactly 16, but earlier experiments for all practical purposes took atomic weight of oxygen as 16 and measure the atomic weights of all other elements with respect to oxygen.

So, this value is acceptable and now it became 1.0, it will combined with 1.00778 grams of hydrogen will combine with 8 grams of oxygen to give you; however, subsequently oxygen isotopes of 16, 17, 18 mass numbers are also there, they have been discovered. So, there are two types of mass numbers are there: one refers to the chemical atomic weight of 16.00000 and the other is known as physical atomic weight that value is 16.00447. The former is

universally accepted for routine purposes, but for exact processes we use 16.00447 ok. So, for in our course we use oxygen is 16.000 ok.

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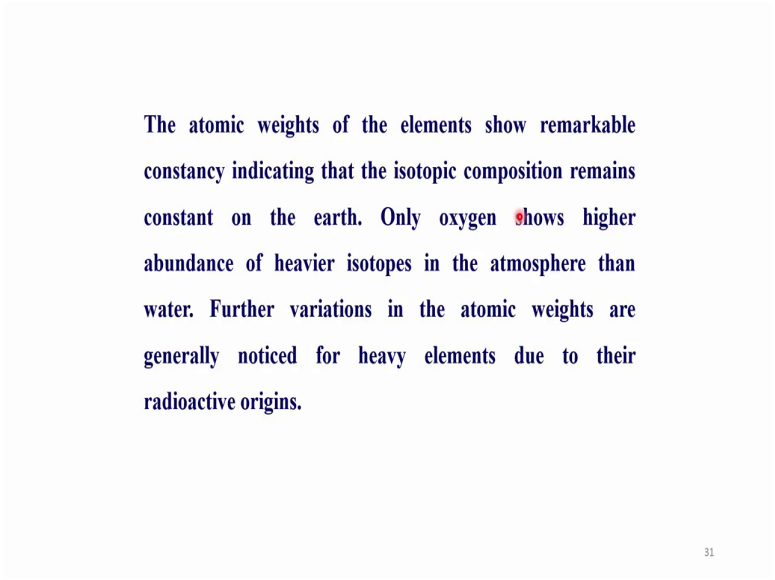

So, the atomic weights of elements show remarkable constancy indicating that the isotopic composition remains constant on the earth; that means, in the whole world isotopic composition of any element remains constant. Only oxygen shows higher abundance of heavier isotopes in the atmosphere than water. But, if you take water and the atmosphere together the there is no change, exactly same.

So, further variations in the atomic weights are generally noticed for heavy elements due to their radioactive origins, that is possible. I will not go into details of these discussions, but just giving you some sort of a an introduction to the structure of atoms. What is the proton,

what is neutron, what is electron, what is (Refer Time: 26:28), meson, what is (Refer Time: 26:30) etcetera.

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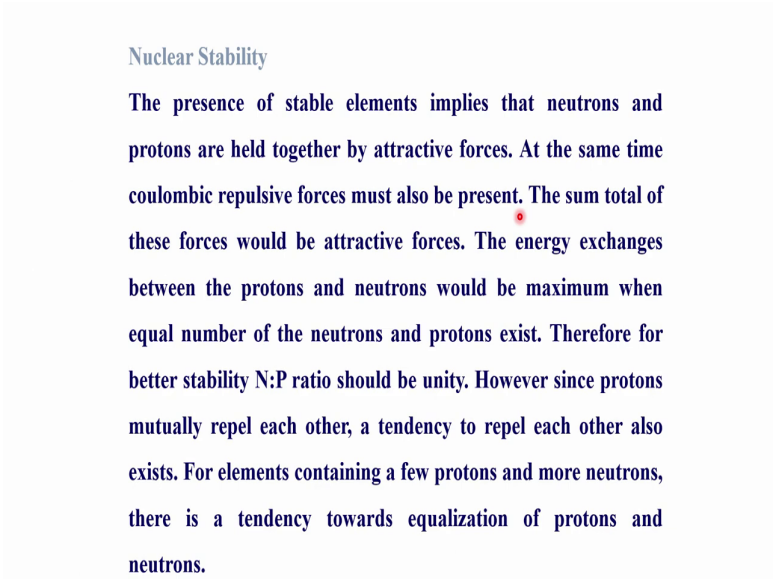

So, we are talking about the nuclear stability, we said even the atomic number substances are more stable, odd atomic numbers are not so stable. Even atomic numbers are more a predominant compared to odd atomic numbers, elements. So, the presence of stable elements implies that neutrons and protons are held together by attractive forces right. At the same time the if the there are 2 protons in the nucleus, they should also be repelling each other.

Protons and neutrons may stay together, but protons and protons should be repelling each other. Similarly, electrons outside around the nucleus should also be repelling each other, at the same time they would be attracted towards nucleus. So, the repulsive and attractive forces

should match for the atom to be stable. So, for better stability of the nucleus N, neutrons to proton ratio should be unity.

Since, protons mutually repel each other a tendency for mutual repelling is possible. So, for elements containing few protons and more neutrons there is a tendency towards equalization of protons and neutrons. Suppose, there are particular elements with not with more than known number of protons and neutrons, the tendency of the atom is to lose more neutrons. So, that proton neutron ratio should become equal then it becomes stable.

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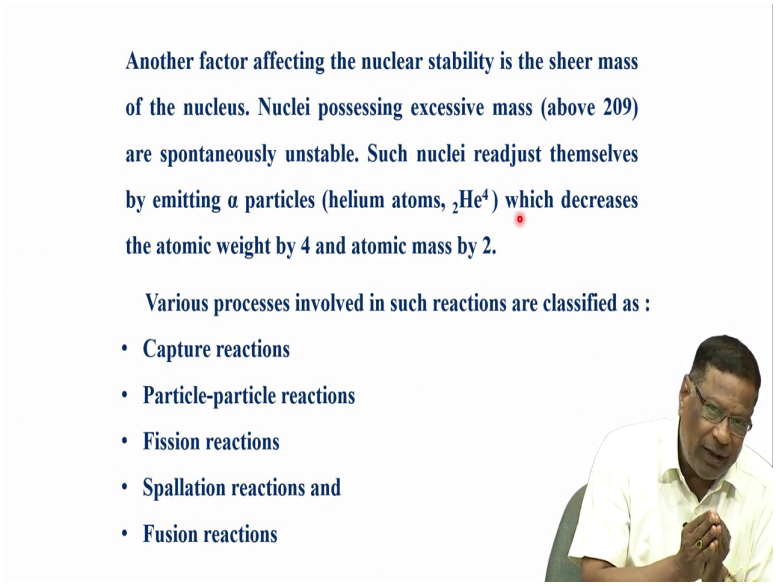

So, another factor that affects the nuclear stability is the sheer mass of the nucleus. Nuclei possessing excessive mass very high mass nah across the, if you look at the periodic table it goes up to 109 atomic weight, a atomic number. And, if you had approximately double that number including neutrons they go around 208, 209 etcetera. They are all spontaneously

unstableness such concentration of protons and neutrons cannot stay together, its very heavy, very active, very reactive.

So, such nuclei readjust themselves by emitting alpha particles that is radioactivity. So, that decreases the atomic weight by 4 and atomic charge by 2; that means, the daughter of their nuclear reaction which is losing which is radioactive and losing alpha particle produces an element which is having 2 atomic charge less and a 4 atomic mass less. So, what are the processes that are involved in such reactions? They are all remember we are talking about the nuclear reactions, not the reactions what do you think are happening in our laboratories.

These are all, all these things happening nuclear reactors or in the surface of the stars where temperatures of million degrees are very common. So, what kind of reactions take place among the nucleus? These are classified as capture reactions, particle-particle reactions, fission reactions, spallation reactions and fusion reactions. All these things end up trying to give you equal number of protons and neutrons ok.

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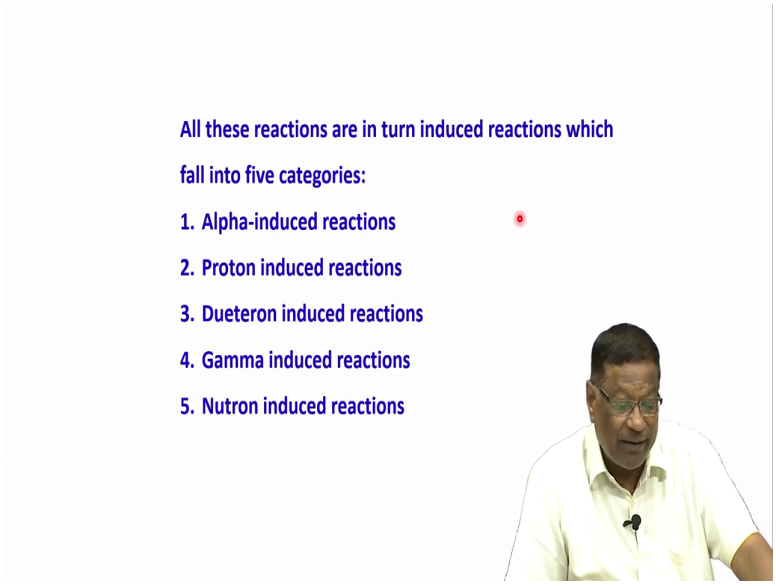

So, they are all induced reactions and they can be classified as induced reaction containing alpha induced, proton induced, neutron induced, gamma radiation induced, reaction or neutron induced reactions. Ultimate aim is to produce a stable nuclei.

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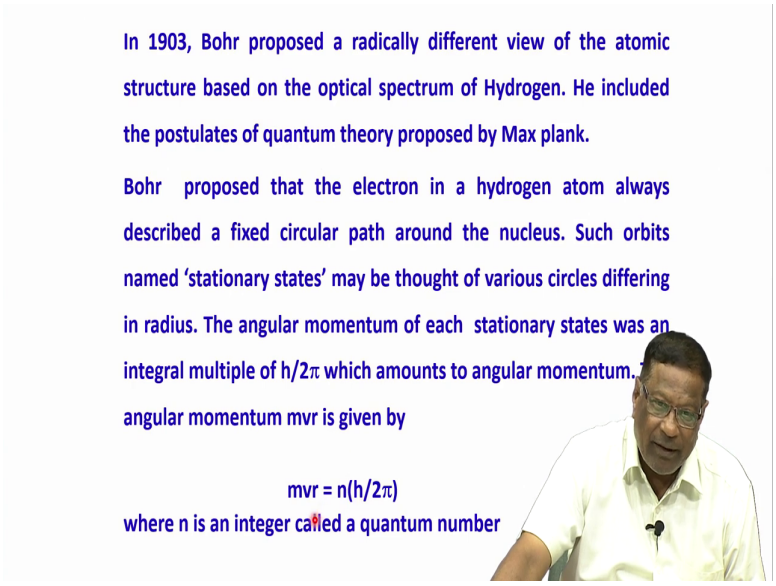

So, now we talk a little bit about the electrons. So, in 1903 Bohr proposed a radically different view of the atomic structure based on the optical spectrum of hydrogen. He included the postulates of quantum theory proposed by Max plank that is a history. So, Bohr proposed that electron in a hydrogen atom is moving around the nucleus in a fixed orbit so, it will not fall into the nucleus. Such orbits are named as stationary orbits, stationary states; it may be thought of various a circle around the nucleus.

I already shown you that figure and containing hydrogen, helium, lithium etcetera, but the circles radius is different. For hydrogen single electron is there, for helium 2 electrons are there, for lithium third orbit is added. So, the diameter of the third orbit would be different from the second one helium ok, second orbit. So, the if a particle is moving in a circular motion in an orbit, it must have what is known as angular momentum its ok.

This angular momentum of each stationary state was an integral multiple of h by 2 pi, this is the quantum mechanics part coming in which amounts to angular momentum. The angular momentum is given by n h by 2 pi, where n is a number integer called as quantum number ok.

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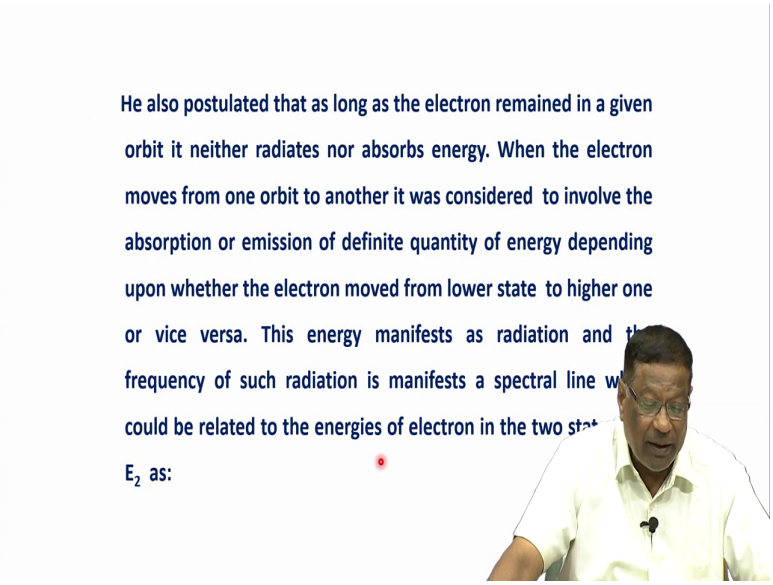

This is very fairly simple to understand. He also postulated that as long as the electron remained in a given orbit it neither radiates and as the nor absorbs energy. When the electron moves from one orbit to another orbit, it was considered to involve absorption or emission of definite quantity of energy depending upon whether the electron moved from the lower state to higher energy or vice versa.

So, this kind of energy manifests as radiation and the frequency of such radiation manifests as a spectral line in which could be related to the energy of the electrons in two states that is E 1

and E 2; you can call them anything. But, two states we call it energy 1, energy 2 state that is the orbit of the energies, energies of the two orbits ok.

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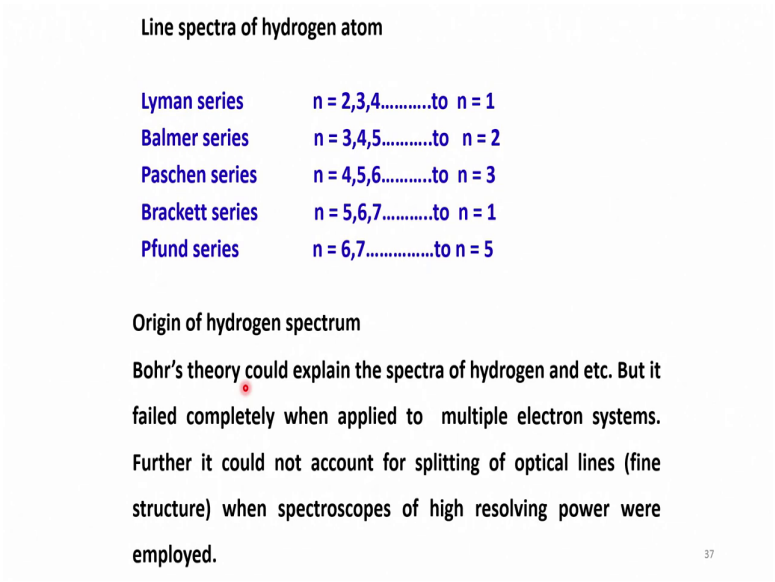

So, if there are number of energy states, the electron can move from n is 2 from the first orbit to 2 3 4 5 6 7 up to infinity. And, if there is an electron in the second orbit, it can move to 3rd, 4th, 5th, 6th etcetera, it all move to 1 ok. And, if there is an electron in the 3rd orbit, it will be move to 4, 5, 6; then 4th should be go move from 5, 6, 7 etcetera. So, these are called different spectral lines appearing and Lyman series says electron is there moving from 1 to 2, 3, 4; that is one series, that is known as Lyman series.

And, then we have Balmer series, this kind of spectral lines appeared in the visible region when n is equal to 2, electron is in the second orbit and it is moving to 3rd one spectral line, 4th another spectral line, 5th another spectral line. Like that number of spectral lines will be

visible and they are known as Balmer series and then we have Paschen series, Brackett series and Pfund series. All these spectral lines appear in different regions.

One is in ultra violet, one may be in visible region, one may be in a Balmer series actually is in invisible region, Lyman is in ultra violence. This these are all in near infrared like that. So, this is the supposed to be the origin of hydrogen spectrum. Suppose, there are more electrons, then it is very difficult to attribute which electron; if there is only one electron I can say it n maybe at 1, it may be a n maybe is equal to 2 and from 1 to 2, 3, 4 it may move like that.

But, if there are more elements, suppose 10 electrons are there then I cannot say which is which. So, the spectrum looks very complicated because, you cannot identify which one is which. So, Bohr's theory could explain the spectra of hydrogen alone, but not other elements. It failed completely when applied to multiple electron systems.

Further it could not account for splitting of the optical lines, when spectroscopes of high resolving power; sometimes what happens is single line normal condition it shows one single line. But, in the under magnetic field high resolving power it will show as a double line, Bohr cross theory could not explain many of such phenomenon.

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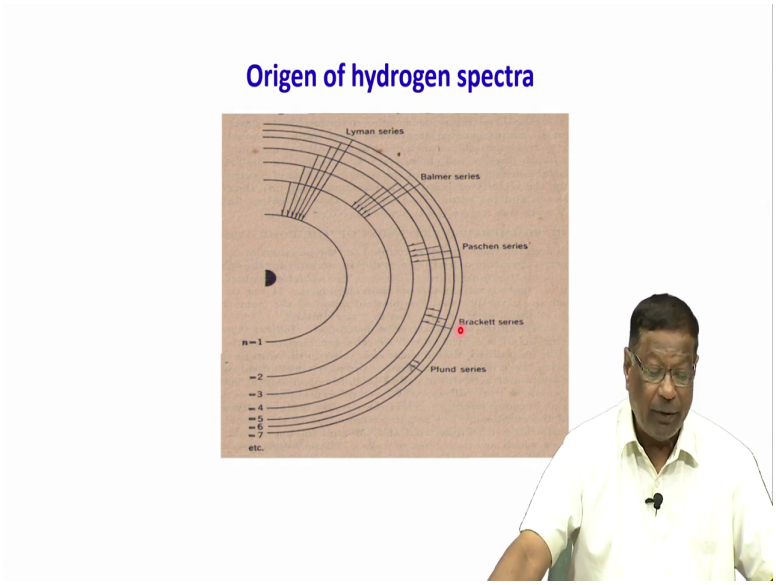

So, this is the how the spectra originates. So, here you can see this is the first one electron here n is equal to 1. So, 1 to 2, 2 to 1, 2 to 1, 3 to 1, 4 to 1 these are all Lyman series, this is Balmer series. They do not fall up to first orbit; n is equal to 3, here that is Paschen, Brackett series, Pfund series like that there are different kinds of electronic spectra appearing for hydrogen.

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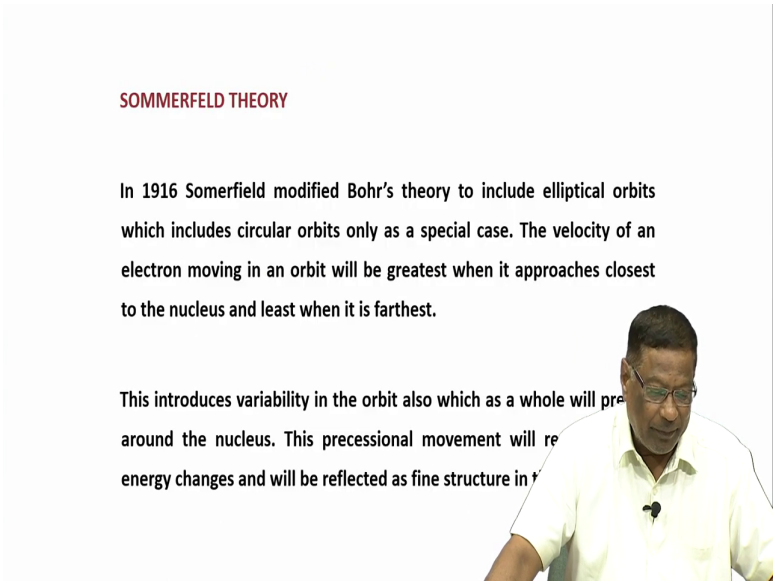

So, we will continue our studies on the electronic structure in our next class, that is a we will basically what we have learned today is the structure of the atom and a little bit of theory about the organizing, understanding the chemistry of the atoms.

Thank you very much; we will meet again in the next class.