Analytical Technologies in Biotechnology
Prof. Dr. Ashwani K. Sharma
Department of Biotechnology
Indian Institute of Technology, IIT Roorkee

Module - 2
Radioisotopes Techniques
Lecture - 1
Basic Concepts 1

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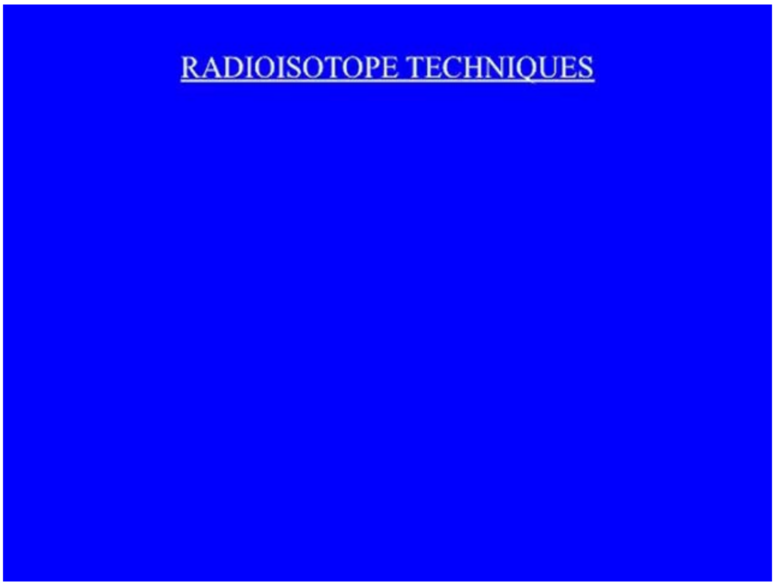

In this lecture we are going to start a new topic, that is radioisotope techniques and in subsequent lectures we will be discussing different parts of this technique. Now, we are going to discuss in this particular topic, the basic concepts methods of detecting radio activity and these with three methods main three methods. One based on ionization of gases, where g m counters are used second based on excitation of solids and liquids, where scintillation counters would be discussed and third exposure to the photographic film, that is auto radiography. We are also going to discuss about in brief radio imino acid, then we are going to discuss different application of this technique and particularly safety aspects.

Now, let us start with a brief introduction, and then we will get into specifics. Radio isotopic technique is an advanced technology with deals especially with the research of special property preparation and application of radio isotopes on the basis of theory of nuclear physics, radio chemistry, and related subjects. It is a important part of nuclear science and technology. Now, radio isotope what does radio isotope means it refers to the isotopes of a particular element possessing radio activity. Now, isotopes are nuclei having the same number of protons, but different number of neutrons.

So, we will discuss this in detail a little later isotopes of an element have seem characteristic atomic number, so that means it have same number of protons in their atomic nuclei, but they have different mass number. So, these atoms are said to be containing unstable combinations of protons and neutrons. Now, if there is unstable atomic nuclei it may it will spontaneously decompose to form a nuclei with higher stability. Now, this decomposition process where an unstable atomic nuclei decomposes to form a stable nuclei is called radio activity.

Now, the energy and partials which are released during the decomposition process are called radiation. Now, an unstable nuclei decomposes in nature the process is referred to as natural radio activity when an the unstable nuclei are prepared in the laboratory the decomposition is called induced radioactivity. So, there are you can like you have in nature lot of isotopes being radio isotopes or having radio activity, but you can also prepare them synthetically. Now, radio isotopes are widely used in industry medicine and scientific research and have been used to follow physical chemical and biological processes almost from the time of their discovery.

Probably the application with the biggest impact has been in the biological science where radio nuclei's have been incorporated in the in to biologically acting molecules and have been used to diagnose a wide variety of diseases. And also to treat many diseases other uses in the life science are related to using radioactive isotopes as markers for an existing species. There are many examples like for example; nitrogen 30 is used in plant studies copper 67 to track copper catalyst in python plant tones. Likewise, tritium or 30 h sulphur 35 or iodine 125 all of them are used to label proteins p 30 or phosphorus 32 is widely uses to label nucleic acid and phosphor protein like ways sodium that is Na 22 or chlorine 36 are used to study iron transfer.

Now, all this are very much utilized in biological sciences, now the advances in the imaging technology. In recent years has had a profound impact on the use of these radio nuclei in positron emission tomography of pact emission and the couple of other imaging modalities to provide very precise insights into human diseases. So, this is you can say a lot of a different applications are there of radio isotope technique. Now, this technique all we called radio tracer technique this allows extraordinarily sensitive detection of a radio isotopically labeled samples.

Now, it could go from 10 is to power minus 6 moles to 10 is to power minus 40 mole of a substance being detected, whereas chemical detection the quantities are less than 10 is to power minus 7 mole. So, you have much higher sensitivity of this particular technique the use of radio activity has led to the development of several experimental approaches. For example, double labeling methods where you can analyze two substances simultaneously to label them separately, this pulse chase method for following a substance at a time after it synthesis without interference of material can currently synthesize. So, in pulse chase you can follow something which is synthesized at a particular time and it will not be disturbed by concurrently synthesized material it could be exchange analysis for measuring participation of substances. The actions there could be whole lot of different methods which have been developed for like for experimental approaches.

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Now, let us get little bit into history of radio isotopes or radio activity now radio activity was discovered in 1896 by the French scientist Henri Becquerel while working on phosphorescent materials. Then Rutherford coined the term alpha ray and beta ray in 1899 to describe the two distinct type of radiation emitted by thorium and uranium in

1903 Nobel Prize was awarded to Marie query for discovering radium and polonium. Later in 1923 Pustule discovered the element hafnium he made notable discovery on the mobility of ions isotopes separation and his work on radio isotope tracer which had an important biological applications won him the Nobel for chemistry in 1943.

In 1948 scientist discovered that gamma rays could be detected using photo multiplier tube in 1950s pharmaceuticals labeled with radio activity were developed hat allowed the study of organs many organs including the heart liver kidney and bone. Now, the invention of the gamma scintillation camera by American engineer Halagur in then 1950s brought major advances in nuclear medical imaging and rapidly elevated the use of radio isotopes in medicines.

So, there are lot of advancement has taken since then and you can go on in the industry, so this was brief history about the radio activity or the radio isotopes being used in different areas of a life sciences and other sciences. Now, let us get in to the specifics the basic concepts of radio isotopes or radio activity the nature of radioactivity. Now, the nature of radio activity as we said that there are unstable isotopes, so before we get into that let us see the atom structure or atomic structure and atomic stability.

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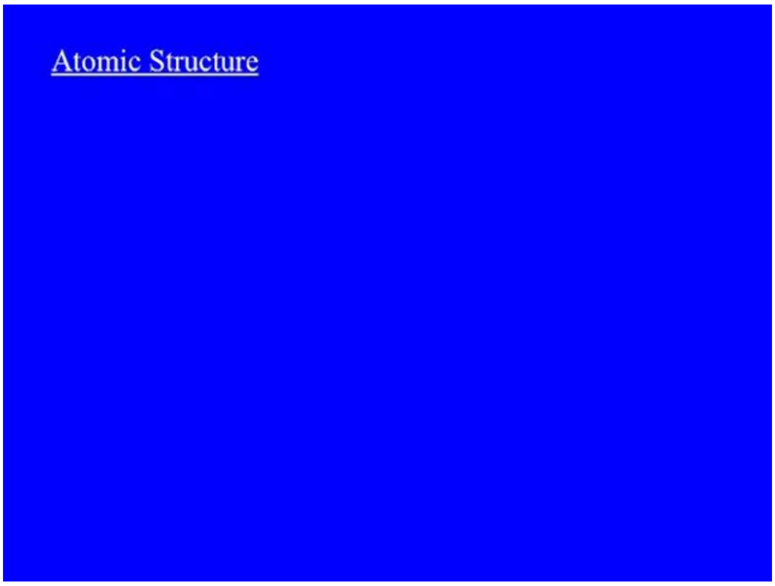

Now, an atom is the smallest piratical of an element now atom it is made up of what, it is made up of a positively charged nucleus surrounded by cloud of negatively charge electrons the number of protons equals. The number of electrons as atom as a whole is electrically neutral, now the number of protons in the nucleus of the atom is the characteristic value of and a n element and the number is defined as atomic number. In addition to protons an atomic nuclei also contains neutrons that is uncharged particles with a mass approximately equal to that of proton and the sum of proton and neutron in a particular nuclei is known as mass number.

Now, if you have atoms of same element having different mass number that is different number of neutrons they are known as isotopes. Now, the number of isotopes of an element can vary for example, they could be three isotopes of hydrogen there are seven of carbon and twenty or more for elements of five atomic number. Now, before we go into the atomic stability, we just little bit try to understand the atomic structure on your screen here. Let us little bit understand this atomic structure before we move on into the next label here that is the atomic stability. So, like I said that an atom is made up of a positively charged nuclei with surrounding electrons.

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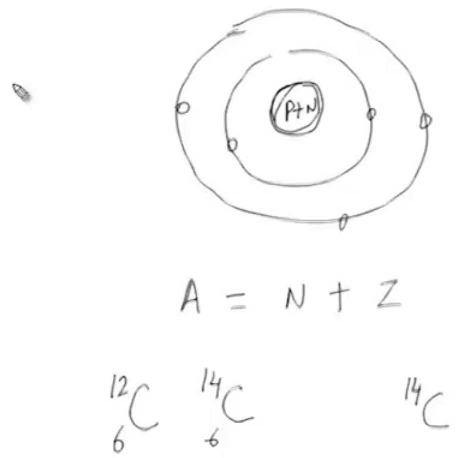

So, what you have essentially that you have a nucleus which is center part and it is the heaviest part of an atom and then you will have surrounding electrons which are distributed in different orbitals. So, this nucleus is contains protons plus neutrons actually and these are electrons which are projected in the different orbital. So, what you have is mostly the proton number and the electron number is same. So, the positively charged a nuclei has equal number of negatively charged electrons, it is electrically neutral.

Now, the atomic weight of an atom is given by that is atomic mass is given by the two thing, which is number of neutrons and number of protons z is number its atomic number, the number of protons is the atomic number and it is the characteristic value of a particular atom. Now, to take you further when we say this you can mostly denote for convenience, we denote particular atom by say if you have to denote carbon, we denoting it with a single letter C or oxygen by O or nitrogen by N.

Now, this C will represent they will be a subscript and a super script subscript will say that it has a particular proton number or atomic number. I would say and super script will give you what are the protons you can find out, what is the neutron number by simply calculating or substituting the value after subtracting it from the atomic number from the atomic mass. Now, there could be like I said there could be many isotopes of a particular atom again before that for convenience mostly like there could be lot of thing like you can write this as C 640 has a different isotopes or otherwise. Now, most of the time for convenience we represent this as simply by the atomic mass here rather than writing atomic number.

As we consider atomic number is same for each isotope here, so what you have is you have different number of different atomic mass, but the same atomic number that will characterize the particular atom. So, atomic number has to remain same hope you have been able to understand a simple atomic structure here now let us get back to our this continue our discussion here.

So, we are seeing the atomic atoms of same element having different mass number that is different number of neutrons they are known as isotopes. The number of isotopes of n element can vary that could be one two three or many of them for higher element elements of high atomic number. Now, these neutrons and protons constituting the nuclei and surrounding electrons of an atom are governed by various forces which keep the atom together.

Now, the force of repulsion between the protons because protons are positively charged and like charges repel each other in electromagnetic field. This is overcome by a strong force that holds the nucleus together and energy associated with this force is known as binding energy. So, there is a force which keeps the nucleus together although you have protons of the same charge clustered in the nuclei.

Now, there also neutrons in the nuclei which kind of are present in there they are electrically neutral. Now, in stable atoms binding energy is large enough to hold the nucleus together, but this different in unstable atom here what happens is that the binding energy is not large enough to hold the nucleus together. So, what happens unstable nuclei of an atom constantly change and they will lose protons or neutrons or electromagnetic radiation in order to become stable.

Now, these are called radioactive atoms and the phenomenon is known as radio activity so what is radio activity it a release of energy or matter or energy and matter resulting from changes in the nucleus of an atom. Now, the radioactive decay is spontaneous process and can be caused by the forces within the nuclei. So, it is not like from outside it is induced it is within the nucleus that is forces are causing this and this is completely spontaneous process. Now, these disturbances could be different like electro static forces or weak nuclear forces or orbital small disturbances from quantum vacuum fluctuations that are hard to say, but the process is spontaneous in itself.

Now, ratio of neutrons here we are again coming why it could be unstable the ratio of neutron to protons in the nucleus determines whether an isotope of a given element is stable enough to adjust in nature or not. Now, most stable isotopes are those where an element tend to have an equal number of neutrons and protons. Now, unstable isotopes also known as radio isotopes or radio nuclei these are the emit particles and or electromagnetic radiation as a result of change in the composition of the atomic nucleus.

So, these unstable isotopes they contain an unstable combination of neutron and protons. Now, all elements with atomic number which are high atomic number say above eighty three or so are radio isotopes and elements with atomic number will have most like they have mostly there are radio isotopes. The, atoms or elements with smaller atomic number, but at least have one or more radio isotope, now when a radio isotope tries to stabilize by emetic energy or matter it may transform itself into a new element remember that the atomic number is the characteristic value of a particular atoms.

So, if atomic number changes, so is the character of the element atom. So, if there is certain emission which leads to the change in the atomic number then it will transform itself in to a element and this process is known as trans mutation radio nuclei occurs naturally and can also be produced artificially by nuclear reactors. Now, they could be nuclear reactors particle accelerators like cyclotron or by radio nuclei generators, so that could be both that could be natural as well as artificial for different application.

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Let us little bit see what are different kinds of radio nuclide or radio isotopes. Now, a radio nuclide an atom with unstable nucleus is characterized by an excess energy and under goes radioactive decay to emit radiation in the form of subatomic practical or gamma rays they occur naturally and can be produced artificially. Now, there are three types of naturally occurring radio nuclides they are primordial secondary and cosmogenic. So, radio nuclides which are primordial these ones originate from interiors of a star for example, uranium and thorium which are originated from interior of stars and with very long half life.

So, there will we will discuss, what is half life in a little while then there are secondary radio nuclides and these radio nuclides are radiogenic isotopes and they are derived from the decay of primordial radio nuclides. So, what you have they have shorter half life, so they have come from primordial ones and they have shorter half life then the primordial radio nuclide remember primordial radio nuclides have very long half life. Then there is third one that is cosmogenic radio nuclides and is being formed continuously in the atmosphere due to cosmic rays.

For example, carbon 40 is been formed because of that, so artificially radio nuclide can be produced by nuclear reactors which like for example, thallium has been produce from nuclear reactors or allodium. They could be produced by practical accelerators like cyclotron for example, fluorine 80 or by radio nuclide generators which is technetium 99 m generator used in nuclear medicine. Now, the parent produced in nuclear reactor is molybdenum 99, so you have different examples where you could produce there are natural radioactive isotopes or artificially produced radio isotopes or radio nuclides all right.

So, this was little bit about the atomic structure and atomic stability alright let us get into which are different types of radioactive decay able like we are saying radio activity is something where matter like sub atomic particles or electromagnetic radiations are emitted. So, to become or to acquire stability, so what are these different types of radioactive decay actually, now radioactive decay is the process where loss of energy by emission of ionizing radiation occurs from an unstable nucleus of an atom.

Here, an unstable nucleus of an atom called the parent radio nuclide transforms to a atom with a different nucleus in a different state or a different nucleus either of which is named daughter nuclide. Now, often the daughter and parent are different chemical elements, so in such cases the decay process results in nuclear transmutation. Now, let us get in to the different types of decays and we are discussing few important types of decays here and before we go into the details. Let us try to understand them a little bit here on your screen, so decay by alpha practical emission there could be decay by electron emission there could be decay by positron emission and there could be decay by emission of gamma rays.

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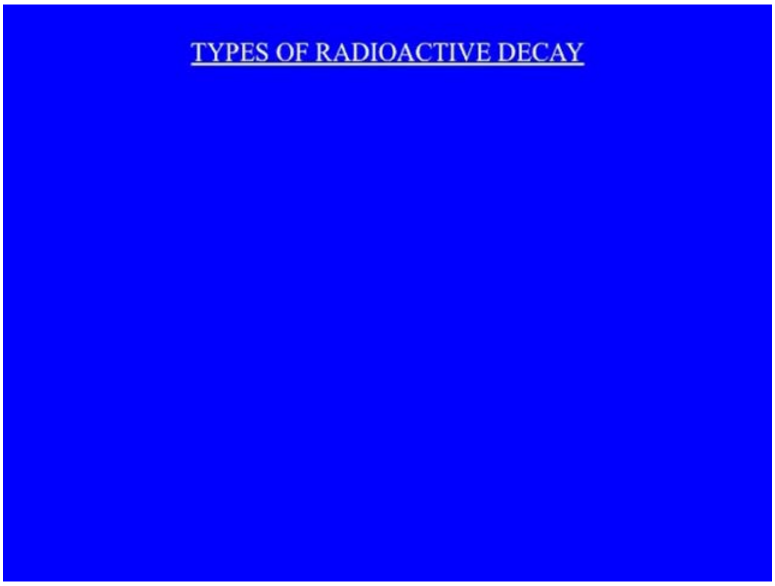

Let us see what these on your screen are, let us get see what is different types of radio isotopes decay here, now like I said there could be decay by different types of subatomic particles.

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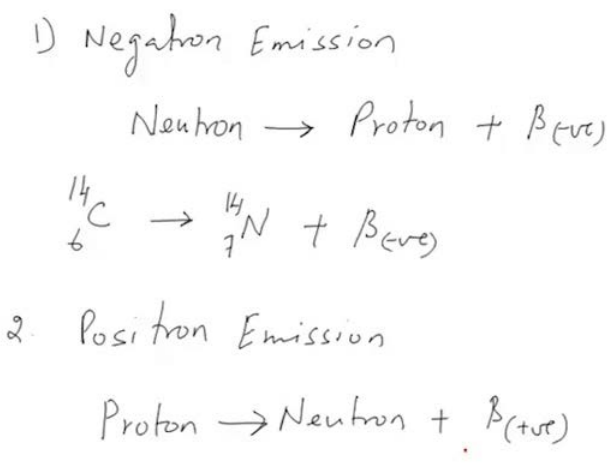

There could be one there could be negatron decay by negatron emission an negatron emission when we say then it is a simple negatively charged particle eta particle or electron and it is called negatron because it has a nuclear origin. Let us see how it is produced, so if you have a neutron in this particular case neutron is converted to proton and plus a beta particle that is an electron and we call it negatron. Of course, now if I have to take one example of this particular one this is very simple example is where C 14 or carbon 14 is converted to plus what you have is you have converted this 14 C. You can see here, the atomic number had changed 6 carbon has 6 atomic number whereas nitrogen has 7 in the sense b formed because neutron has been converted to a proton.

So, there could be a emission by negatron emission or they could be decay by negatron emission, now if is the second one there could be decay by positron emission. Now, positron is just opposite to negatron like beta particle which is positively charged rather than negatively charged. Now, what happens here in this particular one rather than neutron been converted to proton it is proton which is converted to neutron plus a positively charged particle or beta particle as you can see for example.

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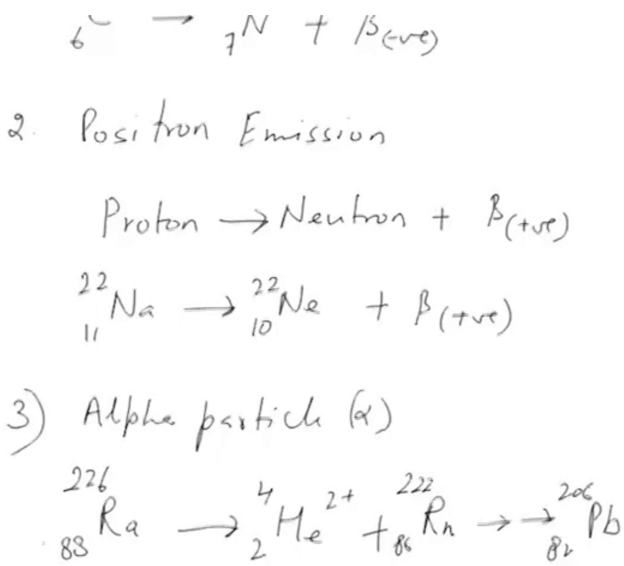

There could be one example like Sodium been converted to here, you can see the atomic number has decreased actually and you have a positively charged particle. Now, we will discuss this in detail what happens to this positron as such then there could be third one and which is decay by alpha emission. So, that is alpha particle emission, now alpha particle is a very carries a particular weight it is a helium nucleus and doubly positive charge actually. So, here you have your you can say that it is not as light as beta particle and here you will change the atomic number by 2 and the mass number by 4.

For example, if you have a radium which has atomic number of 88 and the atomic mass of 226 then it is converted to a helium nucleus or alpha particle which is with 2 atomic number and 4 atomic mass and it is like I said doubly charged plus subsequent like radon is created which is a 2 atomic number less and the 4 atomic mass less. Now, this like a series actually which will be carried on till a stable nuclei is formed and which is formed at the end it is somewhere around it is formed when lead is formed 206 p b is formed. So, alpha particle emission is another one, now there could be another ones also like by electron capture and other we will go on discussing them as we go along I hope you have been able to understand.

There could be different types of radioactive decay and like I said it could be decay be alpha particle emission decay by negatron emission decay by positron emission or decay by emission o gamma rays. Now, let us discuss each of these in little detail, so let us discuss first alpha decay. Now, alpha decay is observed in isotopes of heavier elements which is like atomic number to say approximately 52 or greater actually, now many time a complex decay series by alpha emission results till formation of a stable isotope of a new element like I told you in a little bit earlier. For example, radium like I you radium is it decays by alpha emission and it will decay to radon and subsequently radon will decay finally, to lead actually till it gets stable nuclei.

So, that is a heavy atom or you can say it is a heavy nuclei, now reason alpha decay occurs is because the nucleus has too many protons which causes excessive repulsion and in an attempt to reduce the repulsion a helium nucleus is emitted. Now, emission of alpha particles results in a considerable lightening of the nucleus that is decreasing in atomic number of 2 and decrease in mass number of 4. So, it is like if you compare the two one which is the original parent and daughter they have lot of difference in term. So, atomic mass and atomic number, now alpha emitters are not frequently used for biological work we will discuss later on this alpha emitters are extremely toxic and if ingested due to large mass and ionizing power.

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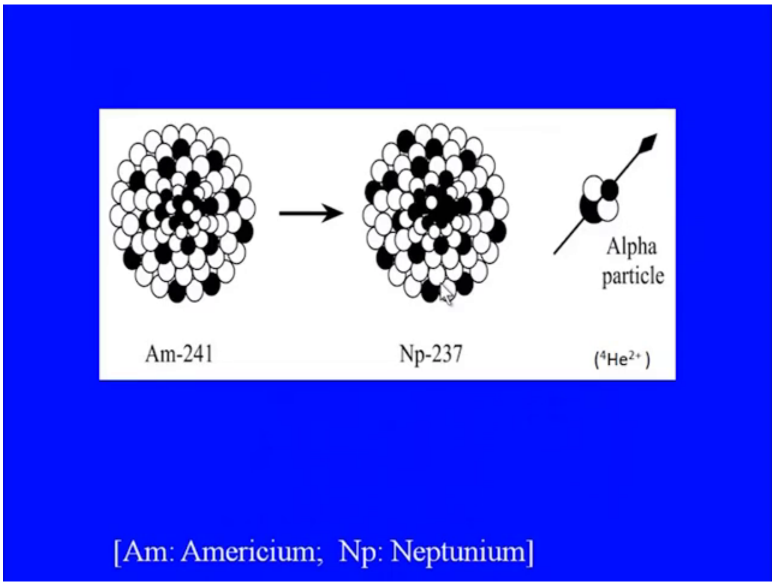

So, these are toxic entities, now this is one example where we have shown here the figure that this is you can say protons and neutrons and you can say there are large number of protons and as such and there are neutrons here. Now, this particular one Am 241 that is Americium 241 changes to neptunium 237 with the emission of alpha particle all right. So, this is like a typical representation of how alpha particle emission is taking place, so this was about how alpha decay takes place.

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Now, let us move on to negatron emission of beta decay now decay by negatron emission is very important, it is used frequently in biology. Now, this occurs when the neutron to proton ratio is too high than the nucleus and it causes in stability the neutron is converted to a proton by the ejection of a negatively charged beta particle. It is called negatron for its nuclear origin

So, neutron converted to proton plus negatron, now here neutron to atomic number ratio decreases like I showed you that atomic number increases by 1. So, ratio decreases, but mass number remains the same here, now radio isotopes emitting beta particles are frequently used in biological world. A few examples if we say like 32 p is the beta emitter carbon 14 is a beta emitter 3 h is a beta emitter 30 s is a beta emitter and there could be many more examples here.

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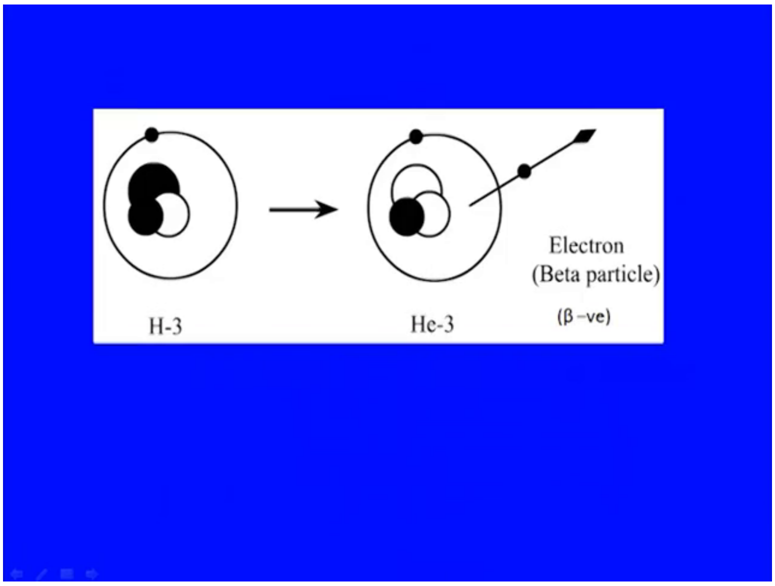

This is a typical it is a figure which shows beta emission you can see there are two neutrons and one proton and now here the proton one of the neutrons is converted to proton. So, there are two protons here, so your atomic number has increased and there will be a emission of a negative electron or beta particle. So, this was about the emission by or decay by negatron emission. Now, let us see the decay by positron emission, now the positron emission occurs when the neutron to proton ratio is too small, so proton will turn in to neutron here and the positron is emitted which is basically a positively charged electron a positively charged particle opposite to the negatron.

So, here what will happen, proton is converted to neutron and positron and the ratio that is n by z ratio increases and atomic number decreases by one and mass number will be remaining will be remaining constant. Now, positrons are extremely unstable and have only transcended existence so what happens once they have dissipated there energy then track with electrons and are annihilated.

Now, the mass and the energy of the two particles is converted to two gamma rays emitted at 180 degrees to each other and this phenomenon is known as back to back emission phenomenon. Now, a positron emission used in biological sciences in brain scanning technique this technique is called positron emission tomography so this is quite useful for medical science.

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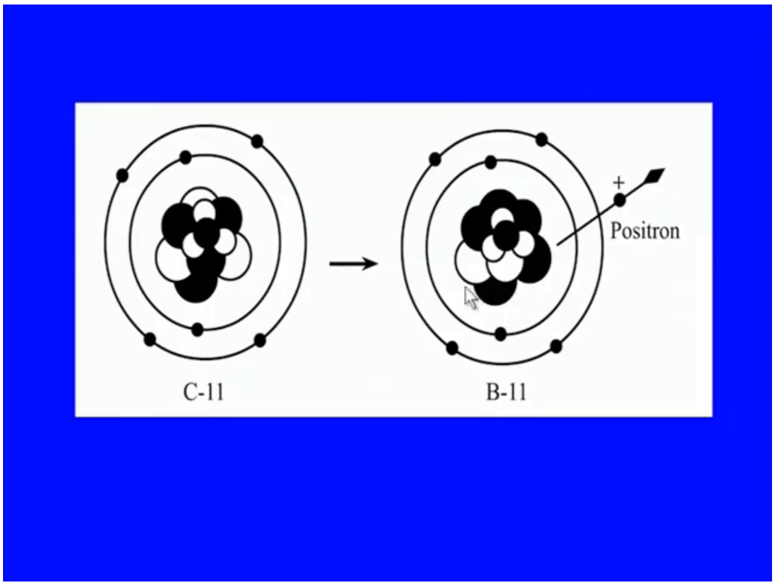

If you see here figure which shows the positron emission if you can see here there are number of protons and neutrons and number of protons decreases here and there is a emission of positron or positively charged particle C 11 is converted to B 11 here that is carbon 11 to beryllium 11.

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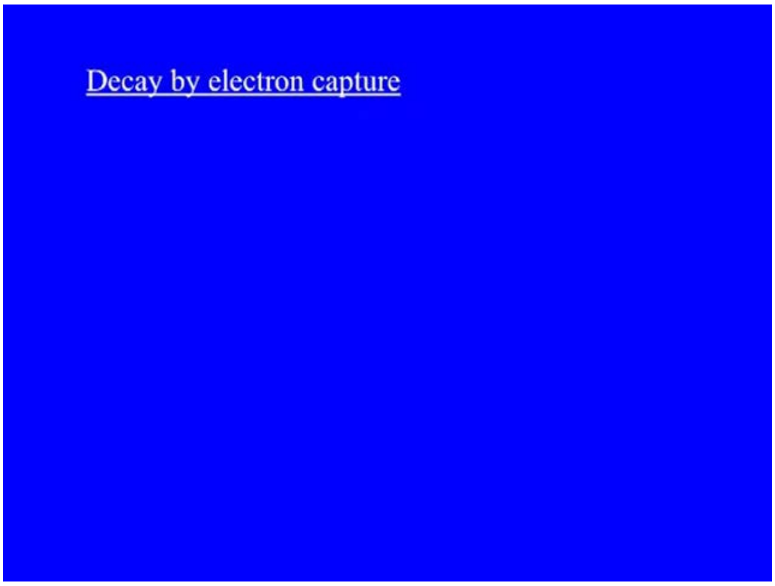

Now, let us see decay by electron capture ah this is another characteristic decay where x rays are generated. Now, if you see it occurs when the neutron to proton ratio in the nucleus is too small and so what happens that when the ratio is too small the nucleus captures an electron from k or l electronic shell will basically turns the proton into a neutron that is proton plus electron is converted to neutron plus x rays.

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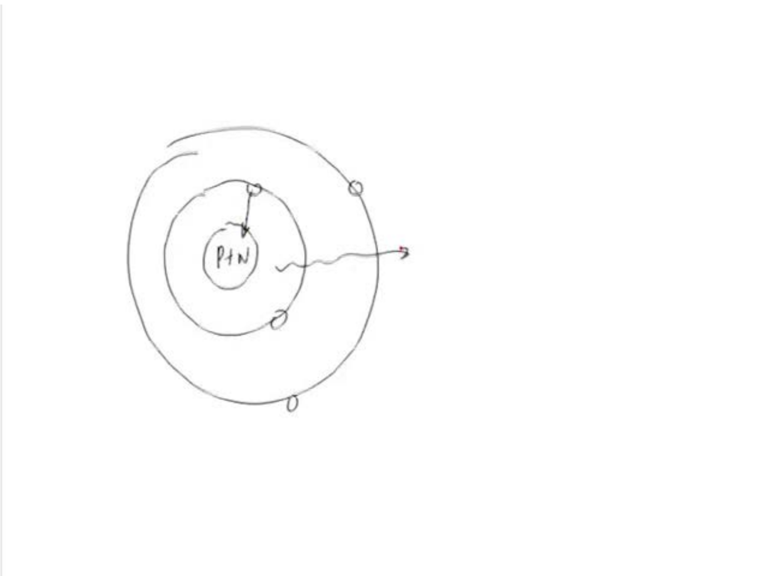

Let me show you this on screen you have proton plus neutron in here and you have say k or one shell containing the electrons. Now, in this particular case where x rays are generated this one will take this will be taken up in here and then the like you can say electron is captured in here and then generation of x rays will take s place in this particular case. So, this is another way of what you called of decay here.

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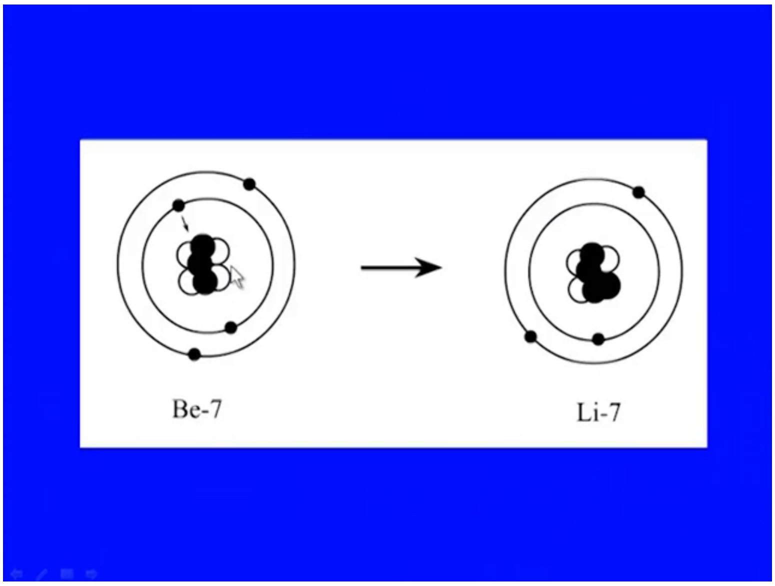

Let us see this in here also and here beryllium 7 this one example, what I have showed you this beryllium seven where this particular electron is taken up by the nucleus and it is converted the proton. So, like I showed you proton plus electron is taken to neutron plus x rays, so what happens here proton one proton is less a neutron is generated and electron the x-rays are generated in this particular case here.

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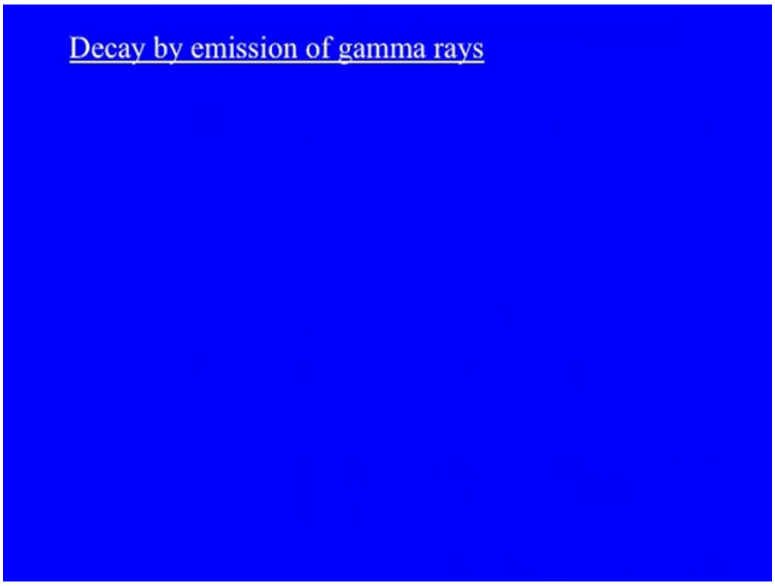

Now, let us move to the last one of the decay that is decay by emission of gamma rays. Now, this particular one involves electromagnetic radiation rather than alpha beta particles, so here in essence gamma rays do not carry any charge or mass. So, there should not be any change in charge and mass rather it is a electromagnetic radiation. Now, this occurs because the nucleus is in exited state at high energy level and falls to the lower energy state by emitting high energy photons known as gamma particles.

Now, gamma rays emission is frequently accompanied by alpha or beta particle emission, so it might like change the atom. Now, the emission of or may not emission of gamma radiation in itself does not change atomic mass or atomic number because it does not carry any mass of charge gamma radiation are has very low ionizing power, but they are highly penetrating because of their speed.

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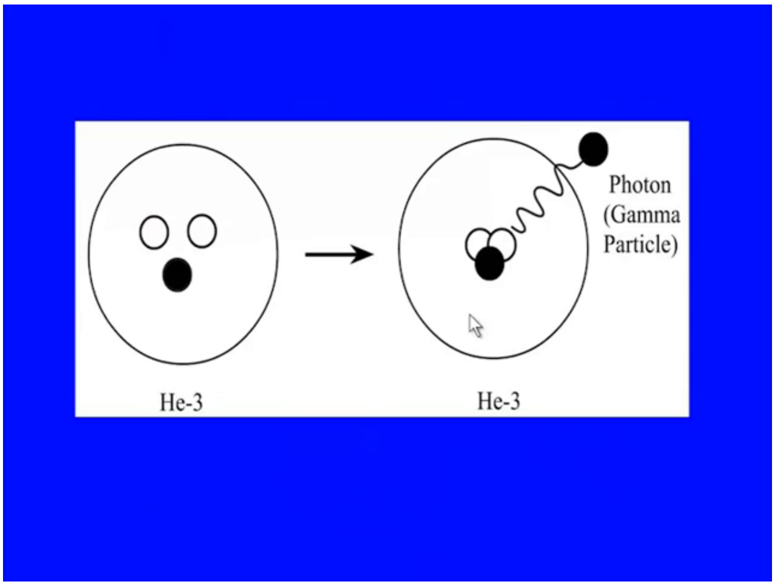

Now, this is typical a figure where H e 3 is in higher state when it comes back it emits a gamma radiation of photon. Now, if you go around it is like what we have discussed in here there are four different types of decays we have discussed they could be lot of other kinds of decays also which we are not going into detail. But what we have discussed here is one there is decay by negatron emission positron emission alpha particle and gamma radiation and then also one we have electron capture where x rays are generated actually.

Now, all these decays are due to the illus ratability of the atom of the atomic nucleus because of which is neutron to proton ratios are typical certain times it is low or sometimes it is high. But like I said if it is kind of equal that is more stable atom if they are not then it is a what you called unstable radio nuclide is created in this particular case. So, let us move on, so this was about different types of decays.

Now, let us move on to what are decay energy and units of radio activity radioactive decay energy will be expressed in terms of electron volt. Now, one electron volt is defined as the energy acquired one by one electron in accelerating through a potential difference of one volt, or you can say work done on electron in moving it to a potential difference of one volt. Now, one electron volt refers to a very small amount of energy and it equals only 1.6 into 10 is to the power minus 92 for majority of isotopes the term million or mega electron volt is used or more applicable.

Like for example, alpha emitters have decay energy in the range of 4 to 8 million electron volt, while beta and gamma emitters will generally have decay energy somewhere, less than 3 million electron volt. So, you have like have to use a higher like you have to use a what you called electron volts in terms of say higher number which is mega or you can call it million electron volt rather than simple electron volt. Now, for a particular beta emitter beta particles are emitted in a continuous range of energy from zero to a maximum value which is e max.

So, you have beta particles which could be emitted in a very small with a very small energy and to a very large energy and there would be a mean where you can say have a plot of relative probability of emission of a beta particle as a function of energy. This is called beta spectrum if you consider gamma radiations, like I said they are less than 3 million electron volts they will also range somewhere, around ten thousand electron volts to 10 million electron volts actually. So, in this lecture we have tried to discuss some of the basic concepts which is the nature of radio activity how the particular atom, or is stable or unstable and how that unstable atom by different types of decay, which could be electromagnetic radiation or sub atomic particles tries to become stable.

We have discussed about alpha decay, we have discussed about negatron decay, we have discussed about positron decay and we have discussed about the gamma radiation decay in the subsequent lecture. We will be discussing about like we are talking about the beta spectrum. We will discuss about beta spectrum and we will discuss about the interaction of the radio activity with matter and other different aspects of radio activity before starting like I said three methods which we are going to discuss. And so today we will end this lecture here.

Thank you.