Introduction to Biomedical Imaging Systems
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Lecture - 10
Physics of Radiography

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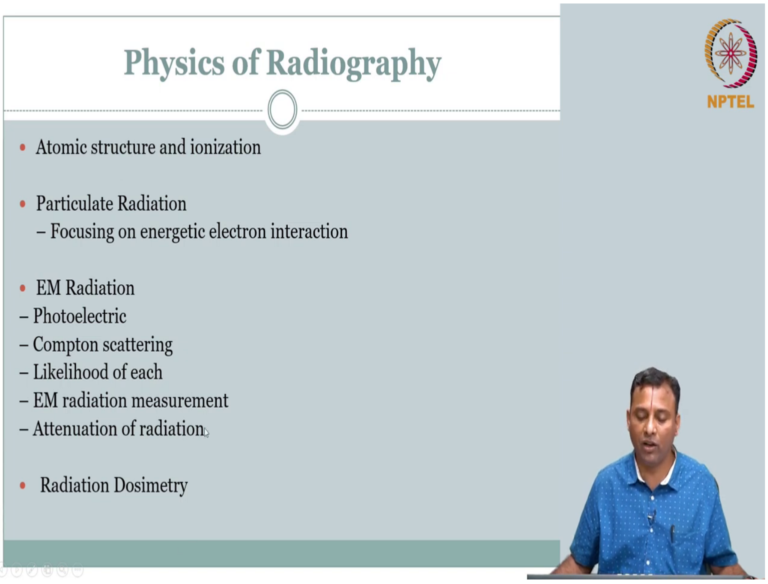

So, it is time we move make a baby step towards the first imaging modality that we want to cover which is going to be Radiography, right. So, we talked about our projection radiography if that was the title we put in the contents then its projection radiography. So, essentially what recall right the way we want to organize and present the content is any modality we take we would start with the physics of the modality and then go towards the instrumentation aspect of it and then, towards the image formation, image reconstruction and finally, talk about the image quality aspects.

In that regard the first modality we will start with X ray based imaging right. So, projection radiography and CT, Computational Tomography right, computed tomography X ray computed tomography. So, we will start with the physics of that, right.

So once we finish the physics, then we will go to you know cover the projection radiography first and then we will say when we go to CT we will say the physics is already covered and then, proceed with the instrumentation and the image recon for CT. So, clearly the physics that we are going to cover is going to be used or we will be able to make reference to it in the first two modalities, projection radiography and CT.

Also maybe at points when we are there I will like to clarify that some of the things that we will cover here is in principle right to a large extent very you can carry forward that for also the PET imaging, ok. Essentially when the photons are interacting with tissue right, we will say we did similar things for interaction of X ray energy. Now, when you have gamma it is just the energy is different and therefore, these are the nuances.

So, pay attention to this part right, make yourself comfortable that way when we go to the other modalities whatever we can carry forward from here we will make use of it ok. So, physics of radiography. So, we will start overview of what we want to do is, we will start with the basic structure of an atom right.

So, these are all atom atomic structure and ionization. In fact, we kind of use this term even in the introduction that these are ionizing radiations right. So, these are ionizing and then there is ultrasound and MRI where it involves no ionization. So, we did use those terms now it is time for us to formally define what it is what we mean by ionization.

So, before we do that, we will do one slide review of atomic structure just so that you know how what aspect of atomic structure we exploit which modality comes out of it, ok so just for that purpose. So, this is nothing there is there is should not be anything new in any of the content regarding atomic structure, protons, electrons and things like that ok.

So, in some sense atomic structure is just for you know its like kind of your starters. So, you get to into it, but mainly we will understand the different types of radiations, especially particulate radiations and even within particulate radiation for the purposes of this chapter, we will talk about electron.

See particle is what, we have we will go into it in the atom; electron is one of the particle right. So, we will talk about energetic electron and its interaction with the tissue that will be the focus and then the other one is electromagnetic radiation. In fact, electron interaction is what we will not with respect to tissues per see we will, talk about electron interaction with the material.

And then, here we will again talk about the other type of radiation which is electromagnetic radiation and these are the important effects. So, the some sense after the first few slides in fact, when I say few slides it will still take some time for me to cover, because I do not want to rush through.

Even though you may know it you probably are very familiar I would like to go little slow here, because this kind of forms a big picture understanding of the different modalities how each one is slightly different from the other.

So, all likelihood the first topic we will cover in this lecture and the subsequent lectures and so we will lead up till the types of radiation in this lecture and then, in the subsequent lecture we will go one after the other on this, right. So, these are all subject specific. So, we are getting into the subject specific topics, ok. So, having said that let us move on to the first one. First one is atomic structure and ionization. So, what do we mean by ionization?

We need to define that, in order to do that we need to start and talk about atomic structure. Of course, there is going to be radiation dosimetry that we will cover because we talked about ionization or we will talk about ionization and then, we already mentioned in the previous lecture about exposure to X ray and stuff so, there is bio safety involved, right. So, we need to understand what this radiation dosimetry ok. So, we will cover all of this in the physics.

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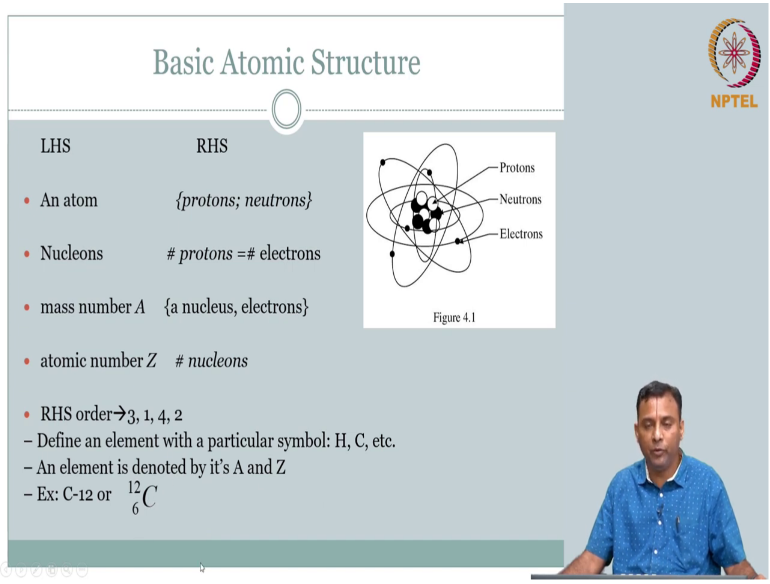

So, basic atomic structure, basic atomic structure is everything that you know. So, early 20th century whatever they imagined right the planetary system kind of organization right, you have the nucleus at the centre and then there are orbits electron spinning around the orbits, the same model is what it is. So, that is the basic atomic structure.

So, order of interest you have protons and neutrons at the core right and then you have the electrons that are spinning around ok. So, since this is very known material from perhaps high school right. Typically I want to I it is not like I want to deliver this, because this will be boring, you know it. So, you will not.

So, let us just give yourself a challenge right. So, I am just going to have LHS and RHS you please connect which is what ok. So, take some time. So I have an atom, I have nucleons, mass number, atomic number on the left hand side. So, since you know this from whenever right, high school.

Maybe it is a good time you refresh maybe you did not read about this after that and you are in typical electrical engineering, mechanical engineering in your higher years and you are not really had a chance to work with the material side of it. So, maybe you forgot. Can you refresh your memory?

See how powerful your memory is right an atom. So, what does an atom here is an example of an atom. So, what does an atom contain? I see protons and neutrons and electrons. Protons and neutrons are at the centre so, that is nucleus so and nucleus and electrons.

What is nucleons? Nucleons are I see here right, nucleons are the constituents of nucleus. So what do I see? Protons and neutrons right this labelled ok. So, that is what that is so, what is your mass number, thus anything you know ring a bell mass number an atomic number. Atomic number maybe is that is easier if you can recall atomic number are corresponds to maybe the number of electrons turns, out the number of electrons and number of protons are same because, atom is net neutral.

So, maybe atomic number is the number of protons and number of electrons. And your mass number has to do with your nucleons, that is the number that is there inside. What is nucleus, protons and neutrons are there some of those is your nucleons ok. So, just go brush you know it is all reasonable I know you know it, but just to make sure go one more time read about it and the reason for that is I mean, just from what we have covered so far and the list of contents that we will be covering for this syllabus.

You already saw ok, there is some x rays, radiation, ionization all that you know and then there is this nuclear medicine nuclear medicine and then, I also mentioned MRI the nuclear magnetic resonance. So that means, there is some nuclear that we are talking about is that same as here some is it here also you have nuclei right.

So, is it something related, right? Yes so, essentially the idea is when you are talking about the outer electrons which we will do right, that we will cover in the X ray part of it. But in nuclear medicine that exploits energy that is coming out from the centre nucleus and then, nuclear magnetic resonance is the magnetic property right; magnetic resonance property at the nucleus.

So, in some sense we will start with the electrons in this chapter right and then, as you can see if the activity is from the nucleus so, then that gives rise to some modality and then if it is radioactivity, then that is one modality if it is from nucleus, but it is not radioactivity but, it is to do with the spin property then that gives magnetic resonance right, exploited in magnetic resonance imaging.

So, you know basic structure of atom how from their different modalities can be traced ok. So, this is something that we covered. So, what we will do now is so much is fine like we need to move on with more interesting stuff. So, just to complete this define the element with the particular symbol. So, it is a over bit right. So if you have a element, you already call it as hydrogen, carbon etcetera, right.

So, in order to represent that we could also use its atomic number and mass number, right so, there are several ways to denote it. So, carbon 12 C 12 or you can write its mass number and atomic number. So, it is a if you say 6 that is good enough, but anyway you can also call it as carbon, right.

So, there are several ways to do it, several conventions so, some of the common ones are like this. What is interesting in this is, you can recognize the atomic number and mass number and you have a name to it.

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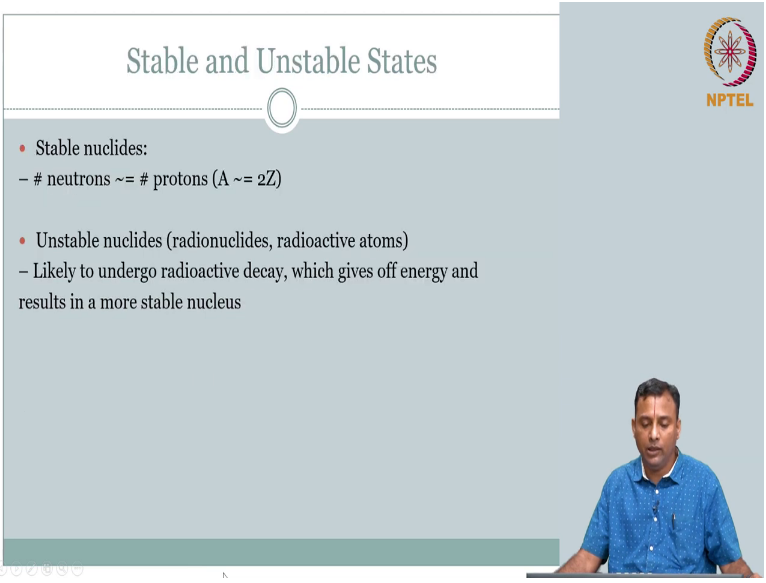

But, based on the relationship between that you can comment on something stable nuclide or unstable nuclides. So, what do we mean by stable nuclides? If the number of neutrons is approximately equal to number of protons right, in the nucleus if the number of positive charges right protons is approximately equal to number of neutrons. Remember the atom is net neutral. So, number of electrons is on the outside. So therefore, this is net neutral.

So number of neutrons, if the number of neutrons is approximately equal to number of protons, you can also look at it this relationship right between atomic number and mass number. So, mass number is approximately 2 times the atomic number, then that is considered a stable nuclides. So, this has to do with the stability of the nucleus.

Unstable nuclides are called radio nuclides. So, where so if it is a radio nuclide then that atom is called radioactive atom, why is it unstable? Because, statistically it is likely to undergo a radioactive decay, right. So, it is in a energy state where it is not stable. So, it will give out some energy and come back to a stable state.

So stable nucleus means, it is going to have this proposition ok. So, unstable nuclide stable nuclides so these are the states, two states that are there and then, if you really look at it with the second part right. In when we go to the nuclear medicine the signal will come essentially because of this radioactivity, right. But, here we are not worried about the unstable nucleus part, right or the radio nuclides.

Radiography is different from radioactivity. Here we are not the first part when we do radiography that does not mean radioactivity. Radioactivity means, it comes from the nucleus ok, unstability instability of the nucleus. So, that is a settle difference. So, radiography we are not talking about radioactivity, radioactivity is exploited in nuclear medicine ok, fine.

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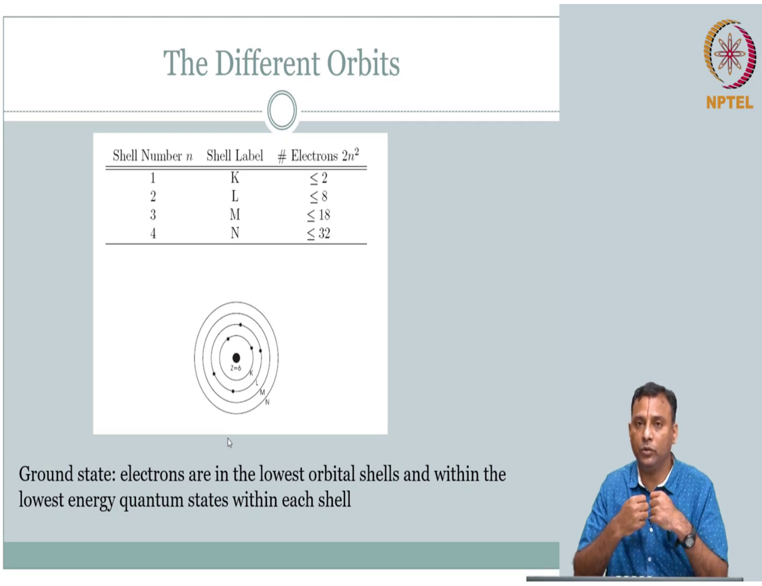

So that means, we talked about stability instability of nucleus, but when you talk about and then we talked about the organization of electrons around the nucleus right. So, depending on right so, there is a structure to it. So, how does a electron we saw the first structure diagram where the electrons are spinning around right, it their orbits it was shown in a 3D sketch.

So, you have number of electrons, but then the number of electrons are also organized that orbits that you have is so organized that it is labelled as K. So, you have orbit that is closer to the nucleus which is K referred to as K shell, L shell and M shell and N shell and so on and so forth.

And by nature what happens is, the number of electrons right for a given atom that tries to organize such a way that it will first fill the K shell and not only that, it can have only so many electrons in a shell in a respective shell. So, that the energy is in a low energy state so that means, there is already a number of electrons that can be in a particular shell.

So, the quantum states that the electrons can be right it is restricted. So, K shell you have maximum of 2 electrons. So, this N is the shell number. So, as you go away right outer orbits you can have more electrons that can recite and this is a distribution ok. So, why is this important? This is important because left to itself the ground state requires that each of the electron not only occupy the shell that is starting from K right.

Electrons are in the lowest orbital shells and within the lowest energy quantum state. So, within a shell it is positioned, so that also gives the lowest quantum, quantum state. So, in some sense the atom it is favourable for the electrons right to be in this shells in these shells right, within the influence of your nucleus. So that it can be less energy, ok. So, that is your ground state or the low energy shell, left to itself in nature this it will be organized such that it is in the low energy state that is the take home message.

So that means, we need to talk about these energies if this is lower energy state and if I want to and if I say that these electrons are attached right, it is revolving around the nucleus there is a positron, there is a protons at the centre and so that it is net neutral. That means, there is a energy with which it is binding, right to the nucleus.

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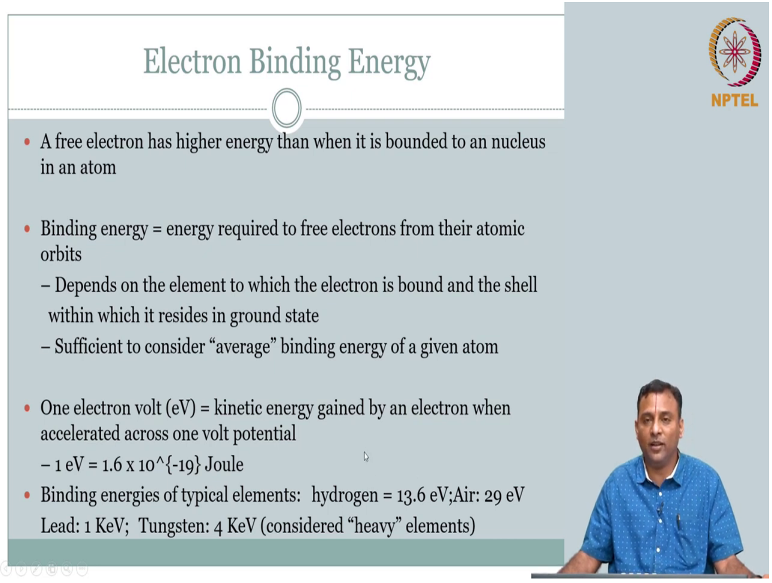

So that means, we need to talk about electron binding energy. So, in some sense if we already see through and look at the fine print in a definition of ground state right, in ground state we said the electron is so organized that it is in the lowest the atoms in the lowest energy state or the ground state.

So, if it is organized like that so, the electrons are not free it is in the orbit right. If it is organized that is your ground state, imagine if the electron is free what energy will it have. If the electron is free the free electron will probably have more energy, right. Why? Because that is the idea that is the lowest energy state so, if it is free probably it will have higher energy in other words to think about it that means, I need to supply some energy to release this electron, right.

So, your electron binding energy in some sense is the energy that it you need to overcome, you need to supply so that you can free the electron. But, when you talk about the electron, now the question is I have different shells which one are you talking about, right I mean naturally.

If so you have so many electrons you have in K shell, L shell, M shell is the energy going to be same. You might know or intuitively you can guess this the centre you have positive electrons are negative. So, it is all nicely revolving around it. So, if the closer you are right the more influence or the positive charge is going to be, the farther you are the lesser so, maybe to bump the electron remove the electron from the outer shells I may need to supply only less energy.

If I have to really remove something from the shell that is closest to the nucleus I may need to give more energy right, I have to spend more energy to pull it out. So, that means that energy is also dependent on so for a given atom that energy is dependent on which electron you are talking about, right,

So, let us just put that together. A free electron has higher energy than it is bound to a nucleus of an atom. It is a mere statement, but I think you should read this statement as a natural follow up of our understanding of ground state. In the ground state, if it is a low energy state if the electron is free that means, it has to have high energy, right.

So that means, where does the energy come from right? That means, you can think about it both ways. It has high energy so if it is bound to the if you make it if the electron goes binds it is self to the atom right, reconfigures itself then energy has to be sent out in the process.

So, that it goes to the ground state or if it is in the ground state if you give it some energy then, you can free the electrons. So, that will be the energy that you supply right. So, naturally you are supplying more energy to what was the ground state. So, the electron is going to have a higher energy state. So, free electron is going to have a higher energy than when it is bound to the nucleus.

So, when we talk about the binding energy now what is this binding energy, this is the energy that you need to supply to free the electron right. Energy required to free the electrons that is the binding energy. So, it is not the energy that it is. So, in some sense it is so it is bound to this nucleus you have to supply an energy that is greater than this bounding energy, right that is what is called a binding energy.

So, you have to supply an energy that is greater than the binding energy to free the electron ok. So, that is you are binding energy but then, you look at it from their atomic orbit. So, for a given atom right it might be easier to free the atom, free the electron from the outer orbit, right.

So, the binding energy is not even for a given atom, binding energy is not same for all the electrons in the atom it depends on the shell right. But, for practical purposes in this course right because the we have an application main so, we work with the so in our scale of the energies that we are talking about we do not really care about that detail we will be ok with the average energy, ok.

So, clearly the binding energy depends on the element to which the electron is bound naturally and the shell within which it is residing in the ground state. Both are so I mean so if you have a larger atom right, if you have larger atom then there are more number of protons the nucleus, right.

So, the electrons if in the K shell for example, is going to be more attracted, right you need to spend more energy to release that. It also depends on the shell number. So, the atom and the shell number of the electron both have a role to play in the determining the binding energy. For our purpose we will say on an average what is the binding energy for a given atom ok. So, much for binding energy and this is a very important concept.

So, let us make a you know example first when we talk about energy let us get the units out first and then we will have some feel for what numbers are we talking about with respect to. So, 1 electron volt right, is actually very straightforward electron volt how do we read when you have an electron right it is a energy that we are talking about. So, you have a kinetic energy, so you have an electron, electron is what negatively charged right, e minus negatively charged.

So, if you make this electron travel right. So, I have a voltage drop, voltage drop you have a voltage drop and if you have a voltage drop current flows right. So, that means the electrons move. So, kinetic energy gained by an electron when accelerated across 1 volt potential, that is your 1 electron volt ok.

So, 1 electron volt is so many Joule so this is the energy that we are talking about. So, now, if we define this then all the energy that we are going to talk about binding energy amount of energy you need to supply what causes ionization all of them when we talk about energy you will be able to relate to this units electron volt, right.

So, one electron when it is accelerated over a one volt difference right, what is the kinetic energy ok? So, that is your one electron volt that is going to be your units. So, you know typical energies just so that we complete because we said it depends on the element type. So you look at here, binding energy of typical elements: hydrogen is 13.6 electron volt, air 29 look at here lead, tungsten, kilo electron volt; kilo electron volt.

So, without much detail here just looking at the numbers and a typical atom that we sense where it could be so, where do you see hydrogen, ok. We are water bodies H2O right. So, we have lot of hydrogen's look at the value 13.6 electron volt is the binding energy required for hydrogen right. Whereas, look at lead or tungsten 4 kilo electron volt, naturally they do not have inside us, right.

So, if you are talking about some energy that needs to be provided to free the electrons, to free the electron from hydrogen I need only 13.6 electron volt, right. Whereas, if I supply that

13.6 electron volt or 15 electron volt is nothing lead and tungsten it is in the kilo electron volt, ok.

So, in that sense nothing will happen if I supply some energy 14 K 14 electron volt or 20 electron volts or 100 electron volts to a lead nothing is going to happen, you are not going to be able to free the electrons; whereas, hydrogen requires very small quantity right. So, by mistake if I supply some quantity of energy thinking I want to you know free the electrons in lead, but instead of lead you know human tissue is there then you see the problem. So, many electrons would be freed right, ok.

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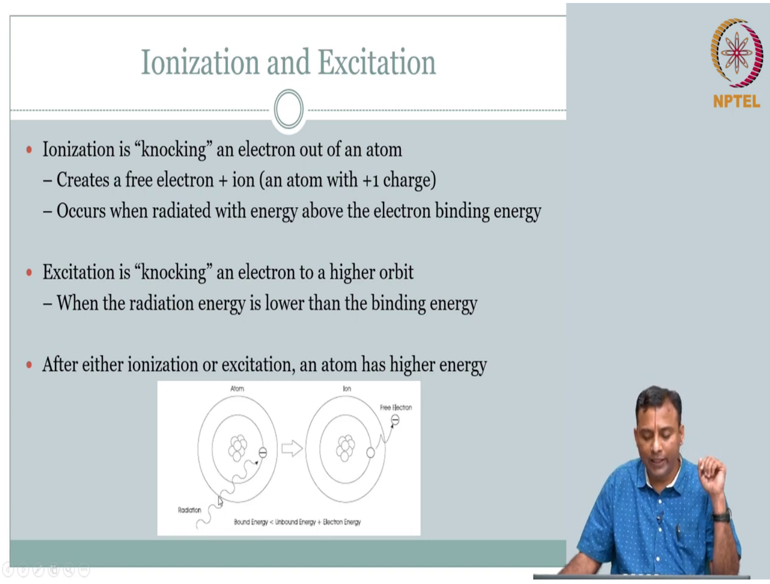

So, we will talk about that in a subsequent slide as well, that is a important concept which you will now ionization and excitation. What is ionization? Or knocking of an electron out of an atom, now you understand we talked about binding energy of a electron. So, that is the energy that I need to supply to free the electron.

Now, what is ionization? Ionization is knocking an electron out of the atom. So, in order to do ionization right in order to knock an electron out of the atom what should I do? I need to supply energy that is greater than the binding energy. So, if I supply an energy that is greater than the binding energy the electron will be kicked out. What happens if the electron is kicked out? Atom is neutral I send energy and kick out the electron then the electron is free and then, the atom will then positive right.

So, you have to you have ions, ions are created right. If I supply energy and knock an electron out then I am creating ions right, e minus and then this one will be plus. So, I have created ions. So, the process of kicking an electron out to form an ion is ionization. So, in order to do ionization, what do you need to do?

I have to supply energy that is greater than the binding energy. So now, you see the problem, right, now you see the problem. The if you do ionization right, you are breaking the stable atom into its ions ok. So, what will happen immediately? So, first it is creates a free electron right plus an ion. So, an atom with a positive charge that is your ion, right.

So, you create a free electron and then there is ion that is why it is ionization ok. When does it happen? Occurs when radiated energy above the electron binding energy. So, when you hit when radiated with energy meaning, you supply energy you subject this atom to an energy that is greater than binding electron binding energy only then ionization takes place, right.

So, what do you mean by excitation? Excitation means like excited you put in some energy right then you are excited, right. You are in a ground state dull, then you infuse some energy you get excited, but that is not detrimental by it is self right. Because, so in some sense you are providing energy here also, so you are making it go away raise above the ground state energy level.

But then, it is not knocking the electron out, if it knocks the electron it is ionization. So, excitation is knocking an electron to a higher orbit not outside the atom to a higher orbit. So, I am putting some energy to pull the electron out. So, from K it is coming to L, it is coming to M, right. In order to completely come out of the atom it needs to come out of all the influence, but I did not provide that much energy, I just provided energy such that it was trying to come out from K, it was coming to M and that is it energy is expanded.

Then, what happens is that from the ground state it is now in an excited state meaning the electrons is occupying the higher orbit. So, left to it is self what it will do. So, when the radiation is lower than the binding energy you just excite, you do not kick it out of the atom or you do not knock it out of the atom.

So, either case if you look at it nature has said that it has to come to ground state ok. So, how does it come to ground state? So, now you have supplied energy, so now, you have a high energy state both the free electron on the ion on the higher energy state, because you supplied some energy.

So, immediately what will happen is the electrons will try to come from the ground state for the atom, likewise if you does kicked up to outer orbit right in case of excitation it will now come back to its lower orbit state, lower energy state. In the process, it will send out the excess energy ok, after either ionization or excitation an atom has higher energy, right.

Now, immediately what it will do? It will try to come back to ground state ok. So, diagrammatically representing that this is your atom, you send some energy so it is called as radiation here right, we will come to that. So, you have radiated with the energy is what so its radiation. So, you are supplying energy. So, the energy that you supply if you have enough energy that is greater than your binding energy, then it kicks out the free electrons so, you have a hole.

So, same thing if it does not kick out the electron in the outside the atom, but if it kicks it into higher orbits then also you will have a hole. So, either excitation or ionization you essentially have higher energy state and there is a hole that is created, because of the electron that is left out or moved out of that shell.

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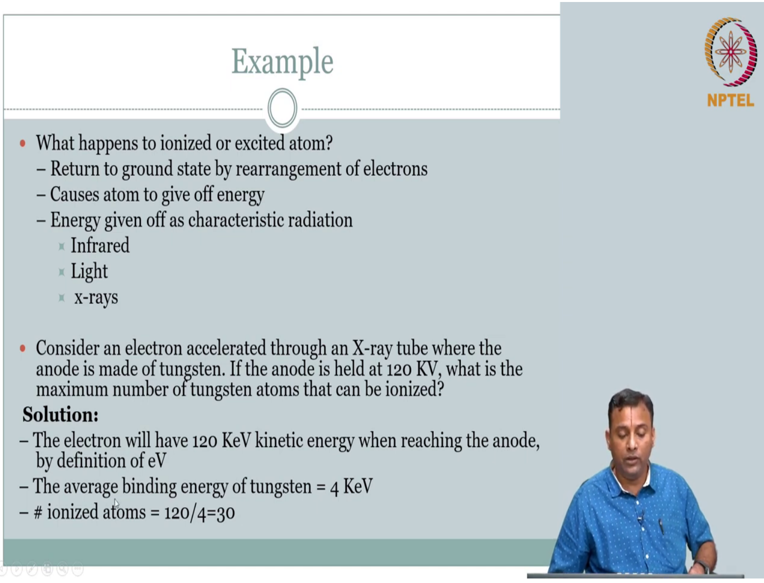

So, now immediately what will happen is, immediately what will happen is it cannot stay in that high energy state it has to come back to ground state, right. So that means, it has to it has now excited that all the energy it went up it has to lose all the energy to come back to ground state or because it has to come to the ground state that is the natures order, in the process of coming to the ground state it has to shed the extra energy right, send out the extra energy.

So, returns to ground state by rearrangement of electrons, why rearrangement right? We talked about when it comes to ground state it so chooses its alignment, it comes to the shell and even within a shell it takes a quantum state that is the lowest configuration that it can and therefore, that is rearrangement.

So, causes the atom to give off energy yeah, it has to give off the energy because there is excess energy. So, when this energy that is given off right, it is called as characteristic radiation and why it is characteristic? Because the energy that comes out is characteristic of so these are all energy if you look at your spectrum that we saw in the introduction class, right.

You had infrared light x rays, visible light x rays, gamma rays right all of them are based on energy. So, we had wavelength, energy axis, remember frequency axis, we had all the three there. So, essentially if you give the energy out and if that energy comes out in one of these that is we call as the characteristic radiation, it is characteristic of the energy gap that it is coming that is making this excess energy come out in this particular wavelengths, ok.

So, that is your characteristic radiation. So, now let us for example, right take a case to just get a feel for a number, you have electron that is accelerated through X ray tube where the anode is made of tungsten ok. So, when I say electron is accelerated that means, I have voltage drop and recall your definition for electron volt. If 1 electron right is accelerated across a one volt potential difference, the kinetic energy acquired is your electron volt remember.

So here it is not 1 volt, it is 120 kilo volts. So, when I have an electron that is accelerated through X ray tube right, where the anode material is given as tungsten and the potential differences 120 kilo volts right. So, what is the maximum number of tungsten atoms that can be ionize. So now, in some sense we are putting all the terminologies together.

So, if you have to answer this question, if you have to answer this question what do you need to know? Binding energy, I need to know the energy that is there that is hitting this tungsten, the kinetic energy that is hitting the tungsten. So, we say energy that is needed and then that energy is obtained from as the kinetic energy of this electron dropped across 120 kilo volts and then, what is asked ionization of tungsten atom.

So then, you will have to know something about the tungsten atoms a characteristic right, what is that binding energy. So, if you know the binding energy of the tungsten then you can quickly calculate and say I know the energy that is being supplied to that tungsten, right. Because, it is 1 electron accelerated across volt 1 volt is the kinetic energy is one electron volt, now it is 120 kilo volts. So, it is 120 kilo electron volt is the energy. That is what the tungsten atom is bombarded with that is what it is radiated with.

Now, if we know the tungsten's binding energy, it is average binding energy of tungsten atom then, I can calculate for 1 electron right 1 electron to leave, 1 atom to be ionized. I need so much binding energy, if I hit with 120 kilo electron volt how many atoms can be ionized, right simple.

So, the electron will be 120 kilo electron volt kinetic energy when it is hitting the anode, when it is reaching the anode. So, anode you have tungsten. So, the average binding energy of tungsten is 4 kilo electron volt which is what we saw in a couple of slides ago right. So, this is there then you can immediately calculate the number of atoms that can be ionized, right. 120 by 4, because it is kilo electron volt and right K gets cancelled. So, you have 30 atoms.

So, you get the feel for what ionization is what energy level are you talking about, remember what is the I so for our purpose what is so this is fine, right. Is this too much or too little? Ok. 30 atoms are ionized right, hitting 120 kilo electron volt. Your ionizing tungsten you are not really worried right now, what will I be worried, what will you be worried, I want to make sure I do not ionize the body that means, relation to hydrogen. So, we are interested in ionization of hydrogen, ok.

So, all the energy we are interested in ionization of hydrogen for all practical. So, here ionization of tungsten is explained because, you have to generate x rays right. So, this will come in X ray tube, ok.

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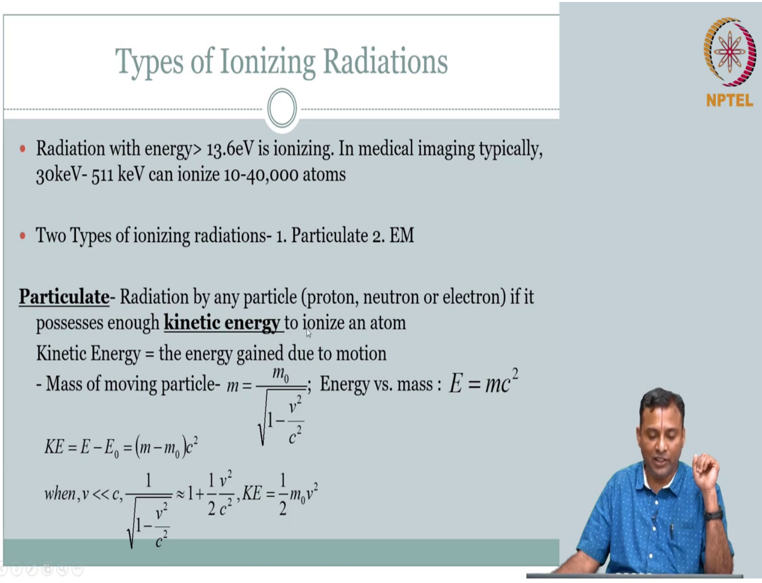

So, for all practical purposes what we will be interested in radiation energy greater than 13.6 electron volt, we will call it ionizing radiation. Because, that is enough to ionize hydrogen, ok. So, clearly what is called what is the energy that is needed for ionization depends on the material that you are talking about. So, 13.6 electron volt cannot ionize tungsten, but it can ionize our hydrogen, which is what we are composed of right, lot of hydrogen.

So, for our purpose any energy that you radiate the body with which can which is greater than 13.6 which is the binding energy of hydrogen, which is ionization of which can cause ionization of hydrogen is ionization for us. It is we need to call it as ionizing radiation, clear.

So, in medical imaging we employ x rays right, ionizing radiations we talked about first is X ray base. So, X ray energy in this range right 30, 40, 60 if it goes out, it can ionize so many atoms for hydrogen right, because its only 13.6 here you have kilo electron. So, you can actually go thousands of atoms can be ionized, clear. So, that is important.

So, that is the radiation ionizing radiation when we call when we talked about in you know medical imaging, when we talked about bio safety we said radiation in fact, we will cover radiation dosimetry in the end, alright. So, when we talk about ionizing radiation with respect to human body, we are interested in ionization of hydrogen, the electron binding energy of hydrogen is 13.6. So, anything greater than this has a potential to ionize human body ok, so, that we will keep in mind.

So, now the question is how do you cause ionization? I mean, so that you do not want to cause ionization let me let me not phrase it that way. How much radiation you need to give right, how do you give, these are two aspects? So, if I want to generate in the X ray tube example that we saw, we wanted to create ionization why? Because ionization itself is not an issue. After ionization what will happen? It will try to go back to its ground state and therefore give out energy in a certain characteristic range, right.

So, when the tungsten in the previous example is bombarded. So, many atoms are ionized, then what will happen? It will the atoms will try to go back to its ground state, thereby it will give out energy and that energy comes out in the X ray range that is why its X ray tube right. So, it will give out energy and that energy that comes out is in the X ray range.

So, in some sense you are creating X ray energy and in the modality what we want to do? We want to use that as a probing signal we want to send X ray energy through the body right and then, make use of it. See, how it interacts with the body and so detect whatever is coming through on the other side. So, in some sense the we are talking about through transmission. So, you are sending X ray energy through the body what comes out on the other side, it is through the body through transmission.

So in fact, in some sense in the gamma also that is what we do. The radiotracer is going, the energy radioactivity energy is coming in at different ranges say gamma energy, but it is essentially the energy that is coming out, but it is coming out from inside to outside through the body it is coming, through the tissue it is coming. So, in this case in the first part X ray imaging we send the X ray generate the x rays outside send it through the body and collect it outside through the when it leaves the exits the body, correct.

So, in some sense you can have two types of ionizing radiations one is, you can already we saw particulate, what is particulate? Particles what are the particles in atom that we are in one example we already saw, electrons protons right. So, how can I use a particle for ionizing radiation, just now we saw a electron which is a particle if you give voltage drop it gains kinetic energy bombards on tungsten ionizes it and once the after ionization when it gets back the atom tries to go to its ground state, it releases X ray energy.

So, you can create ionization using particulate or you can use electromagnetic radiation. So, there are two types of radiations. Here again you will notice what is an example of electromagnetic radiation? I kind of said it. So, what happens in the X ray tube, we said after the x rays are generated that X ray has to go through the body, that X ray is just the energy, right X ray energy its energy packets.

So, it is a electromagnetic radiation. So, the electromagnetic radiation is sent through the body and that energy if again is greater than your binding energy of your hydrogen's we call it ionizing. So, you can cause ionization by two types of radiations, one is particulate, the other is electromagnetic.

Particulate will be exploited in the instrument to generate source of energy whereas, electromagnetic radiation is going to interact with your tissue or cause radiation ionizing radiation right, it is going to cause ionization through the tissue ok. So, particulate is any particle proton, neutron or electron if it possesses enough kinetic energy that is what it is ok.

So, yes you can actually also create a charged particle and direct that particle through your body right, you can do that. But, typically in the example that we saw, we already saw that particulate radiation was exploited in the X ray tube. So kinetic energy, what is the kinetic energy?

Kinetic energy is due to the motion right, it came so it has a mass and it is moving. So, you can in some sense we will have to talk about the mass of the moving particle. Mostly we use we do not take consider to speed of light, right. The velocity is very negligible then the relativity theory does not mean much. Whereas, these particles electrons upon a (Refer Time: 49:06) can be actually moving at a velocity that the fractions of c ok.

And therefore, we will have to get the mass not just as the rest mass, but because of the velocity it has a relativity, relative mass. So, mass of this moving particle is m naught which is the rest of the state of the mass, but if it is accelerated it moves with the velocity v, which is a reasonable fraction of c.

Then, we will have to use m the rest mass so, the velocity increases the mass also increases right. The velocity is 0 or very insignificant compared to c then, m is equal to m naught that is your rest mass ok. So, why is mass important because, energy and mass are related by E is equal to mc square clear.

So, this is the energy we are interested in the kinetic energy. So, what is kinetic energy? Kinetic energy is you have rest state some energy because of velocity or moving acceleration you have some other. So, the kinetic energy is the difference between these two right. So, kinetic energy is E minus E naught.

So, quickly you can substitute E is equal to mc square so, m minus m naught c square. If v is negligible then it comes down to your typical KE which is half mv square or half m naught v square ok. So, that is your particulate radiation. So we will actually stop here, we will continue forward because, we have now covered the two types of radiations and we started with what is particulate and where does it get the energy.

What we need to still do is, understand what how you know what are the typical interactions of this radiation with the material likewise, then we will introduce electromagnetic radiation and what are the types of interaction of this electromagnetic radiation with the material.

If we cover that, that is a huge step of the underlying remember, underlying what in X ray projection radiography or X ray ct we are interested in catching the attenuation property of the tissue to the X ray energy. So, if we cover the what do we mean by these and how ionizing radiation and how does it interact if we cover that we are getting our clues as to what our potential signal is right. So, we will stop here we will continue forward with this material in the next lecture.

Thank you.