**Fundamentals of Nuclear Power Generation**
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**Module - 01**
**Lecture – 02**
# Building Energy and Mass Defect

Hello everyone and welcome back to this MOOCs course entitled fundamentals of nuclear power generation. Now, today we are in to the second lecture of module 1, where we are discussing about the very fundamentals of this course. We are just preparing the backdrop to the course through some kind of informal discussions.

I hope you enjoyed the previous lecture, where we had just to general talk about the introduction to the topic of nuclear power. We discussed about the global and national energy scenarios through some projections and stats and thereby started tried to establish the importance of nuclear power in context of the present day energy demand and also considering the depleting reserve of fossil fuels and then, we also discussed a bit about the historical development of a nuclear power.

Today we shall be trying to enter a bit to the technical details and there by complete this particular module, so that we can move forward to more inverted chapters. Just a brief summary of whatever we did in the previous lecture.

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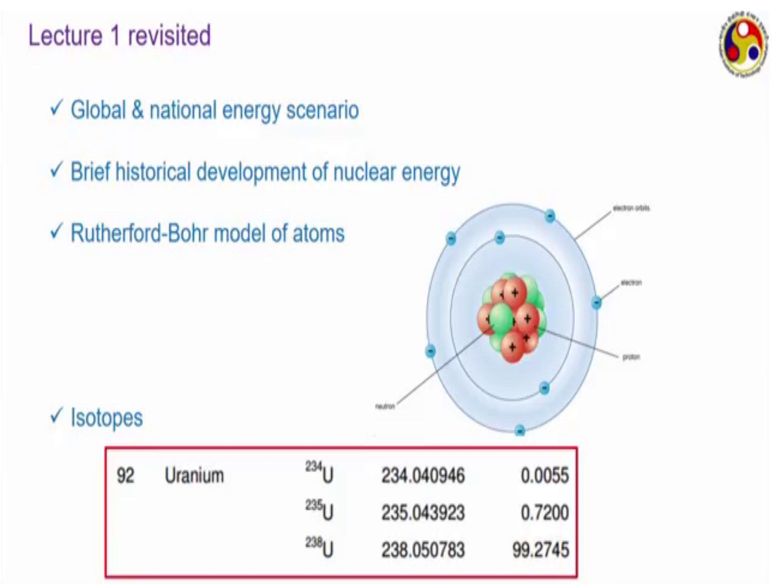

We had a discussion on the global and national energy scenarios and we briefly discussed about the historical development by mentioning the works by some of the eminent scientists and then we discussed the Rutherford-Bohr model of atoms, which is quite similar to the solar system having a heavy nucleus at the center and tiny electrons moving around that in the orbits. Now the, well there are possibility of having several kinds of sub atomic particles at the nucleus, but for the purpose of this course we are considering only 2 kinds of particles in the nucleus 1 is the proton which is positively charged and other is neutron which is having more or less the similar mass of proton, but it is electrically neutral.

The electrons are having the same amount of charge as the proton, but it is of opposite sense and it is mass is extremely small compared to that mass of proton and neutron and we also discussed the very important concept of isotopes. So, from that, we know that it is possible to have for any natural element to have different kinds of nucleus, where the atomic number remains the same; that is the total number of protons inside the nucleus is the same, but their mass number varies because they may be having different number of neutrons and as the atomic number that is the number of protons reside the chemical properties, so different isotopes of the same element, more or less have the same kind of chemical nature , but the nuclear properties depends strongly on the number of neutrons and the basically on the mass number.

So, different isotopes of the same element may have different kind of reactions or response to nuclear reactions. Like, for example, for uranium which is probably the element that you are going to discuss the most in this course has 3 natural elements or 3 natural isotopes I should say. Out of them uranium 235 give is the one, which is the most common nuclear fuel that is used worldwide. It is strongly reactive to the nuclear reactions. So, it has strong nuclear behavior, but the 2 other isotopes u 234 and u 238, hardly has any kind of a nuclear related behavior, we shall discuss in more detail on that.

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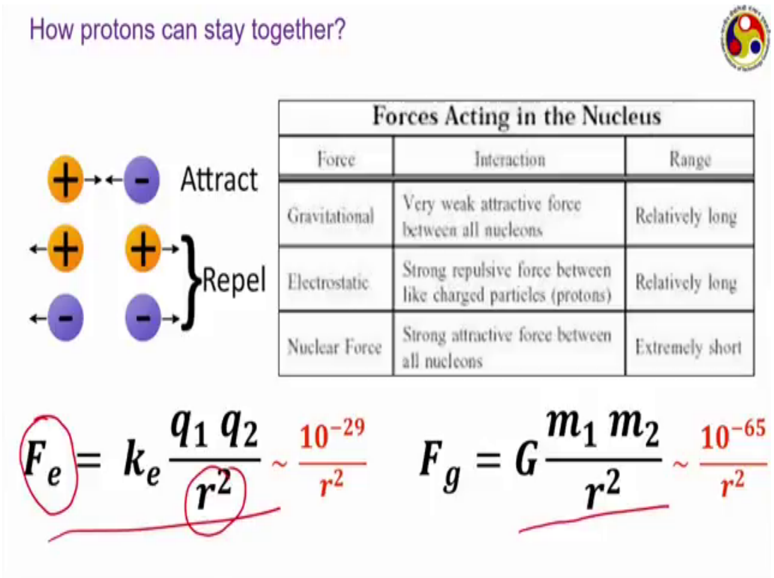


Now, the question with which we have to start today discussion is how such heavy amount of mass can stay in a small volume inside the nucleus. From our previous discussion we know that, inside an atom the most of the space is actually void because when the radius of an atom can be of the order of 10 to the power minus 9 to minus 11 meter that of a nucleus is typically of the order of 10 to the power minus 16 meter and that entire amount of voice (Refer Time: 04:22) occur only by tiny electrons.

So, we can think about an atom, where almost all the mass are basically lumped into the nucleus in an extremely small volume, but from electrostatic, so we know that opposite charges attract each other, whereas like charges are repel each other and amount of or magnitude of such abstraction or repulsion force can be given by the coulombs law of electrostatic attraction or electrostatic repulsion. Just this one, where q 1 and q 2 are the charges of the 2 particles that we are talking about and r refers to the distance between this 2 particles and k is the coulombs constant. When you are talking about the repulsive force between 2 protons q 1, q 2 both of them are equal and the magnitude is 1.602 into 10 to the power of minus 19 coulomb, as I had mentioned in the previous lecture.

Now, when you talk about any nucleus, particularly those of heavier kind, there are several protons present inside the nucleus and all of them are facing this repulsive force because of the presence of other neighboring protons. Neutrons are electrically neutral and therefore, they have electrostatic attraction towards the proton. So, it can understood that, neutrons stay in contact with the protons.

Electrons are oppositely charged to protons, but they are orbiting around the nucleus and therefore corresponding centrifugal force repulse their attraction towards the nucleus and that allows a electrons to stay in the orbits and not jump back to the nucleus, but it is very difficult to understand how protons can stay there. Just think about uranium, uranium is the heaviest naturally occurring nucleus and it has 92 protons inside it is nucleus.

Now, therefore, each of those protons are facing strong repulsion from all the neighboring 91 protons and that can have huge magnitude, particularly when you consider this r that we are talking about here, is of the order of 10 to the power minus 16 meter. So, the magnitude of the corresponding repulsive force can be huge. That means, there has to be some kind of attractive force, which keeps the nucleus together, keeps all those nucleons together inside very, very small volume.

Then, let us check what can be the possible forces that can be present inside the nucleus. Gravity we can definitely be there, whenever you are talking about mass, gravitational attraction is there. Now, to calculate the magnitude of gravity we need to take the help from neutrons laws of gravitation, which is given by this particular form. Here m 1 and m 2 are the mass of the 2 particles that you are talking about and r is the same the distance between this 2 particles.

Now, when we put this particular relation for protons and also compare that with the amount of repulsive force calculated using the coulombs relation, then it can be seen that while for any given value of r, while the magnitude of the repulsive force is of the order of 10 to the power of minus 29, the magnitude of the corresponding gravitation attraction can be more than 10 to the power 30 times lower. So, gravity definitely is negligible or the presence of gravitational attraction can safely be neglected, whenever we are talking about the nucleus and associated calculations.

Electrostatic repulsion, we are talking about that one only. Then, there has to have some kind of nuclear force, which opposes this electrostatic repulsion and keeps the nucleons together. That is expected to be a short range force, while gravitational electrostatic forces are long range that means, they act over longer distance, this expected nuclear force has to be a short range one. So, that it is influence is limited, only inside the nucleus and it must be strong enough to oppose the electrostatic repulsion and that is where the concept of binding energy comes into the picture.

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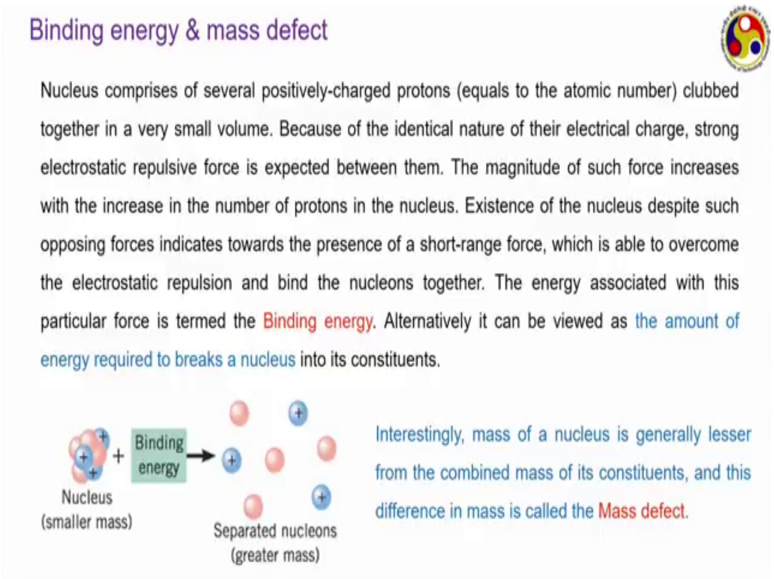


Just to repeat what I have mentioned, in a very small volume of the nucleus we have several strongly charged or positively charged protons clubbed together and therefore, they are expecting strong repulsive force.

Still despite such kind of opposing effect, the existence of the nucleus hints towards the presence of a short range force which is able to overcome this electrostatic repulsion and keep the nucleons together. This particular force is often called the binding force and the energy associated with this is called the binding energy. I repeat, binding force is a force which keeps the nucleons together by opposing the repulsive nature of the proton to proton interaction and the energy associated with this binding force is called the binding energy.

Alternatively, it can be also be viewed as the amount of energy required to break a nucleus into it is constituents. Like, when we have a nucleus and we want to break it, we have supply at least the binding energy so that it is able to break the bonds between the nucleons and break apart into the nucleons or separate sub atomic particles. So, the concept of binding energy is probably the most important one to understand the origin of the nuclear energy.

Now, the nature of the binding energy need to be discussed from the point of view of physics, there are several theories existing in nuclear physics, some of them talk about the exchange of quarks between protons and neutrons, some of them talk about the role of fermions and bosons, but here in this course as you are looking more from engineering point of view, we are not going to enter any kind of details about the nature of binding energy, rather we are just going to take it as the amount of energy associated with the formation of nucleus or the energy that is essential to give the nucleons together in a very small volume.

Now, by providing binding energy or higher amount of energy, if we are able break a nucleus into it is constituents, the most interesting thing to observe is that the combine mass of all this components actually exceeds the mass of the original nucleus itself and that difference is called mass defect. It is really fascinating to think about that, the nucleus which are forming a nucleus their combine mass is greater than the nucleus itself. This mass defect is actually the source of the nuclear energy.

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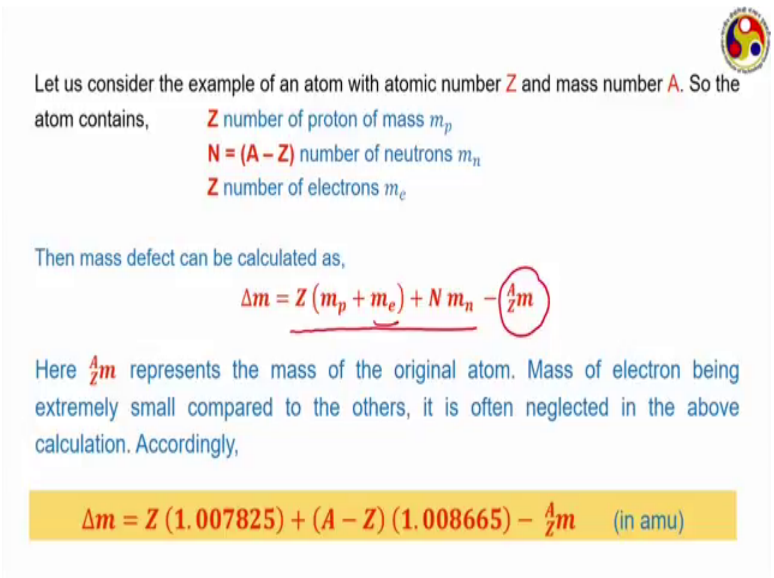


Let us consider an example, let us see we have an atom which is having an atomic number of Z and mass number of A. Therefore, atomic number, represent the number of protons, so this particular atom consider of Z number of protons and also Z number of electrons to keep it electrically neutral and also it is having A minus Z number of neutrons, let us say capital N represent the number of neurons.

So, mass defect can be represented as the difference in mass of the constituents, which is this particular 1 and the mass of the original nucleus. Here, the mass of the electron, that means, this mass is generally, extremely negligible compared to the mass of proton and neutron. If you refer to the value that I presented in the previous lecture, the mass of electron is at least 10 to the power 4 times lower than that of protons and neutrons and therefore, while calculating this mass defect and associated quantities, the mass of electron is quite of a neglected.

Accordingly, by putting the mass of proton and neutron, we can get this particular mathematical relation for mass defect, in terms of amu's, where we have delta m equal to 1.007825, which is the mass of proton into the number of protons plus 1.008665 which is a mass of neutrons into the number of neutrons minus the original mass of the nucleus itself, which can generally be obtained from mass spectrography or some associated techniques.

This particular energy associated with such mass defect is called the binding energy, which I mentioned earlier. You can think about just going back to the previous slides, whenever we are coupling some of the sub atomic particles that is some of the nucleons together to form a nucleus, then it seems that some of the amount of mass is lost because the mass of the new fully formed nucleus is less than the combined mass of it is nucleons and if we can convert this missing amount of mass to equivalent amount of energy, then we can think that energy as some kind of blue which is binding the nucleons together and that is what we refer as the binding energy.

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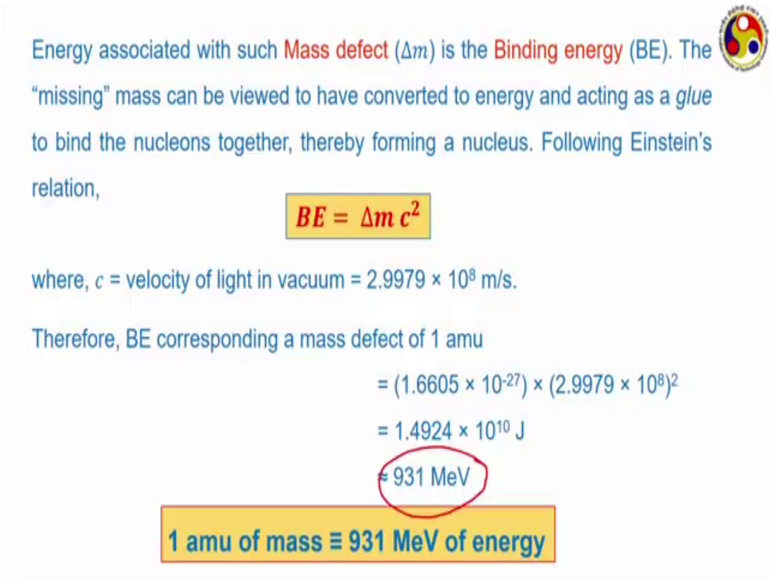


Following the Einstein's relation, this binding energy hence can be represented as at the product of the mass defect and c square where c is the velocity of light in vacuum and it is as per present standard is magnitude is 2.9979 it tend to be about 8 meter per second.

So, delta m is the mass defect and once we multiply that it c square, then we can get the equivalent amount of energy. Therefore, binding energy if we use delta m equal to 1 amu and put the numbers in the earlier relation, then we get the binding energy corresponding to a mass defect of 1 amu is equal to 931 MeV or we can safely say that 1 amu of mass or 1 amu of mass defect is equivalent to 931 MeV amount of energy, that means, whenever a few nucleons have combined together to form a nucleus, if the difference in the mass between the constituents and the final product is equal to 1 amu, then that particular nuclear reaction will be associated with an energy releases of 931 MeV.

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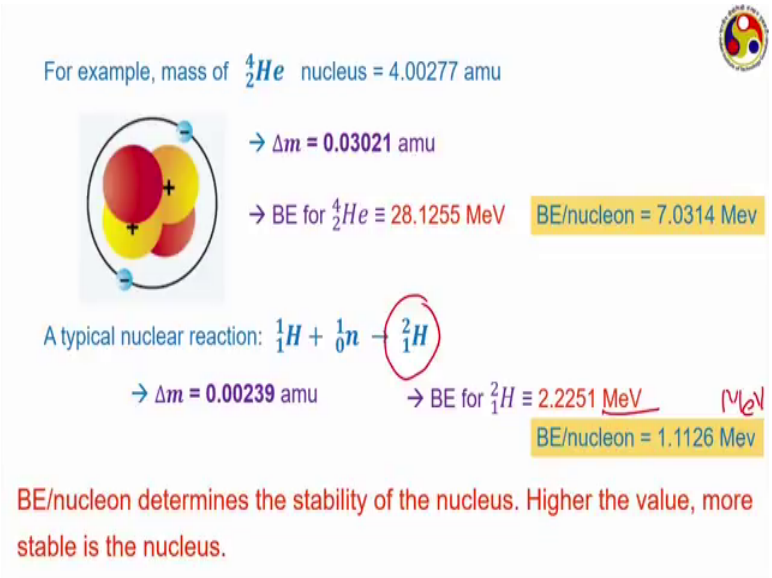


Let us take couple of examples; first we have the example of n helium isotope, the common helium isotope 2 H e 4. So, from the symbols we can say that it is having an atomic number of 2 and mass number of 4. That means, this nucleus is having 2 number of protons and 2 number of neutrons in it is nucleus. Now, the mass of this one is 4.00277 amu, which is a measured value and then from here or from this particular value, if we compare this with the mass of 2 protons and 2 neutrons kept separately, then that will be associated with the merge defect of 0.03021 amu and a binding energy of 28.1255 MeV.

That means, if we want to break apart 1 helium isotope; a common helium isotope, then we have to supply at least 28.1255 MeV of energy and then only we shall be able to separate out this 4 nucleons. Let us compare or study the situation of another typical nuclear reaction; we do not need to understand, how this reaction is happening. Just see, what we have here, we have the common helium hydrogen isotope 1 H 1. You know, that the common hydrogen nucleus consists of only a single proton and therefore, it is mass number and atomic number they are same.

So, this common hydrogen nucleus is absorbing 1 neutron leading to the formation of 1 deuterium. This deuterium is having 1 proton and now 1 neutron, therefore, it is atomic number remains one, but mass number is now 2. If we put the major mass of hydrogen and deuterium here and also we put the information about the mass of neutron, then this particular nuclear reaction you associated with the mass defect of 0.00239 amu and a binding energy of amount 2.2251 MeV.

So, if we want to break this deuterium, we need to supply this 2.251 MeV amount of energy. Of course, this number is smaller compare to the example of helium above, but still we need to supply this amount energy. This way, we can calculate the binding energy associated with the formation of any particular nucleus, just by measuring the mass of that particular nucleus and using the information about the concerned number of protons and neutrons.

As the number of nucleus go keeps in increasing inside a nucleus, the binding energy for that nucleus also keeps on growing, mass defect corresponding to the formation of that particular nucleus keeps on increasing and therefore, it becomes very difficult to compare lighter and heavier isotopes. Like the binding energy associated with helium is written here on this slides. We cannot compare that with the binding energy associated with uranium 235 because, while helium is having only 4 nucleons in it is nucleus, uranium is having to 235 nucleons and therefore, that binding energy of that uranium 235 has to be much higher, compare to this helium, but another measure is found to be extremely important and extremely useful in this context, that is binding energy per nucleon.

We can calculate binding energy per nucleon by dividing the binding magnitude with the number of nucleons presents in that particular nucleus. Like in case of helium, we are dividing this 28.1255 by 4 and so we are getting a binding energy per nucleon as 7.0314 Mev, whereas in case of deuterium, we are dividing this magnitude by 2 because there are only 2 nucleons and therefore, we are getting the value as 1.1126. I am having a mistake on this slide, please ignore that or correct that, the symbol for MeV should have V in capital. So, correct symbol is M small e V, this is the correct one, this 2 are not correct, V refers to the volt and that has to be in capital.

But this binding energy per nucleon is extremely important from the stability of nucleus point of view; it has been observed that higher the value of binding energy per nucleon more stable is the nucleus. That means, to break apart even a single nucleon from that nucleus, we have to supply even higher amount of energy and this way the binding energy per nucleon value has been measured by scientist for different kinds of nucleus and we get this particular graph which is very common, you will get this one in any text books, more or less the similar version of this one and also you can get this one over internet, where we have the mass number on the horizontal axis and the binding energy per nucleon on a vertical axis.

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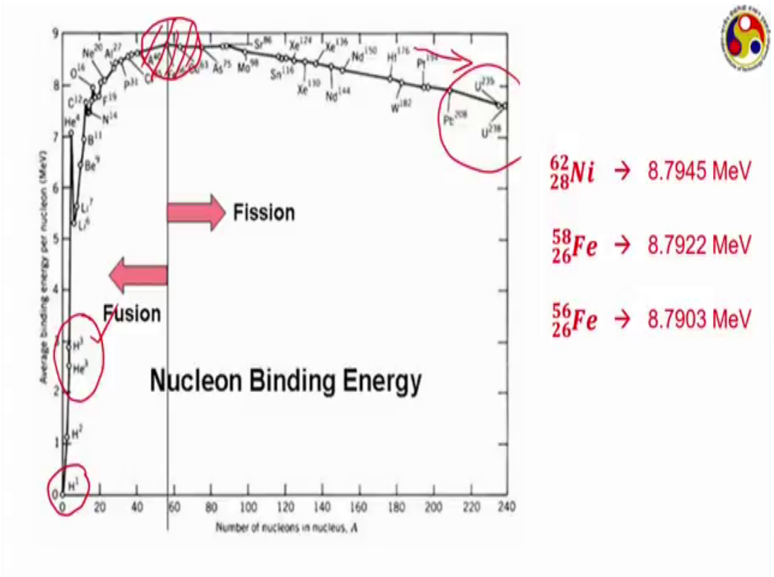


Now, if we start with the lightest possible element that is hydrogen having a mass number of 1. Can you guess, what is the binding energy per nucleon for a common hydrogen atom or hydrogen nucleus? How many nucleons are there? For a hydrogen there is only a single nucleon, that is an hydrogen nucleus consist of only a single proton. So, as there is no other proton, it does not face a kind of recursive force and therefore, it does need any kind of binding energy. Therefore, binding energy per nucleon for common hydrogen is equal to 0, but this value of binding energy per nucleon keeps on increasing as we increase the number of nucleons or the mass number increases and this keeps on growing and reaches a maxima around this zone of mass number of 56, 58, 60 and then it keeps on coming down steadily.

So, the largest value of binding energy per nucleon corresponds to a mass number of around 60. It has been found that among the naturally occurring isotopes, nickel 62 is the one, which is having the highest value of binding energy per nucleon 8.7945 MeV, 2 isotopes of irons are also not far behind iron 58 and iron 56, their values are also very, very close . So, this, particular group of isotopes, which generally corresponds to iron, nickel, cobalt etcetera, which are having mass number around 60, are characterized by the highest possible binding energy per nucleon and therefore, they are the most stable nucleus, that we can have form nuclei reaction point of view.

The nucleus which are having mass number far away from this particular zone, they generally have binding energy per nucleon value much lower than this highest value of approximately 8.8 and hence they are more unstable. The far we move away from this particular zone, we get more unstable nucleus like, when we move towards this particular direction, mass number increases and binding energy per nucleon keeps on coming down and hence the elements are more nuclearly responsive, particular the elements in these zone uranium 235 and as the neighboring nucleus they are strongly radioactive because their binding energy per nucleon is significantly lower compare to this.

The same situation is also prevailing for lighter elements, like the deuterium, tritium helium 3 etcetera. They also having very, very low binding energy and therefore or I should say binding energy per nucleon and therefore, they are also strongly radioactive. Generally, any isotope wants to be at a state which gives us the largest amount of stability and maximum amount of stability from nuclear reaction point of view and therefore, it would like to have its binding energy nucleon value as high as possible, that means, any nucleus whatever may be it is mass number, once to undergo some kind of nuclear reaction, which allows it to move towards this particular band of a binding energy per nucleon, which is around and mass number of 16.

Now, a nucleus which is heavier that is something which is having a mass much higher than 60, the only way it can move towards the direction is by getting broken into 2 species, that means, 1 heavier nucleus, I mean being broken into 2 smaller or lighter nucleus. So, that each of the newly produced nucleus can have a mass number close to 60. On the contrary, the nucleus which are lighter that is something in this particular zone, the only way they can approach that largest stability zone is by combing with another lighter element. So, that 2 light elements combining to a heavier element and the heavier element is having a mass number, close to that zone of higher stability.

Accordingly we get 2 principle kinds of nuclei reaction, one is the fission. Fission corresponds to the breakup of on heavy nucleus into 2 lighter or smaller counterpart and therefore, elements which are having mass number higher than 60, generally quite higher than 60 well, beyond that value. They undergo this fission kind of reaction, whereas the elements which are having mass number much lower than 60, they go throw the fusion reaction. Fusion refers to 2 lighter nucleus combining together to form a heavier nucleus.

Therefore deuterium, tritium, helium 3 etcetera this lighter nucleus are mostly likely to undergo fusion kind of reaction and the entire science of nuclear power generation is based upon controlling this fission and fusion reaction, while fission is the option that is exercised in any commercial nuclear power plant. Fusion probably is a technology which is more prospective because fusion is proposed to generate even higher amount of energy or much larger power density compared to fission, but fusion is an technology which requires much larger amount of control compare to fission and present day scientist are yet to have complete control and this particular technology.

Fission however, has gone through several phases or experiments and it is possible to control the fusion reaction, so that we can harness the positive effect of nuclei energy through this fusion reaction.

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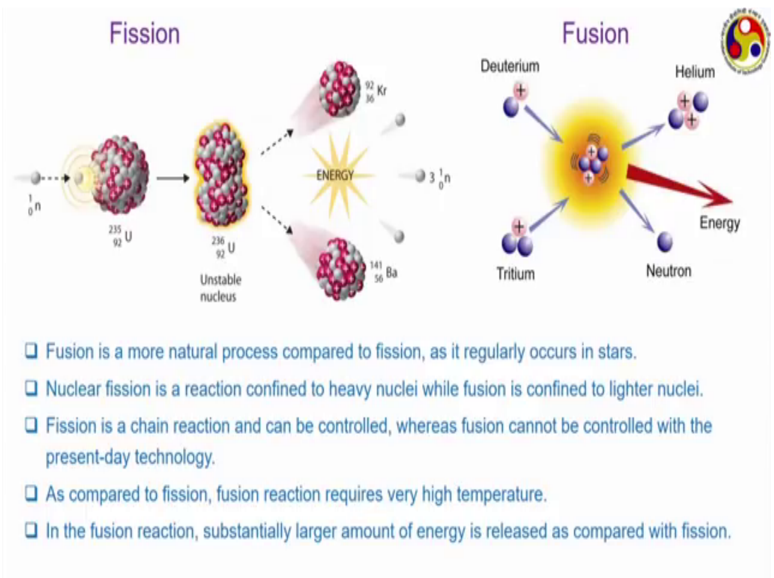


These are the 2 examples that I just refer to one is fission, where we are having in this particular example we having u 235, which is getting broken into 2 lighter components, krypton having a mass number of 92 and barium having a the mass number of 141.

So, this is the fusion reaction, where a heavy nucleus is getting broken in to 2 smaller lighter nuclei. The other side, that is right hand side of your screen we are having the fusion reaction, where in this particular example we have a deuterium and a tritium getting fused together to produce a helium nucleus, which is having a higher mass number and therefore, it is expected to have higher binding energy per nucleon.

Fusion is a more natural process because that you can regularly find in extra terrestrial bodies like the stars, but fission is a reaction which is confined to heavy nucleus and the chain reaction or fission reaction can be controlled as per the present technology. However, we are not in a position to control the fusion reaction, one big problem with fusion is, it requires very high temperature and several other extreme parameters. Research is on and hopefully shall be able to capture the fusion reaction at (Refer Time: 26:28) scale in future.

In the fission reactions substantial larger amount of energy is also released compared to fission because associated elements are much lighter in mass. Just compare the mass of uranium, which is having a mass number of 235 to that of a deuterium, or tritium which are having mass number of 2 or 3 respectively and therefore, fusion gives substantially larger amount of energy release.

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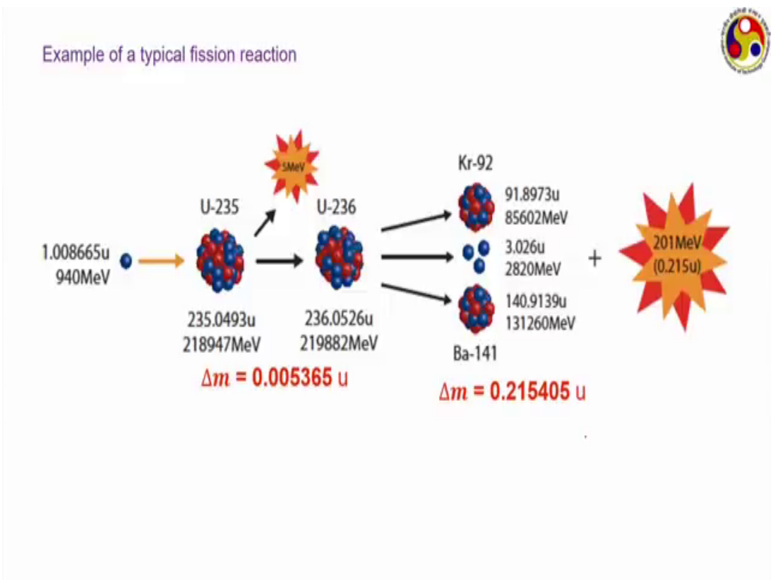

Here we are going in a example of typical fission reaction. Do not need to go the questions like why it is happening or how it is happening, let us just observe the number that you are having.

Here we can see 1 u 235 nucleus is being stopped by 1 particular neutron, because of this they get converted to and U to 36, you can think that the neutron has been swallowed by this U 235, giving rise to a U 236 nucleus and this particular reaction is associated with release of energy amounting 5 MeV, this U 236 is generally a very unstable nucleus.

So, it further goes through a fission reaction, where it gets broken into 2 smaller components one is krypton, having a mass number of 92, other is barium having a mass number of 141. You can see the first stage on the reaction corresponds to the mass deficit or mass defect of 0.005365, you can calculate this number just by seeing the amu values that is present beside each of this nucleus. Like for neutron 1.008665, whereas for the U 235 it is 235.0493 and same way we can calculate for others.

So, this mass defect of 0.05 amu, during the first stage of the reaction corresponds to approximately 5 MeV of energy. So, 5 MeV of energy will be released during the first stage. The same we can calculate the merge defect for the second stage, where U 236 gets broken into krypton and barium and corresponding merge defective value can be calculate as 0.2154 U, which is associated with an energy, that means, if you multiply this one with 931, we get an energy release amounting 201 MeV.

Commonly the fission of 1 U 235, is associated with release of about 212 MeV of energy. Well, combining the figure shown here, we are getting only 206, but the final product that are shown here are krypton and barium they are actually not the final products because you can see particularly for barium, it is mass member is 140, which is far off from this optimum value of 60. Therefore, it is likely that, the product here krypton and barium may go through some further nuclear reactions, there by releasing some more amount of energy and finally getting converted to even lighter nucleus.

So, combining all this energy release from the direct reaction or later decay by the products here, we generally get approximately 212 MeV of energy by fission reaction of 1 U 235 molecule.

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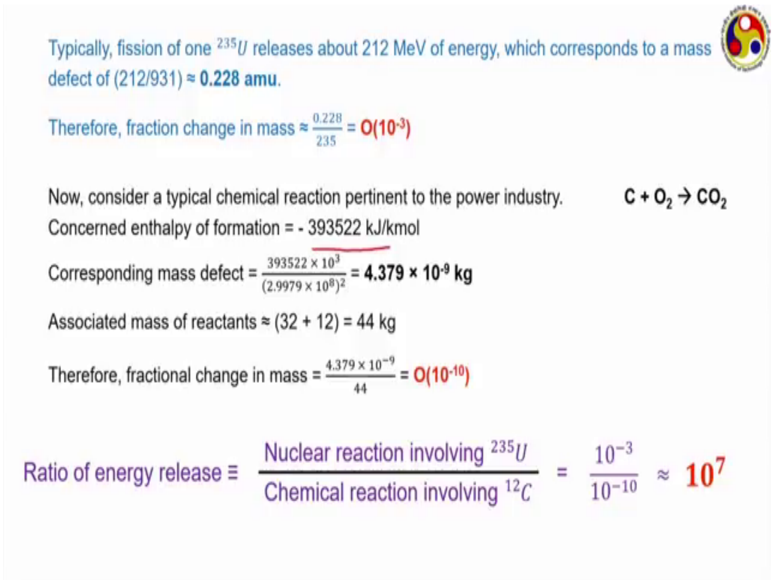


Typically, fission of 1, 235 releases 212 MeV of energy, which are just mentioned. If we divide this value by 931, we get corresponding mass defect as 0.228 amu. Therefore, fractional change in mass is 0.228 divided by the atomic mass of uranium and it comes out to be of the order of 10 to the power of minus 3.

Now, we compare this with a conventional chemical reaction. Carbon is getting oxidized and resulting in CO 2 or carbon dioxide. Concerned enthalpy of formation value is shown here, if this enthalpy of formation probably a (Refer Time: 30:21) thermos dynamics. This is associated with amount of energy released or amount of chemical energy that gets converted with thermal energy because of the combustion reaction of 1 kilo mole of reactants, that is the combine number of moles of carbon and oxygen together has to be 1 kilo mole, then we are going to get this amount of energy release.

Corresponding mass defect hence can be calculated by dividing this figure with C square and it comes out to be order of 0 minus 9 kg, but associated mass of reactants that is 1 mole of reactants, will be associated with approximately 12 for oxygen and 32 for carbon to therefore, 42 kgs of reactants and hence the fractional change in mass comes out to be of the order of 10 to the power minus 10.

This is a very, very important figure or this numbers here are very important to understand the importance of nuclear reaction. There are 2 points to note. Firstly, with chemical reaction we are seeing a mass defect of 10 to the power minus 10 amu. In therefore, we can understand that whenever we are having any kind of chemical reaction, there is some amount of mass defect that goes on between reactants and products and that amount of mass defect gets converted to energy, which we can see at the manifestation during an exothermic chemical reaction, but corresponding value of this mass defect is coming out to be order of 10 to the power minus 10, which is extremely negligible compare to the total mass of the reactants participating in the reaction and hence is often neglected.

So, in conventional chemical reaction during analysis I always keep mass and energy as 2 separate quantities and hardly considered their equivalence, but when you consider this figure with the figure presented above for nuclear the ratio of energy release for nuclear and chemical reaction, there is nuclear reaction involving U 235 and chemical reaction involving U C 12, that is of the order of 10 to the power 7.

That means, the amount of energy that you are going to get by the combustion of 1 kg of carbon plus oxygen. We are going to get 10 to the power 7 times that energy by allowing a nuclear reaction for 1 kg of U 235. That is the most significant factor for nuclear power generation, you probably can remember that during previous lecture while detailing the merits and demerits of nuclear reactions or nuclear power generation I mentioned about a point of higher energy density, this is the point that I was referring to that time.

Energy density refers to the amount of energy that you can harness from some unit quantity or unit mass of the fuel and as you can see here that the energy density of a nuclear reactor will be 10 to the power 7 times of that with a conventional chemical reactor or conventional thermal boiler. That is the principle reason of people focusing on nuclear reaction as the next source of energy generation and because of such higher energy density we can get reactor course to be of much smaller in volume, that way saving more space and sometime of fabrication cost as well.

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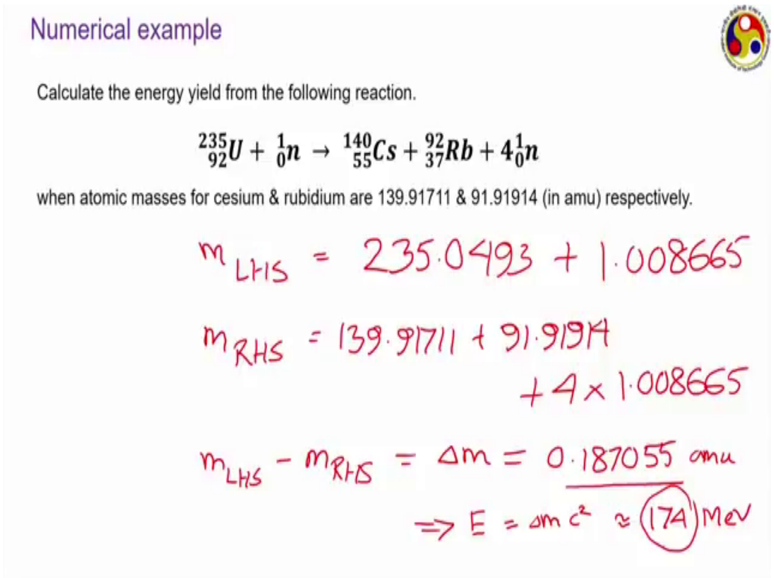


Here, let us try one numerical example, I have taken a sample reaction, where uranium 235 is being stuck by a neutron, leading to the formation of cesium and rubidium and also 4 further neutrons are released during the reaction.

So, let us try to solve this, the atomic mass of cesium and rubidiums are already available here, we know that the mass of U 235 it was present in 1 of the earliest slides, it is 235.0493 amu. So, the mass on the left hand side, U will be equal to the mass of the uranium 235.0493 plus the mass of the neutron, which is 1.008665 all in amus. Mass on the right hand side will be equal to mass of cesium which is given above 139.91711 plus mass of rubidium 91.91914 plus mass of 4 neutrons 1.008665.

So, if we compare this 2 figures, you will find that the mass of left hand side minus mass of right hand side, which we are calling the mass defect is equal to I have chopped out this number, it is equal to 0.187055 amu, correspondingly amount of energy released will be delta m into c square which is equivalent 174 MeV.

So, we can see here that, this particular reaction leads to the formation of 174 MeV of energy, there are several kinds of nuclear reaction possible and ensure just a following this mass valance you will be able to calculate the amount of mass defect that we are encountering and where remembering the relation the conversion of mass to energy that is E equal to m c square or by remembering the equivalence 1 amu mass is equal to 931 MeV of energy. Here, this particular mass value can just be multiplied with 931 to arrive at this particular figure, we do not need to multiply this 6 by 6 square and get the conversion done.

So, we can always solve any such kind of problem, yes. So, this prepares the background for this course and this leads us to the end of this particular module. I am going to summarize the key point that we have learnt here, you are after getting introduced to the topic of nuclear power generation, we have learned about the concepts of isotopes and we have seen that most of the natural elements can have several isotopes because of the presence of the different number of neutrons and the nucleus.

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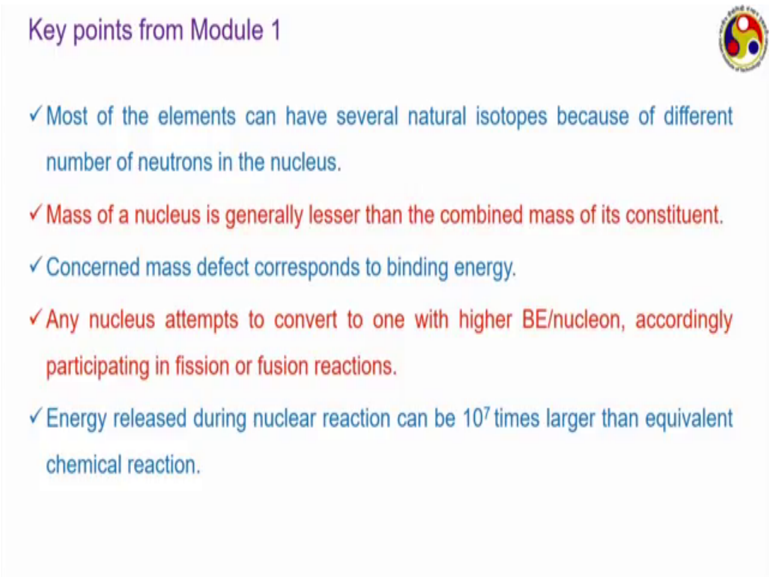


Well, they have the same kind of chemical properties, their nuclear properties strongly vary. The mass of a nucleus is generally lesser than the combined mass of his constituency, which leads to the mass defect. This concerned mass defect corresponds to the binding energy; binding energy can be thought about or can be viewed as the glue which binds the nucleons together in the very small volume of the nucleus.

Any nucleus attempts to have a higher value of this binding energy per nucleon and as we have seen from the earlier graph the highest possible binding energy per nucleon is around 8.8 MeV and therefore, any nucleus attempts to participate in any kind of nuclear reaction, which leads it to that particular value of higher binding energy per nucleon accordingly they can participate in fission or fusion reaction.

And finally, the amount of energy released during a nuclear reaction can be 10 to the power 7 times larger than an equivalent chemical relation, which substantiates the importance of nuclear reaction as a source of power generation. So, that is the end of your module 1. This will be followed by an assignments, which I am sure that you will be able to solve, if whenever you have any query you please write to us and thanks for your attention. In the next one, we are going to start the very important topic of radio activity in module 2.

Thank you.