Chemical Principles 2
Professor Dr. Arnab Mukherjee
Department of Chemistry
Indian Institute of Science Education and Research, Pune
Different Forms of Energy

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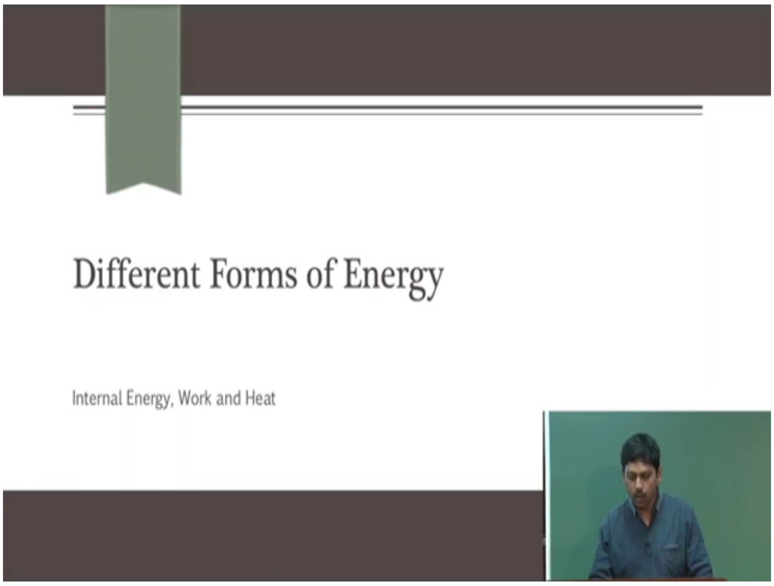

So now we are going to, now you see that the temperature is related to the kinetic energy of the system, right. So therefore we are going to understand what energy means, we know about kinetic energy as half mv square, but is there other form of energy or is it related to all other different things that we see. So it turns out that there are energies can be distinguish into three different types one is internal energy of the system, another is work, another is heat. Although we will see that they are all same but one can distinguish from the other by using certain measures.

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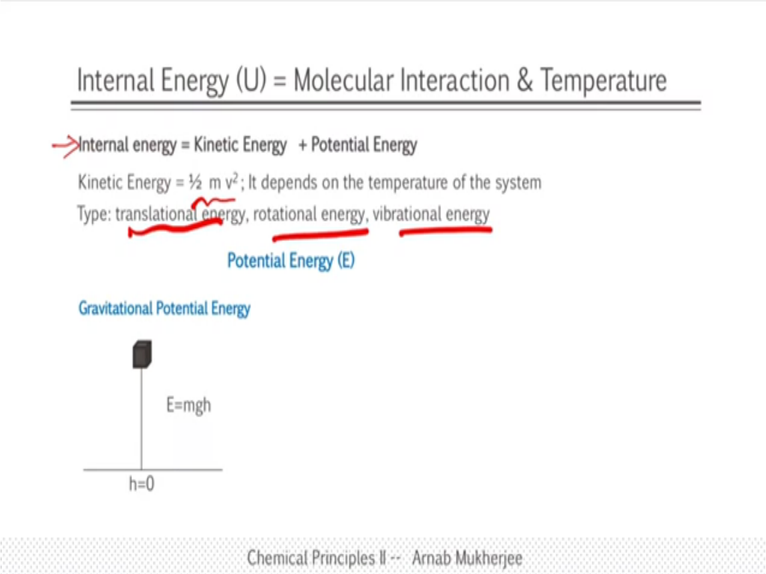

First we will discuss about internal energy of the system. Now internal energy of the system can be two things kinetic energy and the potential energy, so kinetic energy plus potential energy which we know as the total energy in thermodynamics it is called internal energy of the system. Now kinetic energy we know that it is half m v square, (but potential) so translation kinetic energy, rotational kinetic energy, vibrational energy are different forms of that, but potential energy is kind little bit complicated and there is a lot that is hidden in the potential energy, we know very well about the gravitational potential energy, right.

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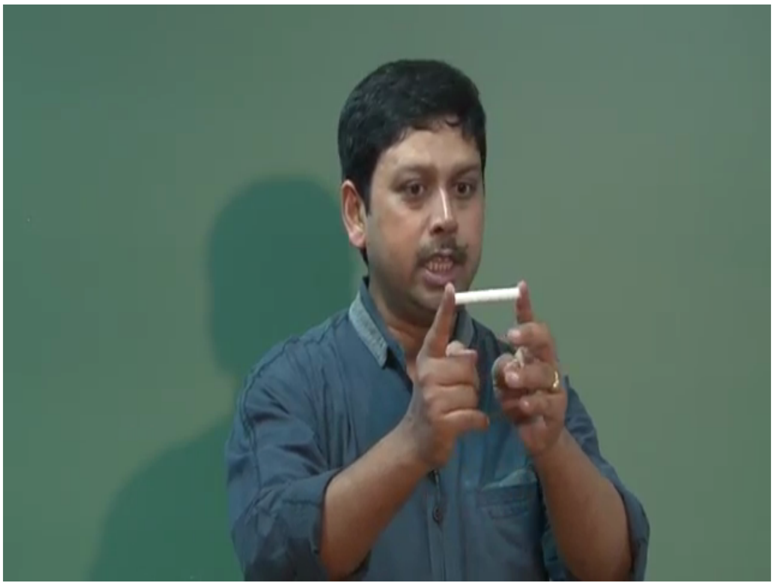

So let us say an object is held at certain height, so let me get a chalk, so when a chalk is held let us say at a particular height it has certain (potential energy) gravitational potential energy, what is meant by that is that it is high compared to the ground you know by value of H and therefore it has the potential energy of MGH and this is the energy that is stored here, which means that if I release that energy this energy is going to go to the environment we heard the sound so now that energy has converted to initially kinetic energy and therefore sound and later on it also used to break the chalk, okay and then rest dissipated to the environment.

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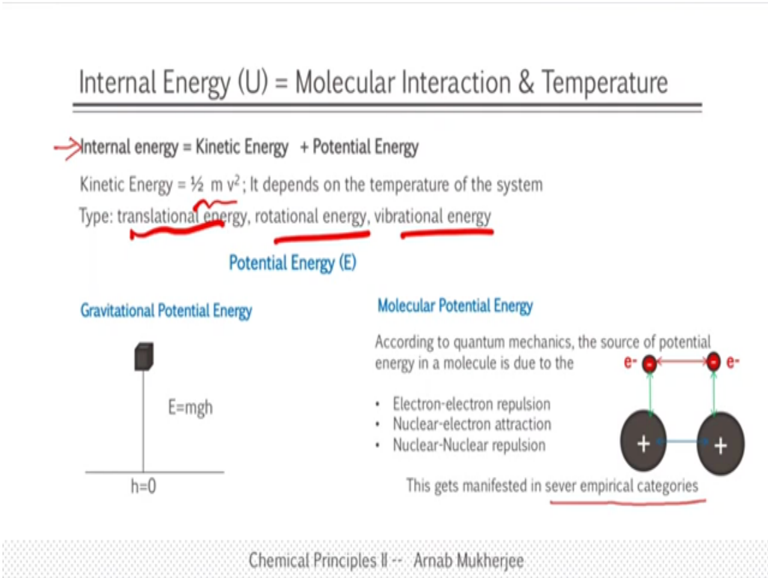

So that was the energy that was stored in that chalk as the gravitational potential energy but there is more to eat, there is gravitational potential energy and molecular potential energy is the constituent of the chalk itself, so let us say irrespective of what the height is let us say the chalk is lying on the ground does not matter or it is resting on the hand it has a certain potential energy and that potential energy we can say that it is a molecular potential energy and the origin of that potential energy actually comes from the fact comes from like say Quantum mechanics that says that every atom or every system is constituted of atoms and every atom is constituted of electrons and protons and there is electron-electron repulsion, nuclear-electron attraction and nuclear-nuclear repulsion.

Once we have all those parameters eventually one can solve Quantum mechanical equation which was actually discussed in chemical principles 1 and one can obtain the energy of the system and that energy as we know as Quantum mechanics we will get both the kinetic energy and the potential energy of the system that means we will get the internal energy of the system.

However, it is not always possible to solve Quantum mechanical problems from big systems, therefore this interactions manifest in several empirical categories, we categorize this fundamental interactions between electrons and protons and between different electrons and different protons into several empirical categories which is known as bonding or nonbonding interactions.

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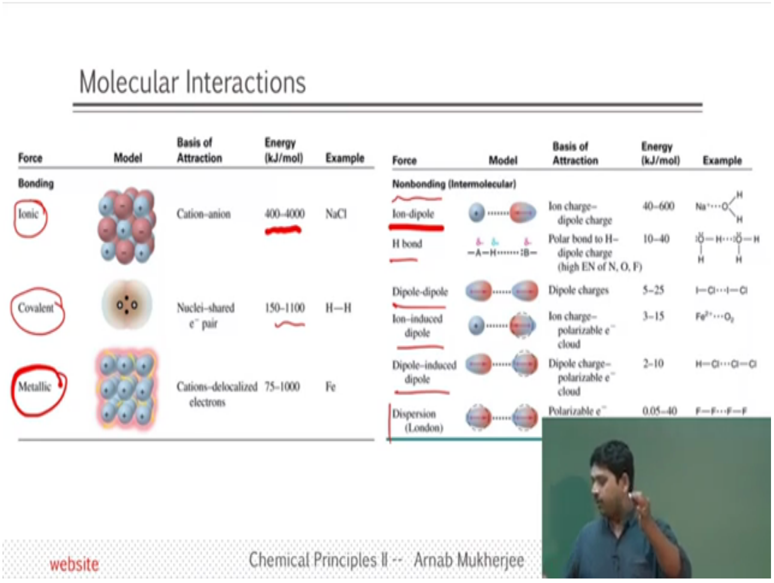

So we know about that there are ionic bonds present, there is a covalent bond we have a definition of what is covalent bond when carbon-carbon bond, ethane molecule will be a covalent bond or carbon hydrogen bond in a methane molecule, then there is a metallic bond and each bond will have a certain amount of energy associated with that. So this energy typically means that they are stabilized by that much value of energy.

And there are nonbonding interactions is also present where we do not have okay so in bonding typically will be described by if there is a electron sharing between two given pair of atoms. However, let us say electron is not fully shared however, there is certain other kinds of interactions like ion dipole interaction, hydrogen bond is another type of interactions non-covalent, dipole-dipole, ion induced dipole and dipole induced dipole and dispersion dipole interactions.

So just see that they are empirical you know understanding of what is going on more fundamentally in Quantum mechanical level and once one categorizes this particular interactions one can understand that how much potential energy is stored within a molecule. For example this is calcium carbonate it is a chalk, so therefore it is a calcium carbonate, so there is energy stored within this particular system and how do we know the energy is stored in this system? Because we have a way to release that energy from this, right.

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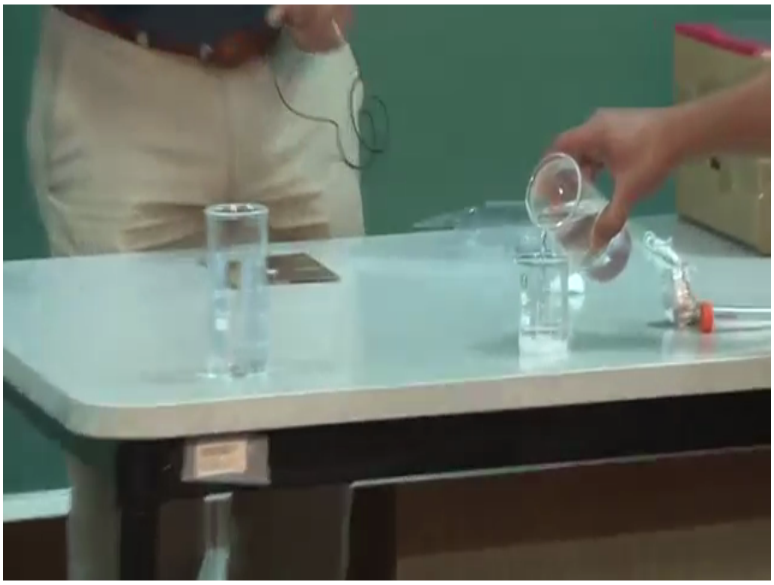

So we are going to do that in a moment, so we are going to release the chemical energy stored in the chalk to outside, do you have an idea how to do that? Correct, okay so this is calcium carbonate and this is sodium hydroxide, so this is a molecule, this is a molecule perfectly stable, right there is no problem with any of these two right now ad what do you say about the potential energy system, we do not have any idea about the potential energy of the system is right now but there is energy hidden within this and this hidden energy can be released when we do some chemical reactions, then this will be converted to something else.

So before we do that which water we are going to use? We are going to measure the temperature and we are going to use this one quickly, so let us use the hot water so again the temperature remains to be 35.6 is getting cooler because of the atmosphere (())(6:55) is pouring the water in sodium hydroxide we are going to start it right let it equilibrate and pour it here okay let me pour on the calcium carbonate, right getting hot?

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So yes I can feel the temperature from outside but I will just measure it by my infrared thermometer, it is 59 degree now.

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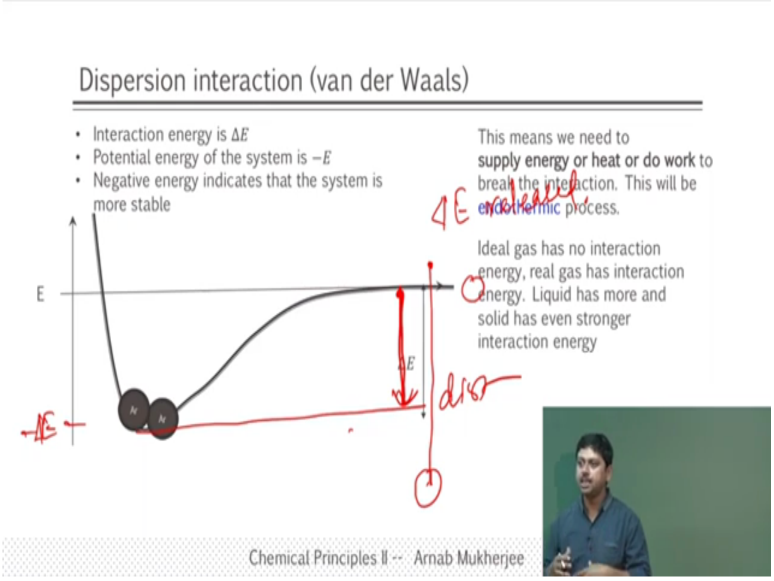

What was there in the bond between sodium and hydroxide ion because water separates them it is releasing that energy. So we are going to show you by an example of that, so here I have drawn a particular potential energy profile, so y axis is potential energy and x axis is the distance between these two particles. So when the distance between two particles is actually large here I am showing it here but let us say two particles distance is this much, let us say this is the distance then the potential energy is actually higher as these particles will come closer and closer what is going to happen is potential is going to decrease.

So when the potential energy is going to decrease where the energy will go? It will go to the environment, so whatever is so it is called stabilization of the energy, so now that now the system has become stabilized or system has gone to a lower energy level the energy that was there in the system has to go out and that is what we typically see as something called exothermic reaction.

So exothermic means whatever was the energy before that system has now become stabilized and the difference amount has gone out, endothermic is just the opposite of that we have to supply energy to the system and system has gone there. So this particular equation however we are showing two organ molecules and we are showing non covalent interaction and this profile is called Van der Waals interaction.

So even when there is no charge there is still and induced dipole induce dipole interactions which we call dispersion interaction and those particles are interact through that dispersion interaction and one can fit this kind of profile to understand the interaction between the two particles. So as I said the interaction energy is delta E, potential energy of the system is minus E so right now it has become minus E, so it was started with 0 now it has become minus E let us say and therefore E or minus delta E and delta E amount of energy is released delta E released, okay.

So this means that we need to supply energy or heat or do work to break the interaction and this will be an endothermic process and ideal gas molecule as I said has no interaction energy and however, real gas systems will have interaction energy. So real gas meaning you know when we talk about organ molecules or nitrogen molecules, oxygen molecules they will have interaction with each other and those interactions are typically stabilizing interaction.

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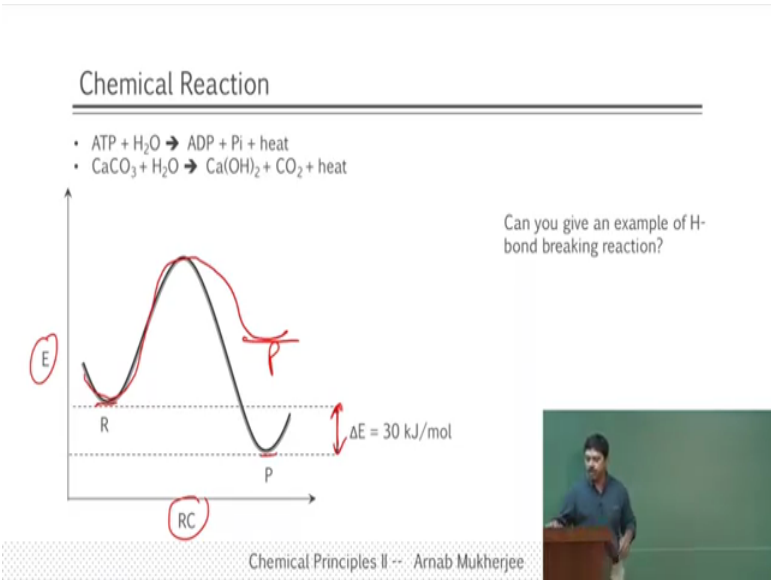

So now so we are giving two more examples, we have talked about ATP before as a molecular motor so what ATP does is that it used water and gets converted to ADP and the energy that is stored in its bond is being released as heat or some other energy or when molecular motor like (())(11:05) uses that it uses that energy to work and calcium carbonate example you have given that and typically we denote that as energy versus reaction coordinate profile, where if the product is lower than the reactant then we call it exothermic reaction and this is the amount of energy that releases and if it is other way round where it is higher than reactant, then that will be a endothermic reaction in which we have to supply the energy and you will see that it will be very useful in thermo chemistry later on.

Okay, so now I have a question for you is that can you give an example, so this is an example of chemical reaction that we are given right ATP and calcium carbonate, can you give an example of hydrogen bond breaking reaction which we can actually observe, some example where hydrogen bond breaks?

[Processor-Student conversation starts]

Student: (())(12:00).

Professor: No, I am saying a physical example which you can actually show in front of you.

Student: Melting of ice.

Professor: Melting of ice, say when ice melts, ice has actually it is not entirely wrong actually correct, so ice has four hydrogen bonds when it melts it still retains hydrogen bonds however not all four, on an average it retains 3.6 hydrogen bond, it is not 3 also. So if you calculate the average, then it will be normal what it is 3.6, so you were right that from 4 it goes to 3.6. However, another example more non intuitive I would say but this is a good example of ice melting.

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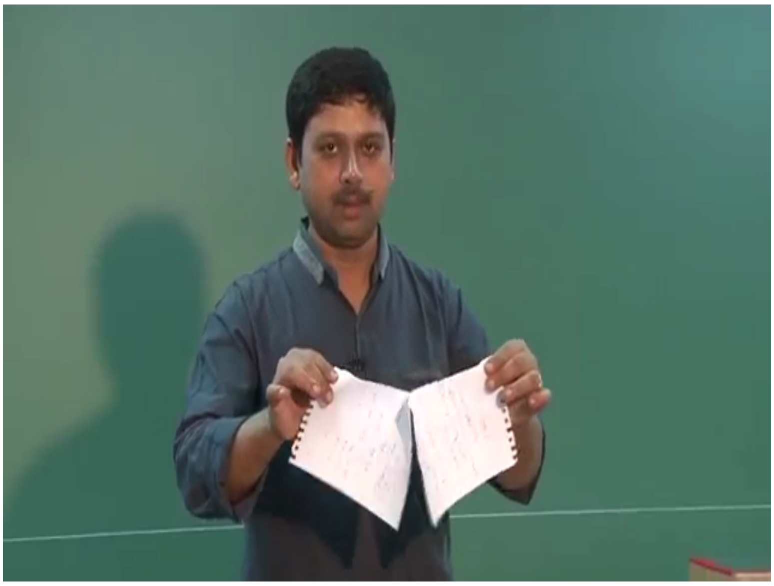

So give me a piece of paper, okay so this is the paper, I have broken the hydrogen bond with sounds, so this is again an example and instead if I burn that if I burn the paper then I am going to do a chemical reaction in which after initial initiation of my light which helps it to cross the barrier for burning it will be an exothermic process giving us both heat and light and that is because of a chemical reaction is going to give rise to carbon dioxide, okay.

So we understand that that internal energy of two different kinds one is you know (potential) gravitational potential energy, another is molecular potential energy and molecular potential energy can be understood from different possible interactions all will have the root of same root as Quantum mechanical description.

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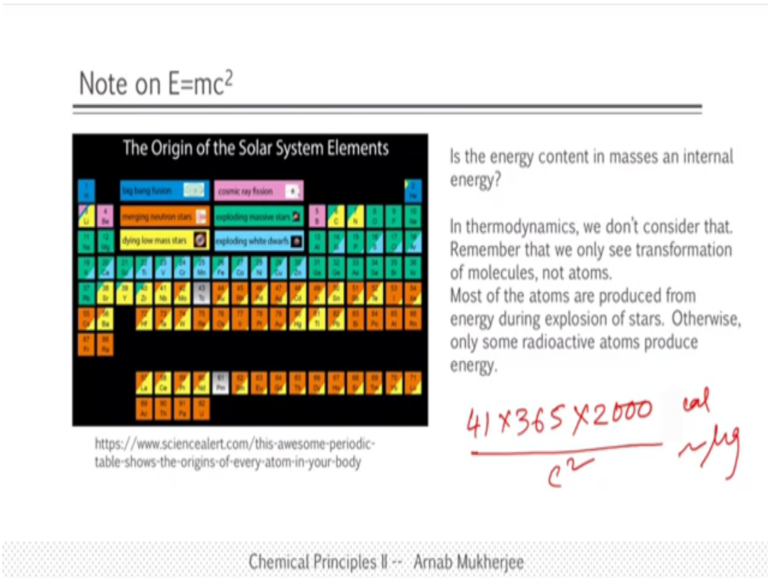

One more that I should emphasize is that energy that people call as mass energy you coming from Einstein's equation of E equal mc square, so just because of formation of this particular mass lot of energy has been used, right for this much mass we know one has used like huge amount of energy for that mass multiplied by c square, c is the velocity of light so you can understand (())(14:16) will be 9 into 10 to the power 16 I am going to multiply with the mass in order to get the amount of energy.

So do you think we can ever use that energy from the paper? See we are using which kind of energy we are using the energy that is stored in bonds or some other kind of non-covalent interactions, what about the energy stored in the mass? Can we ever use that? You can say that you know radioactive or fission reactions and all we can use that, but not fully you know part of it of course, right but other than that in a normal place like here if you could use this mass into energy our all energy problem would be solved, it turns out that when you have to use that when you have to convert the mass into energy the process requires or the other way round energy into mass the process requires enormous energy itself.

And the elements that are there that are present on earth for example carbon, hydrogen, nitrogen, oxygen, etc they never got produced on earth they were produced after the big bang after the big bang hydrogen and helium were the two atoms that got produced first and for all other heavier elements like lithium, beryllium onwards it required big events like explosion of starts and supernovas and things like that to create mass from energy.

So initially in big bang everything was energy as I said the temperature was 10 to the power 31 kelvin, right after that mass has formed, matter has formed and formation of that matter required enormous of energy. So this is the table taken from you know from this particular website that shows you that what kind of events created, what kind of masses or matters.

For example hydrogen and helium required big bang fission or (cosmic) big bang fission created hydrogen helium as I mentioned before and then for lithium, beryllium required cosmic ray fission and then and boron also and then all this ruthenium and all that required merging of neutron stars, so when two neutron stars merge you know we can imagine that amount of energy that will be produced that much energy is required to convert to a mass which is normally you know is never possible on earth.

So therefore in thermodynamics we do not consider E equal to mc square ever into the picture as the energy, so when you talk about energy internal energy of the system we do not consider E equal to mc square because that is not possible on earth. Another calculation, another thing I want to ask you is that let us say every day you are eating something and let us say from your childhood you have growth to this much weight or let us say I take about my example.

So when I was born my weight was 0.5 Kg, right now it is 80 Kg, so how much energy I must have taken in order to form a mass of 80 Kg compared to 0.5? Will you multiply by mc square? So it turns out that we take normally 2000 calorie per day and an adult person let us say everybody takes that from childhood onwards. So from childhood onwards if I calculate that the energy intake that I have which is my weight is my age is 41 years 365 days and every day I take 2000 calorie that much energy I have taken in my whole life.

If you convert to mass I have to divide by c square, right equal to mc square, this will correspond to a micro gram of energy micro gram of mass. So taking all that if had it been converted to had it been converted to mass all that energy I would have gain only a micro gram. So certainly that means what? That energy has not made us grow in size, what all we have done is that we have taken mass and put it inside, we have taken a rice and the content of mass that mass we have taken it in.

The energy that is required is to maintain our body temperature and do other functions it is just the oil in the machine rather than machine itself, okay. So with that we will end today's lecture.