Solid State Physics
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Lecture – 02
Atom to Solid Structure (Contd.)

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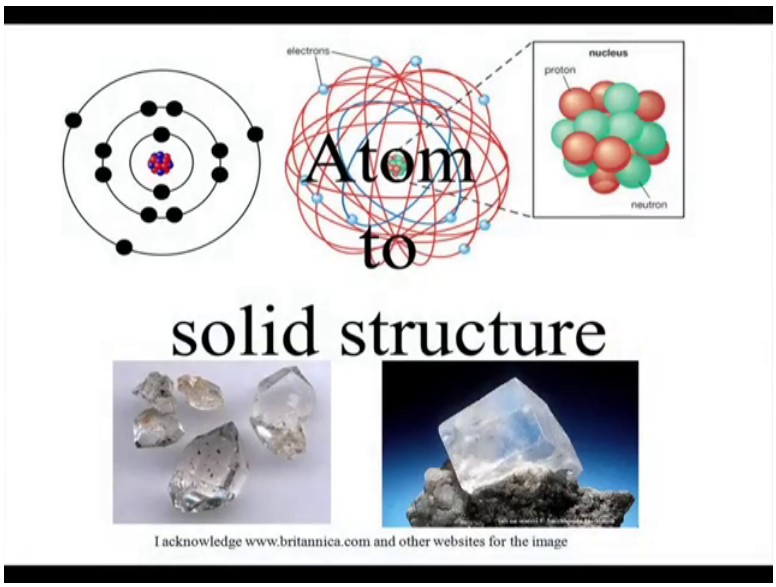

So, in the lecture 2, we will continue the atom to solid structure.

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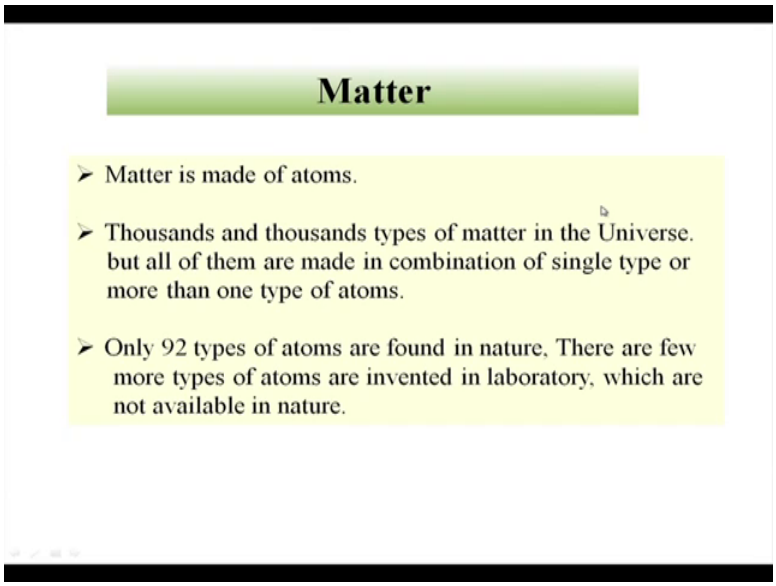

So, today we will discuss about the matter, which is made of atoms. You know this thousands and thousands type of matter in the universe exists, but all of them are made of atoms; either of single type of atom, or more than one type of atoms.

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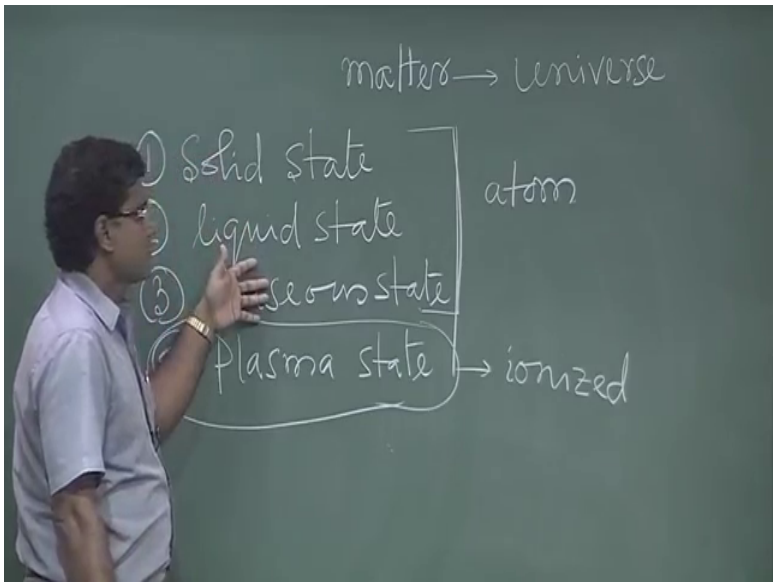

And also you know that, there are 92 types of atom are found in nature, but there are few more types of atoms, which are invented in laboratory, and they are not found in nature. So, whatever, matter is found in nature, so that are made of mainly this 92 types of atoms.

So, matter in universe, are found mainly in four types, or in four states. So, it is a solid state, matter is found in solid state. Then it is found in liquid state, gaseous state and plasma state. So, mainly this, in these four states, we see matter in universe, but there are some other state of matter, under some extreme conditions. So, which is not found in nature, but one can artificially one can create some other states also; however, we will concentrate our discussion on this 4 state.

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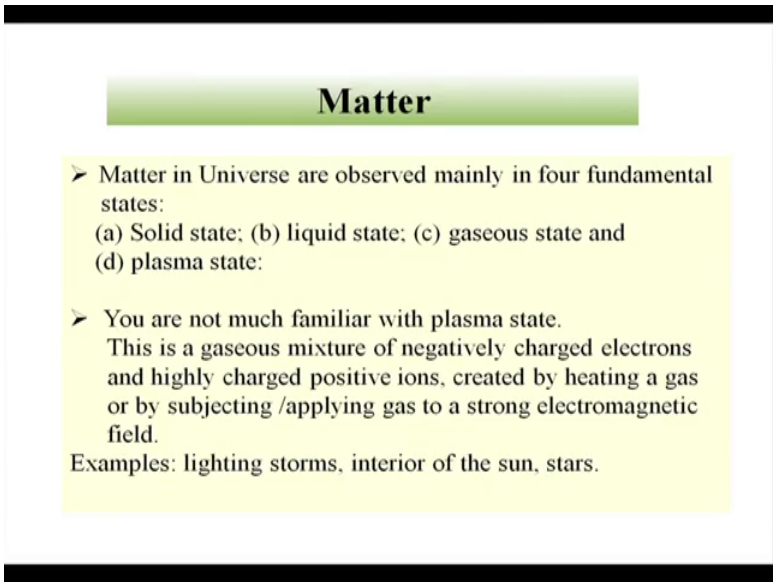

And then we will come back to the solid state. So, solid state, liquid state and gaseous state; these are quite familiar to you, but plasma state is not much familiar to us. So, plasma state is basically, this is a gaseous state of negatively charge electron, and highly positively charged ions, created by hitting of gas, or by applying gas to a strong electromagnetic wave.

So, as per example, so this lighting storms, then interior of sun and stars; so, they are the basically in plasma states. And other three states, is basically neutral atom. This is also atom, but it is ionized form. So, these states; solid state, liquid state, gaseous state; so, these states, are formed due to the aggregation of atoms and how to differentiate this different states, that we will discuss. So, in terms of inter atomic distance of between atoms, we can define this different states.

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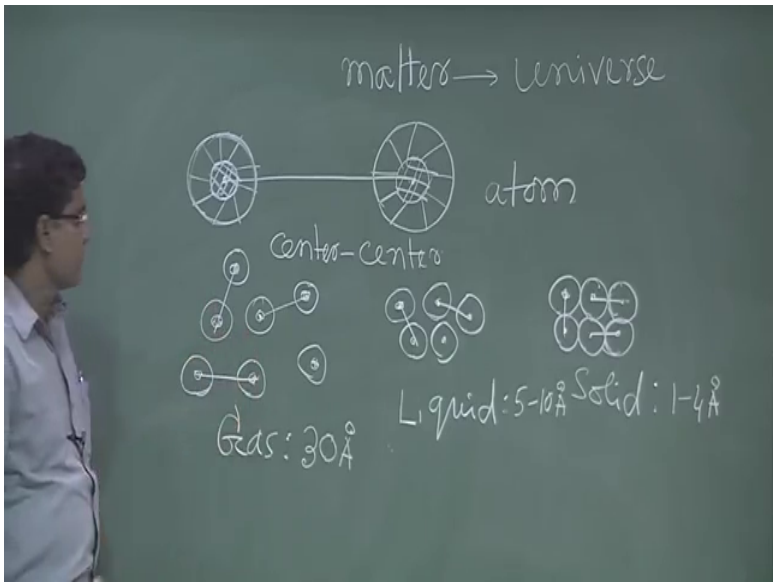

So, you know that atom (Refer Time: 06:14) considered a spherical hard balls, having positive charge and negative charge. So, these are nucleus, and this surrounding these negative charge electrons. So, inter atomic distance, in terms of inter atomic distance we can define the states. So, inter atomic distance is basically, the distance between the center of 2 atoms . So, center to center distance, geneally we take as a inter atomic distance

Now, this inter atomic distance wherein, it is very large. So, in assembly of, in assembly of atoms, in assembly of atoms so when this distance, inter atomic distance, a large, then it is basically it is in gaseous state. When these inter atomic distance are very small, its atoms are compact. So, this inter atomic distance, these are very small, then its solid state. And when inter atomic distance in between these two, so then it is basically liquid state correct. So, rough estimation one can do for this inter atomic distance. So, in case of gaseous state by inter atomic distance the average inter atomic distance is around. In this case it is around 30 angstrom, and in case of solid, the inter atomic distance is say around, I think if the range of 2 to 4 angstrom, and liquid, it is between its around 5 to say 10 angstrom. So, one can estimate this this inter atomic distance. So, as per example we can try for that gaseous state.

So, you know that, inter atomic distance of gaseous state, we can estimate, but for that we have to consider, we have to take in a container, and we have to keep that gas at a particular temperature and pressure ok.

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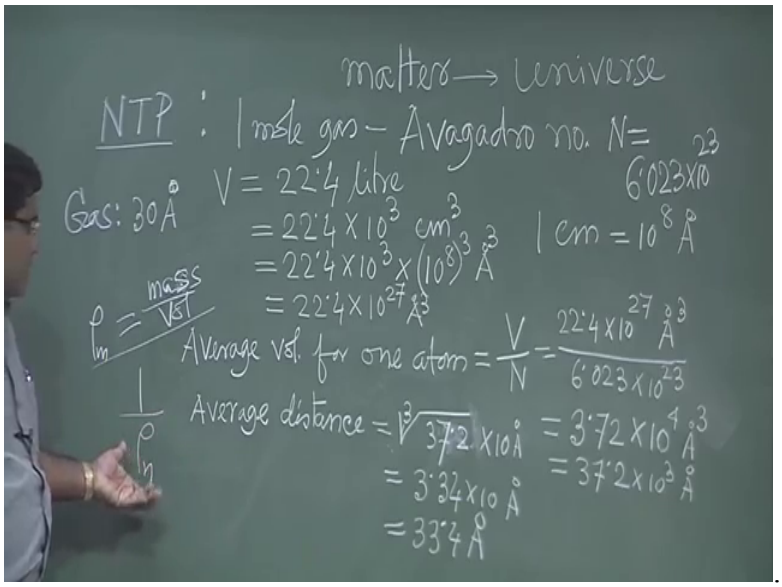

So, we consider the natural temperature and pressure; that is atmospheric pressure and room temperature. So, at this natural temperature and pressure, we know that 1 mole gas contains avagadro number of, avagadro number that is n equal to 6.023 into 10 to the power 23 number of atoms. So, 1 mole gas at N T P this, its volume is 22.4 litre. So, 22.4 litre means 22.4 into 10 to the power 3 milli litre or centimetre cube. So, this also seems the distance as I told for gas average, inter atomic distance is around 30 angstrom. So, we want to get this volume in in this angstrom unit. So, one can convert it. So, say 22.4 into 10 to the power 3 into 1 centimetre, 1 centimetre equal to 10 to the power 8 angstrom, so centimetre cube. So, it will be 10 to the power 8 cube, angstrom cube. So, this 22.4 into 10 to the power 27 angstrom cube.

So, in this volume, this how many number of atoms are there. This many number of atoms are there. So, average volume for 1 atom we can find out. So, average volume for 1 atom in that gas, 1 atom to be V by N. So, that will be 22.4 into 10 to the power 27 angstrom cube divide by 6.023 into 10 to the power 23. So, it will be, basically its 4 time 6 is 24, so slightly less than 4. So, its, I have calculated, so it is around 3.72 into 10 to the power 4 angstrom cube. So, that is the volume for 1 atom.

So, if you consider a cube. So, then the length or width or breadth height of that cube, you will get taking the cube root of this volume, taking the cube root of this volume . So, that that will be the average distance. So, average distance. So, that will be basically cube root of 3.72 into. So, this one can write basically 37.2 into 10 to the power 3 angstrom. So, 10 to the power 3 it will, so cube root, it will give 10, and then for this. So, basically you can write into 10 angstrom.

So, cube root of this one if you calculate. So, it will come. Sorry this is 37.2, because here 2 multiply with 10, 37.2. So, this will be between 3 and 4, because 3 into 3 into 3 27, 4 into 4 into 4 this is 64, so it will be in between. So, if you just calculate you will find, it will be 3.34 into 10 to the power into 10 angstrom. So, that is basically 33.4 angstrom. So, as I told this, it is inter atomic distance will be around 30 angstrom. So, after calculation also, it is around 30 angstrom.

So, that way one can estimate the inter atomic distance for liquid, for solids. So, basically if you know density of these states. So, from there one can, number density one has to find out number density. If you know the density rho, so density is basically mass for volume. So, from mass you can find out the number of atoms, 1 gram mole contain 6, the avagadro number of atoms. So, basically then you can convert to this mass density to the number density. So, basically number of atoms per unit volume. So, then 1 by that number density, if this is write mass density. So, one has to find out number density. So, 1 by that number density; that will be the basically n volume of that.

So, from here this way also one can find out the inter atomic distance. It is just estimation its not exact, so one can just guess, what will be the order of the distance in case of gas, in case of solid and in case of liquid. So, now, we will see the solid state of matter. So, matter in a solid state, solid state of matter.

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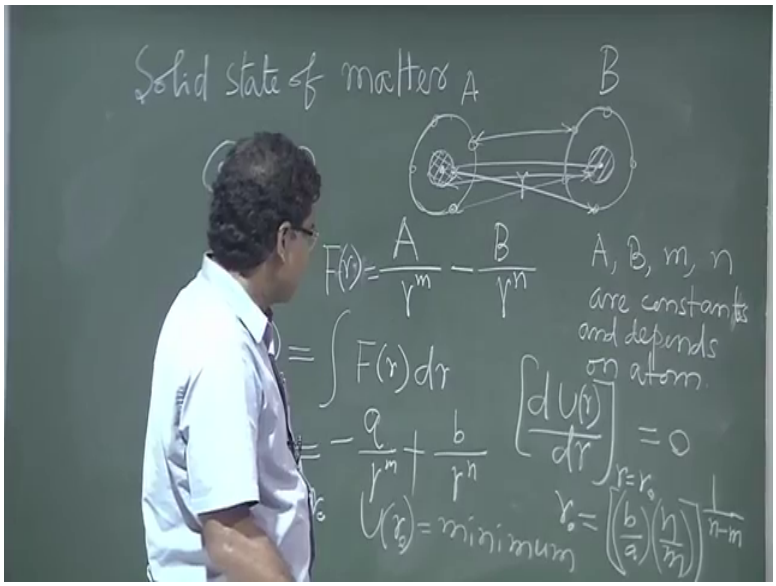

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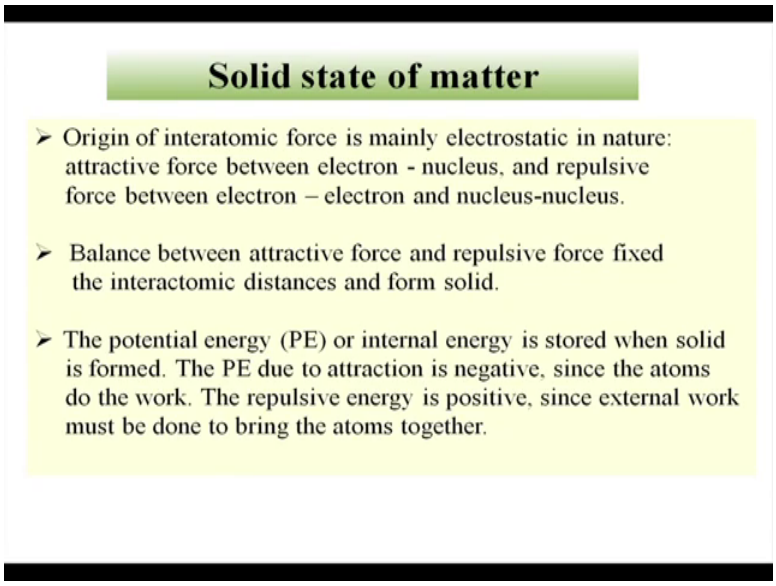

So, in solid state of matter, atoms are very close to each other, and they hold each other. So, what is the origin of the force, to hold them together? So, this, origin of this force; that is basically electrostatic force, magnetic force also it is there, but it is very weak. So, mainly electrostatic force holds atoms together in solid.

So, from where that electrostatic force are coming. Say if you take the atom. So, two atom at a, say distance r, inter atomic distance r. So, this atoms have nucleus, and negative charge. So, when they come close to each other, then that electron nucleus

nucleus. So, nucleus, so the repulsive force acts. And on the other hand electron of this, and the nucleus of the other one are opposite charge and vice versa; so, electron of this, and nucleus of other one, so they will attract each other. So, both attractive force and repulsive force are acting, on this system up to say 2 atoms.

So, in solids there are many atoms, so similar way this this type force will act with other atoms also. So, this repulsive force and attractive force acts on the system, so that net force, net force on the system one can write. So, this force generally, we say in, its force is basically proportional to the, electrostatic force it is proportional to the power to the some power of the inter atomic distance, inversely proportional to the power of some to some power of the inter atomic distance. So, so one force will be repulsive, and another force will be attractive. So, if I write this atom a and this atom b.

So, if I write a, this basically a and b, this two atoms, and a here I am writing as a some constant, characteristic constant of this atom. So, A by r to the power some power, say m, and another force is, if I write this power to the power some say n. So, mainly this 1 by r to the power m, and another one is 1 by r to the power n. So, this A b m n are constant are constant, and depends on the atom. So, it is called atomic, it is basically called characteristic constant of atom.

So, if you; so, net force will be the, basically this will have attractive force and the repulsive force. So, if you take summation of them. So, you will get the total force. So, one force is basically repulsive and attractive, if one becomes positive, another become negative. So, but in case of inter atomic distance, here internal energy, potential energy basically represent better way than the force. So, the force, from force one can find out the internal energy say u r. So, these are, this force is basically function of r. So, one is find out the force at equilibrium distance, stable configuration. So, if this is the force, then one can find out the potential energy for this system. So, basically one has to integrate this force with respect to distance; and if you integrate it, so then basically; so, it is not difficult to integrate. If you integrate it, so basically you will get that, I can write directly the expression.

So, it will come like this; r to the power m minus b r to the power n. So, A b is basically new constant, new characteristic constant; so, this when you will integrate, you will this A, you will get in terms of A b m and n. So, that way different new constant A and b, and

this will be plus. So, from this potential energy, you can find out the minimum potential energy, because system preferred to stay at minimum energy. So, you can find out a equilibrium distance for, where the energy of the system will be minimum. So, say at distance, at distance r equal to r 0.

So, this u r will be u r 0 will be minimum. So, for that basically that there is a procedure, you know that if you differentiate this one with respect to r, and find out energy at r equal to r 0. So, when this will be 0, when this will be zero. So, for that condition what is the value of r; that will be r 0 if we tell that is r 0. So, that will be the equilibrium distance. So, if you do this step, then you will find that you will get r 0, you will get r 0, you will get r 0 basically equal to say b by A, b by A power is b by A n by m 1 by n minus m. So, that will be equilibrium distance, for that the energy will be minimum.

So, system will prefer to stay at this inter atomic distance. So, that is the in solid, when it is formed it is in solid. So, that will be the basically inter atomic distance we will tell that this is inter atomic distance, and that potential energy versus distance.

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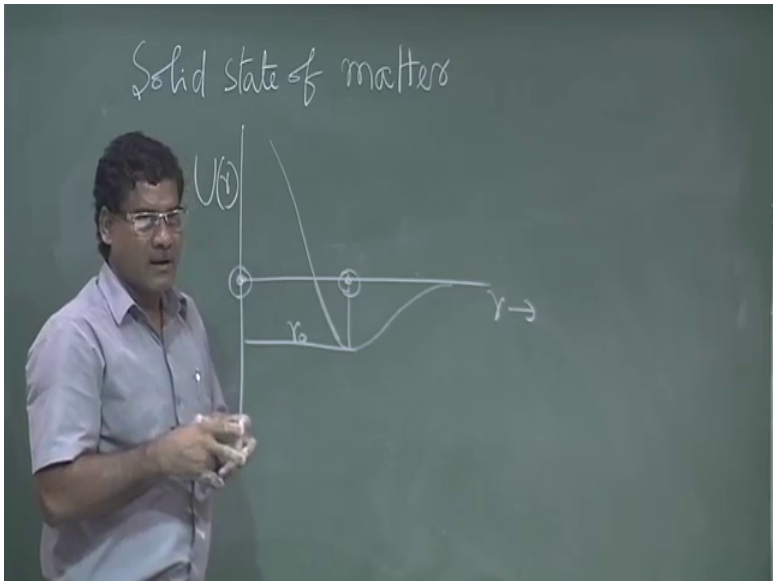

If you plot from that expression, we will get nearly this type of curve. So, this is u r and this is r. So, this will be the minimum energy, and that distance means one atom is here, then another atom is here. So, that will be the r 0. So, that is the basically inter atomic distance. So, thus solid, that atoms in a solid will be stable, and they will have inter atomic distance of this range, and this r 0 is generally 1 to 4 angstrom.

Thank you. So, we will continue.