Solid State Physics
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Lecture – 17
Crystal Structure (Contd.)

So, we will discuss bonding in solids in this class.

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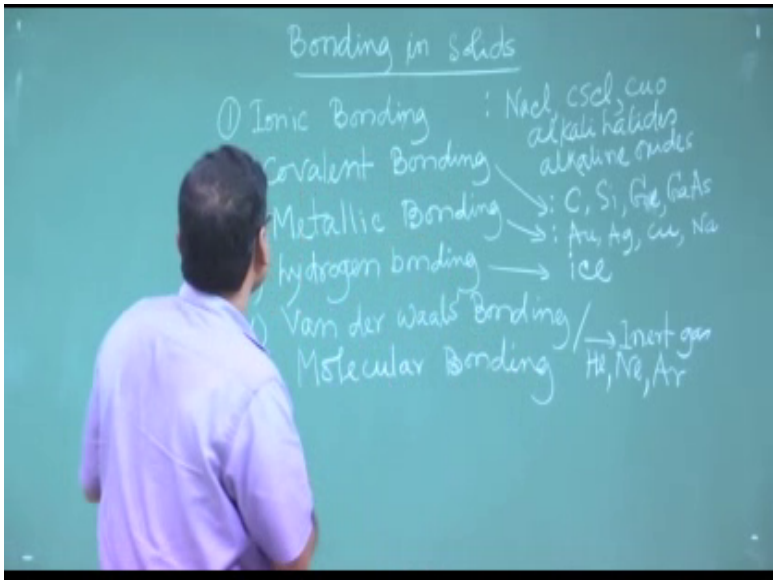

So, there are mainly five types of bonding are found in solid crystal. So, they are ionic bonding, then covalent bonding, metallic bonding, then forth is hydrogen bonding, and fifth is van der waals bonding, or it is also called molecular bonding, right.

So, if you are familiar with this most of the bonding. So, this when it forms molecule. So, this etcetera, we found due to the ionic bonding, covalent bonding. So, that is you are familiar with this, but I will discuss, what are those bonding as well as in which materials we see such bonding and that we find out. So, this example of ionic bonding in solids. So, this sodium chloride, potassium chloride, also cesium chloride. So, all alkali, with all alkali halides and alkaline oxide. So, copper oxide.

So, this we can tell that, all alkali halides, lithium alkali atoms and lithium sodium potassium; these are alkali atom halides. These your fluorine chlorine iodine. So, all halides as and these alkaline oxide materials nearly had this ionic character, ionic

bonding. So, this and covalent bonding, where we find out covalent bonding, you can, this in diamond carbon. Basically, in diamond form silicon germanium right, germania gallium arsenide in this material, we see this covalent bonding ok.

And then metallic bonding, we see this in metal. So, this it can be gold, silver, copper right this sodium material, sodium solid. So, this solids are made, because of this metallic bonding and hydrogen bonding. So, (Refer Time: 06:01) nice example of this bonding, one can see in ice formation and this van der waal bonding. It generally, if we seen this, inert gas say at low temperature, inert gas forms the solid. So, they are, is solid is formed, because of this van der waal force, van der waal bonding for this molecular bonding.

So, this is basically, your this inert gas, neon, argon, helium. So, these are the inert gas. So, when this inert gas forms solid at low temperature. So, this solid is this atoms are hold in solids, because of this molecular bonding or van der waal bondings. So, I will discuss one by one say, ionic bonding, what is the ionic bonding? Basically, bonds between two ions, one is positive ions and another is this negative ions. So, like sodium chlorine is a classic example.

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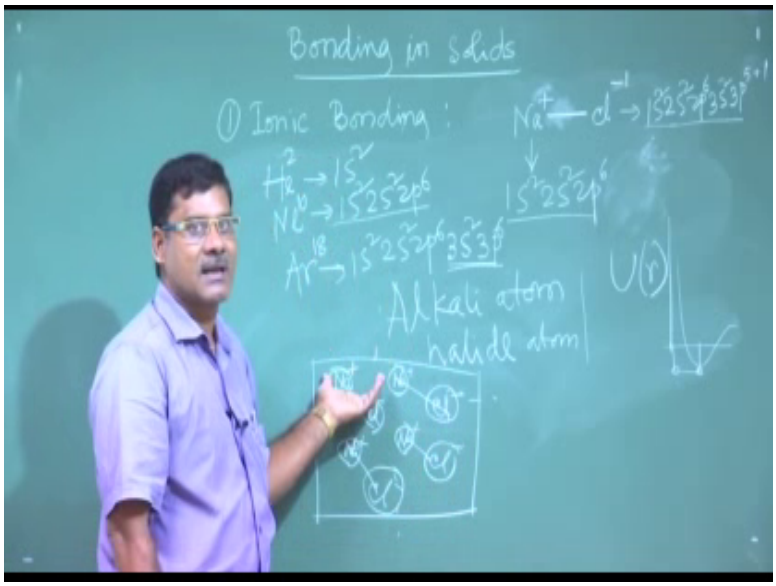

If sodium atom and this chlorine atom, they come closer then sodium gives, lives one electron or gives one electron to chlorine right. So, sodium loses one electron and chlorine gain one electron. So, this sodium lies a positive ion and chlorine is a negative

ion right. So, why this sodium want to give one electron and chlorine want to aspect one electron. So, that is because of electronic configuration of this atoms. So, you know for sodium, this how many electrons are their, electron, this 11 electrons are their. So, electronic configuration is 1 S 2, 2 S 2, 2 p 6, 3 S 1 right.

And chlorine is having how many electron, 17 electrons. So, it is electronic configuration 1 S 2, 2 S 2, 2 p 6, 3 S 2, 3 p 3 S 2 3 p 5. So, this 4 10 and 5 plus 2 17. So, you know this electron, this inert gas, electronic configuration of inert gas, this, that is the preparable configuration, stable configuration. There is no valance electron. All are 4 electron.

So, inert gas are. So, helium has 2 atoms, 2 electron right. So, this 1 S 2. So, this cell is filled, right. Similarly, for neon 10 electron. So, 1 S 2, then next 1 S 2, S 2 p 6. So, outer cell is filled. So, for neon sodium, it has 11 electron. So, if it lives, this electron. So, this. So, then it would get, this configuration of this neon inert gas configuration ok.

So, in outer most cell is 8 electrons are their. So, it is sometimes called octet rule also octet rule also. So, this. So, it will be more stable, if it lives one electron and for this chlorine. So, this configuration of chlorine and this is configuration of sodium and here if. So, 1 S 2, 2 S 2, 2 p 6, 3 S 2, 3 p 6. If it is 3 p 6 then, it will get next inert gas configuration. That is basically, argon. So, argon is 1 S 2, 1 S 2. So, here 1 S 2 2 S 2 2 p 6 3 S 2 3 p 6 right.

So, this 10 and this 8 2 2 4 as 6 4 6 10 and this 8 8. So, this basically, 18 electron, this is 10, this is 2. So, again here in outer most cell 8 electrons. So, it will if any atoms gets this configuration. So, it is the stable configuration. So, chlorine will go in this configuration, if it takes one more electron. So, it will accept one electron. So, (Refer Time: 13:31) it will lead this electron. So, there is exchange of electrons between this 2 sodium is giving and chlorine is taking. So, that is the form, they have, they are exchanging between them something.

So, they this, that is the basically, they form bonding between them. So, that is the, that is the called ionic bonding. So, that means, all alkali atom, if it leads 1 electron, it gets stable configuration atomic configuration and all halide atom. So, that is chlorine fluorine iodine. So, this atom, if it, if they accept 1 electron. So, they will be stable

electronic configuration. So, wherever they will get chance to give electron and to take electrons. So, they will prefer that (Refer Time: 15:00) So, this is the reason that when many atoms not one sodium atom one chlorine atom if many sodium atoms and many chlorine atoms if they put together.

So, they will form solid. So, they will arrange themselves in such a way, they will arrange themselves in such a way. So, etcetera etcetera . So, they will arrange themselves in such a way, that they can form ionic bonding, they can hold each other exchanging the electrons, just donating electrons by one atom, and accepting that electron by their another atoms ok

So, this, in case of sodium chlorine, this is the. So, this is there picture, where two types of electrons are, atoms are there ,one of them are prefer to donate one electron and another one is prefer to accept that electron. So, thus they will form basically, they will form basically bonding and hold each other. So, that is why the solids of alkali halides alkaline oxides. So, alkaline, they are basically they can, they have two, they can lead 2 electron and oxide oxygen, it can take accept 2 electrons ok.

So, ionic crystal ionic bonding will see, that is you need this, to different types of atom; one will leave electron as many as it will leave. So, we need the acceptors. So, there should be another type of atom, which can accept them. So, only then they will form crystal due to this ionic bonding. So, this basically, because of this bonding, because of this bonding atoms are hold in the crystal, but how they will arrange that configuration it depends that the total energy of the system, total potential energy of the system has to be minimum.

So, when I have, earlier I have shown in that the total potential energy of the system has to be minimum that potential graph, I have shown earlier right . So, this is for between two atoms. So, you have many atoms from one to other. So, there is, they have to accommodate or they have to find the configure in such a way that total energy will be minimum, and that is nature prefer. So, that way automatically in that is self organization of these atoms in a structure; such that the total potential energy will be minimum.

So, giving calculation of this potential energy you remember that I told; that is this force. So, basically relation between this potential energy and force that we have seen. So, d 2, basically d 2 electro static force, electro static force two types; one is repulsive force and

the attractive force. So, balancing between these two force will give the many 0, when the force should be 0, at that zero force basically this potential become minimum. So, that will be taken as a, minimum that equilibrium position from between these two atoms.

So, here in general that we told that balancing between the repulsive force and attractive force right. So, we have to find out that what is the original of these repulsive force and attractive force. So, that should be their, then only we will get the equilibrium distribution of atoms in the solids. So, in these crystals; obviously, we have positive ions and negative ions. So, repulsive force between positive and negative iterative, and attractive force between this opposite ions sodium and chlorine ok.

So, this is the origin of this electro static force, which hold the, which will hold the atoms in a crystal. So, in this ionic crystal, this is a, obvious this, there are electro static force in this system. So, next I will discuss this covalent bonding

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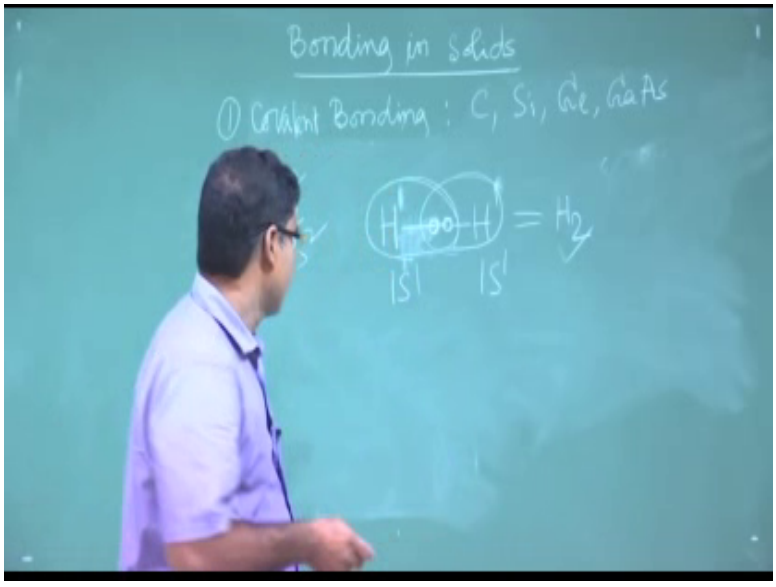

So, example is basically carbon, silicon, germanium right, gallium arsenide. So, these are the materials where we see the covalent bonding is responsible for the formation of the solids crystal right.

So, what is covalent bonding, what is covalent bonding that you know, that the sharing of the electron between two atoms right. So, basically if you take h 2, the hydrogen gas

right. So, 2 h. So, 2 atom hydrogen atom with a come close, they can form hydrogen molecule. So, they basically hydrogen gas h 2 at why they form, how they form, there must be some bonding between this two, so that; one is basically this is having one electron, this is having one electron right. So, 1 S 1 1 S 1 right.

So, if, because this stable configuration is 1 S 2, to have that 1. So, this hydrogen it will prefer to have one electron right, one electron and this other one also will prefer to have one electron. So, what they do. They just, this hydrogen just give one electron, this hydrogen gives one electron. So, 2 electron is kept in middle between this two atom as if. So, this hydrogen is, as if we are sharing this two electron, and this also sharing this electron. So, thus they are filling the stable configuration helium configuration h 2 h e is power 2. So, this is having 1 S 2 is the inert gas stable configuration. So, they are having this similar to this configuration as if. So, they fill more stable than this individual hydrogen atoms.

So, thus they prefer to form this h 2. So, instead of staying this as a hydrogen atom, they prefer to stay as a hydrogen molecule h 2. So, this this type of bonding which is holding this two hydrogen together. So, this is the covalent bonding. So, this is the example of covalent bonding. So, now, I am telling this carbon, silicon, germanium, gallium arsenide they are the crystal, where covalent bonding is responsible for holding the material. So, basically then we have to

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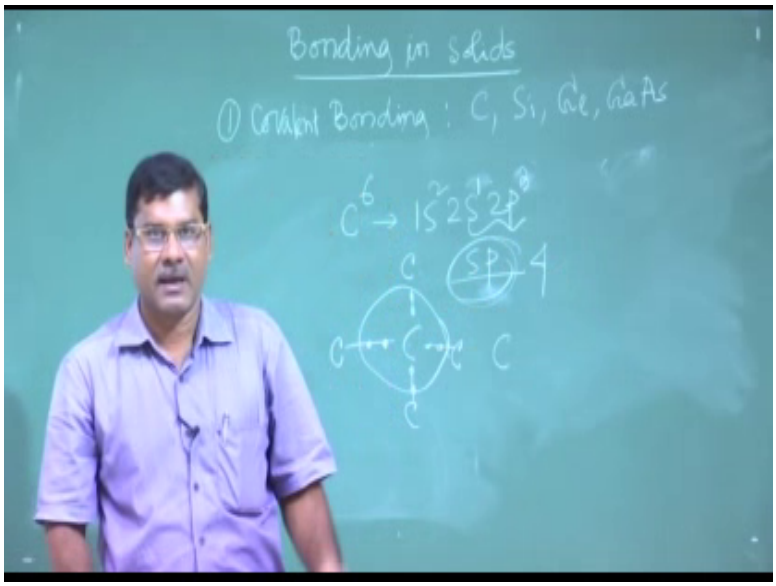

So, that there is a shading of the electron among the atoms. So, let say carbon, how many electrons are there, I think 6 electron carbon, 6 electron. So, electronic 1 S 2 2 S 2 2 p 2 2 P 2. So, here basically 2 S and 2 P, they energies, as are almost same, is very close. So, these two basically. So, this electron. So, 2 S 2 and 2 p 2 instead of 2 S 1 and 2 p 3. So, it can take that configuration also. So, then we tell that this S p 3 is p. So, one is electron and this p 3 electron. So, this says, it is S p hybridization, it form S p hybridization hm.

So, this S 1 electron p 3 electron S p 3 hybridization. So, then basically this 4 electron, this 4 electron will have this 4, this equivalent energy level. So, S p 3 hybridization. So, they are equivalent, but their direction. So, as if this the S p 3. So, these equivalent 4 electrons are their. Now if two carbon atoms come closer as a octet rule. So, they differs to have this 8 electron. So, in S p 3 hybridization, they are 4 electrons though they will have, try to have more 4 electrons ok.

Then they will feel more comfortable or the stable configuration. So, this carbon have 4 S p 3 hybridization, and this other one also. So, they will prefer to. So, each carbon atom will prefer to share with this 4 carbon atom. So, from each one electron, from each one it has 4 electron outside reaches at a and 4 from this 4. So, they will get this. So, they as if gets sharing ok.

So, it has 4 electrons, it is sharing with 4 carbon. So, then this, it will feel to, that is 8 electrons. So, this basically, the sharing the. So, this is at the, this bonding is basically covalent nature, covalent bonding. So, in this material. So, carbon silicon germanium. So, they are, we say, because of this covalent bonding, the crystal are formed. So, then again this. So, this again this carbon will hold again one here, and with other C. So, they said the changes will go one, and it will form the, like the solid crystal right

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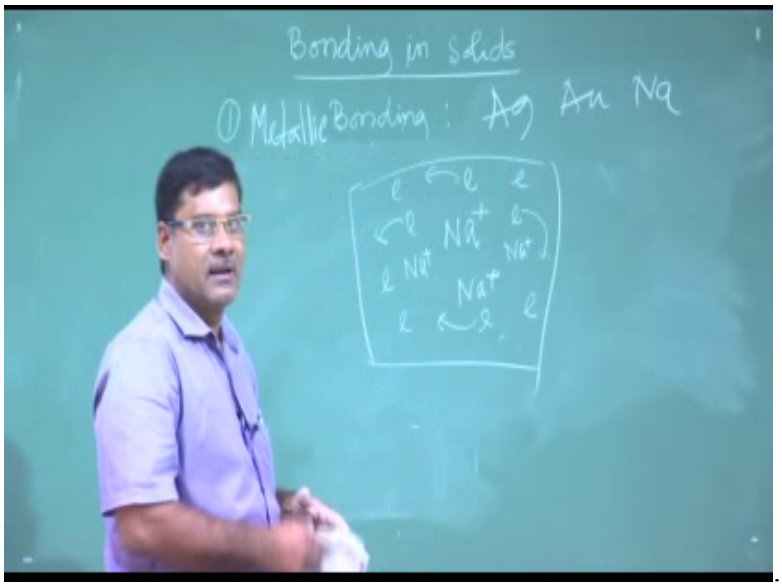

So, similarly metallic bonding. So, metallic atoms as I mentioned silver, gold, sodium etcetera. So, of this all, this metal outside electrons are there, outside electrons are there, balance electron either one. So, in case of sodium, this outside there is a 1 electron. So, I think silver. So, 1 as to see electronic configuration. So, if it leaves outside electron in case of sodium say. So, 11 electron, if it leaves 1 electron. So, it gets stable configuration. So, this basically sodium ion plus and this it leaves all electron.

So, thus many sodium comes together, sodium atoms come together. So, they feel to leave 1 electron. So, basically what this electron does. So, this the, it forms the core of ions sodium ions, and this all electrons, it is not attached with this sodium ion all that time, as if it just moved in, they are moving around the all ions. So, basically we will see this electron C, and the positive ions core.

So, overall this, this positive ions and this, this electrons there. So, it is not electron for a particular ions, overall this all electron sharing with all this sodium ions positive ions. So, this type of bonding. So, hold this type of sharing of the electron C ,electron C with this hole core of ions. So, this type of bonding holding, is basically metallic bonding. So, this also we tell this free electron gas. So, these types of metals choose the electrical property jm conductive property, that we will discuss, when we will learn this in electronic electrical property of the metal. So, these are metallic bonding.

So, type of bonding holds this materials in solid form. So, similarly this. So, this 3, these are mainly all in most of the solids, we see this type of bonding. So, these are called primary bonding and this two, other two are there. So, this are basically, it is called secondary bonding. So, this is hydrogen bonding.

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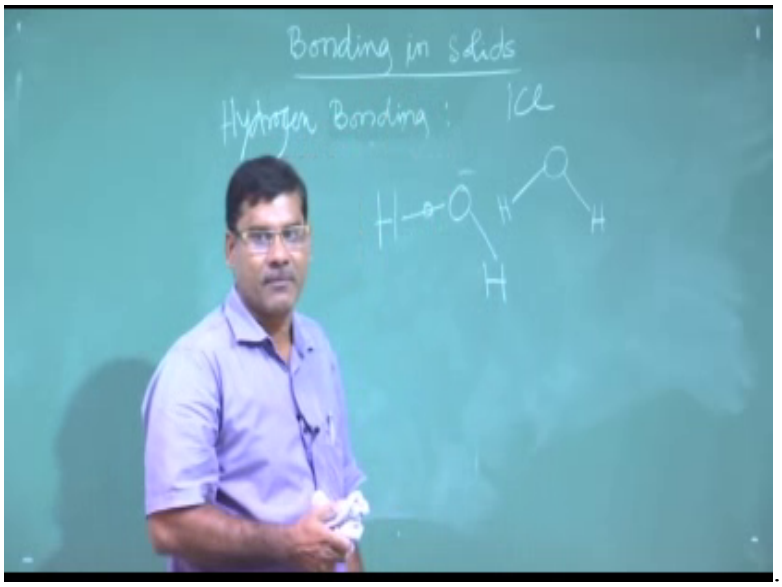

So, that is it is seen in as I told inert gas. No it is seen in this ice in. So, I added this h molecule is formed, it is not hydrogen bonding. So, it is here, it is a covalent bonding. So, hydrogen bonding is basically different. So, it helps to bond with other two atoms. So, hydrogen helps to bond with other two atoms, these are ice. So, basically what you know. So, oxygen and this. So, oxygen if it gets two electrons. So, it will get stable configuration, and if it leads one electron, it will get the stable configuration. So, ok

So, as you see it gives two electrons shared with. Sorry. So, it has one, is one electron and oxygen have, I think it is 8. So, if it has this two electron. So, thus they share electron, oxygen share electron with hydrogen, two hydrogen or two hydrogen share electron with oxygen. So, it forms a dipole is permanent, dipole. So, now, when there are many water molecule together. So, they form basically the. So, due to this dipole, dipole interaction, they will hold each other, because of this dipole interaction. So, this type of bonding holding, and this will happen through the hydrogen, and this type of bonding is basically is, it is called hydrogen bonding

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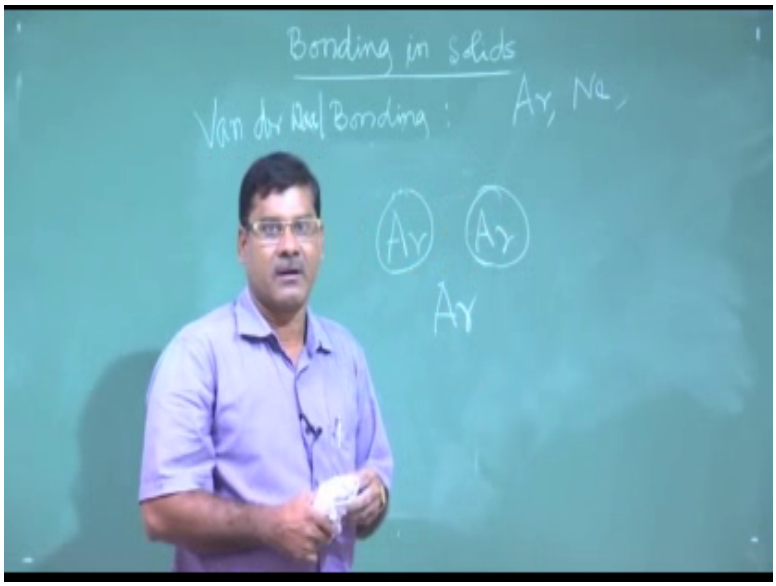

And last one, this van der waal bonding, van der waal bonding. So, that is argon gas neon gas inert gas basically, when at low temperature they form of the crystal. So, here they, here this argon atom are this, table argon atom are stable right, but when they come together. So, why they will how, this atoms will be hold together. So, that is we are telling this, because van der waal bonding. So, molecular bonding, it is they will also molecular bonding. So, (Refer Time: 36:19) what is there. So, basically this is the neutral fine. So, it is a stable configuration, but to when another similar atom, same atoms are coming closer. So, then basically here arrangement of the charge is disturbed, arrangement of the charge disturbed, because of this other atom coming closer to it.

So, that is the basically it is. So, it will form this, whatever it has positive charge and surround in this electronic. So, they are now disturbed. So, it will form a temporary dipole movement. So, each one will form a temporary dipole movement, because of the just distortion of the atoms, distribution of the ions charge ionic charge. So, each will behave as a temporary dipole.

So, now, this is the source of, electro static force dipole dipole direction. This type of bonding, holding of this inert atoms, these are very weak, and that is this type of interaction is called van der waal interaction, van der waal force, and holding these things in together in a solids. Of course, here at low temperature that is the, that is called van der waal bonding or molecular bonding. So, this is about the different kind of

bonding or interaction among atoms, which are responsible for formation of the solid. So, I will stop here.

Thank you.