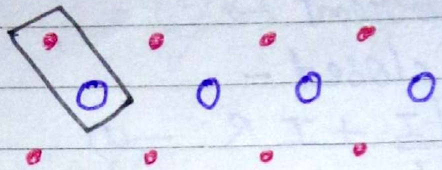
Crystal →

(i) A three dimensional array of atoms
(ii) Well arranged in periodic nature
(iii) Equally spaced & high M.P. & B.P.

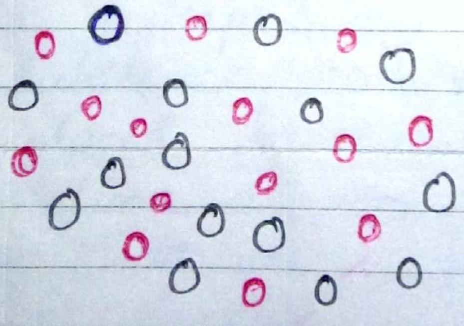
Crystal = Lattice + Base

(iv) Ex- Sugar



Amorphous (Non-Crystal) —

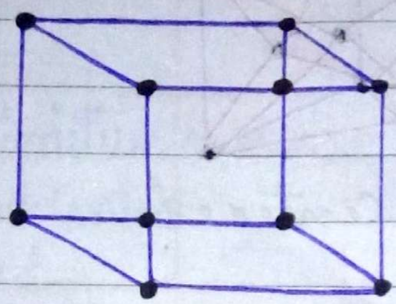
(i) Three dimensional non-repeated array of atom.
(ii) Irregular in shape.
(iii) Gradually soften over a range of temp.
(iv) Worst arranged in non-periodic nature.
(v) Unequal spaced.



(vi) Example – rubber, glass, plastic etc.

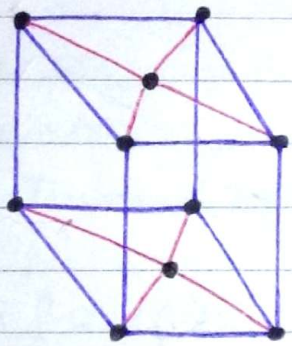
✱ Different Cubic Structures —

(a) Primitive →



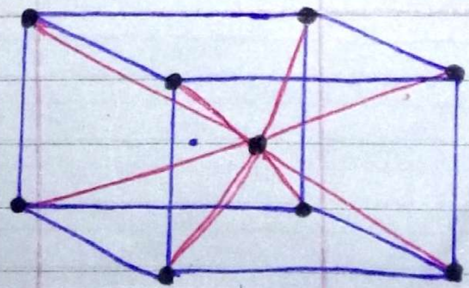
(primitive)

(b) Base-Centered



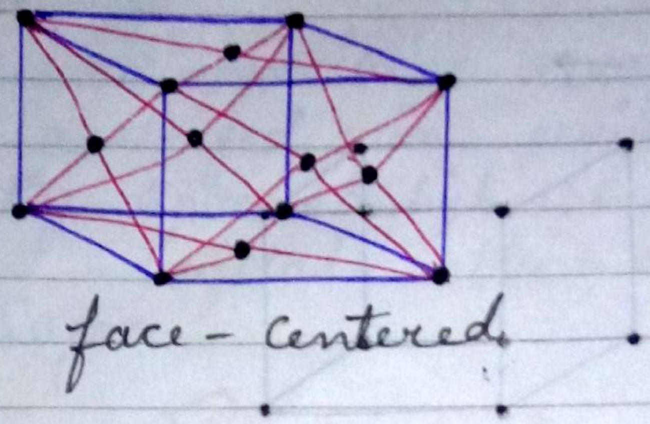
(Base-Centered)

(c) Body-Centered →



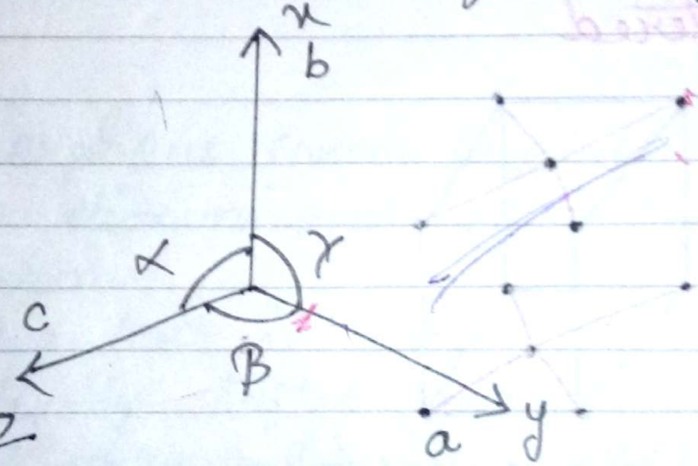
(Body-centered)

(d) face-centered



face-centered.

✱ There are seven crystal system—



S.No.	Crystal system	Possible Variations	Axial distance or edge lengths	Axial angles	Examples
1.	Cubic	Primitive, Body-centered, face-centered	$a = b = c$	$\alpha=\beta=\gamma=90°$	NaCl, Zinc blende, Cu
2.	Tetragonal	Primitive, Body-centered	$a = b \neq c$	$\alpha=\beta=\gamma=90°$	White tin, SnO_2, TiO_2, $CaSO_4$
3.	Orthorhombic	Primitive, Body-centered, Face-centered, end-centered	$a \neq b \neq c$	$\alpha=\beta=\gamma=90°$	Rhombic Sulphur, KNO_3, $BaSO_4$

4.	Hexagonal	primitive	$a=b\neq c$	$\alpha=\beta=90°$ $\gamma=120°$	Graphite, ZnO, CdS.
5.	Rhombohedral or trigonal	Primitive	$a=b=c$	$\alpha=\beta=\gamma=90°$	Calcite ($CaCO_3$), HgS (cinnabar)
6.	Monoclinic	Primitive, end-centered	$a\neq b\neq c$	$\alpha=\gamma=90°$ $\beta\neq 90°$	Monoclinic sulphur, $Na_2SO_4 \cdot 10H_2O$
7.	Triclinic	Primitive	$a\neq b\neq c$	$\alpha\neq\beta\neq\gamma=90°$	$K_2Cr_2O_7$, H_3BO_3, $CuSO_4 \cdot 5H_2O$

Semiconductors →

- Semiconductors possess resitivity or conductivity to intermediate to metals and insulators.

Resistivity → $\rho \approx 10^5 - 10^0\ \Omega m$

Conductivity → $\sigma \approx 10^{-5} - 10^0\ Sm^{-1}$

- Classification of semiconductors on the basis of the source and the nature of charge carriers.

(i) Intrinsic semiconductors
(ii) Extrinsic semiconductors

(i) Intrinsic Semiconductors →

- The pure semiconductors (impurity less than 1 part 10^{10}) are called Intrinsic semiconductors. Ex— Ge, Si.
- The number of electrons (n_e) is equal to the number density of hole (n_h).
- They are not useful directly in the applications to improve there conductivity we add an element of IIIrd and (Vth) group.

Intrinsic semiconductors → The semiconductors in which free electron-hole pairs are thermally generated are called intrinsic semiconductors.

(ii) Extrinsic Semiconductors →
The semiconductors obtained by adding or doping the pure semiconductor with small amounts of certain specific impurity atoms having valency different from that of the host atoms are called extrinsic semiconductors.

On the basis of impurity there are two types of semiconductors →
(i) n-type semiconductors
(ii) p-type semiconductors

	n-type semiconductors	p-type semiconductors
1.	These are extrinsic semiconductors obtained by doping impurity atoms of group V to Ge or Si crystal.	These are extrinsic semiconductors obtained by doping impurity atoms of group III to Ge or Si crystal.
2.	The impurity atoms added provide free electrons and are called donors.	The impurity atoms added create vaccancies of electrons (or holes) and are called acceptors.
3.	The donor impurity level lies just below the conduction band.	The acceptor impurity level lies just above the balence band.
4.	The electrons are majority charge carriers while holes are minority charge carriers.	The holes are majority charge carriers while electrons are minority charge carriers.

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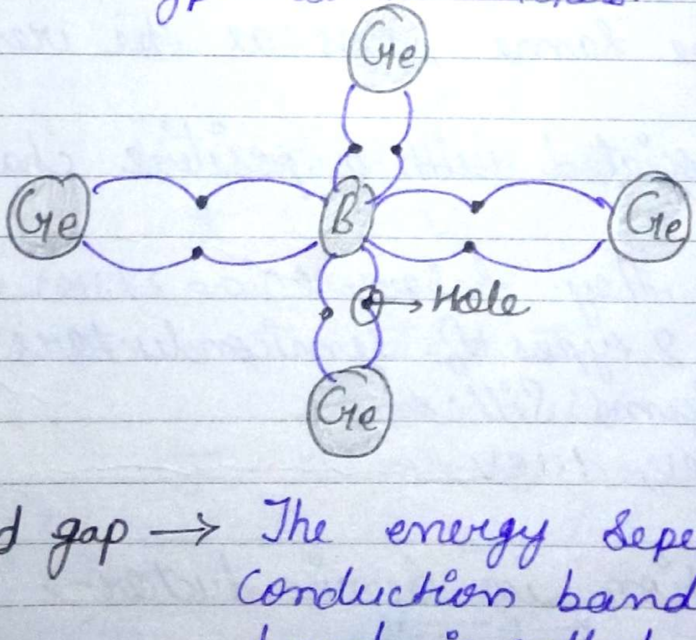
Motion of charge carriers in a definite direction is called drift.

5. $n_e >> n_h$ | $n_h >> n_e$

Ex → n-type →

- When we doped with a group 15 element like P or As, which contains five valencies electrons, they occupy some of the lattice sites in silicon and Ge crystal.
- Four out of five electrons are used for bonding then the remaining electron becomes delocalised.
- These delocalised electrons increase the conductivity of doped silicon.
- This increase in conductivity is due to the negatively charged electrons, hence silicon doped with electron ~~n-type~~ rich impurity is called n-type semiconductors.



☆ Band gap → The energy seperation between conduction band and valence band is called band gap.

- There are two types of band in a solid. The ~~upper~~ lower band is valence band and upper band is conduction band.

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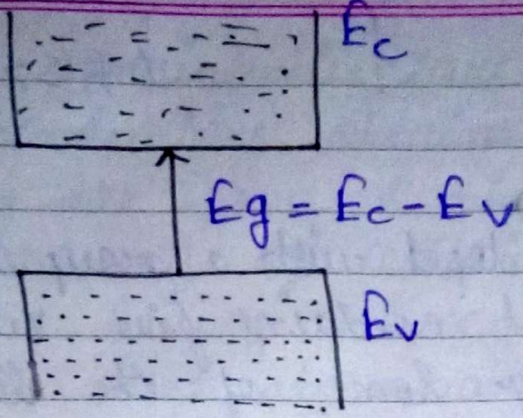


✱ Holes →

- The vacancy or absence of an electron in the band of a ~~conductivity~~ covalently bonded crystal is called a hole.
- Holes are positive charge carriers.

Characterstics of holes →

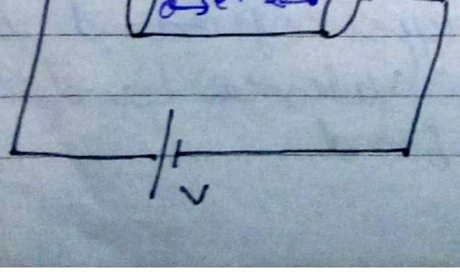
(1) A hole is just a vacancy created by the removal of an electron from a covalent bond of semiconductor.

(2) It has the same mass as the removed electron.

(3) It is associated with a positive charge of magnitude e.

Semiconductor
→. At T = 0K they behave (0°c = 273K) as insulators.
→. There are 2 types of semiconductors →
Germenium, Silicon.
E_g 0.7eV, 1.1eV

✱ Drift Motion in Semiconductor →



$$I = \frac{Q}{t}$$

$$I_e = \frac{Q_e}{t}$$

$$I_e = \frac{Ne}{t} \quad \text{—(4)}$$

$$I_n = \frac{Q_n}{t} = \frac{Pe}{t}$$

Current density

$$J \rightarrow \frac{I}{A}$$

$$V = \frac{I_e}{A} = \frac{Ne}{tA} \times \frac{l}{l} = \frac{Ne}{(Al)} \times \frac{l}{t}$$

$$J = \frac{N}{V} e\, V_e \quad [V \rightarrow \text{Drift velocity}]$$

$$J_e = n e V_e$$

$$J_n = n e V_e \rightarrow ~~I_n = V_e n e~~$$

$$V_n < V_e$$

Because V_n are heavier than V_e

$$J = J_e + J_n$$
$$= n e V_e + n e V_n$$
$$J = e(n V_e + n V_n) \quad \text{—(5)}$$

Drift velocity ∝ Electric field

$$V_d \propto E$$
$$V_e \propto E$$
$$V_n \propto E$$

$$V_e = \mu_e E$$

$$\boxed{\mu_e = \frac{V_e}{E}} \rightarrow \text{Mobility of electrons}$$

Similarly, $V_h = \mu_h E$

$$\mu_h = \frac{V_h}{E}$$

Mobility of holes

Intrinsic Semiconductors →
Electrical conductivity of semiconductors increases, with rise in temperature, since more electrons can jump to the conduction band. Substances like silicon and germanium show this type of behaviour and are called intrinsic semiconductors.

Extrinsic Semiconductors →
The conductivity of these intrinsic semiconductors is too low to be of practical use. Their conductivity is increased by adding an appropriate amount of suitable impurity.
This process is called

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* Atoms →

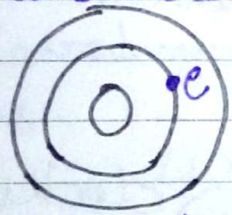
Central part is called nucleous.
Mostly mass of atom is contains in nucleous.

Nucleous → Proton (+ve charge)
Nucleous → Neutron ( )

proton → $e = 1.6 \times 10^{-19}$ C
$M_p = M_n \to 1.67 \times 10^{-27}$ Kg

Neutrons → chargeless
$M_n \to 1.67 \times 10^{-27}$ Kg

Orbital electrons →
Spin and revolue of electrons.



$F_e = \frac{Ke^2}{r^2}$

Centripetal force = $\frac{mv^2}{r}$

Atomic no. (Z)
Mass no. (A)

$_Z X^n$

$e = 1.6 \times 10^{-19}$
$W_e = 9.1 \times 10^{-31}$ Kg

$A = n + Z$

The electrons are represented by

n: principle quantum number
$n = 1 - \infty$

* Electronic configuration →

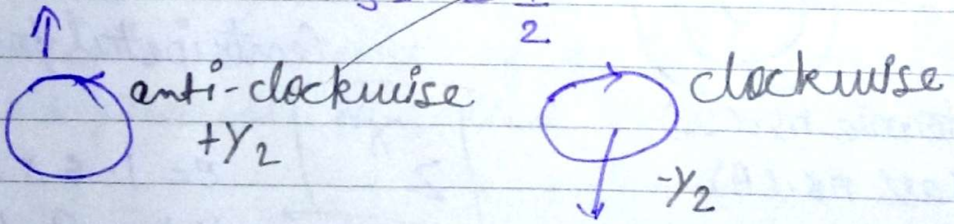
Germanium →
$Z = 32 \to 1s^2, 2s^2\ 2p^6, 3s^2\ 3p^6\ 3d^{10}, 4s^2\ 4p^2$

The electrons are represented by 4 quantum numbers

l = Orbital quantum number
$l = 0, 1, 2, \ldots (n-1)$

Sub shell	l
s	0
p	1
d	2
f	3

m_l → Magnetic orbital quantum no.
$m_l \Rightarrow -l \rightarrow +l$
Total number of Values = $(2l+1)$
S → Subshell
m_s → Magnetic spin quantum number
$m_s = \pm \frac{1}{2}$



✯ Sub shell

s	$l = 0$	2
p	$l = 1$	6
d	$l = 2$	10
f	$l = 3$	14

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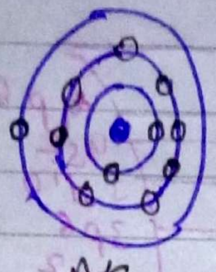
Na → 11



Na

$2n^2 \rightarrow$

$2(1)^2 \rightarrow 2$

$2(2)^2 \rightarrow 8$

$2(3)^2 \rightarrow 9\times2=18$

$1s^2, 2s^2\ 2p^6, 2s^1$

✱ Band theory of Crystals →

Nuclear / coloumb potential b/w electrons and nucleous →

(Potential energy of) $V(r) = \frac{K q_1 q_2}{r}$

$K = 9\times10^{9}$

$q_1 = -e$

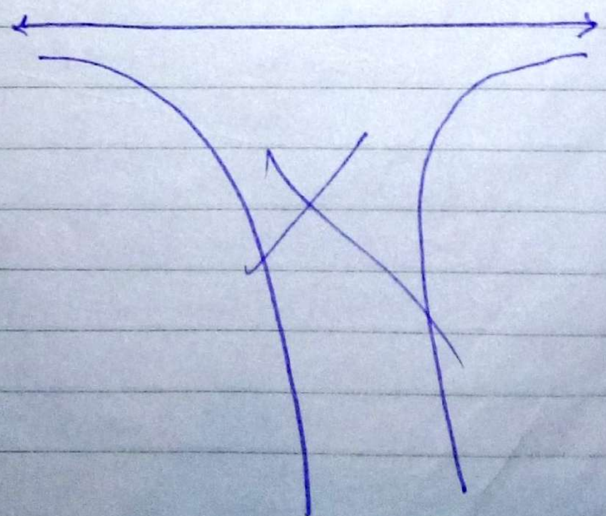
$q_2 = Ze$

Potential energy in nucleous & electrons $U(r) = -\frac{KZe^2}{r}$

$U \propto \frac{1}{r}$

if $r=0$ $U(r) = \infty$

$r=\infty$ $U(r)=0$



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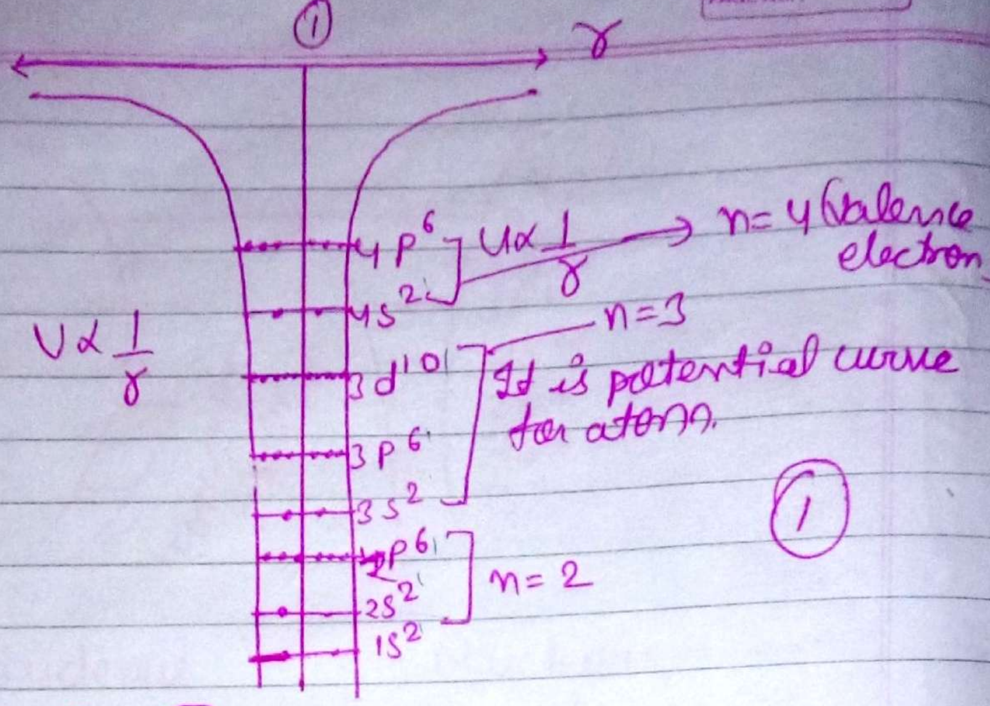
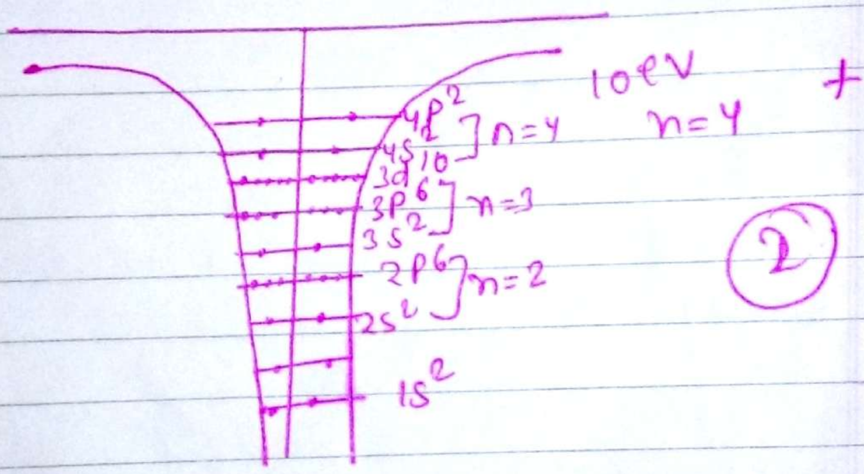
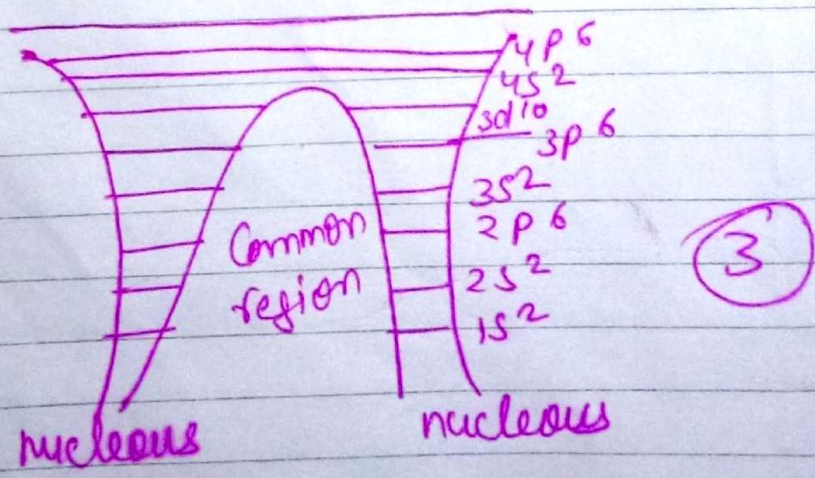
fload →



Sum → ① + ② = ③





Energy band → The seperation between these levels in the group is so small so that they almost form a continuous band is called Band energy.

- ⇒ When two atom brought to near in easily the valence level are start with break. In this process the each level divided into two level one have the greater energy and second lower energy compare to the original level.
- When interaction are start to break and finally all the levels are divided into 2 levels.
- The common part of the potential is of lower energy compare to the original energy to the valence electrons are now free to come from one atom to another atom.
- If there are 'N(numbers) atoms in the system then each will be divided in to ~~N-State~~ N-level having seperation order of 10^{-15} m they appear as a band levels.
- The combination of these energy levels is called band.

There are two types of band —

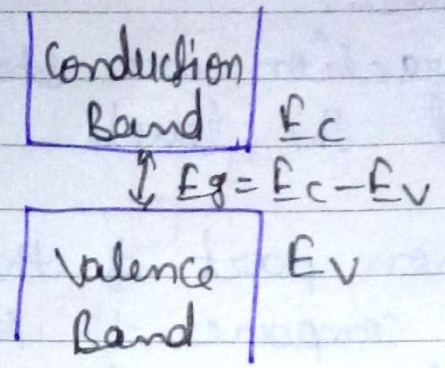
① Valence band →
The lower band which is completely filled with unexcited atom is called valence band.

Completely filled electrons

② Conduction band → Above of the valence band which is completely empty in unexcited state is called conduction band.

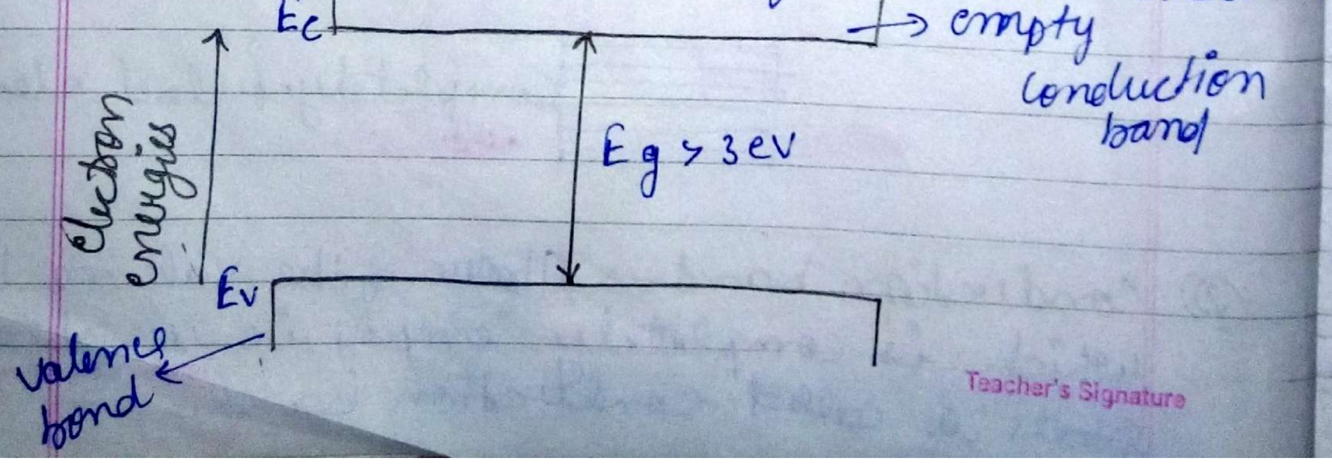
Band gap

- The energy seperation b/w valance band Conduction band is called Band gap. It is called forbidden gap because there is no allowed energy level.



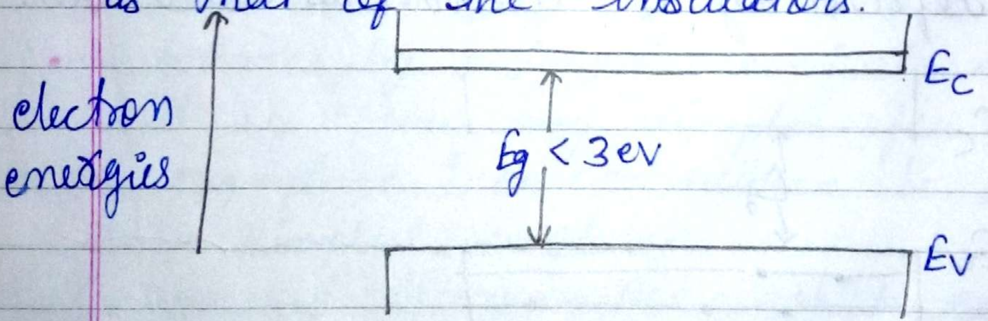
Insulators → (energy band structure)

- Insulators are those which do not allow the flow of current.
- In terms of energy band a large band gap Eg exists ($E_g > 3eV$)
- There are not electrons in the conduction band, and therefore no electrical conduction is possible.
- In this we have to note one thing that the energy gap is large so the electrons cannot excited from the ~~bala~~ valence band to the conduction band by thermal excitation.



✱ Semiconductors (energy band structure) →

- Semiconductors are those substances ~~which~~ whose electrical conductionlity lies in between ~~and~~ conductors and insulators.
- In terms of energy band, the valence band is almost filled and conduction band is almost empty.
- The energy gap (E_g < 3eV) between valence and conduction bands is ~~almost empty~~ very small.
- Because of the small band gap, at room temperature some electrons from valence band can acquire enough energy to cross the energy gap and enter the conduction.
- The electrons can move in the conduction band.
- The resistance of semiconductors is not as high as that of the insulators.



✱ Conductors (energy band structure) →

- Conductors are those substance which easily pass the electric current.
- It is because there are large number of electrons available in a conductor.
- In terms of energy band, either the conduction is partialy filled and the valence band is partialy empty or the valence and conduction band overlap each other.

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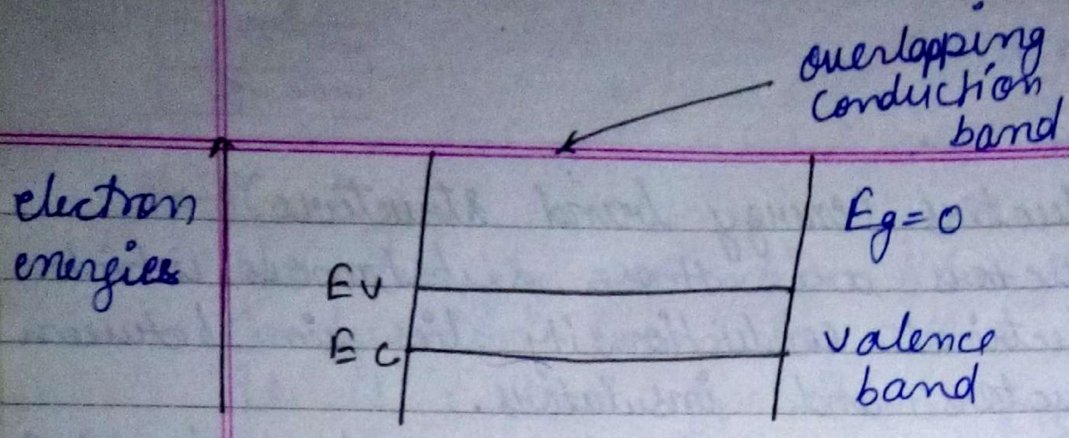
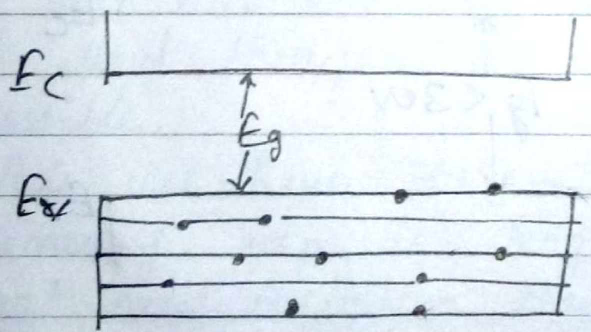
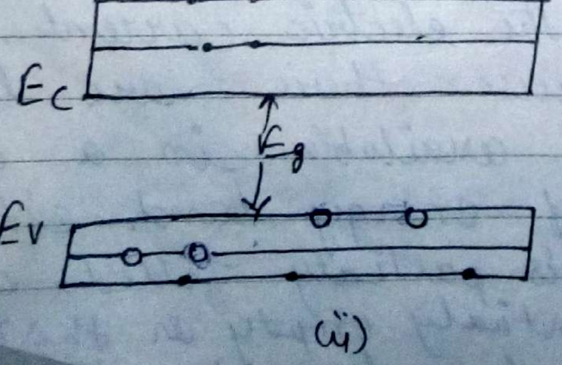


✱ formation of hole →

- At 0 K no electron jumps from valence band to conduction band. It means germanium or silicon semiconductor at 0K behaves as as an insulator.
- When the temperature of germaium and silicon increases then some electrons gains thermal energy due to thermal agitation and jump into the conduction leaving behind equal no. of electron in valence band as shown in fig.
- This deficiency of electron is called hole.



(i)



(ii)

Dispersion forces or London forces
Dipole - Dipole forces
Dipole induced dipole forces
~~Hydrogen bond~~

✱ Intermolecular forces →

Intermolecular forces are the forces of attraction and repulsion between interacting particles (atoms and molecules).
This term does not include the electrostatic forces that exist between the two oppositely charged ions and the forces hold atoms of a molecule together i.e. covalent bond.
~~They are~~ Attractive intermolecular forces are also known as Van der Waals forces.

✱ Structure of ~~atom~~ Matter →

- Matter is anything that has mass and occupies space. It is found in nature in the form of either element or compound.
- Element is that matter which can neither be broken down any further into a simpler substance by ordinary chemical means nor built up from any simpler for of matter.

→ For example → Iron can neither be decomposed into other simplest substance.

- Compound is a matter which can be built up by combining two or more than one element.

→ For example → water

different thinkings about matter →

(i) Kanada → Matter cannot be subdivided into smaller pieces without end.

(ii) Democritus → He argued that matter consists of a very large number of extremely small particles called atoms.

iii) John Dalton →

(i) Each element consists of a very large number of extremely small particles called atoms.

(ii) Atoms of the same element are identical in all respects but different from those of other elements.

(iii) Compound is a collection of molecule.

(iv) Molecules of a compound are identical in all respects.

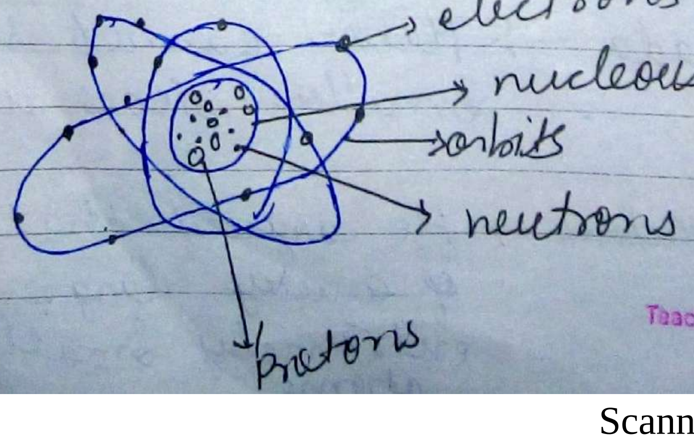
(v) An atom can neither be created nor destroyed.

- Matter is a collection of molecules which exists in the free state and has the same chemical properties as that of matter.

✦ Atomic structure →

- Atoms to all elements consist of three fundamental particles electrons, protons and neutrons.

Acc. to atomic structure an atom is composed of electrons moving in various fixed circular or elliptical orbits around a heavy nucleous made up of proton and neutrons. as



(a) Electrons → They are negative charge small particles moving the positively charged nucleous but fixed orbits.
mass → 9.1×10^{-31} Kg
charg → 1.6×10^{-19} coloumb
No. Electrons = No. protons

(b) Nucleous → A central hard core of an atom is called nucleous. It Contains protons & and neutrons. protons are +vely charged particles and neutrons are neutral.

(c) Atomic Number Z, atomic mass A and atomic mass of an atom M →
Nucleous = Z + N
atomic number = Z
Z = total no. of protons
N → total no. of neutrons
Atomic mass number = A
Ex → Ge ⇒ 32 protons(z) and 41 neutrons(N)
Atomic mass number = 32+41 = 73

✱ Electronic configuration →
There are some Subshells are also present with the exception of K-shell which is its own subshell.
No. Subshells = principal quantum No.
K Shell → 1 Subshell → S subshell
L shell → 2 Subshell → S, P Subshell
M Shell → 3 subshells → S, P, d subshell
N shell → 4 subshells → S, P, d, f subshell

Shell	Total No. of electrons	no. of sub shells	Name of Subshells	Electron distribution in subshell s	p	d	f
K (n=1)	2	1	s	2	-	-	-
L (n=2)	8	2	s, p	2	6	-	-
M (n=3)	18	3	s, p, d	2	6	10	-
N (n=4)	32	4	s, p, d, f	2	6	10	14

electronic configuration of some elements →

element	Symbol	Atomic No.	configuration
Hydrogen	H	1	$1s^1$
Carbon	C	6	$1s^2, 2s^2 2p^6$
Neon	N	10	$1s^2, 2s^2 2p^6$
Silicon	Si	14	$1s^2, 2s^2 2p^6, 3s^2 3p^2$
potassium	K	19	$1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^1$
iron	Fe	26	$1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^6, 4s^2$
Germanium	Ge	32	$1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^2 4p^2$
Xenon	Xe	54	$1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^2 4p^6 4d^{10}, 5s^2 5p^6$

Interatomic force →

- When atoms or molecules are brought close to each other, the distribution of charges in them becomes such that the force of attraction between opposite charges of the atoms or molecules becomes greater than the force of repulsion between similar charges. Thus a net force of attraction act between them. The net force of attraction between them atoms. The net force of attraction between the atoms is called interatomic

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(i) Ionic bonds →

- Ionic bond is formed when an atoms of elements such as Na, K, Ca, Ba, Mg etc. interacts with the atom of electronegative elements such as oxygen, sulphur, halogens etc.
- These ions have opposite charge, so they are attracted towards each other. This force of attraction is called ionic bond.
- electropositive element → give electron(s) → cation
- electronegative element → take electron(s) → anion
- Example →
- $Na \rightarrow Na^+ + e^-$ (gives electron → Na^+)
- $Cl + e^- \rightarrow Cl^-$ (take electron → Cl^-)
- $Na^+ + Cl^- \rightarrow [Na^+][Cl^-]$ (ionic bond is formed)
- Properties → (i) H.M.P (ii) brittle and hard
  (iii) bad conductor of electricity
  (v) liquids having ionic bond good conductor of electricity.

(2) Covalent bond → M.P < M.P (ionic solids)

This bond is formed when electrons are shared between two atoms. In covalent bond equal number of electrons are shared between the given atoms. Ex → Hydrogen

$H^{\cdot} + {}^{\cdot}H \rightarrow H{:}H$

The bond formed during sharing of electron is called covalent bond. Bad conductors of electricity even in liquid bec. no ions are present.

(3) Metallic bond →

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- The attractive force between the lattice ions and the free electrons which binds the atoms of the metal together is called Metallic bond
- Example → Ag, Cu, Fe, Na, Hg etc.
- They are malleable, ductile and high tensile strength..

H.M.P. (tungsten) and [L.M.P. (mercury).

Vander waal's force –

- The attractive forces between instantaneous dipole and induced dipoles are Vander wall's forces.
- It is a weak bond.
- The melting point of Solids having vander waal's bond is very low.

Ex → At Very low temp. inert gases get converted into their Solids form.

- The Solidification of Ne, Ar, Kr gases means that attractive forces acts between their atoms.
- The bond generated between the atoms due to these attractive forces is called vander waal's forces.

★ States of Matter →

- Matter exists in three states solid, liquid and gas.

Ex → Ice ⇌ water ⇌ steam
(Solid) (liquid) (gas)

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Solid → Wood, stone, Metals, ~~Stone~~ etc.
gases → Oxygen, nitrogen, air etc.
liquid → Water, milk, alcohols, oils etc.

(b) General properties of matter —
There are several properties which are common to all matter.

(1) Matter occupies space →
All material bodies occupy space. The space occupied by the matter is measured to be in terms of its volume.

(2) Matter has mass →
Everybody posses mass. Not a single matter in universe is maseless.

(3) Matter offers resistance →
It is not possible to go through the rigid wall. It is also difficult to walk in the storm and through the water upstream. These examples show that matter offers resistance.

(4) Matter is divisible →
All the matters are divisible whether they are in solid, liquid or in gaseous state. They can be divided into smaller particles. But the smallest particles which cannot be divided further by simple process is called molecules.

(5) Porosity →
All the matters in the universe are porous.

(6) Compressibility →
Due to spacing between molecules of the matter. It can be compressed to more or less extent by the application of force.

(7) Elasticity →
It is a property by virtue of which the substances regains its original shape or size after the external deforming forces. Steel > rubber. Liquids and gases are less elastic.

(8) Adhesion →
The force of attraction between the molecules of two different matter is called adhesive force. Drop of water on a glass plate.

(9) Cohesion →
The force of attraction b/w the molecules of same matter is called cohesive force.
Solids > gases (cohesive force).

(c) Special ~~properties~~ Of Matter —
• There are ~~cer~~ certain properties which are noticed in a particular state but not in all the three states of matter. These properties are called special properties.

(i) Solid →
A solid is a state of matter ~~in~~ which has definite shape and size. This due to the fact that the distance between the molecules of solid is very ~~less~~. less. Some of the special properties of ~~spec~~ solids are given below —

(a) Rigidity → It is the property in which the distance between the atoms or molecules of substances remains constant.
No body is perfectly rigid.

Hardness →
It is a property of solid in which a body offers resistance to being cut or to be scratched by another substance. Diamond is the most hardest solid than others.

Brittle →
It is the property by which the matter can be broken into smaller pieces by hammering or throwing on the ground. Ex – Glass.

Ductility →
It is the property of a solid by which the solid matter can be drawn into a thin wire. Ex – gold, platinum

Malleability →
It is the property of a solid matter can be converted into a thin sheet by hammering. Example → gold, lead etc.

Incompressibility →
Solids have a definite volume. Even if a very large magnitude of force applied on solids. There is negligible change.

(ii) Liquid →
A matter in liquid phase ~~to~~ has tendency to retain its volume only but not its shape because the intermolecular forces are ~~between~~ comparatively less in liquids.

(a) Liquids have no shape of their own — When liquid is poured in a vessel it takes the shape of that vessel. No force is required to change the shape of liquid.

(b) Liquid maintains its own level-
Due to high molecular motion of a liquid. It always flows from higher level to lower level.

(c) Liquid exerts pressure —
Liquid exerts pressure on the walls of the vessel in which liquid is filled. Liquid exerts pressure equally in all direction of vessel.

(d) Liquid pressesses surface tension—
Surface tension is the property of a liquid by virtue of which the free surface of te liquid behaves like a stretched membrane.
Ex – The rise of water in capillary tube.

(iii) Gas —
In gases the internmolecular forces between the molecules are negligible and molecules of the gases move randomly in all directions within the container.

(a) Gases have no free space —
Gases spread quickly and occupy the space within the container. Hence gases have free surface.

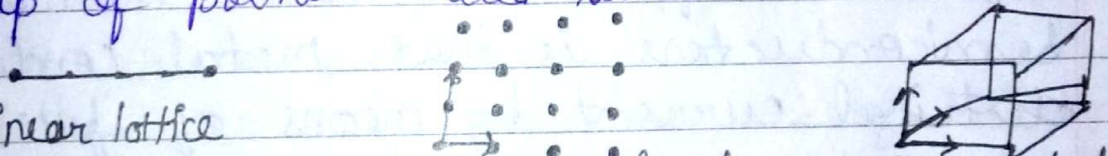
(b) Gases are highly compressible —
The volume of all the molecules of the gas is very small in comparison of the volume of the container. So the gases can be compressed easily.

✱ Crystal Structure of Solids –

Lattice – The lattice is defined as an array of points in space such that the environment about each point is same with the environment about any other point.

A Crystal has definite and regular shape so it is made up of regular and periodic arrangement of atoms or molecules or ions.

The crystal structure may be defined in terms of an idealized geometrical concept of group of points called lattice.



Linear lattice   Two dimensional lattice   Space lattice

lattice + basis = Crystal Structure

✱ Electrical conductivity →

The current density J depends upon the electric field E and it is directly proportional to it.

$$J \propto E$$

$$\text{or} = J = \sigma E \quad (A/m^2)$$

where σ is constant and called electrical conductivity of the material of conductor.

Thus electrical conductivity is define as the ratio of the current density to the electric field.

$$\sigma = \frac{J}{E} = \frac{q n v_d}{E} \quad (\text{mho}/m)$$

Mobility —
It is defined as the drift velocity per unit electric field, i.e.

$$\mu = \frac{V_d}{E} \quad (m^2/V\text{-}s)$$

Electrical conductivity

$$\sigma = q n \mu$$

~~Electrons and holes in un~~

* Electrical properties of Germanium and Silicon.

Important difference between metals and semiconductors is that metal conducts ~~electrical~~ current by means of free electrons only whereas semiconductors conduct current by means of electrons and holes.

Important properties of Germanium and Silicon.

Property	Silicon	Germanium
Atomic number, Z	14	32
Atomic weight, M	28.1	72.6
Density d	2.33×10^3	5.32×10^3
Relative permittivity ε_r	12	16
Concentration of atoms N	5.0×10^{28}	4.4×10^{28}
Hole diffusion constant	1.3×10^{-3}	4.7×10^{-3}
Electron diffusion Constant	3.4×10^{-3}	9.9×10^{-3}
Hole mobility	0.05	0.18
Energy gap at 0K	1.21	0.785

Donor impurity — V group

- When the four electron of fifth group make bonding with four electrons of Ge or silicon, then one atom ~~got free~~ of fifth no. of fifth group get free due to weak binding with parent atom.
- At normal temperature this free electron is transferred to the conduction Band. Thus every atom of impurity element of fifth group contibutes one free electron as a charge carrier and due to this property the fifth group impurity is called donor impurity.

Acceptor impurity → III group

When we mix the element of ~~third group~~ third group with fourth then the three atom of impurity atom form covalent bond with another three atoms but ~~one~~ the fourth atom remains free. but deficiency of one more electron for making bonding. This vacant site of electron is called hole and it has the capability of capturing an available electron. The impurity of third group is called acceptor impurity.