

Solid State

Introduction

Matter exists in solid, liquid or gas phase however that phase will dominate whichever in state at given temperature and pressure

kinetically at molecular level thermal energy and interparticle forces determine the phase of the matter.

Solid phase exists at low temp.

i.e. when thermal energy is less than interparticle forces

A solid has definite volume shape more interparticle forces less interparticle distance and the particles can oscillate about their mean position. Solids are incompressible and rigid.

Classification of solids

Crystalline

Anisotropic

- ① Regular arrangement of constituent particles
- ② Sharp melting points

No sharp melting point, tiny range over range of temp.

③ Define heat of fusion

No definite heat of fusion

Pseudo solids are super cooled liquids.

④ True solids

⑤ When cut with sharp edged tool the two pieces are plane and smooth

⑥ Long range order

⑦ Very short range order.

⑧ Very short anisotropy

i.e. properties are different in electrical resistivity, electrical conductivity, thermal expansion are different in different direction.

They show isotropy

i.e. the properties are same in all the directions.

⑨ Very short range order.

⑩ No regular arrangement of constituent particles

⑪ No sharp melting point

⑫ No sharp melting point

⑬ No sharp melting point

⑭ No sharp melting point

⑮ No sharp melting point

⑯ No sharp melting point

⑰ No sharp melting point

⑱ No sharp melting point

⑲ No sharp melting point

⑳ No sharp melting point

Crystalline.

NaCl, KNO₃, quartz,
ice, H₂O, naphthalene,
C₆H₆, benzocaine, etc.

The may have
either axis, plane, or
center of symmetry

Amorphous.

rubber, glass, plastic
at quartz, glass
Iogen PVC, fibre
glass etc.

The do not have
elements of
symmetry.

Classification of Solids

Based on nature
of bonding i.e.

Ionic Solids

1) Covalent Network Solids

2) Metallic Solids.

3) Molecular Solids.
— Polar molecular solids
— Non polar molecular solids
— Hydrogen bonded molecular
solids.

Types of crystalline solid	constituent particle	Nature of bonding	Examples	Physical nature	Electrical conductivity	Melting P.O.T.
① Molecular solid:						
- Non polar	Molecules	London (or) dispersion force	$\text{N}_2, \text{CO}_2, \text{CCl}_4,$ $\text{Ar}, \text{He}, \text{P}_4, \text{C}_6,$ Benzene.	soft (gel like) at room	Insulator	Very low
- Polar	Molecules	Dipole-Dipole interaction	$\text{HCl}, \text{SO}_2, \text{H}_2\text{O}$ Urea, P_4O_{10}	soft (gel like) at room non visc.	Insulator	low
- Hydrogen bonded	Molecules	π -bonding	ice	hard (volatile fig) solid at room	Insulator	low
② Ionic solid	ions	ionic	$\text{NaCl}, \text{CaCl}_2,$ $\text{Na}_2\text{O}_4, \text{MgO},$ $(\text{NH}_4)_2\text{SO}_4, \text{LiBr}$ calcite (CaCO ₃) chalk	hard, but brittle	Insulator in solid state but conductor in molten (or) aqueous state.	high
③ Metallic solid	metal ions (Kernels) in sea gage's.	Metallic bonding	$\text{Cu}, \text{Fe}, \text{Ag},$ Brass, Mg, Sn	hard but malleable and ductile.	Conductor	Fairly high.
④ Covalent or Network Solids	atoms	covalent bonds	graphite, diamond, $\text{SiC}, \text{Silica}$ SiO_2 quartz, AlN	hard (Except graphite) + soft	Insulator (Except graphite) + conductor	Very high
1) network						

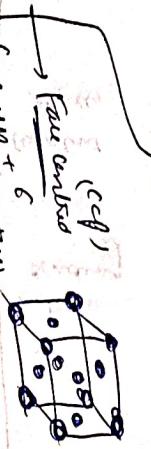
Important terms:

① Crystal lattice \rightarrow the regular s-p arrangement of constituent particles in solid crystal lattice.

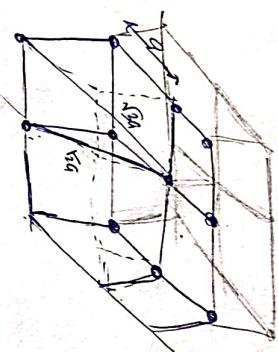
② Lattice point \rightarrow the position occupied by constituent particles within the crystal lattice at lattice points.

③ Unit cell \rightarrow the smallest repeating unit which when repeated generates crystal lattice in unit cell.

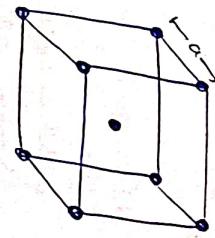
Types of unit cell
1. Simple unit cell
2. Primitive unit cell



+ Body



Body centred cubic: new
connected



$$4r = \sqrt{3}a$$

$$\frac{2(2r)}{\sqrt{3}} = a$$

All the adjacent corner atoms touch to the body centred atom.

- (2) No. of atoms per unit cell $\approx 1 + 8\left(\frac{1}{8}\right) = 2$

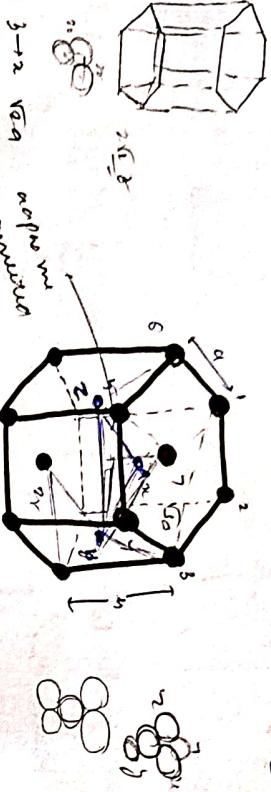
(3) Co-ordination no = 8

(4) Density (ρ) = $\frac{Z(M_N)}{a^3}$

Face centered $\left| \begin{array}{c} \text{Nearest neighbors} \\ | \\ 12 \end{array} \right|$ and nearest $\left| \begin{array}{c} 12 \\ | \\ 12 \end{array} \right|$

58.4% vacant

(4) Hexagonal close packing (hcp)



coordination no = 12
 $\rightarrow 2 + 3 + 6 = 12$

density $\rho = \frac{\sigma (N_{Ave})}{a^3 n}$

$$\sigma = 2r$$

$$N_{Ave} = \frac{6(\sqrt{3})}{4} \times a^2$$

V_{unit} = $A \cdot h$

$$= \sigma (\sqrt{3} \times a^2)$$

(45) Packing fraction \rightarrow

$$\sigma = \frac{4}{3} \pi r^3 \times \frac{N_{Ave}}{V_{unit}}$$

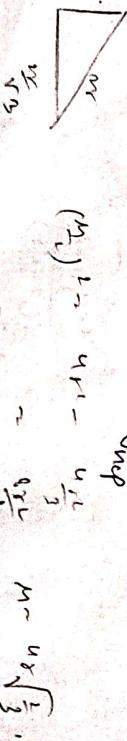
Face center

$\left| \begin{array}{c} \text{Nearest neighbors} \\ | \\ 12 \end{array} \right|$ and nearest $\left| \begin{array}{c} 12 \\ | \\ 12 \end{array} \right|$

" (unit cell) nearest of hcp.

" nearest $\left| \begin{array}{c} 12 \\ | \\ 6 \end{array} \right|$

" 2nd nearest



$$\approx \frac{1}{2} \times 11.23$$

$$\approx \left[\frac{\sqrt{3}}{4} \times (\sqrt{2} + 1)^2 \right] \times \frac{4}{3} \times \sqrt{\frac{2}{3}}$$

$$\approx \frac{1.1425}{3} \times \sqrt{\frac{2}{3}}$$

$$\approx \frac{11}{3} \times r_{100}$$

$$\approx \frac{3115}{11} \times 10^{-10}$$

$$\approx \frac{285.93}{11} \times 10^{-10}$$

$$\approx \frac{31.45}{11} \times 10^{-10}$$

$$\approx 1.57 \times 10^{-10}$$

$$\approx 0.274$$

$$\approx 0.0274$$

$$\approx 0.00274$$

1. Packing fraction

2. Coordination no. pairing efficiency

Site radius

Efficiency

$$\sigma = 2r$$

$$r_{12} = 4r$$

$$B.C.C.$$

$$2$$

$$8$$

$$64\%$$

$$74\%$$

$$79\%$$

$$82\%$$

$$84\%$$

$$85\%$$

$$86\%$$

$$87\%$$

$$88\%$$

$$89\%$$

$$90\%$$

$$91\%$$

$$92\%$$

$$93\%$$

$$94\%$$

$$95\%$$

$$96\%$$

$$97\%$$

$$98\%$$

$$99\%$$

$$100\%$$

Close packed structure

in 1 dimension

oooooo

(2) in 2 dimension

hexagonal close packing



square close packing - arr. abab... pairing up.

pairing efficiency = $\frac{\pi r^2}{a^2}$

$$\approx \frac{\pi r^2}{a^2} = \frac{\pi r^2}{(1+1/\sqrt{2})^2 r^2} = \frac{\pi}{1+\sqrt{2}}$$

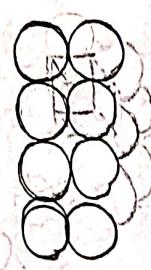
$$\approx 0.78 \times 0.7$$

$$\approx \frac{\pi r^2}{(1+1/\sqrt{2})^2 r^2} = \frac{\pi}{1+2/\sqrt{2}}$$

$$\approx \frac{\pi r^2}{(1+1/\sqrt{2})^2 r^2} = \frac{\pi}{1+3/\sqrt{2}}$$

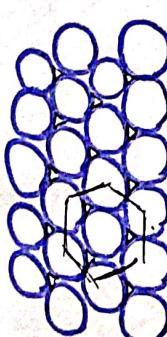
in 3 dimension

hexagonal close packing



3-Dimensional close packing

(a) square close packing
(AAA ---) simple cubic



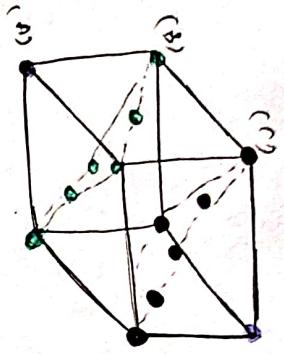
(b) From two dimensional hexagonal close packing
hexagonal closed packing
(ABC ---) face centered cubic

$$\text{Efficiency} = \frac{\text{Volume of spheres}}{\text{Volume of unit cell}} = \frac{\frac{4}{3}\pi r^3 n^2}{a^3 h^2} = \frac{4\pi r^3 n^2}{3(a^2 h)^2}$$

$$\approx \frac{4\pi r^3 n^2}{3(4\sqrt{2}/3 \times \pi r^2)^2} = \frac{4\pi r^3 n^2}{3(16/3 \times \pi r^2)} = \frac{3\pi r^2 n^2}{16}$$

$$\approx 0.74$$

(b) ABC ABC ABC ...
fcc or (ccp) unit closed packing



(n)

repetition of layer efferring L.

~~A B C A B A B~~

~~A B C A B C~~

↓ varies in size from fast to slow.

Q A compound formed by elements A and B crystallized in cubic structure where A atoms are at the corners and having face centres what is the simplest formula of the compound.

A corner face centre
 $\delta \times \frac{1}{8} = 1$
 $\delta \times \frac{1}{2}$

= A₁B₂

P - corner & body centre O - face centre
 $\delta \times \frac{1}{8} = 1$
 $\delta \times \frac{1}{2} = 2$
 $\delta \times 3 = 3$

A corner

$\delta \times \frac{1}{8} = 1$

1

$\delta \times \frac{1}{2} = 2$

2

$\delta \times 3 = 3$

3

O

C - edge centre

$\delta \times 12 = 12$

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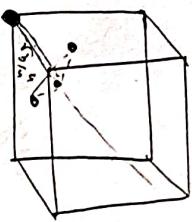
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JCC

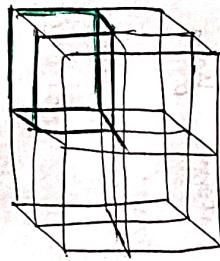
8. Aromatic voids.

1) Tetrahedral voids.



Mar. Body diagonal is along 1 void along.

Tetrahedral voids in FCC lie on the body diagonals and there are two tetrahedral voids on each body diagonal.

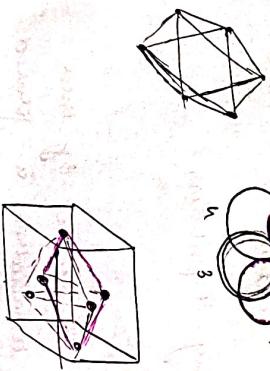


The distance of one tetrahedral void from nearest corner is $\frac{\sqrt{3}}{4}a$ i.e. $\frac{1}{4}$ of body diagonal.

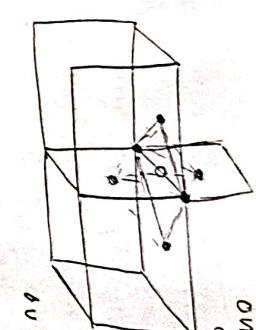
2) Octahedral voids. (formed spheres)

on joining the centers of three spheres, an octahedron is formed.

radius can be written as
unit cell void



one octahedral void is at the body center and remaining octahedra are at the **edge centers**,
i.e. at the **edge centers**,
per octahedral void.



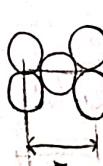
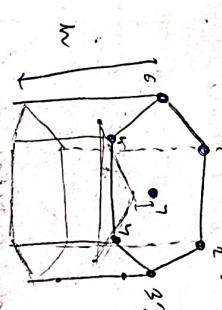
$$\text{No. of O.V} = 2 \times \frac{1}{4} = \frac{1}{2}$$

face up

$$\text{No. of O.V} = 2 \times 4 \times \frac{1}{6} = \frac{4}{3}$$

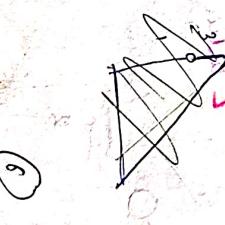
completely in unit cell

$$\text{octahedral voids} = \frac{1}{4} + \frac{1}{2} \left(\frac{1}{3} \right) = \frac{7}{12}$$



7 in diameter so 7 in per void

Octahedron voids are formed by joining centers of three spheres. So 7 in diameter is 7 in per void.

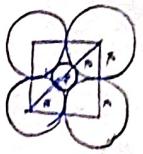


$$O.V = \frac{3}{4} \left[\frac{a}{2} \right] = \frac{3a}{8}$$



$$\left(\frac{1}{4}, \frac{3}{4} \right) \text{ from base of CCP}$$

Octahedral voids



$$\frac{2r + 2r}{\sqrt{2}} = \sqrt{2}r - 1$$

$$= 0.614$$

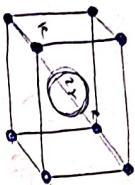
Octahedral void

$$\sqrt{3}a = 2(r+r)$$

$$\sqrt{3}(2r) = 2(r+r)$$

$$(\sqrt{3}-1) = \frac{\sqrt{3}}{r}$$

$$0.732 = \frac{r}{r}$$

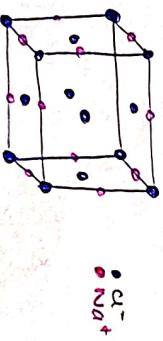


(NaCl) (Rock-salt)

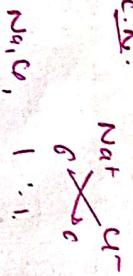


Na⁺ → octahedral voids

No. of atoms per unit cell



C.N. CN of cation = Nearest anions
CN of anion = Nearest cation.



No. of Cl⁻

1 : 1.

(v) In S (sphalerite)



Na⁺ → $\frac{1}{2}$ (No. of Tetrahedral voids)
in alternate Tetrahedral voids

No. of ions per unit cell

$$m^{+2}$$

$$m^{-2}$$

$$1 : 1$$

Y nothing is
superscript hole
vacancies as
minerals.

Coordination no:

$$m^{+2} \rightarrow S^{-2}$$

$$12 \times \frac{1}{2}$$

$$= 6$$

corner of hex and face
voids are included

not hole.

Ans (Wurtzite).



No. of ions per unit cell

$$m^{+2}$$

$$m^{-2}$$

$$= 6$$

$$6^{-1}$$

$$1 : 1$$

$$m^{-2}$$

$$6^{-1}$$

$$1 : 1$$



No. of Zn²⁺

1 : 1.

c.n. Zn²⁺

6

1 : 1.

No. of S²⁻

6

1 : 1.

No. of Zn²⁺

6

1 : 1.

No. of S²⁻

6

1 : 1.

No. of Zn²⁺

6

1 : 1.

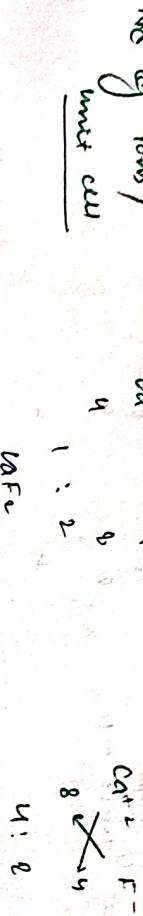
No. of S²⁻

6

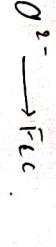
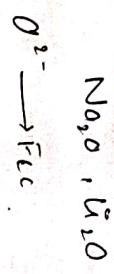
1 : 1.

3) Fluorite

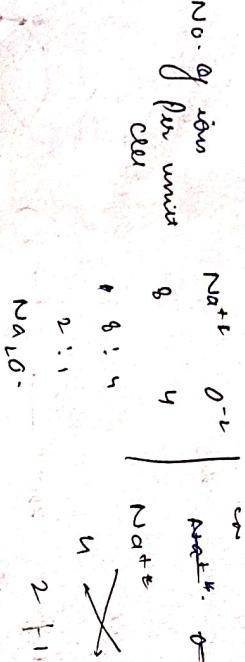
F^- ions alone have no extra valence due to one present longer.



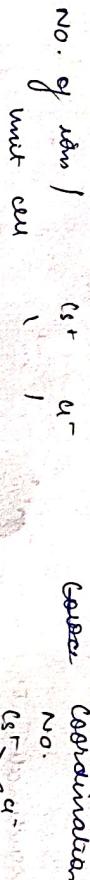
(5) Anti-Fluorite



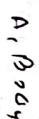
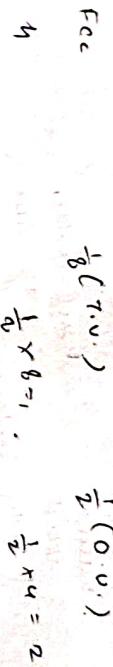
have corner atom
of FCC & tetrahedral
void for formation
isante val. to
coordination no



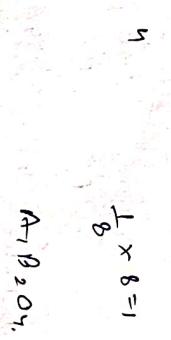
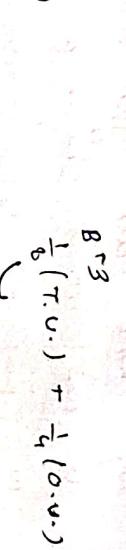
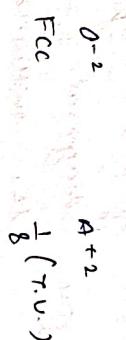
(6) Cubic lattice:
 $\text{CsCl} \rightarrow$ Bacteria cation has to cubic of CsCl are
present here.



7) Spinel Structure (AB_2O_4) ex: Magnetite

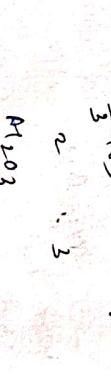
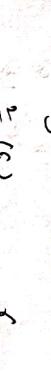
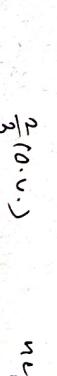
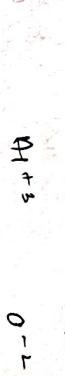


8). Amure Spinel (Al_2O_4)

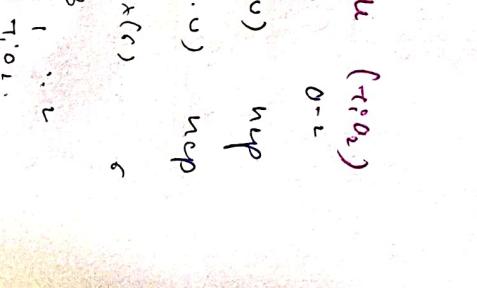
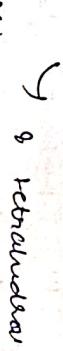
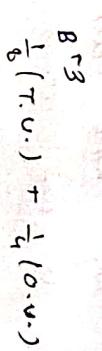


$\frac{1}{6}(8) \times \frac{1}{4}(4)$ voids are 40°
 $\Rightarrow 2$ efficient usage.

9). Corundum (Al_2O_3)



10) Rutile (TiO_2)



15) Penicillium (ca 7103)

$$Ca^{+2} \quad Tr. + H_2O - 2-$$

Far centres
of cure.

$$C \propto \frac{1}{L^2} = 3$$

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10

In a row you see structure of (MgB_2) of all the atoms along a face diagonal are missing two determine the molecular

Nat *u-*
v-u.

252

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A_{1c}.B₁₃

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$$y = -\int \frac{1}{2} \left(x^2 + y^2 \right) dx$$

$$F_{CC}^{-1}(A^t)$$

of $(A + B)$
the diagonal
matrix

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with

c) y starts along $f(x)$ and opinion goes in mining

$$A = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

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(a) A storm along an anti-parallel dimension.

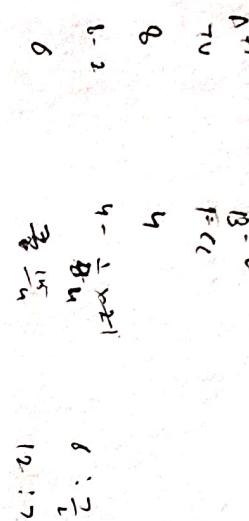
age centre of body diagonally approach & legs
when running.

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19. 8

(b) if down among it any, body aggression or

Q. In an ionic crystal type structure of MgO if one ion atom along a body diagonal is missing then determine the molecular formula.



~~Diagram~~ - 9.5

$\Delta 9.5$

Defect in lattice

Point defect

wire defect
plane defect

Stochiometric / Natural / thermo dynamic defects

Non-ionic defect

Vacancy defect

Interstitial defect

Substitutional defect

Frenier / intercalation defect

Plastic

Anti-site defect

Missing

Non stoichiometric impurity defect

Impurity defect

metal defect

metal defect

Intercrystalline metal defect

In all the above electrical neutrality is maintained

Vacancy Defect

If few or more atoms are missing from the lattice points

vacancy defect can also develop when a lattice is heated.

Interstitial defect

Constituent particle occupy few interstitial few sites also

Schottky defect

It is a type of vacancy defect in ionic solids and few cations and anions are missing from the lattice points such that electrical neutrality is maintained.

Eg:- In NaCl there are approximately 10^5 existing
pains per cm³. at room temp. and in
ions there are about 10^{10} ions. so there

In one existing defect per 10^{10} ions
this defect is known as ion vacancies
with high concentration no and in which
cation and anion are of almost similar size

Eg:- Na₁, K₁, KBr, AgBr, CsCl.

Frenkel Defect

The smaller ion usually cation is dislocated from
its normal site to an interstitial site.
Thus it creates a vacancy defect.
at its original site and an interstitial defect
at its new location.

Frenkel defect is shown by some solids with
non ion and in which there is large
difference in size of ions

Eg:- Cu, AgI, AgBr, AgCl

AgBr shows both Schottky and Frenkel defect

Impurity Defects

① Interstitial impurity defect:

In the original lattice of iron impurities of
size C are introduced which occupy interstices
This changes the properties of material.

② Schottky impurity defect:

If we take NaCl containing a little amount
of silver is crystallized. Some of the
sites of Na⁺ ions are occupied by Silver
ions. To maintain electrical neutrality same size
replaces 2 Na⁺ ions. So suppose the site
of one ion and the other site remains vacant.
Thus the no. of cation vacancies = No. of silver
similarly AgI with silver can also form such defects.
Thus formation like that can increase the type
of defect.

Non - stoichiometric defect

③ Metal excess defect:

metals excess defect occurs when
cations of metal are present in amorphous
state which are not in their normal state

on the surface of the crystal. It can diffuse to the surface and combine with sodium atoms to form Na^+ ions. The released electrons diffuse into the crystal and occupy anionic sites. This crystal now has excess of sodium and the anionic sites occupied by impurities are called

F- colour F- colour F- colour
winter winter winter

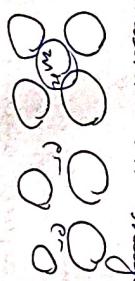
This import wear colour to Nac crystal

to her daughter and violet or blue bloom

Metal cures due to the presence of extra cations at interstitial sites.

Mn is white in colour at room temp. on heating it turns orange and turns yellow.

Now there is even a π in the crystal (Li_2MnO_3)
the even more to the interstitial sites
and the electrons are present in measuring
interstitial sites



Moral Definitions

there are many series which are difficult to
prepare in stoichiometric composition and
contain less amount of metal

To maintain electrical neutrality some iron atoms are first removed in the oxidation state also other than +2.

D strawine r. of Cationic sites, vacant.

more compound was made for more detailed test. This was 0.01 g. and was very empty.

feosso ke 100 formula units me when they get
known wrong ans 0-1 100 wrong

Kun Fe+2 and laur 1-2+3 93-m w01

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 $\text{F}_{\text{Fe}} + 2 \approx 93 - 75$
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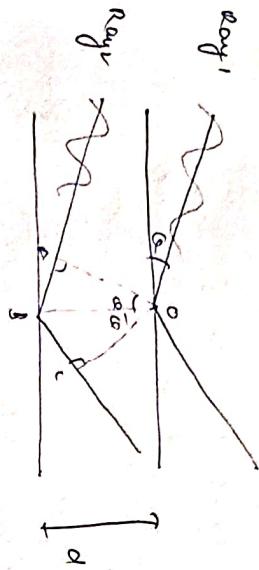
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(b) No. of rays $F_{Fe^{+3}}$ ion.

$$= \frac{14}{34} \times 100$$

Bragg's law { to determine distance between crystallographic planes

X-ray diffraction



$$AB + BC = n\lambda$$

$n = \text{order of diffraction}$

X-ray are used in this experiment as no wavelength is of the same order as interlayer distance (d)

From the given figure ray r_1 and ray r_2 , will constructively interfere after diffraction only when distance between them is λ . $(AB + BC)$ is integral multiple of wavelength.

A simple cubic lattice having atoms placed at distance 2.77 \AA is exposed to X-rays. If $\lambda = 1.62 \text{ \AA}$ cause Laue 'a' if

there is 1st order diff. diffraction.

$$\text{order} = m$$

$$m = 1.62 \times 10^{-10} \sin \theta = 1 + 1.62 \times 10^{-10}$$

$$\sin \theta = \frac{1.62}{1.62 \times 10^{-10}}$$

$$\sin \theta = \frac{1.62}{1.62}$$

Electrical Properties of Solids

Conductor

$$L \sim 10^7 \Omega^{-1} \text{ m}^{-1} - 10^4 \quad 10^{-4} - 10^{-10} \Omega^{-1} \text{ m}^{-1}$$

less than 10^{-10}

annulator



can be overcome by raising T.

for & conduction band.

Semi-conductors:

At the

Pure semiconductor like Si, Ge (natural semi-conductors), have very low conductivity at room temp.

and it can be increased by doping with other

with p type valent impurities (n-type semi-conductors)

or with tri valent impurities (p-type semi-conductors) application of n-type and p-type semi-conductors.

① Doped :- used in a combination of n-type and

p-type and n-type in n-type

- ② Transistor : Transistor are made by sandwiching a layer of n-type of semiconductor between two layers of other type i.e. either p-type or n-type. These are used to detect or amplify radio or audio signals.

- ③ Solar cells : solar cells are efficient photodiodes to convert light energy to electrical energy.

In As semi-conductors have very fast response.

In Cd, CdS, MgTe, are example of p-type semi-conductors. TiO₂, MnO₂, ReO₃, lanthanum silicate metals UO₂, VO₂, Cr₂O₃ and TiO₃ show metallic or insulating properties depending on temp.

Piezoelectric substances

On applying mechanical stress few crystals produce electric signals due to displacement of ions
Eg: Tetrahedral Ba, lead, barium lead zirconate PbZrO₃, Barite, ammonium dihydrogen phosphate: (NH₄HPO₄).

Pyroelectric substances

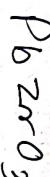
On heating produces electric current

Ferroelectric substances

In ferro piezoelectric crystals domain can remain polarized even after removal of electric field and on applying electric field are in opposite direction the direction of polarization can change.
Note :- all ferroelectric solids are ferro piezoelectric but not vice versa.
Ex: BaTiO₃, K₂PO₄ (Rouelle salt), sodium potassium Tartrate)

Anti ferroelectric substances

dipoles align in opposite direction in equal numbers such that the net dipole moment is zero.



LiNbO₃

Magnetic Properties

- ① Paramagnetic contains distant or unpaired e⁻. They are weakly attracted by magnetic field and gets magnetized in the same direction as external magnetic field. but lose their magnetism in absence of magnetic field.

Eg: O₂, Li⁺, Fe²⁺, Cr³⁺, TiO₂, TiO₃, UO₂, V₂O₅, Co²⁺.

② Diamagnetism

all paired, and they lose their magnetic qualities due to

canceling of magnetic moment.

Weaving repelled by magnetic field. i.e. they are weakly magnetised in opposite direction

Ex H₂O, NaCl, Cr

Ti₄O₂, Ag_2O , Al_2O_3

(3) *Hg, N₂, etc.*

— (S) V. Mont.
have unpaired

四

In Ag , Cu atoms are paramagnetic
but they are diamagnetic

Ferromagnetic

In solid state the metal ion of ferromagnetic substance are grouped together into small regions called domains each domain act as a tiny magnet and in absence of magnetic field their dipoles are randomly oriented and their magnetic moments get cancelled.

When placed in external magnetic field all domains get oriented in the direction of magnetic field and a strong ~~field~~ magnetism is produced.

This magnetic magnet magnet makes magnet magnet

Fe, Co, Ni, Cd, Cr₂O₃

Annie

But in presence of magnetic field their domains rotate in opposite direction in equal numbers and cancel each other's magnetic moment.

They do not attract or repel in magnetic fields.

0 $\bar{\text{Ex}}$ $\bar{\text{Tr}}$ Huo

Fe_2O_3 , 60.0, Ca_3O_4

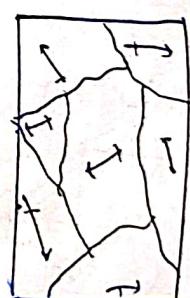
11

The domains orient in various no. in anti-parallel direction and are weakly attracted by magnetic field

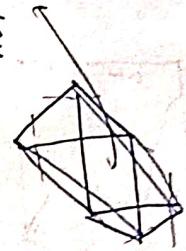
Fig. 1: Fegon's magnetite
ferrites like

MgFe_2O_4 , magnetite

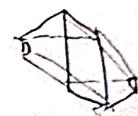
Note on heating fuso, antifuso, and fusin
are converted to parafusin.



Truncated octahedron



Has wider & less flat end faces.



Crystallizes
as hexagonal.

Iron pyrite
or magnetite



Diamond

Iron pyrite
or magnetite

Octahedral void in center
alternate tetrahedral voids in present.



Elements of symmetry in a cube.

- ① Centre of symmetry \rightarrow 1 (so rectangular plane)
- ② Plane of symmetry \rightarrow 9 (3×3 square plane) or (body diagonal)
 \rightarrow 3 (body diagonal edges)
- ③ Axis of symmetry \rightarrow 13 $\frac{1}{23}$ (body diagonals).

Through face centers
of opp faces,

The mineral magnetite (one form of iron crystallizes
in one of cubic lattice with edge lengths 4.27 \AA
the density of magnetite 4.83 g/cm^3

(1) In which cubic lattice does the magnetite crystallize

- (i) Find the density of magnetite

$$a = 5.87 \text{ \AA}$$

$$f = 2 \times \frac{M}{N_A} = 2 \times \frac{55.87}{6.02 \times 10^{23}} = 11.24$$

$$S = \rho V =$$

$$\frac{4.27^3}{(5.87)^3} \times (5.87)^3 \times (10^{-10})^3 = 6.2 \times 10^{-10} \text{ g/cm}^3$$

$$n = 3.9 \rightarrow \text{Roughly same as rock has no
lattice vacancy holes}$$

$$n = 3.9 \rightarrow \frac{2 \times 1444}{6 \times 10^{-7} \times (5.87)^3} = 10^{-30}$$

2 = 3.9 \rightarrow Larger & more open lattice holes
than magnetite has
fewer centres, easier. $4 - 3.9 = 0.1$ unit per
unit cell.

$$f = (0.1) \frac{M}{N_A} = \frac{55.87}{6.02 \times 10^{23}}$$

$$f = 0.1 \times \frac{55.87}{6.02 \times 10^{23}} = 9.2 \times 10^{-24}$$

$$f = \frac{4.27^3}{8.9} \times \frac{1}{100} = 0.12$$

RbI crystallizes in the structure in which each Rb^+ is surrounded by 8 I^- ions ($R_{\text{I}} = 0.17 \text{ nm}$)

Find length of one side of RbI_2 unit cell.

Rb^+ is present in cubic void

I^- is present at corner.

$$r_{\text{Rb}} = a \sqrt[3]{\frac{1}{2}}$$

$$\frac{4x}{a^2} \approx 1$$

$$a^2 = \frac{962}{173}$$

$$= r$$

$$r = \frac{4x}{a^2} \approx 1$$

NaH crystallizes as rock salt - the edge length of cubic unit cell of NaH is 4.11 \AA

a) calculate the ionic radius of H^- given $r_{\text{Na}^+} = 0.94 \text{ \AA}$

$$a = r + r$$

$$a = 4.11 + r$$

$$4.11 = 2(0.94 + r) \approx 2.3$$

$$r = \frac{4.11 - 2.3}{2} = 0.94 \text{ \AA}$$

$$a = r + r$$

$$a = 4.11 + r$$

$$4.11 = 2(0.94 + r) \approx 2.3$$

$$r = \frac{4.11 - 2.3}{2} = 0.94 \text{ \AA}$$

b) calculate the density of NaH

$\text{R}_1 = \sqrt{3} - 1$

$$\frac{R}{R_1} = 0.732$$

$$R = (\sqrt{3} - 1) R_1$$

$$R = 2(\sqrt{3} - 1) R_1$$

Q A strong current of trivalent gaseous Boron is passed through Germanium crystal due to short decrease in the density of crystal due to short replacement of the ~~and~~ by B & due to vacancies created by missing one atom. In one such experiment 1.8% are taken. & the Boron atoms are found to be 100 ppm by weight in the final crystal and the density of the crystal decreases by 4%. Calculate % of missing vacancies due to the 1 which are placed on my Boron atoms ($\text{B}_n = 22.0$)
 $B = 11.5$

On increasing pressure can increase and on decreasing temp can decrease