

Unit cell

A unit cell is the most basic and least volume consuming repeating structure of any solid. It is used to visually simplify the crystalline patterns solids arrange themselves in.

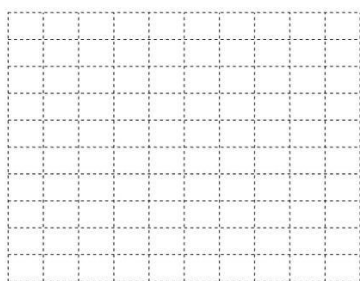
Characteristics of a crystal lattice

1. In a crystal lattice there is the parallelepiped constructed from vectors which correspond to translational periods called unit cells.
2. These can be chosen in different ways. Commonly, unit cells are chosen so that its vertex coincides with one of the atoms of the crystal.
3. Then lattice sites are occupied by atoms, and of the atoms of the crystal. Thus, the lattice sites are occupied by atoms, and vectors that connect the nearest equivalent atoms.
4. The unit cell contains at least one atom of each of the types that make up the crystal.
5. Providing that the unit cell is made up of only one type of atom, it is called monatomic, anymore than that and it is polyatomic. Correspondingly a monatomic lattice is often identified as a simple lattice and a polyatomic one, a composite lattice.

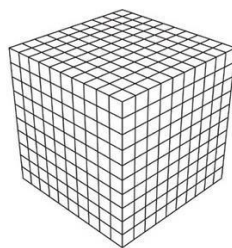
Two dimensional lattice

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One dimensional Lattice



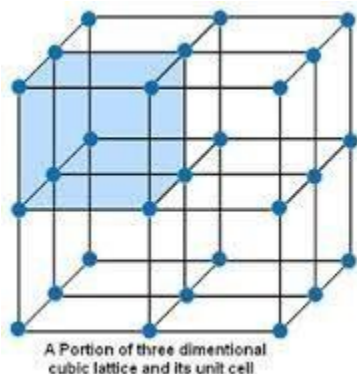
Two dimensional Lattice



Three dimensional Lattice

It is a regular arrangement of points in the plane. The unit cell that does not contain any interior point is called primitive unit cell.

3 D dimensional lattice



The constituent particles of a crystalline solid are arranged in a definite fashion in 3-D space.

Primitive unit cell

Unit cells in which the constituent particles are present only at the corners are called primitive unit cells.

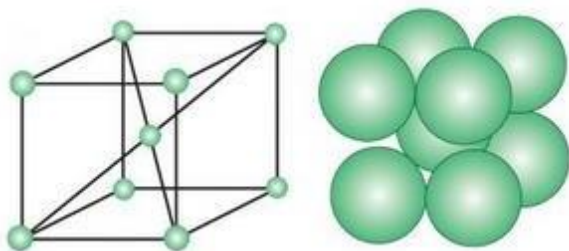
Non-primitive unit cell

Unit cells in which the constituent particles are present not only at the corners of the cell but also at some other position.

Type of non-primitive unit cell

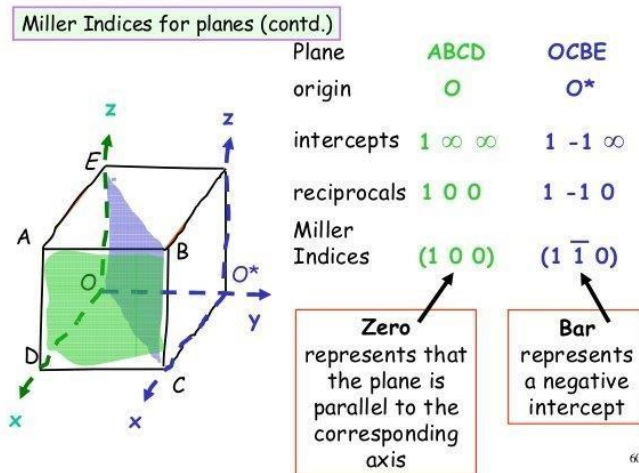
Face centered
End-centered
Body centered

Space filling structure and open structures



The figure shows the open and space filling structure of BCC lattice. In open structure, the atoms are represented far from each other. In space filling structure, the atoms are packed closely.

Miller indices



Miller indices form a notation system in crystallography for planes in crystal (Bravais) lattices. In particular, a family of lattice planes is determined by three integers h, k, and l, the Miller indices.

Coordination number

A unit cell of solid represents by points connected by lines where points represent the constituent particles and lines help to visualize the symmetry of solid. The arrangement of particles can be explained in one, two and three dimensional. When the arrangement extends to two or three dimensional, each lattice point is surrounded by a certain number of other spheres. The number of spheres which are touching a particular sphere is known as coordination number. For example, in one dimensional there is only one way to arrange spheres in which each sphere is in contact with two other spheres, therefore in this close packing of sphere, coordination number is two.

Contribution of atoms present at different lattice sites

An atom at the corners is shared by eight unit cells. Hence the contribution of an atom at the corner to a particular cell = $1/8$

An atom at the face is shared by two unit cells. Hence the contribution of an atom at the face to a particular cell = $1/2$

An atom at the edge centre is shared by four unit cells in the lattice and hence contributes only $1/4$ to a particular unit cell

An atom at the body centre of a unit cell belongs entirely to it, so its contribution = 1

Number of atoms in a unit cell of simple cube

There are eight atoms at the corners. Each corner atom makes $1/8$ contribution to the unit cell so
no. of atoms present in the unit cell = $8 \times 1/8 = 1$

Number of atoms in a unit cell of a BCC

BCC has 8 atoms at the corners and one atom, within the body. Each corner atom makes $1/8$ contribution and the contribution of atom within the body = 1. No. of atoms present in
bcc = $8 \times 1/8$ (at corner) + 1 (at the body centre) = $1 + 1 = 2$

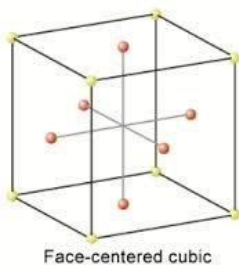
Number of atoms in a unit cell of FCC

FCC has 8 atoms at the corners and 6 atoms on the faces (one on each face). Contribution by atoms at the corners = $8 \times 1/8 = 1$. Contribution by atom on the face = $6 \times 1/2 = 3$. Number of atoms present in fcc unit cell = $1 + 3 = 4$.

Concept of nearest neighbours

We know that the fcc structure is a close packed one its also known as *cubic close packed* so we have six nearest neighbors in one layer, three in the layer above, and three in the layer below. So every structure has some geometry in which every layer have numbers of particles which are neighbors of each other.

Properties of FCC

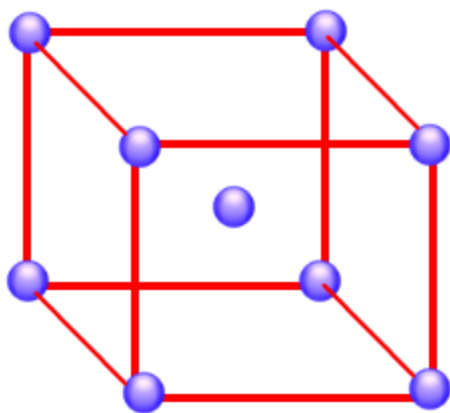


1. The face centered cubic structure has atoms located at each of the corners and the centers of all the cubic faces.
2. Each of the corner atoms is the corner of another cube so the corner atoms are shared among eight unit cells.
3. Additionally, each of its six face centered atoms is shared with an adjacent atom. Since 12 of its atoms are shared, it is said to have a coordination number of 12.
4. The fcc unit cell consists of a net total of four atoms.

End-Centred Unit Cell

If one constituent particle lies at the centre of any two opposite faces besides the particles lying at the corners, it is known as End-Centred Unit Cell. It is also known as base-centred unit cell.

Properties of BCC



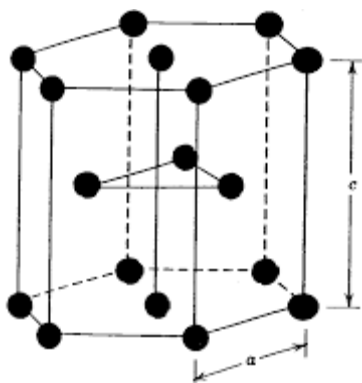
1. The body-centered cubic unit cell has atoms at each of the eight corners of a cube (like the cubic unit cell) plus one atom in the center of the cube.
2. Each of the corner atoms is the corner of another cube so the corner atoms are shared among eight unit cells.
3. It is said to have a coordination number of 8.
4. The bcc unit cell consists of a net total of two atoms; one in the center and eight eighths from corners atoms.

Properties of simple cubic crystal

The simplest cubic system is the simple cubic structure. The unit cell for the simple cubic structure contains one-eighth portions of eight corner atoms to make one complete atom,

molecule or ion in each unit cell. Given the radius of the atom or ion the edge length is just; edge length (a) = $2r$ where r is the radius of the atom or ion.

State the properties of HCP



HCP

1. The hexagonal structure of alternating layers is shifted so its atoms are aligned to the gaps of the preceding layer.
2. The atoms from one layer adjust themselves in the empty space between the atoms of the adjacent layer just like in the F.C.C structure. However, instead of being a cubic structure, the pattern is hexagonal.

Close packing

The packing of the sphere in such a way that the atoms occupy maximum available space and there is minimum empty space. This type of packing is called closed packing.

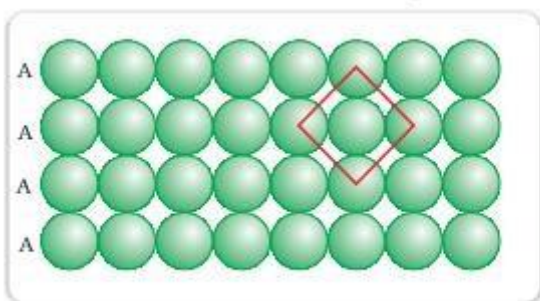
Closed-packing in one dimension with examples



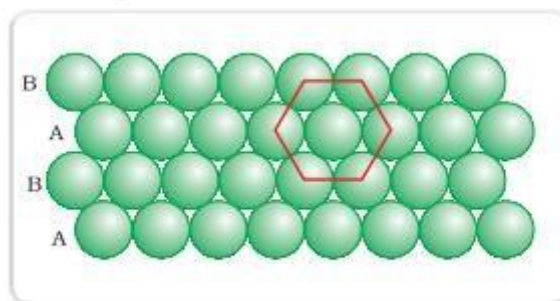
Closed packing of spheres in one dimension.

There is only one way in which the spheres can be arranged in 1-D. The spheres should touch each other in a row.

Close-packing in 2-D



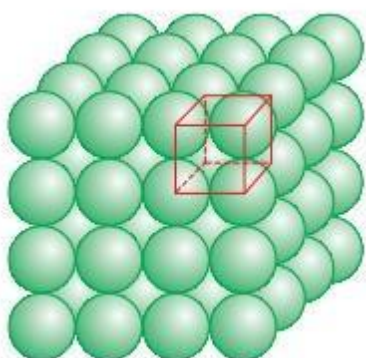
(a)



(b)

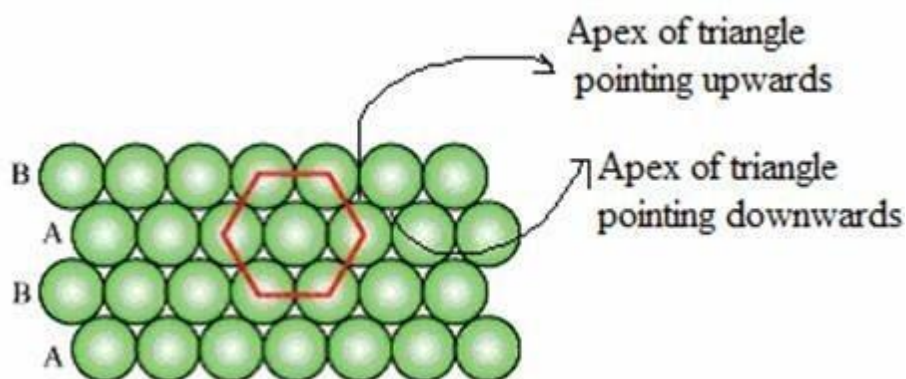
1. When a number of rows are stacked up, a two-dimensional crystal plane is generated. There are two ways of stacking the rows.
2. One way is for the rows to lie one above the other, with one sphere exactly above another. Here the spheres are aligned horizontally as well as vertically.
3. Here each sphere is in contact with four other spheres two on sides, one above and one below. Hence, the coordination number becomes four. If we join the centres of these four spheres, we will get a square. Therefore, this type of close packing is also referred to as square close packing.
4. The other way is for the spheres of the second row to be seated on the first row in a staggered manner, that is, in the depressions of the first layer.

Close packing in 3-D from 2-D square closed packed layers



Three-dimensional close packing from two-dimensional square close packing: To build a three-dimensional structure, it is easier to stack two-dimensional square close packed planes one above the other. The spheres are aligned horizontally as well as vertically. If the arrangement of spheres in the first layer is considered to be of A type, then the arrangement of spheres in the subsequent layers is also of A type. This three-dimensional arrangement is referred to as AAA type packing.

Form 3-D close packing from 2-D hexagonal close packed layers



Place each layer in such a way that they take the maximum space and minimum void space. This is shown in the image.

Packing efficiency

It is the ratio of volume of space occupied by the spheres by total volume. The packing efficiency is 74.05 % for both cubic and hexagonal close packing schemes. $\text{Packing efficiency} = \frac{(\text{number of atoms}) \times (\text{volume of one atom})}{(\text{Volume of unit cell})}$

Relationships between the radius of voids and the radius of sphere

Radius of the tetrahedral void relative to the radius of the sphere is 0.225

$\frac{r_{\text{void}}}{r_{\text{sphere}}} = 0.225$ In a multi-layered close-packed structure, there is a tetrahedral hole above and below each atom hence there is twice as many tetrahedral holes as there are in close-packed atoms.

Number of particles, octahedral voids and tetrahedral voids

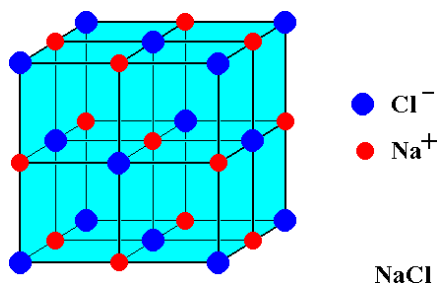
Number of octahedral voids = number of atoms

Number of tetrahedral voids = $2 \times$ number of atoms

The number of particles, octahedral voids and tetrahedral voids

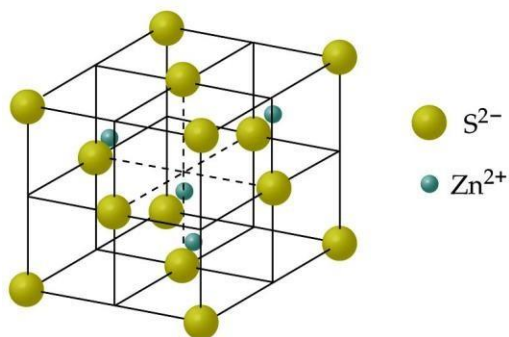
A compound forms hexagonal close-packed structure. How many tetrahedral voids are present in 0.5 moles of it?

Structure of NaCl



NaCl has a cubic unit cell. It is best thought of as a face-centered cubic array of anions with an interpenetrating fcc cation lattice (or vice-versa). The cell looks the same whether you start with anions or cations on the corners. Each ion is 6-coordinate and has a local octahedral geometry.

Structure of ZnS



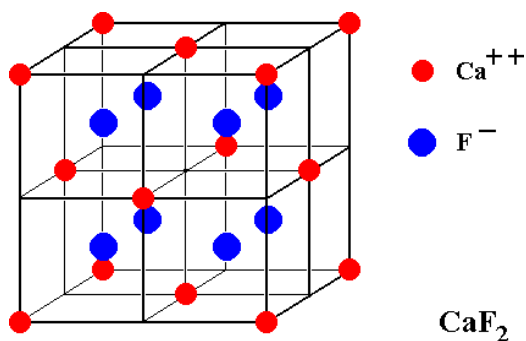
ZnS occurs in two common polytypes, zincblende (also called sphalerite) and wurtzite. The two types have these features in common:

- a 1:1 stoichiometry of Zn:S
- a coordination of 4 for each ion (4:4 coordination)
- tetrahedral coordination

Zinc blende/sphalerite is based on a fcc lattice of anions. In this structure, the cations occupy one of the two types of tetrahedral holes present. In this structure, the nearest neighbor connections are similar, but the distances and angles to further neighbors differs. Zinc blende has 4 asymmetric units in its unit cell.

Zinc blende is best thought of as a face-centered cubic array of anions cations occupying one half of the tetrahedral holes. Each ion is 4-coordinate and has local tetrahedral geometry. Zinc blende is its own anti-type -- you can switch the anion and cation positions in the cell and it doesn't matter (as in NaCl). In fact, replacement of both the Zn and S with C gives the diamond structure.

Fluorite structure



Slightly bigger cations in comparison to other structures

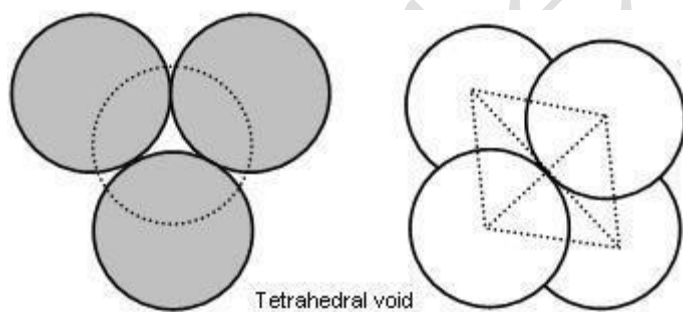
Typical representation of the structure appears as if cations make a FCC lattice and anions occupy the tetrahedral sites

While more appropriate Fluorite structure representation is shown below where eight primitive cubic unit cells made by anions are joined together to make a big cube and cations occupy the centers of four of these small cubes in an ordered fashion

Co-ordination number: Cations - 8 ; Anions - 4

Lattice: FCC

Formation of tetrahedral void

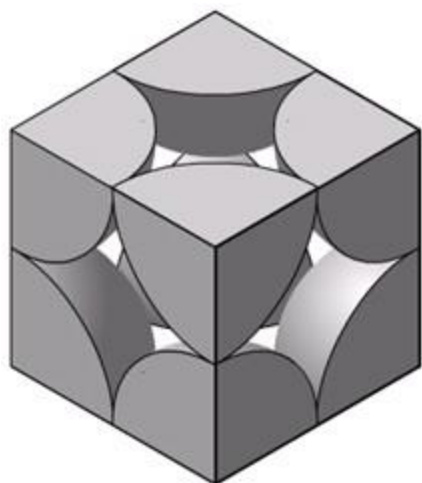


Tetrahedral sites in closest packing can be occupied by other atoms or ions in crystal structures of salts and alloys. Thus, recognizing their existence and their geometrical constraints help the study and interpretation of crystal chemistry. The packing of spheres and the formation of tetrahedral sites or holes are shown below.

Radius-ratio rule

S.NO.	RADIUS RATIO	CO-ORDINATION NUMBER	SHAPE	EXAMPLE
1.	0.0 – 0.155	2	Linear	HF ⁻
2.	0.155–0.225	3	Triangular planar	B ₂ O ₃ , BN
3.	0.225– 0.414	4	Tetrahedral	ZnS, SiO ₄ ⁻⁴
4.	0.414– 0.732	6	Octahedral	NaCl
5.	0.732 – 1.0	8	Body-centered cubic	CsCl

Relation between the edge of a unit cell and radius of the atom in a simple cubic unit cell



In simple cubic from the diagram we can say the edge of a cell a is equal to twice the radius of an atom.

Therefore $a=2r$

Defects

Any departure from perfectly ordered arrangement of constituent particles in crystal is called defect. The two types of defects are point defect and line defect.

Point defects

When the irregularities exist from the ideal arrangement around a point or an atom in solids, the defect is known as point defect. Types of point defects are:

Stoichiometric defects

Non-stoichiometric defects

Impurity defects

Line defects

When the deviation from the ideal arrangement exists in the entire row of lattice points, the defect is called line defect.

Stoichiometric defects

The compounds in which the number of positive and negative ions are exactly in the ratios indicated by their chemical formulae are called stoichiometric compounds. The defects do not disturb the stoichiometry (the ratio of numbers of positive and negative ions) are called stoichiometric defects. Types include:

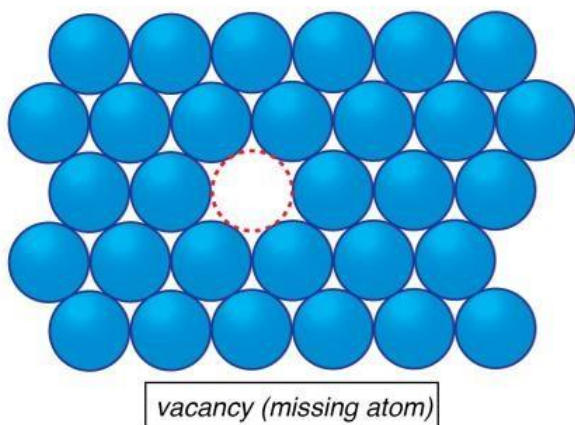
Schottky defect

Vacancy defect

Frenkel defect

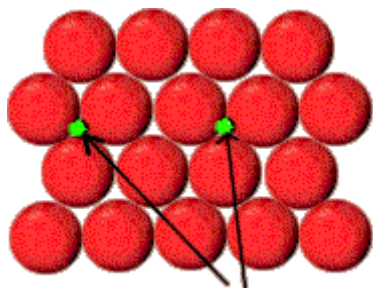
Interstitial defect

Vacancy defects



1. Vacancy defects are lattice sites which would be occupied in a perfect crystal, but are vacant.
2. If a neighboring atom moves to occupy the vacant site, the vacancy moves in the opposite direction to the site which used to be occupied by the moving atom.
3. The stability of the surrounding crystal structure guarantees that the neighboring atoms will not simply collapse around the vacancy.
4. In some materials, neighboring atoms actually move away from a vacancy, because they experience attraction from atoms in the surroundings.

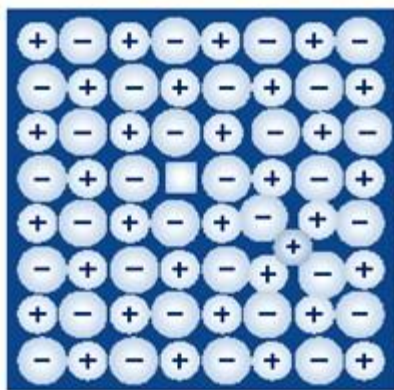
Interstitial defects



Interstitial Atoms

When some extra constitutional particles are present in the interstitial sites, the crystal is said to have interstitial defect. This increases the density of the substance.

Frenkel defects



Frenkel defects

This type of defect arises when an ion is missing from its lattice site and occupies an interstitial position. The crystal as a whole remains electrically neutral because the number of anions and cations remain same. Since cations are usually smaller than anions, they occupy interstitial sites. This type of defect occurs in the compounds which have low co-ordination number and cations

and anions of different sizes. e.g., ZnS, AgCl and AgI etc. Frenkel defect are not found in pure alkali metal halides because the cations due to larger size cannot get into the interstitial sites.

Consequences of schottky defect

It is a vacancy defect. The compounds having this type of defect shows high coordination number, have small difference in the size of cations and anions. Electrical neutrality is maintained. As the number of ions decreases the mass decreases and hence the density decreases.

Consequences of Frenkel defects

This defect is called dislocation defect as smaller ion is dislocated from its normal site to an interstitial site. The compounds having this defect have low coordination number, have large difference in the size of cations and anions. The density remains unchanged.

Non-stoichiometric defects

There are large numbers of inorganic solids found which contain the constituent particles in non-stoichiometric ratio because of defects in their crystal structure. These defects because of presence of constituent particles in non-stoichiometric ratio in the crystal structure are called Non-stoichiometric Defects.

Non-stoichiometric Defects is mainly of two types Metal Excess Defects and Metal Deficiency Defect.

Non-stoichiometric defect due to metal excess and metal deficiency

Metal excess due to anionic vacancies:

These type of defects seen because of missing of anions from regular site leaving a hole which is occupied by electron to maintain the neutrality of the compound. Hole occupied by electron is called F-centre and responsible for showing colour by the compound. This defect is common in NaCl, KCl, LiCl, etc. Sodium atoms get deposited on the surface of crystal when sodium chloride is heated in an atmosphere of sodium vapour. In this process, the chloride ions get diffused with sodium ion to form sodium chloride. In this process, sodium atom releases electron to form sodium ion. This released electron gets diffused and occupies the anionic sites in the crystal of sodium chloride; creating anionic vacancies and resulting in the excess of sodium metal. The anionic site occupied by unpaired electron is called F-centre. When visible light falls over the crystal of NaCl, the unpaired electron present gets excited because of absorption of

energy and impart yellow colour. Because of similar defect if present, crystal of LiCl imparts pink colour and KCl imparts violet.

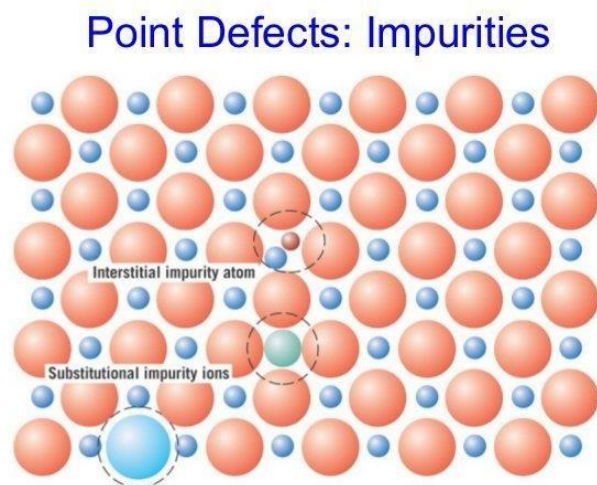
Metal excess due to extra cations in interstitial sites:

Zinc oxide loses oxygen on heating resulting the number of cations (zinc ion) become more than anions present in zinc oxide. The excess cations (Zn^{+} ions) move to interstitial site and electrons move to neighbouring interstitial sites. Because of this zinc oxide imparts yellow colour when heated. Such defects are called metal excess defects.

Metal deficiency:

Many solids show metal deficiency defects as they have less metals compare to ideal stoichiometric proportion. The less proportion of metal is compensated by same metals having higher valency. Such defects are shown generally by transition elements.

Impurity defects



If a foreign atom or ion or molecule is present in a crystal, then it has an impurity defect. Eg. solid solution of cadmium chloride and silver chloride. This defect does not disturb the stoichiometry of crystalline substances.

Substitutional solid solutions

Substitutional solid solution strengthening occurs when the solute atom is large enough that it can replace solvent atoms in their lattice positions. Examples of completely miscible binary systems are Cu-Ni and the Ag-Au FCC binary systems, and the Mo-W BCC binary system.

Interstitial solid solutions

Interstitial solid solutions form when the solute atom is equal to or slightly smaller and can fill the interstices between the solvent atoms. The atoms crowd into the interstitial sites, causing the

bonds of the solvent atoms to compress and thus deform. Elements commonly used to form interstitial solid solutions include H, Li, Na, N, C, and O. Carbon in iron (steel) is one example of interstitial solid solution.

Doping

The process of adding impurities to a crystalline substance to change its properties is called doping. Boron, aluminium is added for doping.

Doping by impurity

In case of ionic solids, the impurities are introduced by adding impurities of ions. If the valencies are different then the vacancy is created. In case of covalent solids such as silicon or germanium, the impurities added can be electron rich or electron deficient. This is known as electronic defects.

Electronic defects

Doping with electron rich impurities is called as electronic defects.

Group 14 has 4 electrons. If P or As is added which has 5 electrons, it form bond with P or As and the extra electron is left. This increases the conductivity as the electrons are increasing. This is n-type semiconductor.

Doping with electron deficit impurities: When to group 14 elements, B or Al is added, they form three bonds with group 14 elements. Thus a hole is created at the site where the fourth electron of group 14 elements is missing. This is electron hole. This type is called p-type semiconductor.

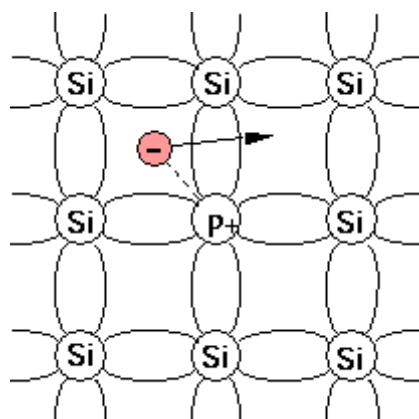
Types of electronic defects

Types of electronic defects are:

Doping with electron rich impurities

Doping with electron deficit impurities

n-type semi-conductors



Semiconductor materials like silicon and germanium have four electrons in their outer shell (valence shell). All the four electrons are used by the semiconductor atom in forming bonds with its neighbouring atoms, leaving a low number of electrons available for conduction. Pentavalent elements are those elements which have five electrons in their outer shell. When pentavalent impurities like Phosphorus or Arsenic are added into semiconductor, four electrons form bonds with the surrounding silicon atoms leaving one electron free. The resulting material has a large number of free electrons. Since electrons are negative charge carriers, the resultant material is called N-type (or negative type) semiconductor. The pentavalent impurity that is added is called 'Dopant' and the process of addition is called 'doping'.

Define and give examples of F-center

An **F-center**, F center or color center (from the original German *Farbzentrum*; *Farbe* means *color*, and *zentrum* center) is a type of crystallographic defect in which an anionic vacancy in a crystal is filled by one or more unpaired electrons. Electrons in such a vacancy tend to absorb light in the visible spectrum such that a material that is usually transparent becomes colored. This is used to identify many compounds, especially zinc oxide.

Cationic vacancies

A metal with higher valency replaces more than one metal ion with lower valency and hence, vacancies are created.

Classification on the basis of electrical conductivity

Conductors

Insulators

Semi-conductors

Conductors

Electrical conductors are materials which contain movable electric charge. The charge may be positive or negative. In case of metallic conductors like copper or aluminum the movable charge particles are electrons and in electrolytic conduction the movable charge particles are ions, either positive ions or negative ions e.g NaCl, KCl.

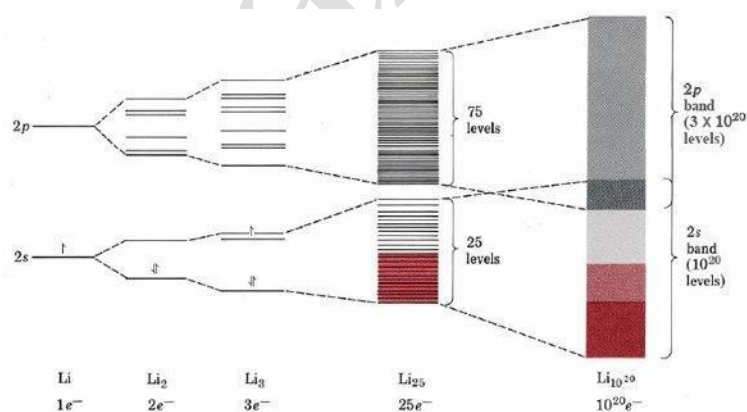
Insulators

Some common insulator materials are wood, plastic and rubber etc. Insulators are used to protect us from the dangerous effects of electricity flowing through conductors.

Semi-conductors

A solid substance that has a conductivity between that of an insulator and that of most metals, either due to the addition of an impurity or because of temperature effects. Devices made of semiconductors, notably silicon, are essential components of most electronic circuits. Example include Ge, As.

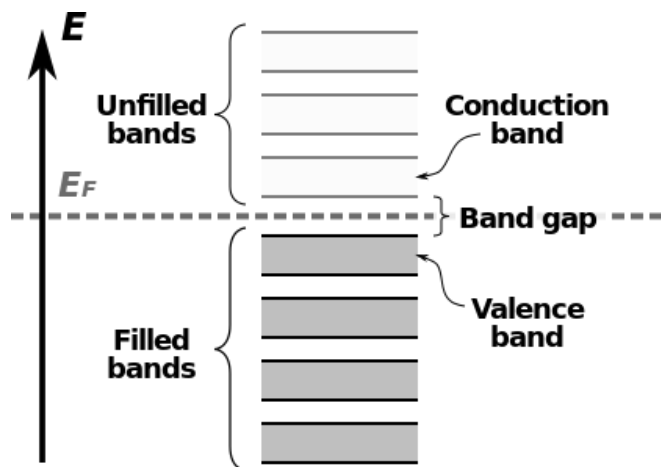
Band theory of metals



When an electron absorbs energy from an electric field, it is excited into an unfilled molecular orbital, constructed from all of the atomic orbitals in the entire metal. As a result, this orbital is

totally delocalized. Therefore, it provides a kind of electronic highway throughout the entire metal, allowing charge to be transported with great ease.

Conduction band



The conduction band is the band of orbitals that are high in energy and are generally empty. In reference to conductivity in semiconductors, it is the band that accepts the electrons from the valence band.

Behaviour of conductor on the basis of band theory

If the valence band is partially filled or it overlaps with the higher energy conduction band then electrons can easily flow under the influence of an applied electric field. Hence the metals conduct electricity.

Behaviour of semi-conductor on the basis of band theory

If the gap between the valence band and the unoccupied conduction band is small, some electrons may jump from valence band to conduction band. Hence the substance shows some conductivity. It acts as a semi-conductor.

Behaviour of insulator on the basis of band theory

If the gap between the valence band and conduction band is large, electrons cannot jump from valence band to conduction band. Hence it acts as an insulator.

Effect of temperature on electrical conductivity

Electrical conductivity of metal decreases with the increase of temperature because on heating, the positive ions of the metal start vibrating and they produce hindrance in the flow of electrons.

Intrinsic semiconductors

An intrinsic semiconductor is an undoped semiconductor. This means that holes in the valence band are vacancies created by electrons that have been thermally excited to the conduction band, as opposed to doped semiconductors where holes or electrons are supplied by a foreign atom acting as an impurity. e.g. silicon and germanium.

Extrinsic semiconductors

Those semiconductors in which some impurity atoms are embedded are known as extrinsic semiconductors.

Extrinsic semiconductors are basically of two types:

1. P-type semiconductors
2. N-type semiconductors

n-type semiconductors

In n-type semiconductors, electrons are the majority carriers and holes are the minority carriers. N-type semiconductors are created by doping an intrinsic semiconductor with donor impurities. A common dopant for n-type silicon is phosphorus. n-type and p-type semiconductors are combined to form a number of diode, solar cell, transistors.

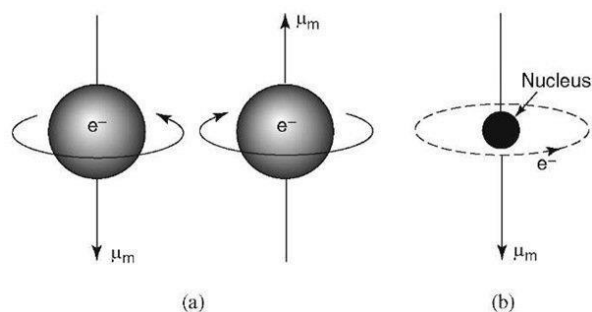
Transition temperature

Transition temperature is the temperature at which a material changes from one crystal state (allotrope) to another. For example, when rhombic sulphur is heated above 96°C it changes into monoclinic sulfur. When cooled below 96°C it reverts to rhombic sulfur.

Magnetic properties of solid

1. The magnetic properties are studied in terms of magnetic moments of the material. It arises due to the orbital motion and spinning motion of the electrons. The net magnetic moment is represented as an arrow.
2. Any solid which possesses magnetic character must have property to attract metal.

Magnetic moment of electron



Electron moving around the nucleus and spinning along its own axis produced the magnetic moment as electrons are charged particles.

Diamagnetic substances

Diamagnetic materials create an induced magnetic field in a direction opposite to an externally applied magnetic field, and are repelled by the applied magnetic field, e.g $TiO_2, NaCl$.

Paramagnetic substances

Paramagnetic properties are due to the presence of some unpaired electrons, and from the realignment of the electron paths caused by the external magnetic field. Paramagnetic materials include magnesium, molybdenum, lithium, and tantalum.

Ferromagnetic substances

Those substances which when placed in a magnetic field are strongly magnetized in the direction of the applied field are called ferromagnetic substance, e.g., iron, nickel, cobalt etc.

Domains of ferromagnetic substance

A magnetic domain is a region within a magnetic material in which the magnetization is in a uniform direction. This means that the individual magnetic moments of the atoms are aligned with one another and they point in the same direction. When cooled below a temperature called the curie temperature, the magnetization of a piece of ferromagnetic material spontaneously divides into many small regions called magnetic domains. The magnetization within each domain points in a uniform direction, but the magnetization of different domains may point in different directions. Magnetic domain structure is responsible for the magnetic behavior of ferromagnetic

materials like iron, nickel and their alloys, and ferrimagnetic materials like ferrite. This includes the formation of permanent magnets and the attraction of ferromagnetic materials to a magnetic field. The regions separating magnetic domains are called domain walls, where the magnetization rotates coherently from the direction in one domain to that in the next domain.

Anti ferro-magnetic substances

In materials that exhibit anti-ferromagnetism, the magnetic moments of atoms or molecules, usually related to the spins of electrons, align in a regular pattern with neighboring spins (on different sub-lattices) pointing in opposite directions, e.g., MnO.

Ferroelectric substance

Ferroelectricity is a property of certain materials that have a spontaneous ferroelectric polarization that can be reversed by the application of an external electric field.

Ferrimagnetic substances

Substances which are expected to possess large magnetism on the basis of the magnetic moments of the domains but actually have small net magnetic moment are called ferromagnetic substances. e.g magnetite.

Curie temperature

The Curie temperature or Curie point, is the temperature at which certain materials lose their permanent magnetic properties, to be replaced by induced magnetism.

Difference between solid, liquid, gas

Gases	Solids	Liquids
Gases have no definite shape and volume and have no rigidity	Solids have a definite volume and shape and are highly rigid	Liquids have definite volume, no definite shape and are less rigid.
Gases exert pressure	Solids exert pressure	Liquid exert pressure
They have low densities	They have generally high densities	They have densities less than solids

Effect of intermolecular forces of attraction on the physical state of a substance

Solids have the strongest intermolecular forces. The molecules are closely packed. Liquids have less intermolecular forces than solids. The molecules of liquids are loosely packed than solids. Gases have the least intermolecular force of attraction. The molecules of gases are loosely bounded and are far apart from each other.

Effect of thermal energy on the physical state of the substance

Faster moving particles excite nearby particles. If heated sufficiently, the movement of particles in a solid increases and overcomes the bonds that hold the particles together. The substance changes its state from a solid to a liquid. If the movement of the particles increases further in the liquid, then a stage is reached where the substance changes into a gas.

Crystalline solids

A crystal or crystalline solid is a solid material whose constituents, such as atoms, molecules or ions, are arranged in a highly ordered microscopic structure, forming a crystal lattice that extends in all directions. E.g diamond, quartz.

Properties of crystalline solid

1. These solids have a particular three dimensional geometrical structure.
2. The arrangement order of the ions in crystalline solids is of long order.
3. The strength of all the bonds between different ions, molecules and atoms is equal.
4. Melting point of crystalline solids is extremely sharp. Mainly the reason is that the heating breaks the bonds at the same time.
5. The physical properties like thermal conductivity, electrical conductivity, refractive index and mechanical strength of crystalline solids are different along different directions.
6. These solids are the most stable solids as compared to other solids.

Anisotropy

When the properties of a material vary with different crystallographic orientations, the material is said to be anisotropic.

Isotropy

When the properties of a material is uniform in different crystallographic orientations, the material is said to be isotropic.

Properties of amorphous solid

The strength of different bonds is different in amorphous solids. There is no regularity in the external structure of amorphous solids. On the other hand, amorphous solids don't have sharp melting point. This is due to the variable strength of bonds present between the molecules, ions or atoms. So, bonds having low strength on heating break at once. But the strong bonds take some time to break. This is the reason that the amorphous solids don't have sharp melting points. Amorphous solids are isotropic in nature. Isotropic means that in all the directions their physical properties will remain same.

Amorphous solid

An amorphous or non-crystalline solid is a solid that lacks the long-range order characteristic of a crystal. E.g glass, plastic.

Uses of amorphous solids

Amorphous solids are very useful materials. Here are a few applications of it:

Amorphous solids glass and plastics are very useful materials and are widely used in construction, house ware, laboratory ware, etc.

Amorphous silica is one of the best materials for converting sunlight into electricity (photovoltaic).

Amorphous solid rubber is used in making tyres, shoe soles etc.

Crystalline solids and amorphous solids

Properties of pseudo solids

The amorphous solid which are super cooled is called as pseudo solids. Glass is the best example of super cooled solid. The solids have irregular shape due to orderly arrangement of constituent of particles. The order range is very short. Heat of fusion of such solid is not definite.

Pseudo solids

Pseudo solids are solids which are considered to be solid though they resemble liquid. They flow slowly in room temperature and are called super cooled liquids. E.g glass.

Crystallites

Due to short range order possessed by amorphous solids, small parts of the amorphous solid may be crystalline while the rest may be non-crystalline. These crystalline parts of the amorphous solids are called crystallites.

Properties of quartz

Quartz is a crystalline silicate mineral with piezoelectric properties.

Quartz is an abundant mineral made up of a continuous framework of SiO_4 tetrahedra. They develop an electric potential with the application of mechanical stress. Crystal oscillator is a common piezoelectric use for quartz.

Pure quartz is colorless and transparent or translucent. Microcrystal varieties are mostly opaque, while macrocrystals tend to be transparent.

Characteristics of ionic solids

They have high melting and boiling points because of the strong electrostatic force
They are soluble in polar solvents but insoluble in non-polar solvents
The ions are closely packed and hence ionic solids are hard

Properties of molecular solids

The constituent particles of molecular solid are molecules of the same compound. The intermolecular forces of attraction of this type of solid is very strong hence they exist in different forms such as polar , non polar , hydrogen bonded molecular solid.

Molecular solids

A molecular solid is a solid composed of molecules held together by the van der Waals forces. Because these dipole forces are weaker than covalent or ionic bonds, molecular solids are soft and have relatively low melting temperature.
There are three types of molecular solids:

Non-polar molecular solids

Polar molecular solids

Hydrogen-bonded molecular solids. Examples are HCl, F, O, N

Characteristics of non-polar molecular solids

The crystalline solids in which the constituent particles are either atoms like those of noble gases or non-polar molecules. The force holding molecules are vanderwaal forces. The main characteristics are:

They are non-conductors of electricity

They are generally soft

They have low melting and boiling point

Examples are H_2 , Cl_2

Characteristics of polar molecular solids

These are the solids in which the constituent particles are polar molecules. The forces holding the molecules are dipole-dipole attraction. The main characteristics are:

They are soft

They are non-conductors of electricity

Melting and boiling points are higher than non-polar molecular solids but not so high

Examples are HCl, SO_2

Hydrogen-bonded molecular solids

In these solids, the constituents are molecules which contain hydrogen atom linked to a highly electronegative atom such as F, O. The intermolecular forces are strong hydrogen bonds. The characteristics are:

Non-conductors of electricity

Melting and boiling points are generally higher than non-polar and non-polar molecular solids

Covalent solids

A network solid or covalent network solid is a chemical compound (or element) in which the atoms are bonded by covalent bonds in a continuous network extending throughout the material. In a network solid there are no individual molecules, and the entire crystal may be considered a macromolecule. E. g diamond, quartz.

Covalent or network solids with example.

Covalent solids are formed by chemical bonds i.e. covalent bonds between the neighboring constituent atoms of non-metallic solids. The solids may be hard, brittle depending on the type of covalent bonding between the atoms and possess high melting point.

Metallic solids

Metallic solids are solids composed of metal atoms that are held together by metallic bonds. These bonds are like huge molecular orbitals that span across the whole solid. This means the

electrons in metallic solids are delocalized. They are not just held between a couple of atoms in a sigma bond. e.g copper, gold.

Metallic bonding in solids

Metallic bonding arises from the electrostatic attractive force between conduction electrons (in the form of an electron cloud of delocalized electrons) and positively charged metal ions. It may be described as the sharing of free electrons among a lattice of positively charged ions. Metallic bonding accounts for many physical properties of metals, such as strength, ductility.

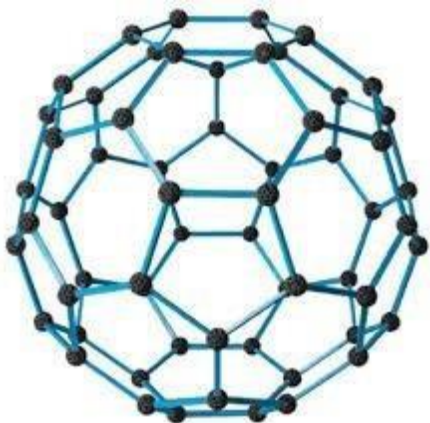
Isomorphism

When two or more crystals have similar chemical composition exist in the same crystalline form, this property is called isomorphism. e.g Na_3PO_4 and Na_3AsO_4 .

Polymorphism

When a particular substance exists in more than one crystalline form, the property is called polymorphism. e.g Calcium carbonate exists in two crystalline forms called calcite and aragonite.

Diamond, Graphite and Buckminster fullerene



1. Buckminster Fullerene is one type of fullerene. Fullerenes are made from carbon atoms joined together to make balls, cages or tubes of carbon. The molecules of Buckminster Fullerene are spherical and are also known as 'buckyballs' formula C_{60} .

Buckminster Fullerene is a black solid although it's deep red when in solution in petrol. The tube fullerenes are called nanotubes which are very strong.

2. Diamond is another allotropic form of carbon in which carbon is tetrahedrally arranged and it is shiny, lustrous, and non conductor of heat and electricity.
3. Graphite is an allotrope of carbon in which carbon atoms are hexagonally placed to form network structure. It is blackish, slippery and conductor of heat and electricity.

Space lattice

A space lattice is an array of points showing how particles (atoms, ions or molecules) are arranged at different sites in three dimensional spaces.