KAS 202

Unit I : State of Matter

State of Matter

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Matter

Matter is anything that has mass and volume (takes up space), and atoms are a building block of the matters. Depending on the temperature, pressure and nature of substance properties(matter), a substance can take on different physical forms. We call these physical forms States of Matter. There are three very well-known states of matter:

1. Solid 2. Liquid 3. Gas

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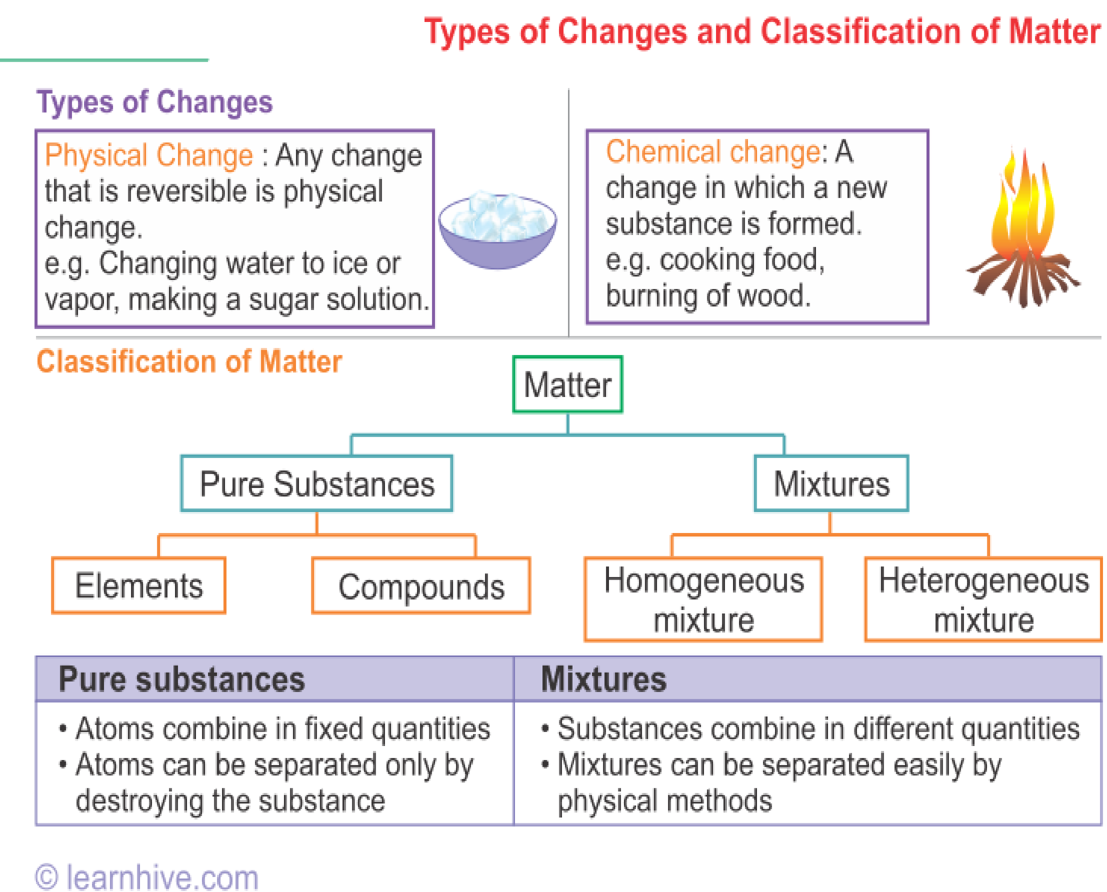
Brief Outline of Matter



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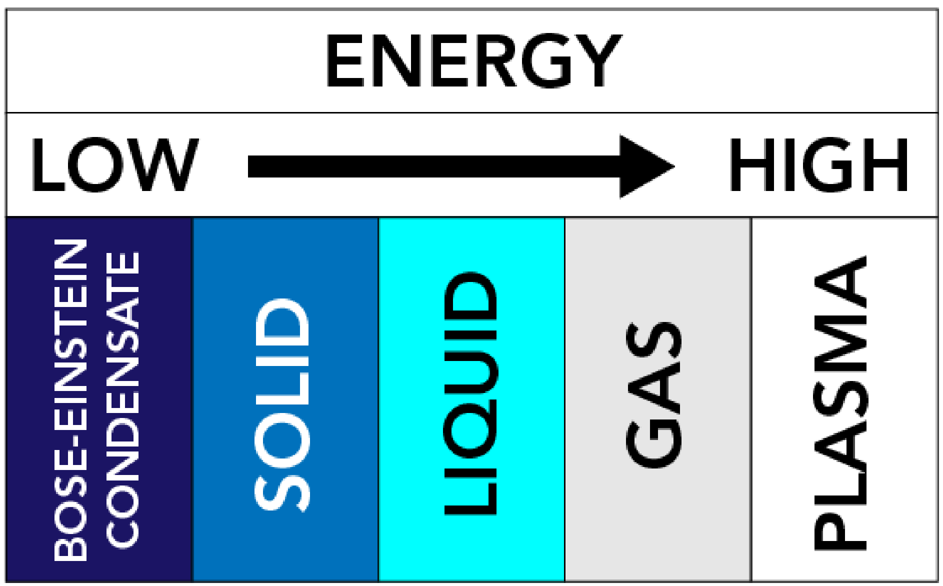
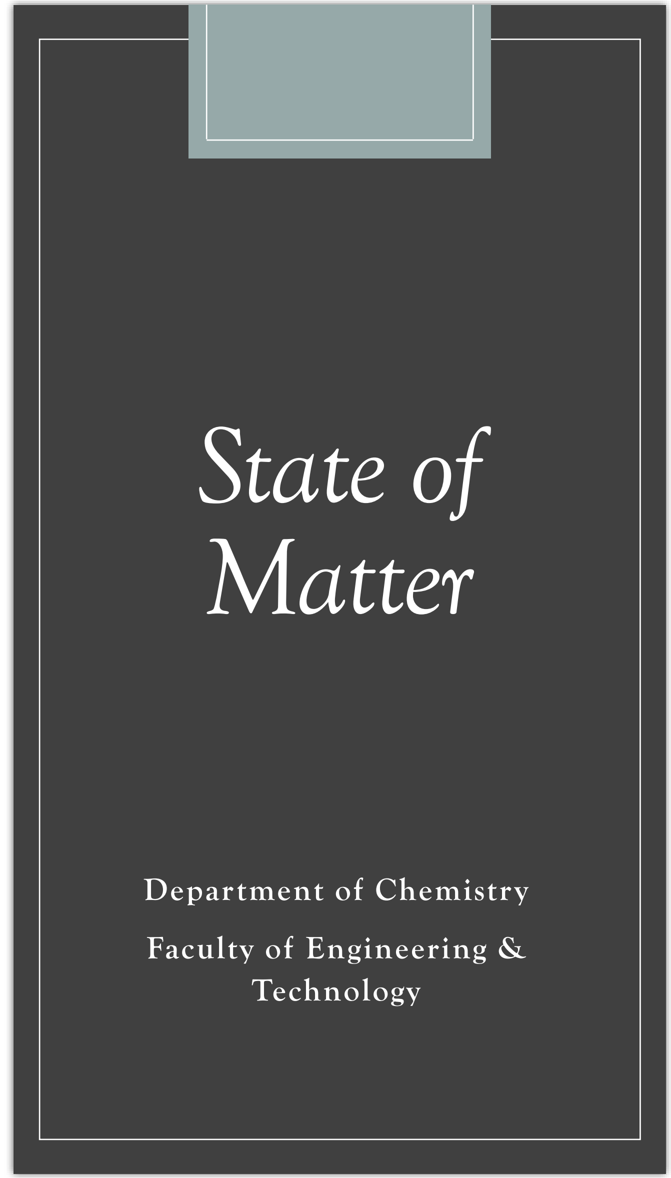
Matter

Other states of matter also exist:

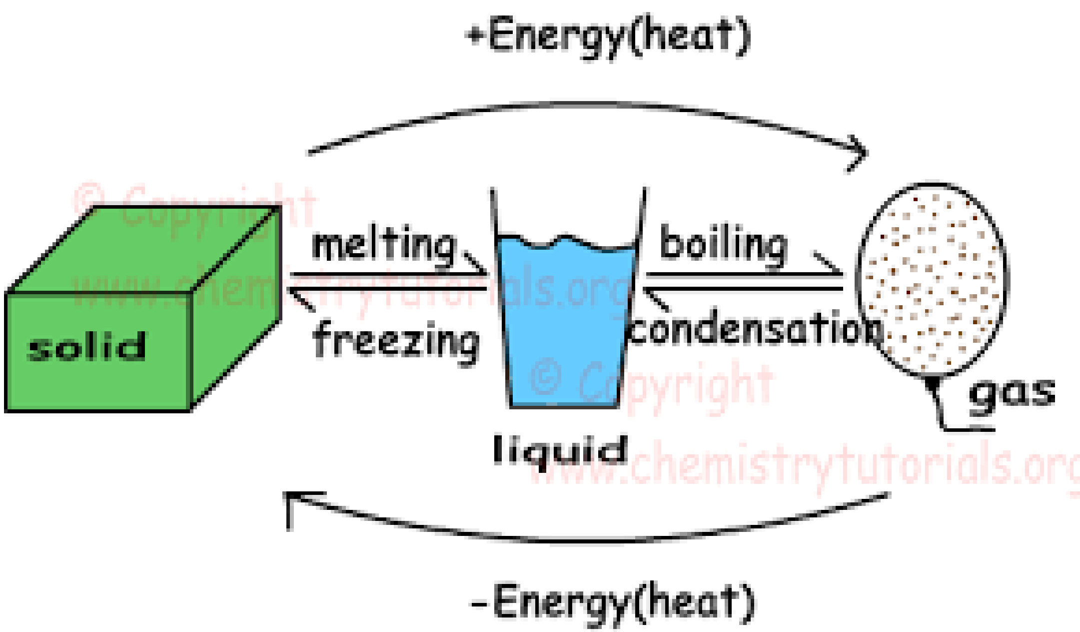
1. **Plasma** (a state of matter similar to a gas, but contains free-moving electrons and ions - atoms that have lost electrons)
2. **Bose-Einstein Condensates (BECs)** (waves of matter that can occur with some types of atoms at super cold temperatures)





Ref: https://letstalkscience.ca/educational-resources/backgrounders/states-matter

Change in State of Matter



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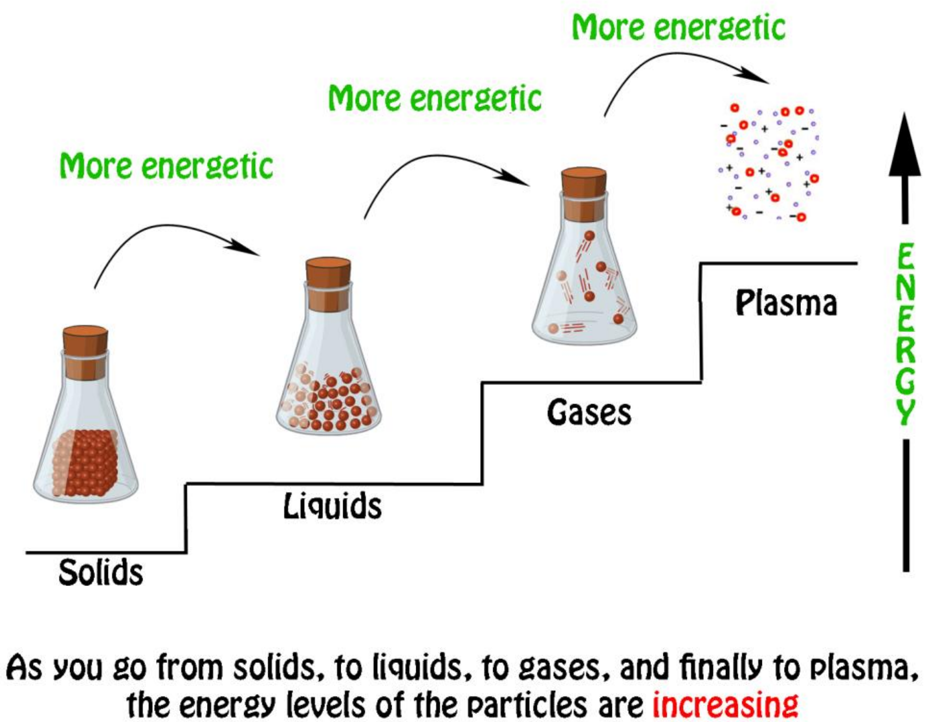
Change in State of Matter



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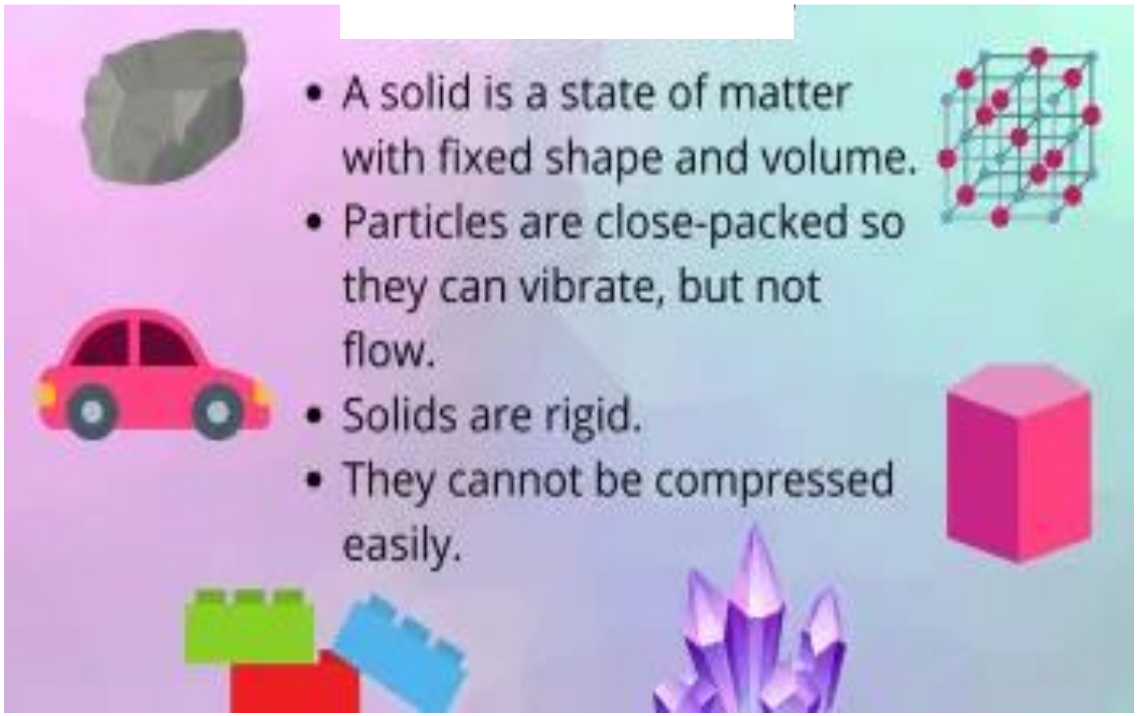
What is a Solid ?



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Type of Solids

SOLID

- **Crystalline Solid**
- **Amorphous Solid**

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Crystalline Vs Amorphous Solid

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#	Crystalline Solid	#	Amorphous Solid
1	Atoms are arranged in regular three dimensional (3D) Order	1	They do not have regular arrangement
2	Sharp melting point	2	No particular melting point
3	Anisotropic	3	Isotropic
	True solid		Pseudo solid
4	More rigid	4	Less rigid
	Long range order		Short range order
	Ex: KNO3, NaCl etc.		Ex: Wax, Polymers

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Anisotropy &Isotropic Properties of Solid

Isotropic refers to the properties of a material which is *independent of the direction* whereas anisotropic is direction-dependent. These two terms are used to explain the properties of the material in basic crystallography.

Characteristic(s)	**Isotropic**	**Anisotropic**
Properties	**Direction independent**	**Direction-dependent**
Refractive index	**Only one**	**More than one**
Light passes through it	**No**	**Yes**
Velocity of light	**Same in all directions**	**Different**
Ex	**Glass**	**Wood**

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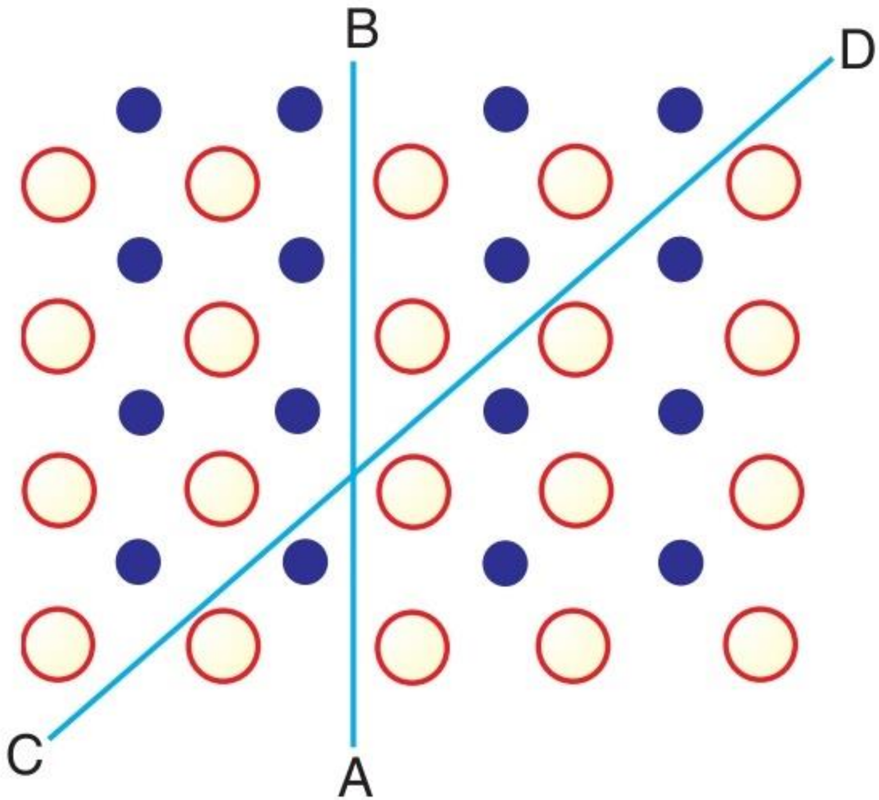
Anisotropy &Isotropic Properties of Solid



Anisotropy in Crystal

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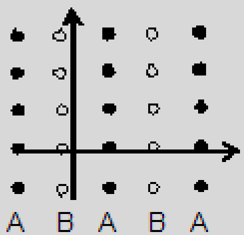
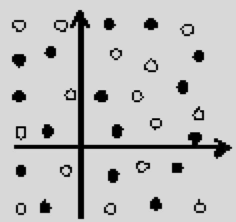
Anisotropy &Isotropic Properties of Solid



Crystalline solid



Amorphous solid

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Electrical Conductivity in Solid Material

Electrical properties of solids are measured in terms of conductivity. Conductivity may be defined as the ease with which electric current can pass through a given substance. All solids do not conduct electricity in equal amounts. Some of them have high conductivity, whereas some of them do not conduct electricity at all. On the basis of conduction of electricity, solids can be broadly divided into three categories:

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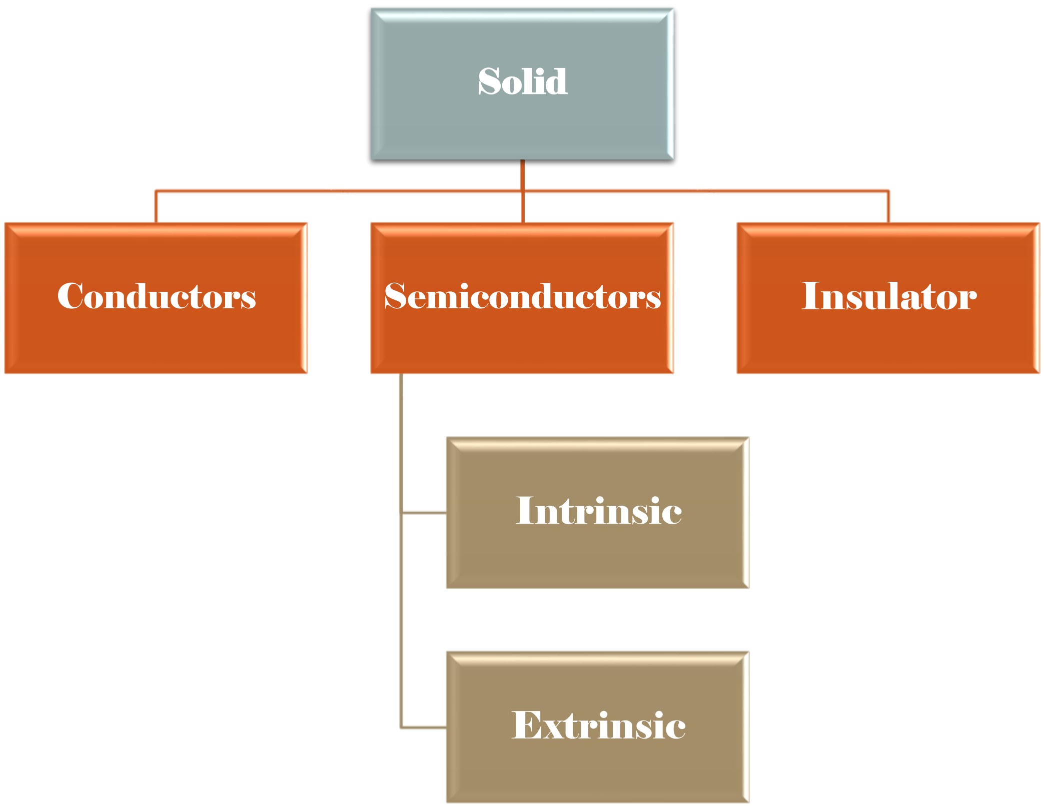
Electrical Conductivity in Solid Material



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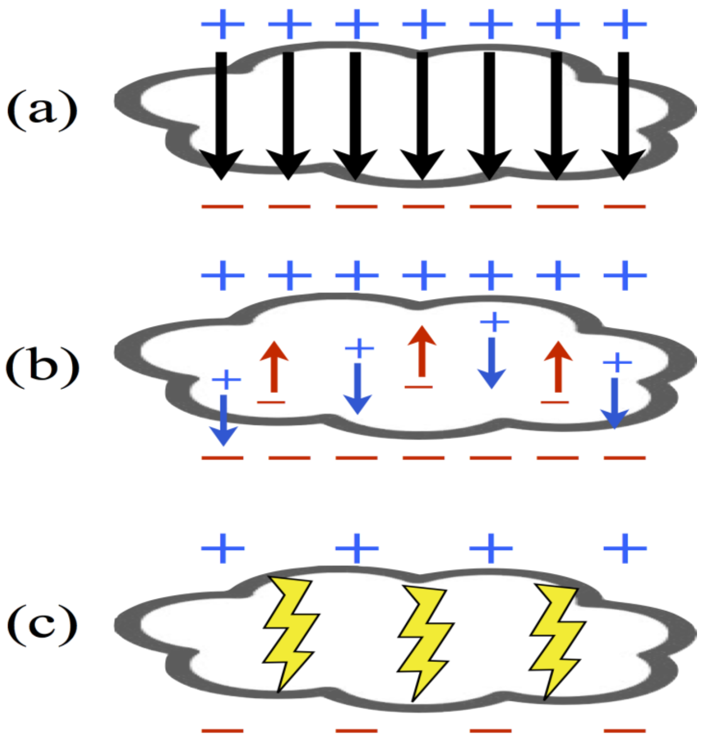
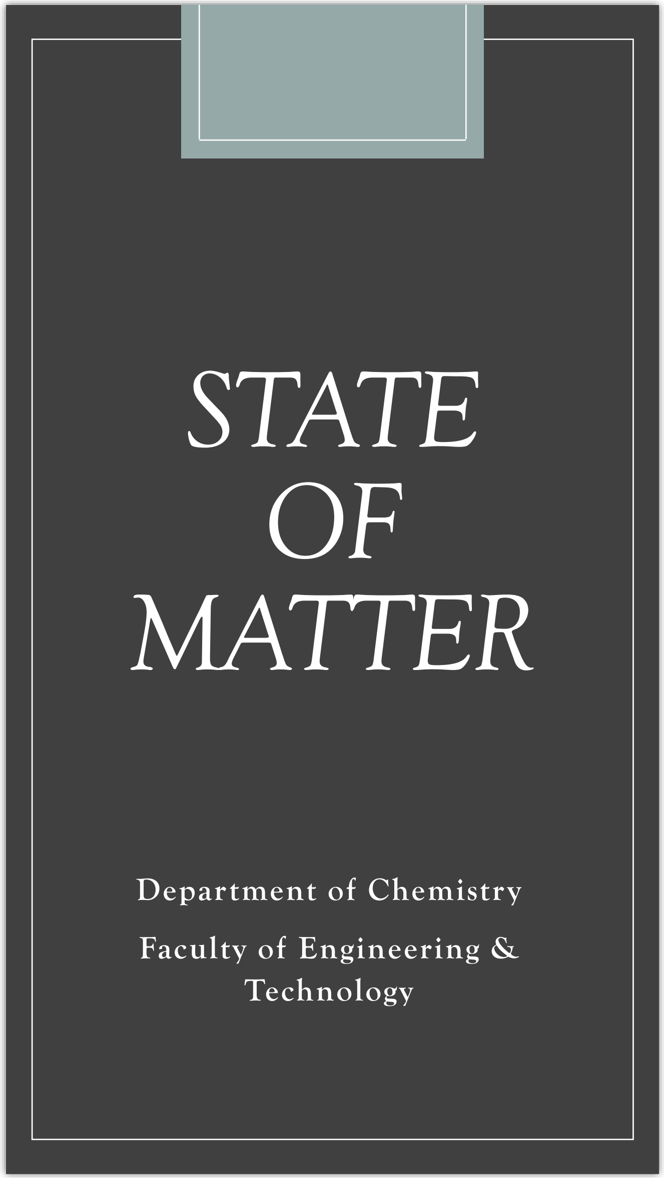
CONDUCTORS VS INSULATORS

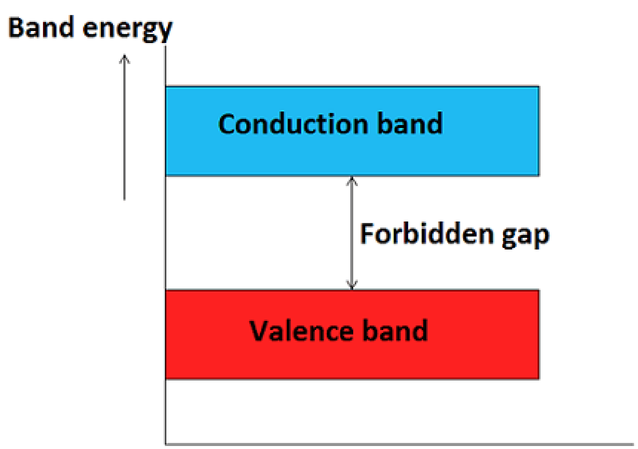




Band Theory of Solid

There are number of energy bands in solids but three of them are very important. These three energy bands are important to understand the behavior of solids. These energy bands are :

- ❑ Valence band
- ❑ Conduction band
- ❑ Forbidden band or forbidden gap



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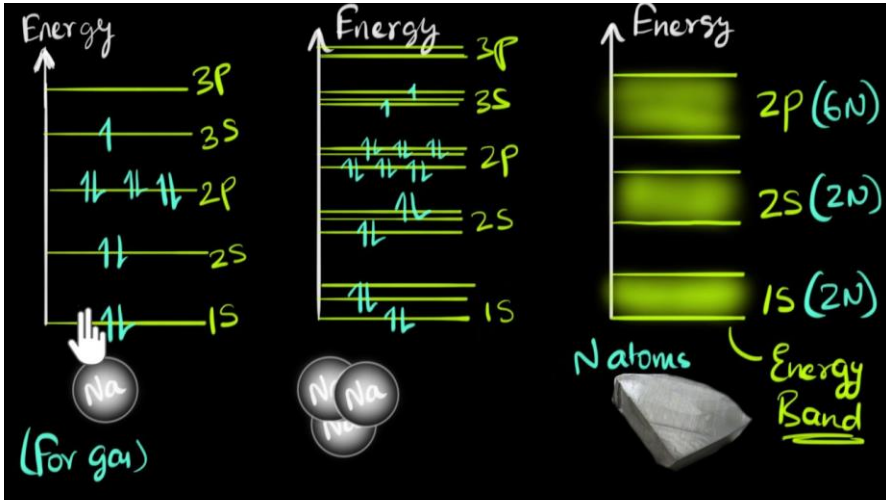
Band Theory of Solid



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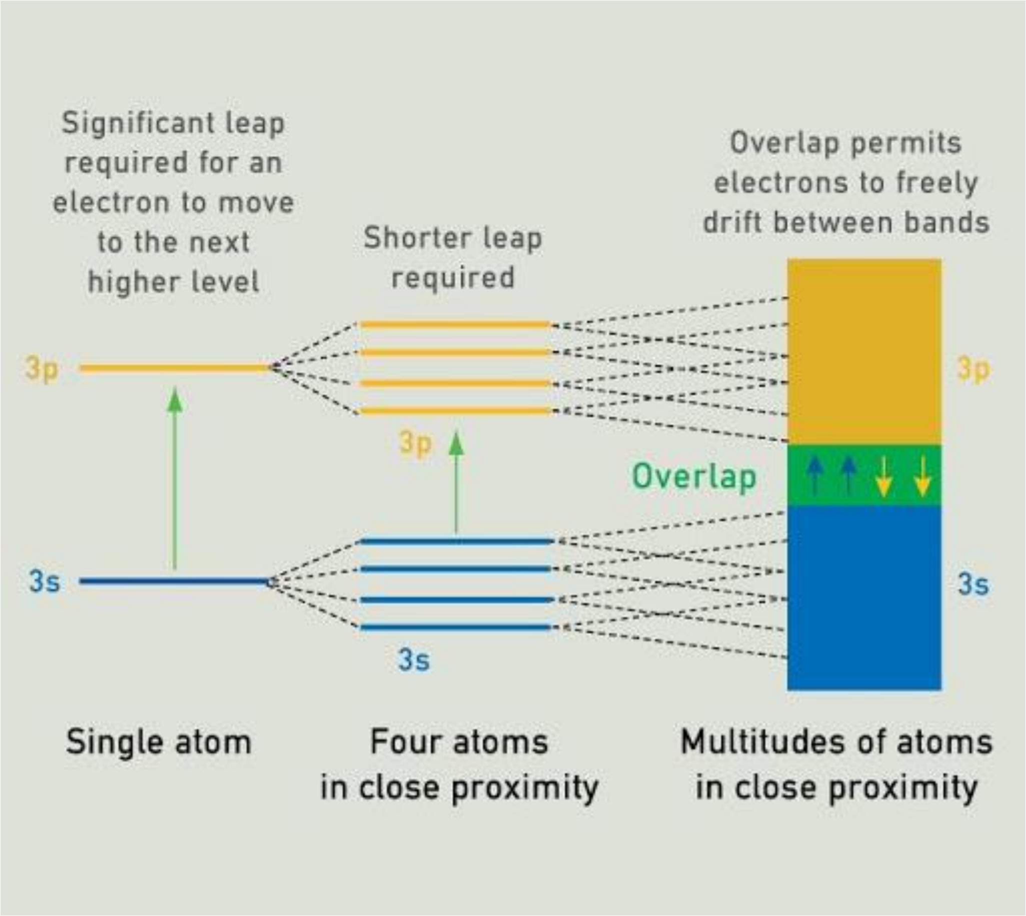
Band Theory of Solid



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Valence Band

- The energy band which is formed by grouping the range of energy levels of the valence electrons or outermost orbit electrons is called as valence band.
- Valence band is present below the conduction band as shown in figure. Electrons in the valence band have lower energy than the electrons in conduction band.
- The electrons present in the valence band are loosely bound to the nucleus of atom.

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Conduction Band

- The energy band which is formed by grouping the range of energy levels of the free electrons is called as conduction band.
- Generally, the conduction band is empty but when external energy is applied the electrons in the valence band jumps in to the conduction band and becomes free electrons. Electrons in the conduction band have higher energy than the electrons in valence band.
- The conduction band electrons are not bound to the nucleus of atom.

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Forbidden Band

- The energy gap which is present between the valence band and conduction band by separating these two energy bands is called as forbidden band or forbidden gap.
- In solids, electrons cannot stay in forbidden gap because there is no allowed energy state in this region. Forbidden gap is the major factor for determining the electrical conductivity of a solid. The classification of materials as insulators, conductors and semiconductors is mainly depends on forbidden gap.
- The energy associated with forbidden band is called energy gap and it is measured in unit electron volt (eV).

1 eV = 1.6 × 10-19 J

- The applied external energy in the form of heat or light must be equal to the forbidden gap in order to push an electron from valence band to the conduction band.

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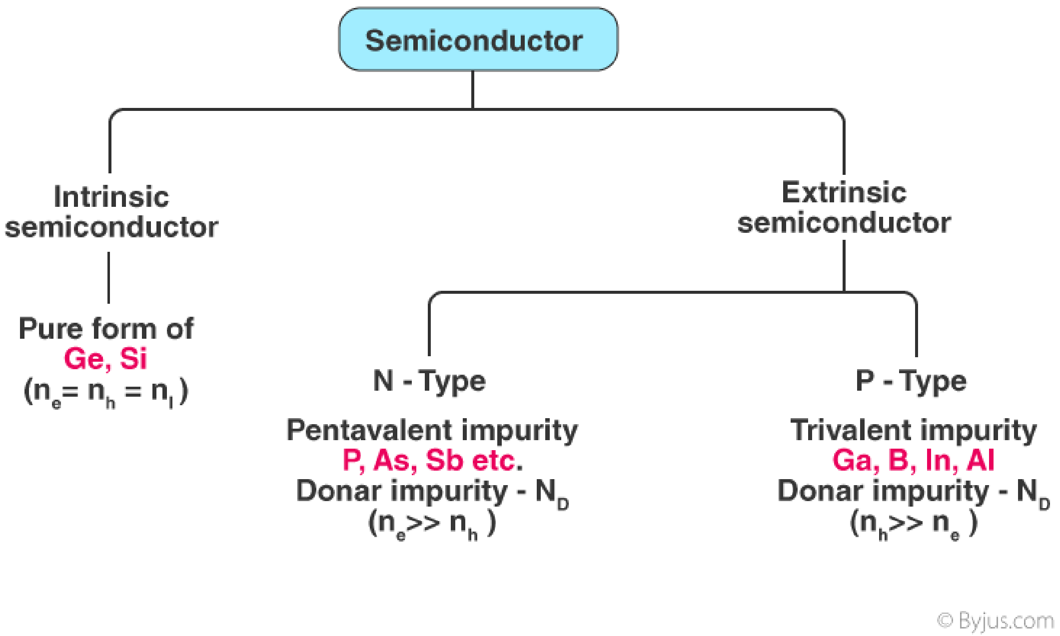
Semiconductor Material



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Semiconductors are the materials which have a conductivity between conductors (generally metals) and non-conductors or insulators (such as ceramics). Semiconductors can be compounds such as gallium arsenide or pure elements, such as germanium or silicon. Physics explains the theories, properties and mathematical approach governing semiconductors.

Ex. Gallium(Ga) arsenide (As), germanium (Ge), and silicon (Si) are some of the most commonly used semiconductors. Silicon is used in electronic circuit fabrication and gallium arsenide is used in solar cells, laser diodes, etc.

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Properties of Semiconductor

- Semiconductor acts like an insulator at Zero Kelvin. On increasing the temperature, it works as a conductor.
- Due to their exceptional electrical properties, semiconductors can be modified by doping to make semiconductor devices suitable for energy conversion, switches, and amplifiers.
- Semiconductors are smaller in size and possess less weight.
- Their resistivity is higher than conductors but lesser than insulators.
- The resistance of semiconductor materials decreases with the increase in temperature and vice-versa.

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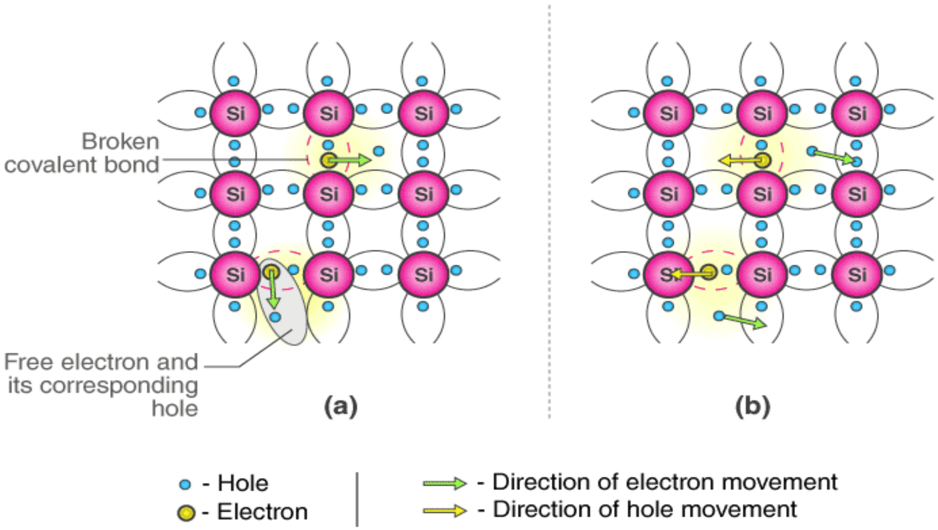
Intrinsic Semiconductor

An intrinsic type of semiconductor material is made to be very pure chemically. It is made up of only a single type of element.



Conduction Mechanism in Case of Intrinsic Semiconductors
(a) In absence of electric field (b) In presence of electric Field

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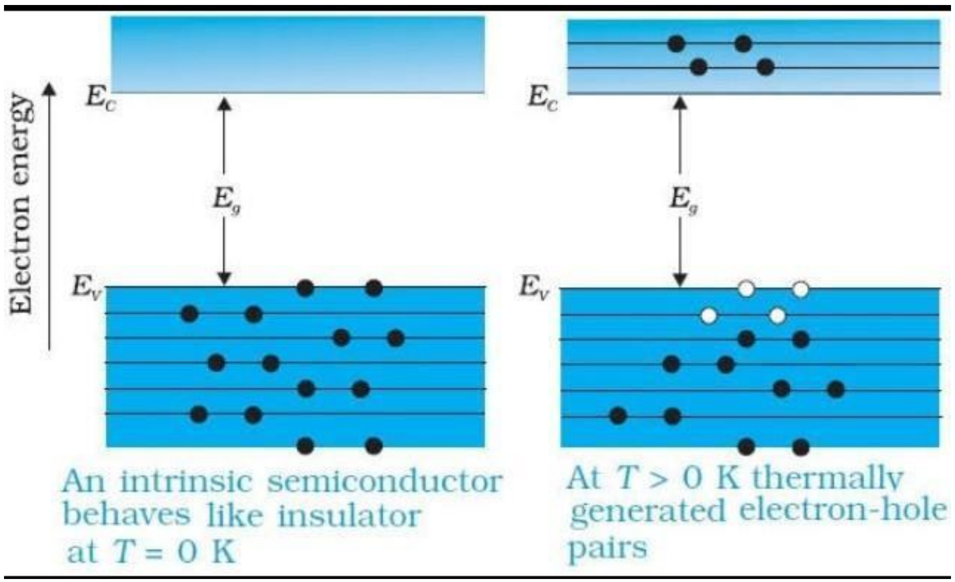
Band Energy of Intrinsic SC



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Band Energy of Intrinsic SC

In intrinsic semiconductors, current flows due to the motion of free electrons as well as holes. The total current is the sum of the electron current Ie due to thermally generated electrons and the hole current Ih

Total Current (I) = Ie + Ih

For an intrinsic semiconductor, at finite temperature, the probability of electrons to exist in conduction band decreases exponentially with increasing bandgap (Eg)

n = n0e-Eg/2.Kb.T

Where,

Eg = Energy bandgap

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Extrinsic Semiconductor

The conductivity of semiconductors can be greatly improved by introducing a small number of suitable replacement atoms called IMPURITIES. The process of adding impurity atoms to the pure semiconductor is called DOPING. Usually, only 1 atom in 10*7 is replaced by a dopant atom in the doped semiconductor. An extrinsic semiconductor can be further classified into:

- ❑ N-type Semiconductor
- ❑ **P-type Semiconductor**

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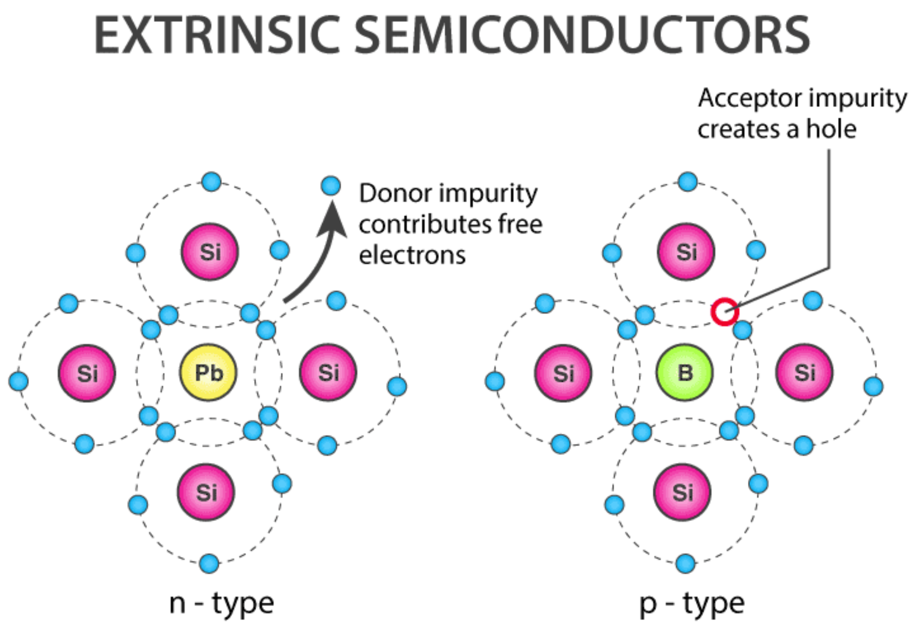
Extrinsic Semiconductor



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Intrinsic Vs Extrinsic Semiconductor

Intrinsic Semiconductor	Extrinsic Semiconductor
Pure semiconductor	Impure semiconductor
Density of electrons is equal to the density of holes	Density of electrons is not equal to the density of holes
Electrical conductivity is low	Electrical conductivity is high
No impurities	Trivalent impurity, pentavalent impurity

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Thank you !!!

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