

Creep

①

The tensile properties of most engineering materials at room temp. are independent of time for practical purposes.

However, at elevated temperatures, the strength becomes very dependent on both strain rate (rate of deformation) and time of exposure. A material subjected to a constant tensile load at an elevated temp. will ~~creep~~ and undergo a time dependent deformation.

The slow and progressive deformation of a material with time at constant stress is called "Creep". After creep sets in, it continues until sufficient strain has occurred so that a necking down and a reduction of cross-sectional area occurs. After this and until rupture, the rate of deformation increases because there is less area to support the load.

Metals generally exhibit creep at high temperatures, where as plastics rubbers & similar amorphous materials are very temp. sensitive to creep.

Creep strength: It is the highest stress that material can withstand without excessive deformation for a specified length of time.
Also called Creep limit.

Creep is important in high temp. applications, such as in materials used in steam power plants, oil refineries, chemical plants, Gas turbines, rocket engines etc.

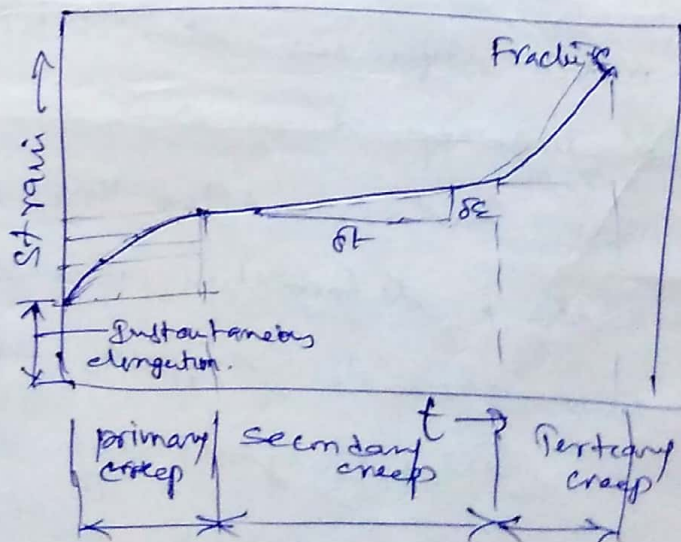
Creep Test

To determine creep behavior of metal, a constant load is applied to a specimen maintained at a constant temp. and the strain (extension of the specimen) is determined as a function of time. The creep test data is presented in the form of creep curve. The curve is for a constant nominal stress and constant temperature.

⊗⊗

The slope of the curve (de/dt) is called as Creep Rate.

The minimum creep rate is determined by the slope of the curve in the secondary stage.



⊗⊗ The creep curve shows three distinct stages.

- ① primary creep
- ② secondary creep
- ③ tertiary creep.

primary creep - Decreasing creep rate.
 primary creep is a period of predominantly transient creep in which the creep resistance of the material increases by virtue of its own deformation.

The second stage of creep is called secondary creep. This is a period of nearly constant creep rate. In this stage the effects of work hardening and recovery processes are exactly balanced. The minimum creep rate is the most important design parameter derived from the creep curve.

The third stage of creep or tertiary creep mainly occurs at an accelerated rate. In this case the effect of work hardening is less than the recovery. This stage occurs when there is an effective reduction in A-sectional area either due to necking or internal void formation.

Factors affecting creep

- ① Grain size - Coarse-grained materials exhibit better creep resistance than fine grained materials.
 Reason - Flow of grain boundaries at high temp.
 fine grains - more grain boundary - ↑ more flow.

∴ Single crystals have high creep resistance than polycrystalline material.

Thermal stability - thermal stability of the microstructure of alloys and its resistance to oxidation at high temperatures

Annealed steel - greater thermal stability - higher creep resistance.

Quenched steel

prior cold working - creep accelerated due to recrystallization (after cold working).

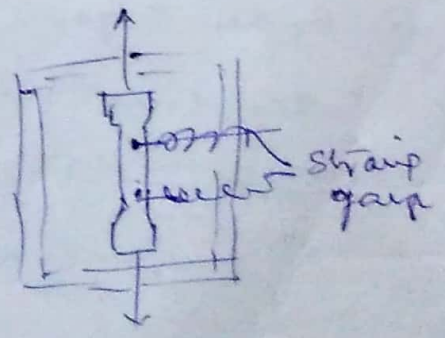
Alloying - increases creep resistance.

Mechanism of creep. -

① Movement of dislocations - by climb and jog. - at high temp.

② ~~Flow~~ Flow of grain boundaries - at high temp.

~~the~~ grain boundary effect is reversed at high temp. i.e. instead of restricting the motion of dislocations at low temp, they allow a flow at high temps.



Diffusion in Solids

Diffusion - Migration of atom from one position ~~to~~ a lattice to another lattice position.

~~Also~~ Atoms move from area of higher concentration to the area of lower concentration.

- Diffusion results uniformity in composition of the material.

The conditions to be met for the diffusion of an atom ^{to} take place from one position to another :

① There must be empty adjacent sites and

② The atom must have sufficient energy to break bonds with its neighbouring atoms and cause some lattice distortion during the displacement.

- Movements in diffusion may be relatively short range, as in allotropy, recrystallisation and in precipitation.

- In diffusion the path of an individual atom is random, zig-zag and unpredictable. However, when the large no. of atoms make such movements, they can produce a systematic flow.

- It increases with increase in temp.

Importance and Applications of Diffusion process:

- ① phase changes - ex: γ -iron \rightarrow α -iron
- ② Metal bonding ex: welding, brazing, soldering, galvanising etc
- ③ Homogenising treatment of castings
- ④ Oxidation of metals
- ⑤ In powder metallurgy techniques.
- ⑥ In Doping of Semiconductors
- ⑦ In Recovery & Recrystallisation
- ⑧ In Heat treatment processes -
ex: Annealing, case-hardening.
- ⑨ In precipitation of phases in age-hardening.

Types of Diffusion process.

- ① Self-Diffusion - Migration of atoms in pure materials.
- ② Inter-diffusion - occurs in binary metallic alloys. ex: Cu-Ni system.
- ③ Volume-diffusion - Atomic migration through the bulk of the metal.

- ④ Grain boundary diffusion - Migration of atoms along the grain boundaries
- ⑤ Surface diffusion - Atomic movement along the surface of the phase.
ex: Solid-Vapour interface.

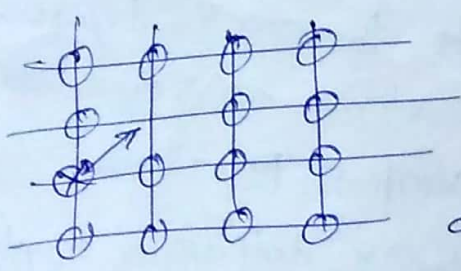
Diffusion Mechanisms

Common diffusion mechanisms are:

- ① Vacancy Mechanism
- ② Interstitial "
- ③ Direct Interchange mechanism.

Vacancy Mechanism

Vacancies move thru' the lattice and produce random shifts of atoms from one lattice position to another as a result of atom jumping.

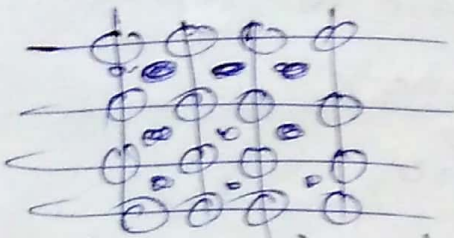


Over a period of time, such diffusion produces concentration changes.

- Vacancies are continuously being created and destroyed at the surface, grain boundaries and suitable interior positions.

② Interstitial Mechanism

- Simpler since the presence of vacancies is not required for the soluble atom to move.

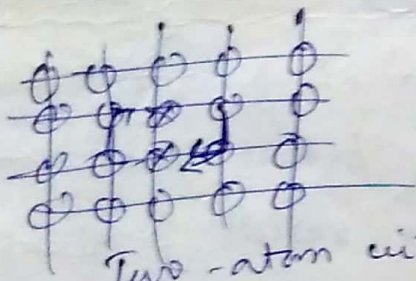


Interstitial mechanism

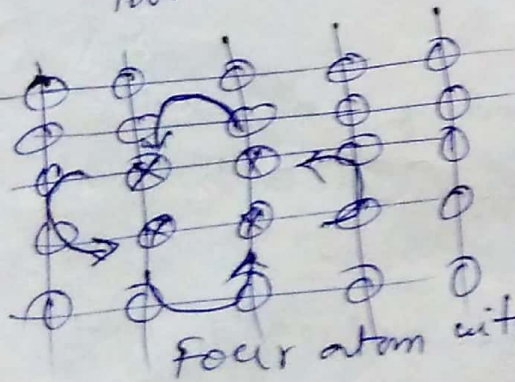
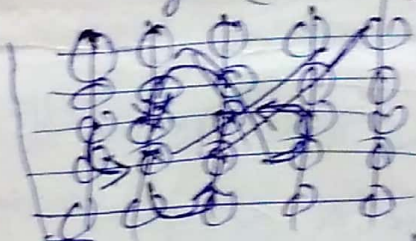
③ Direct-Exchange Mechanism

Two or more adjacent atoms jump past each other and exchange positions, but the no. of sites remains constant. (this may be two-atom or

four atoms interchange (for BCC))



Two-atom interchange



Four atom interchange

- Severe local distortion results due to the displacement of the atoms surrounding the jumping pair

- A no. of diffusion couples of different compositions

are produced. This is also called "Kirkendall's Effect".

Laws of Diffusion (Fick's laws)

- Adolf Fick proposed laws that govern the diffusion of atoms in metals and alloys.
in 1855

- Fick proposed two (2) laws.

① 1st law - for steady state, unidirectional flow of atoms.

② 2nd law - deals with time dependence of concentration gradient; and the flow of atoms in all directions.

Fick's First law - It states that

$$dm = -DA \frac{dc}{dx} dt$$

where dm = Amount of diffusing element that migrates in time dt across a surface of x -section 'A'

D = Diffusion coefficient, cm²/s or m²/s
= Amount of substance diffusing in unit time across a unit area thru a unit ~~concentration~~ concentration gradient

A = Area of plane across which diffusion takes place

$\frac{dc}{dx}$ = Concentration (composition) gradient in x -direction.

dt = Duration of diffusion.

- Negative sign indicates that flow of atoms occurs from higher to lower concentration.

Assumptions for Fick's First Law:

- ① The flux of diffusing atoms is constant throughout in the given direction and is independent of time.
- ② The jump length is constant (same distance moves always)
- ③ Jump frequency is constant.

By definition, the flux J is flow per unit x -sectional area per unit time.

$$\therefore J = \frac{dm}{dt} \times \frac{1}{A}$$

$$\therefore J = -D \frac{dc}{dx}$$

Fick's Second Law

- Steady-state diffusion in which conditions do not change with time is not commonly encountered with engineering materials.

In most cases unsteady state diffusion in which the concentration at any point with in a solid will vary with time i.e. $\frac{dc}{dt} \neq 0$.

For unsteady state, Fick's second law is applicable which states that

$$\frac{\partial c}{\partial t} = D \frac{\partial^2 c}{\partial x^2}$$

where $\frac{\partial c}{\partial t}$ = Rate of change of concentration (with time)
 D = Diffusion coefficient - assumed to be const.

03/07/2018

TAMS

III Semester - 2018-19 A.Y.

Class - 1

⇒ Introduction of the subject

- Material Science
- Metallurgy - Definition classification

⇒ Importance of the subject

- Specific examples of materials importance
- Usage of diff. materials
- Ex: & Imp. organizations deal with materials

Job opportunities for materials engineers.

04/07

⇒ Classification of materials.

⇒ Prerequisites for the subject

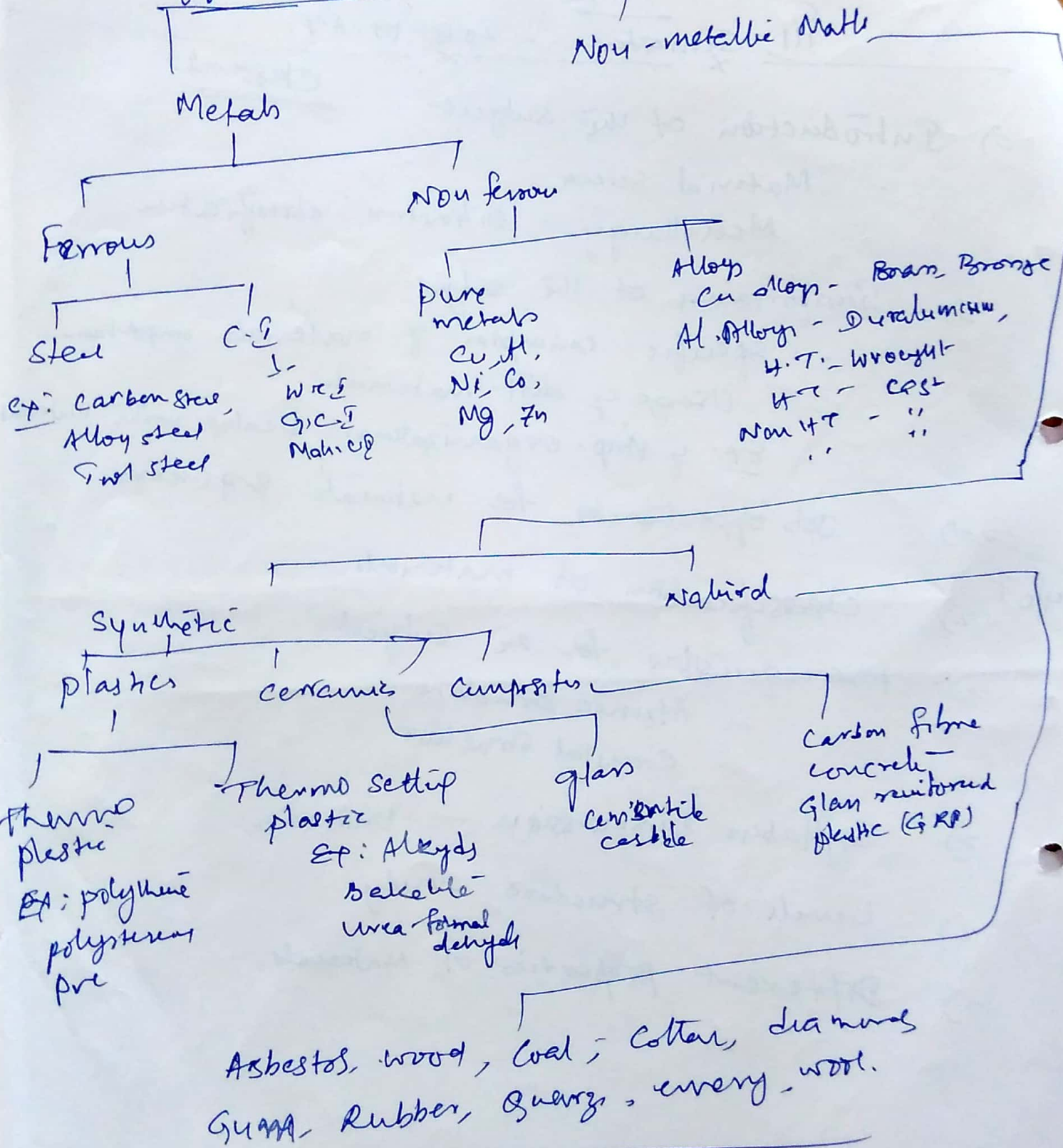
- Atomic structure
- Crystal structure

⇒ Syllabus Discussion - Unit wise

⇒ Levels of structure study.

⇒ Different properties of materials.

Engg. Materials classification



4/7 III Sem A & B

- 1, 20, 4, 8, 10, 25, 63, 14, 62, 30, 5, 24
- 49, 22, 44, 27, 51, 32, 31, 11, 76, 83, 71, 93,
- 12, 80, 37, 26, 90, 79, 18, 82, 86, 69, 78,
- 95, 98

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Levels of structure

- Structure of a material can be studied at various levels of observation
- Level of observation → The magnification and resolution of the physical aid used is the measure for the level of observation.
- Details observed in one level are/were entirely diff. as compare to details observed at other levels.

→ Depending upon the levels, the structure can be classified as:

- | | | | |
|---|--------------------|--|---|
| 1 | Macro structure | - Instrument - Naked eye | Low magnification |
| 2 | Micro structure | → Optical microscope | - 1500 times linear magnification |
| 3 | Sub structure | - <u>Optical</u> ^{SE} microscope
- About crystal imperfections etc | - 1,00,000 times magnification |
| 4 | Crystal structure | - X-ray diffraction | - Arrangement of atoms. |
| 5 | Electron structure | - Spectroscopic Techniques | - About electron configuration in outer shell |
| 6 | Nuclear structure | - Nuclear Magnetic Resonance (NMR) | - About nucleus. |

⇒ Atomic structure

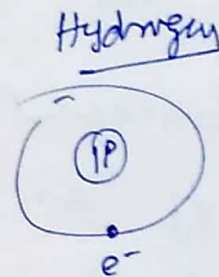
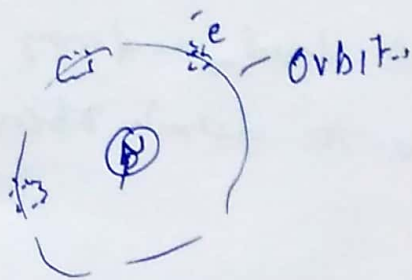
Matter composed of elements

Element " " Atoms

Atoms " " of electrons, protons & neutrons.
 -ve +ve + neutral

⇒ Entire mass is concentrated in nucleus.

Electrical neutral atom - no. of electrons = no. of protons



- The orbital may be considered as an "Electron Probability Density cloud" surrounding the nucleus.
- An electron can be excited from a lower energy state to higher energy state by supply of energy from external source

A.N - no. of protons

A.W - Total no. of protons & neutrons.

Hydrogen	<u>He</u>	<u>Al</u>
A.N - 1	A.N - 2	A.N - 13
A.W - 1.008	A.W 4	A.W 27.

Q7. Fill in A

1, 4, 5, 9, 10, 11, 12, 14, 18

20, 22, 25, 27, 28, 30, 31

32, 35, 37, 48, 57,

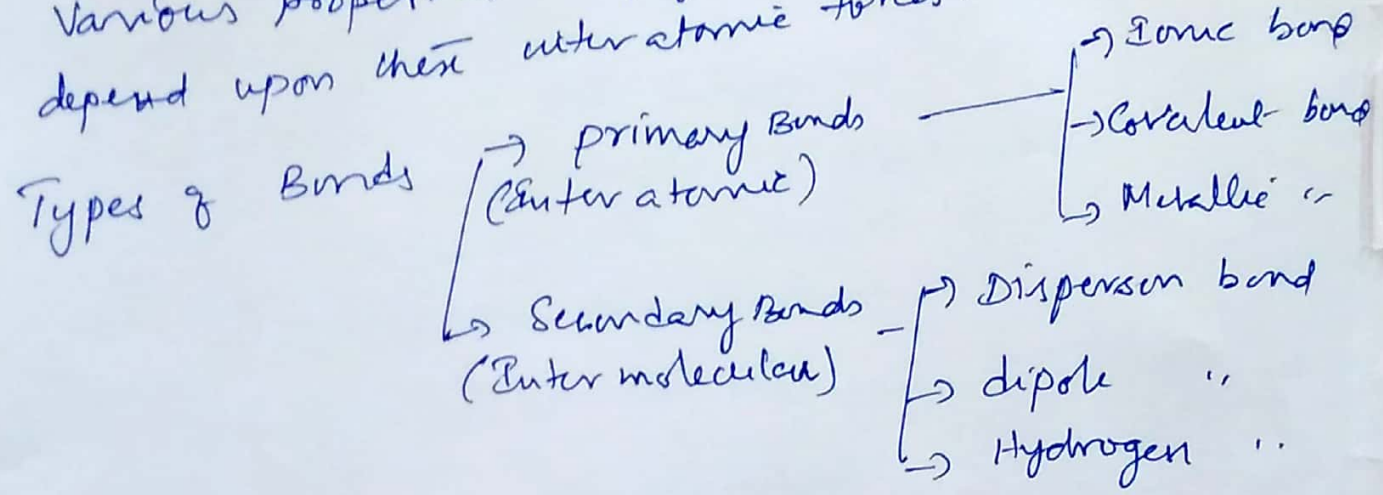
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Bonds in Solids

Atoms are held in the solid state by relatively strong interatomic forces which are generally functions of temp. & pressure.

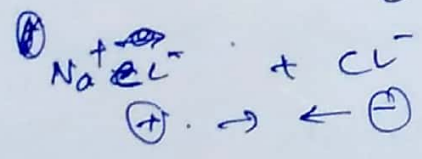
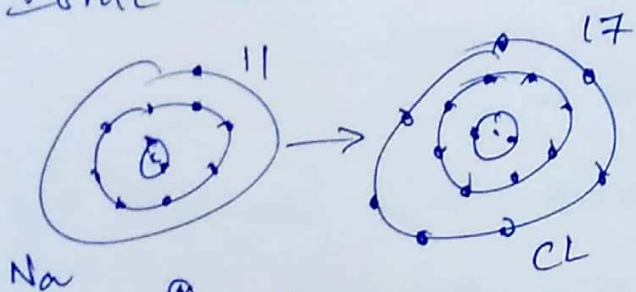
Various properties i.e. physical, chemical, mech, electrical etc depend upon these interatomic forces.



Ex: of Primary bonds.

1) Ionic bond

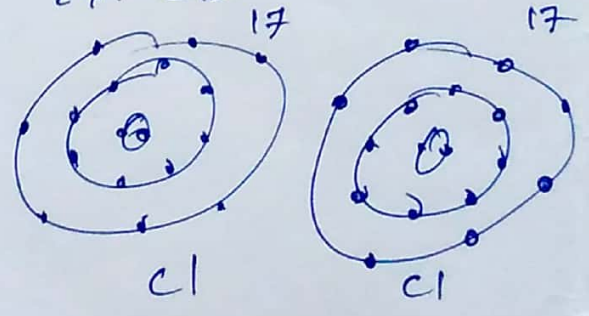
NaCl.



Ionic - Outright transfer of electron.

2) Covalent Bond

Ex: Cl₂



Covalent: Sharing of electrons. Orbital overlap.

3) Metallic Bond

- Bond b/w electron cloud of valency electrons and the positive ions -

- Soft, ductile - electrical & thermal conductivity is high.

