Assignment Sheet-1

Campus: PCE   Course: B. Tech.   Class/Section: 2nd Year   Date: 20/09/2021

Name of Faculty: Surendra   Name of Subject: Material Science Engineering   Code: 3ME4-06

Date of Preparation: Scheduled Date of Submission:

Q. No.	Questions	COs	POs	PSOs
Q.1	Enumerate the different cubic crystal structures (with diagram) and estimate the number of atoms, coordination number and atomic packing factor for them.	1	1	1
Q.2	Identify and describe briefly various crystal imperfections with neat sketch.			
Q.3	Define briefly: (i) Miller indices (ii) Bauschinger's effect (iii) Phase rule (iv) Isomorphous alloy system (v) recovery , re-crystallization and grain growth (vi) Solid solution (vii) Equilibrium diagram	2	2	1
Q.4	Draw iron carbon equilibrium diagram and discuss clearly the various terms, phases and reactions involved in it.	2	1	1
Q.5	Explain binary system when two metal are completely soluble in the liquid state but only partly soluble in the solid state with suitable with neat sketch.	2	1	1
Q.6	Distinguish between homogeneous and heterogeneous nucleation for solidification of a pure metal . how does degree of under-cooling affect the critical nucleus size.	3	2	1
Q.7	Draw an equilibrium diagram of binary system with limited solid state and in which solubility decreases with decrease in temperature , also explain it briefly.	2	2	1
Q.8	Explain line dislocation and burger vector.	2	2	1
Q.9	Differentiate slip and twinning mechanism of deformation.	2	2	1
Q.10	Differentiate the hot and cold working, and elastic and plastic deformation.	3	1	1

Dr. Mahesh Bundele
B.E., M.E., Ph.D.
Director
Poornima College of Engineering
ISI-6, RIICO Institutional Area
Sitapura, JAIPUR

Q-1.) Enumerate the different cubic crystal structures (with diagram) and estimate the no. of atoms, co-ordination number and atomic packing factor for them.

Ans Basic Types of Crystal structure

1.) Simple Cubic crystal structure (S.C)
2.) Body centered crystal structure (B.C.C)
3.) Face centered crystal structure (F.C.C)
4.) Hexagonal close packed structure (H.C.P)

→ Primitive Unit cell or Simple Cubic Crystal

When constituent particles are present only on the corner position of a unit cell, it is called S.C.

Here, each atom at a corner is shared b/w eight adjacent unit cell.

Total number of atoms in 1 unit cell is $8 \times \frac{1}{8}$ = 1 atom.

→ Body Centered Unit Cell :- Such a unit cell contains 1 constituent particle (atom, molecule or ion) at its body-centre besides the ones that are at its corner.

8 corners × $\frac{1}{8}$ per corner atom = $8 \times \frac{1}{8}$ = 1 atom

1 body centre atom = 1×1 = 1 atom

∴ Total number of atoms per unit cell = 2 atoms

→ Face-Centred Unit Cells :- ~~Such~~ a unit cell contains 1 constituent particle present at the centre of each face, besides the ones that are at its corners.

F.C.C 8 corners atoms × $\frac{1}{8}$ atom per unit cell = $\frac{8 \times 1}{8}$ = 1 atom

6 face centred atoms × $\frac{1}{2}$ atom per unit cell = $6 \times \frac{1}{2}$ = 3 atom

∴ Total number of atoms per unit cell = 4 atoms.

H.C.P – This crystal structure shows 1 atom at each corner of the hexagon. The total corner atoms are thus 12. Each corner atom is shared by 6 unit cells. There is 1 atom on each hexagonal face centre

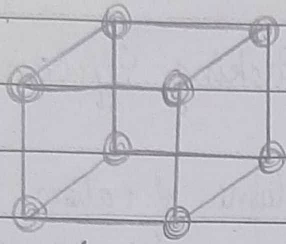
It is shared by 2 unit cells. The 3 atoms at Interior remain unshared. Average no. of atoms per unit cell

$$= \frac{A}{6} + \frac{B}{2} + \frac{C}{1} \Rightarrow \frac{12}{6} + \frac{2}{2} + \frac{3}{1} = 2+1+3$$

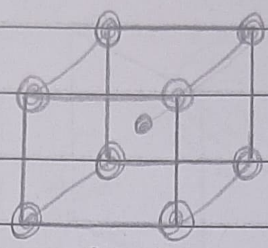
$$= 6 \text{ atoms.}$$

Co-ordination Number :-

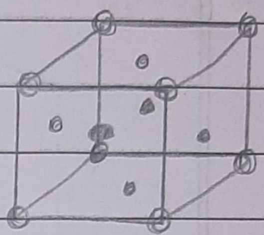
The number of nearest neighbours of a particle is called CN.



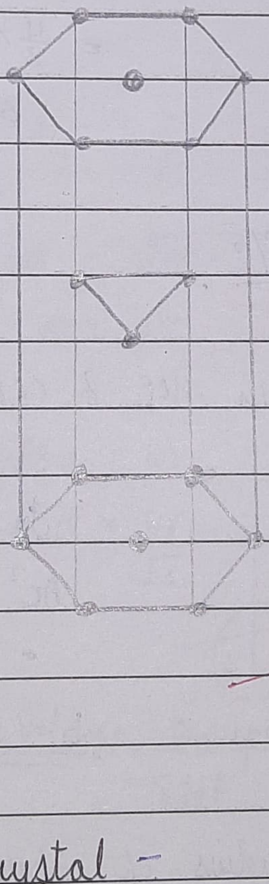
(S.C)



(B.C)



(F.C)



(HCP)

* Packing Efficiency

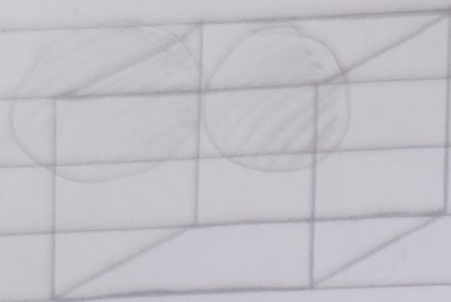
1) Simple Cubic Crystal -

As the particle touch each other along the edge
The edge length or side of the cube 'a' and the radius of each particle, r

$$a = 2r$$

The volume of cubic unit cell $= a^3 = (2r)^3$
$= 8r^3$

Since, a simple cubic unit cell contains only 1 atom.
The volume of the Occupied space



∴ Packing Efficiency

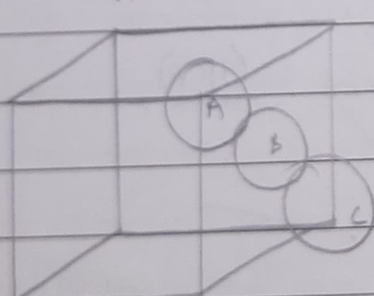
$$= \frac{\text{Volume of 1 atom}}{\text{Volume of cubic unit cell}} \times 100$$

$$= \frac{\frac{4}{3}\pi r^3}{8r^3} \times 100$$

$= \pi/6 \times 100$

$= 52.36\%$

2.) Packing Efficiency in HCP & CCP structure



In ΔABC

$AC^2 = b^2 = BC^2 + AB^2$

$= 2a^2$

$b = \sqrt{2}a$ (Hypotenuse)

If r is radius of sphere

$b = 4r = \sqrt{2}a$

$a = \frac{4r}{\sqrt{2}} = 2\sqrt{2}r$

$$\text{packing Efficiency} = \frac{\text{Volume Occupied by 4 spheres in unit cell}}{\text{Total volume of unit cell}} \times 100$$

$$= \frac{4 \times (\frac{4}{3}\pi r^3)}{(2\sqrt{2}r)^3} \times 100$$

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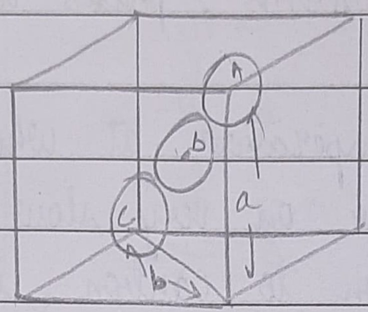
* Packing Efficiency of BCC



As, $b = \sqrt{2}a$ & edge length of cube $= a$

Now,

Hypotenuse (AC) $= \sqrt{a^2 + b^2} = \sqrt{3}a$

~~where $a = 2r$, $b = 4r$~~

also,

$\sqrt{3}a = 4r$

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

packing Efficiency $= \frac{\text{Volume occupied by 2 spheres in unit cell}}{\text{Total volume of unit cell}} \times 100$

$= \frac{2 \times \frac{4}{3}\pi r^3 \times 100}{\left(\frac{4}{\sqrt{3}}r\right)^3}$

$= 68\%$

Dr. Mahesh Bundele
B.E., M.E., Ph.D.
Director
Poornima College of Engineering
ISI-6, RIICO Institutional Area
Sitapura, JAIPUR

Q-4.) Draw iron carbon equilibrium diagram and discuss clearly the various Terms, phases and reactions involved in it?

Ans-4 A map of the temperature at which different phase changes occur on very slow heating and cooling in relation to carbon, is called Iron-Carbon Diagram.

It shows :-

1.) Type of alloys formed under very slow cooling.
2.) Proper heat-treatment temperature and
3.) Properties of steels and cast iron

There are 3 invarient reactions

1.) Peritectic - (at 1490°C)
2.) Eutectic - (at 1150°C)
3.) Eutectoid - (at 725°C)

→ Peritectic - Liquid and 1 solid phase Transforms to 2nd solid phase.

$$\delta + L \xrightarrow[\text{cooling}]{\nabla} \gamma\text{-Austenite}$$

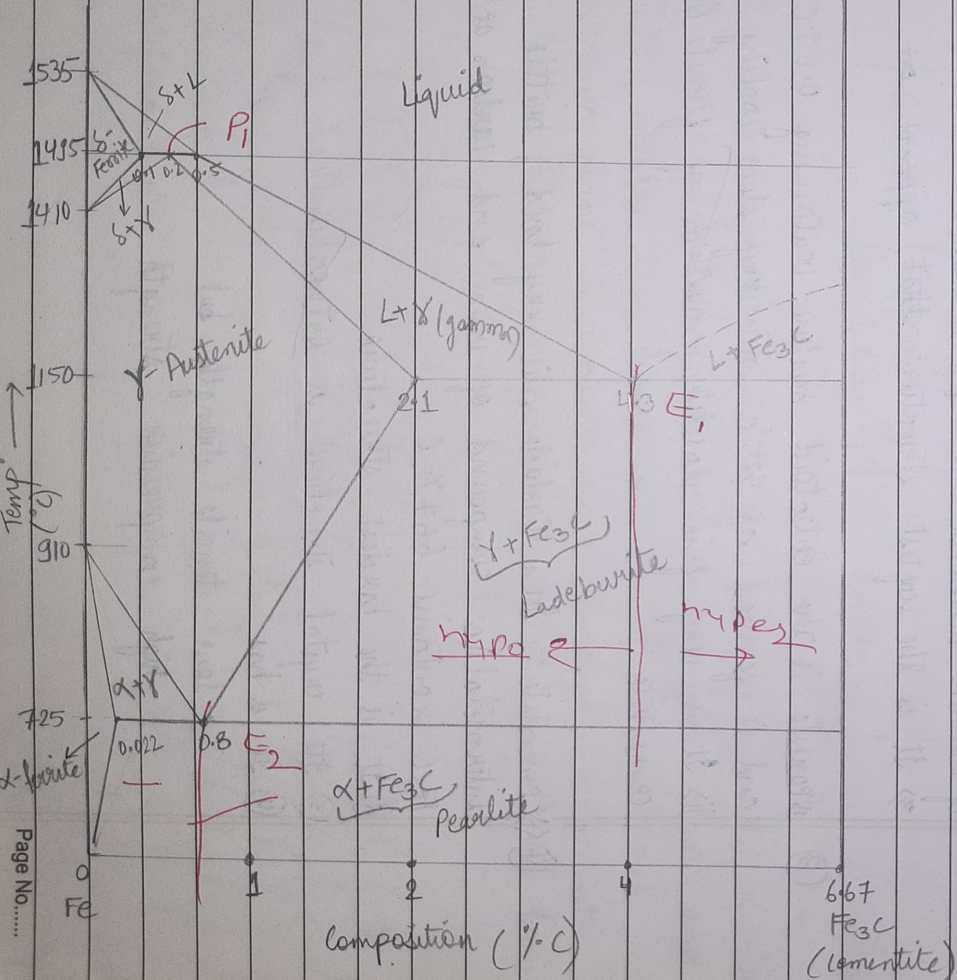
Eutectic - Liquid transforms to 2 solid phases

$$L \xrightarrow[\text{cooling}]{\nabla} \gamma + Fe_3C$$

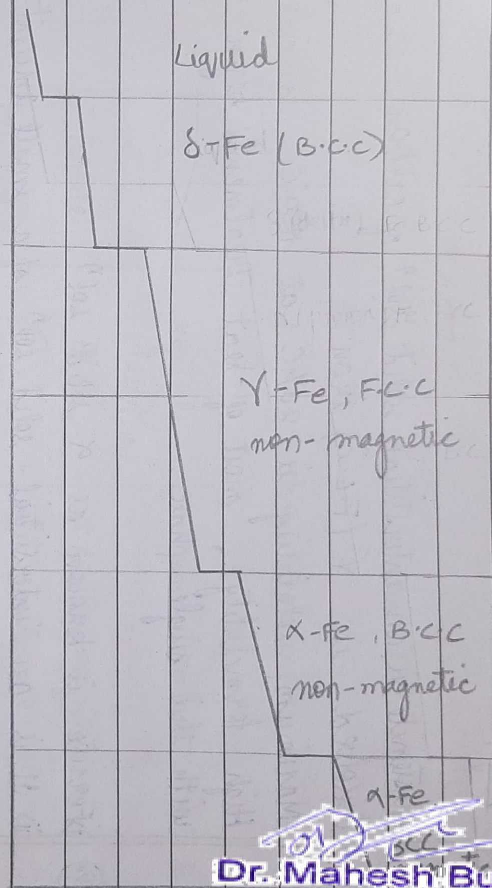
(Lade burite)

Eutectoid - one solid phase transform to 2nd ...

$solid_1 \rightarrow solid_2 + solid_3$ $\quad \gamma \xrightarrow{\nabla} \alpha + Fe_3C$



1535
1495
1410
1150
910
725
δ+L
δ-Ferrite
0.1
0.2
0.5
δ+γ
P1
Liquid
L+γ (gamma)
L+Fe3C
γ-Austenite
2.1
4.3
E1
γ+Fe3C
Ladeburite
hypo
hyper
α+γ
0.022
0.8
E2
α-ferrite
α+Fe3C
Pearlite
Temp. (°C)
0
1
2
4
6.67
Fe
Fe3C
(Cementite)
Composition (% C)



Liquid
δ-Fe (B.C.C)
γ-Fe, F.C.C
non-magnetic
α-Fe, B.C.C
non-magnetic
α-Fe
BCC

Page No......

Terms

(1) Austenite is an interstitial solid solⁿ of carbon dissolved in γ (F.C.C) iron.
2) Maximum solubility is 2.0% C at 1150°C
3) High formability, most of heat treatments begin with this single phase.

(2) i) Ferrite is known as α solid solⁿ.
ii) It is an interstitial solid solⁿ of a small amount of carbon dissolved in α (BCC) iron.
3) It is the softest structure. ~~that appears on~~

(3) i) Pearlite is the eutectoid mixture containing 0.8% C and is formed at 725°C on very slow cooling.
ii) It is very fine platelike mixture of ferrite & cementite.

(4) (1) Cementite :- Iron Carbide, is very hard, brittle intermetallic compound of iron and carbon, as Fe_3C contains 6.67% C.
(2) It is the hardest structure
(3) Its crystal structure is orthorhombic.
(4) It is has
- low tensile strength but
- high compressive strength.

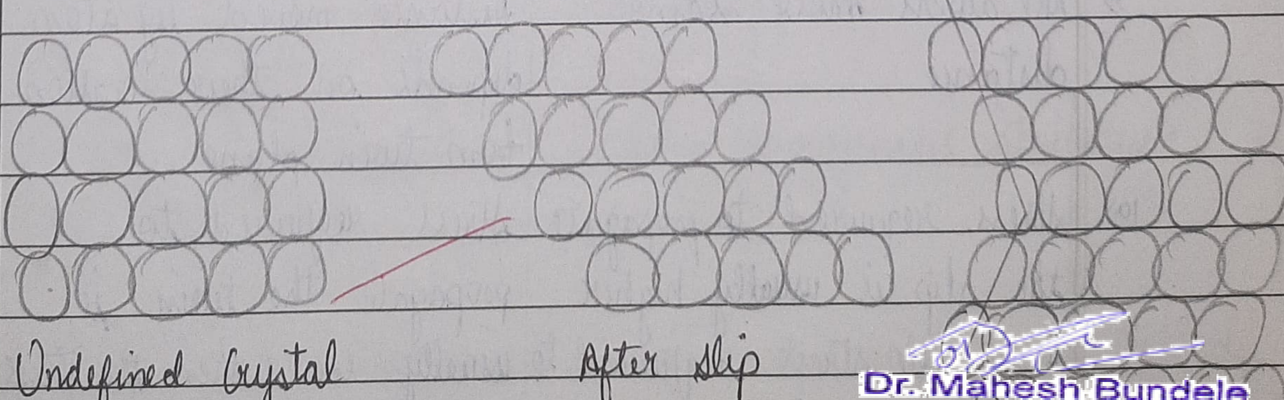
5) Lede burite - It is the eutectic mixture of Austenite & cementite.

- It contains 4.3 % C and is formed at 1150°C.

Principle phases and their characteristics

Phase	Crystal structure	Characteristics
Ferrite	BCC	Soft ductile, magnetic
Austenite	FCC	Soft, moderate strength, non-magnetic
Cementite	Compound of Iron & Carbon Fe_3C	Hard & Brittle

9) Slip is the large displacement of 1 part of a crystal relative to another part along the crystallographic planes and dir^n s, whereas, in twinning, the atoms in each successive plane in a block move through different distances that are proportional to their distance from the twinning plane.



Undefined Crystal After slip

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* Slip V/s Twin

	Slip	Twin
1>	Crystal lattice orientation is same after slip.	Crystal lattice orientation is different in twin zone.
2>	Slip is line defect.	Twin is surface defect.
3>	Commonly observed in BCC and FCC metals	Commonly observed in HCP metals.
4>	Stress required for slip is comparatively low.	Stress required for twin is comparatively higher
5>	Most dominant deformation in any crystal's plastic deformation	Observed for only some metals at some temp^{n}.
6>	Occurs in milli-seconds (slow).	Occurs in micro-seconds (fast).
7>	No sound is created	A clicking sound is created.
8>	Is thin lines under microscope	Is thick lines under microscope.
9>	All atoms move same distance	Distance moved by atom depends on their location from twin plane.
10>	Stress required to propagate the slip is usually higher than the stress required to start the slip.	Stress required to propagate the twin is usually lower then the stress required to st[illegible]
11>	Occurs at low strain rates.	Occurs at hig[illegible]

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Q-10> Differentiate the hot & cold working, and elastic and plastic deformation.

	HOT WORKING	COLD WORKING
1>	It is carried out above recrystallisation temp^r.	It is carried out below recrystallisation temperature.
2>	It refine grain size.	It distorted grain structure.
3>	Large deformation possible.	Less deformation
4>	Less force required.	Large force required.
5>	The material does not work hardened.	It causes strain hardening.
6>	Stress relieving not required.	Stress relieving required.
7>	Poor surface finish	Better surface finish then Hot working.
8>	Homogenous structure.	Non-Homogenous structure.

⇒ The change in shape and size of a metal (object) is called deformation.

When an external force acts on a body the body is ...

Dr. Mahesh Bundele
B.E., M.E., Ph.D.
Director
Poornima College of Engineering
ISI-6, RIICO Institutional Area
Sitapura, JAIPUR

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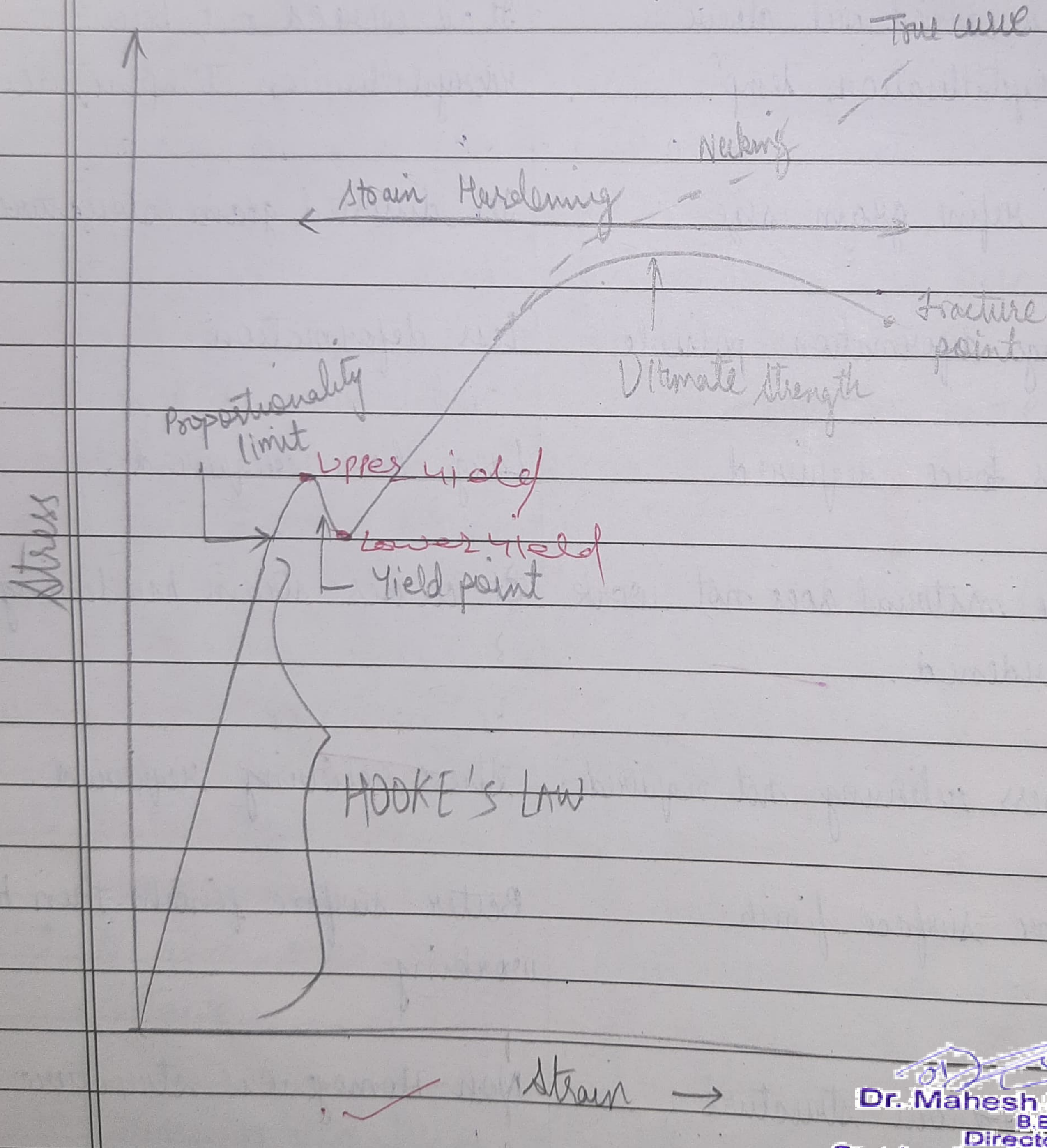
undergo some deformation. If the external force is removed and the body comes back to its original shape & size is called **elastic deformation**. When the stress is permanently deform the metal, it is called plastic deformation.



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	Elastic Deformation	Plastic Deformation
1>	It is a temporary deformation under the action of external loading.	It is permenent deformation.
2>	Once the external load is removed from an elastically deformed body, it regains its original shape.	When the body is plastically deformed, it retains its deformed shape even after the removal of external load.
3>	Atoms of the material are displaced temporarily from their original lattice site. They return back to their original position after the removal of external load.	Atoms of the solid are displaced permanently from their original lattice site. They don't return back to the original position even after the removal of external load.
4>	It is characterized by the property Elasticity.	It is characterized by the property Plasticity.
5>	Amount of Elastic deformation is very small.	Amount of Plastic deformation is very large.
6>	External force required is quite small.	Force required is larger.
7>	Energy absorbed by the material during Elastic deformation is called Module of resilience.	Total Energy absorbed by the material during Elastic & Plastic deformation is called Module of Toughness.
8>	Hooke's law of Elasticity is applicable within its elastic region.	Hooke's law is not applicable if the material is plastically deformed.
9>	Displays Linear stress - strain behavior.	Stress - [illegible] non-linear in plasti[illegible]

Dr. Mahesh Bundele
B.E., M.E., Ph.D.
Director
Poornima College of Engineering
ISI-6, RIICO Institutional Area
Sitapura, JAIPUR

Elastic Deformation	Plastic Deformation
10> Material first undergo elastic deformation under the application of external loading.	It occurs after it is elastically deformed due to the application of external loading.
11> Mechanical & metallurgical properties of solid material remain unaltered when it is elastically deformed.	Many properties of solid material change considerably for plastic deformation.

Q-2.> Identify and describe briefly various crystal Imperfections with neat sketch.

⇒ Defects are classified based on their dimensionality

* point defect (0-D)
* Line defect (1-D)
* Surface defect (2-D)
* Volume defect (3-D)

1.> Point defects :-

i> Vacancy - absence of an atom in a lattice pt. where there is suppose to be an atom. Formed when atoms are removed from their lattice positions as a result of thermal fluctuations (Schottky defects).

ii> Interstitial - Atom located in a 'void' (a position that is not part of lattice) within

crystal structure.
Frenkel Defect :- A vacancy interstitial pair.

→ Substitutional Impurity - Impurity atoms that take up the lattice positions that are ordinarily occupied by the atoms that make up the crystal.

→ Interstitial Impurity - Impurity atoms that are present in the interstitial sites.

2.) Line defects
→ Dislocation - Boundary b/w 2 regions of a surface which are prefect themselves but are out of registry with each other. The resulting lattice distortion is centered along a line.

⇒ Burgers Vector, b :- A vector by which the lattice on 1 side of an internal surface containing the dislocation line is displace relative to the lattice on the other side.

2 Special Cases of dislocation
→ Edge Dislocation - b & normal vector along the dislocation line l are ⊥r.
→ Screw Dislocation - b & normal vector along the dislocation line l are ||.

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3. 2-D defect
Unsaturated bond, surface always have an associated energy.
In equilibrium, shape of a given amount of crystal minimizes the total surface Energy.

4. 3-D defects →
1) Grain Boundary -
• Internal surfaces that seperates grains of different orientation.
• created in metals during solidification when crystal grow from different nuclei.

2) Volume defects :-
Crystal twins →
Grain boundary is not random, but have a symmetric.

3) Stacking faults :-
FCC, ABCABC, ___ ABCABC ABC

4) Voids :-
The absence of a no of atoms to form internal surface similar to microcracks (broken bonds at the surface).

Q-3) Describe briefly :-

i) Miller Indices - Group of 3 number that indicates the orientation of a plane or set of ∥ planes of atoms in a crystal.

* Two or more planes can have same Miller Indices which can be -ve, 0, +ve depending on the intercept on the axes.

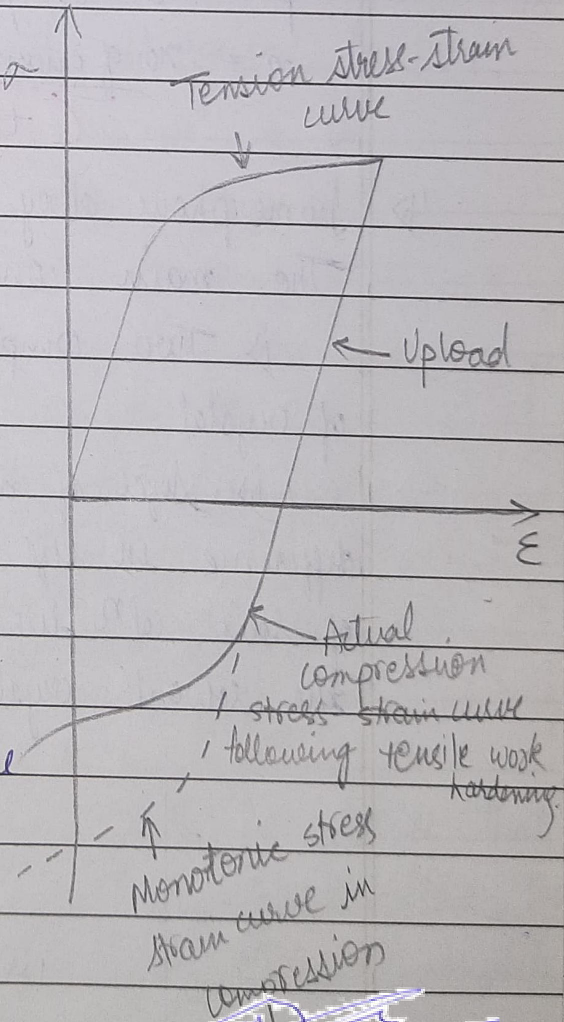
It ~~helps in~~ specific atomic planes and orientation in a crystal.

ii) Bauschinger's Effect -

1) It refers to a decrease in the compressive yield stress due to work hardening in tension.

2) It also refer to a decrease in the Tensile yield stress due to work hardening in Compression.

3) Work hardening can be used to increase the yield strength of a material, but it does so at the cost of a lower yield stress in the reversed dirⁿ of loading.



3) Phase rule -

All changes which take place in a system consisting of several phases, in accordance with external conditions (temperature and pressure) conform to the so called phase rule.

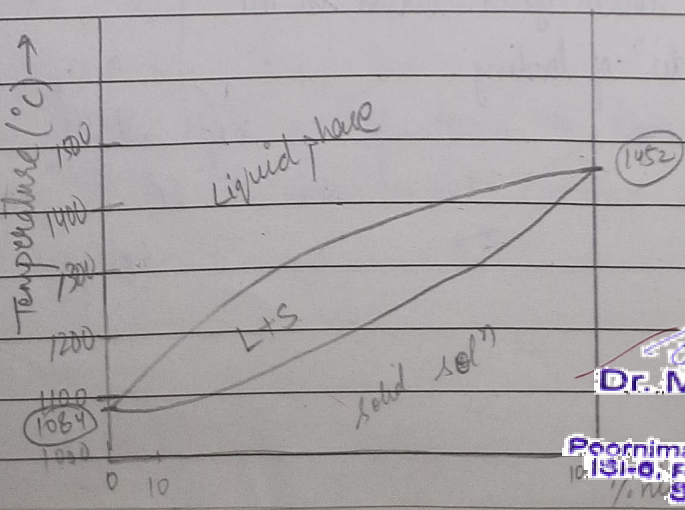
$$F = C + n - P$$

F = no. of degree of freedom
C = no. of components
P = no. of phases in equilibrium
n = no. of external factors
(temp^n, pressure, concen^n)

4) Isomorphous alloy system
The main conditions are :-

i) Two components should have the same type of crystal

ii) Sizes of atoms should be very similar. A difference in size over 15% prevents the formation of solid sol^n due to ~~pressure~~ extreme distortion of the solvent crystal lattice



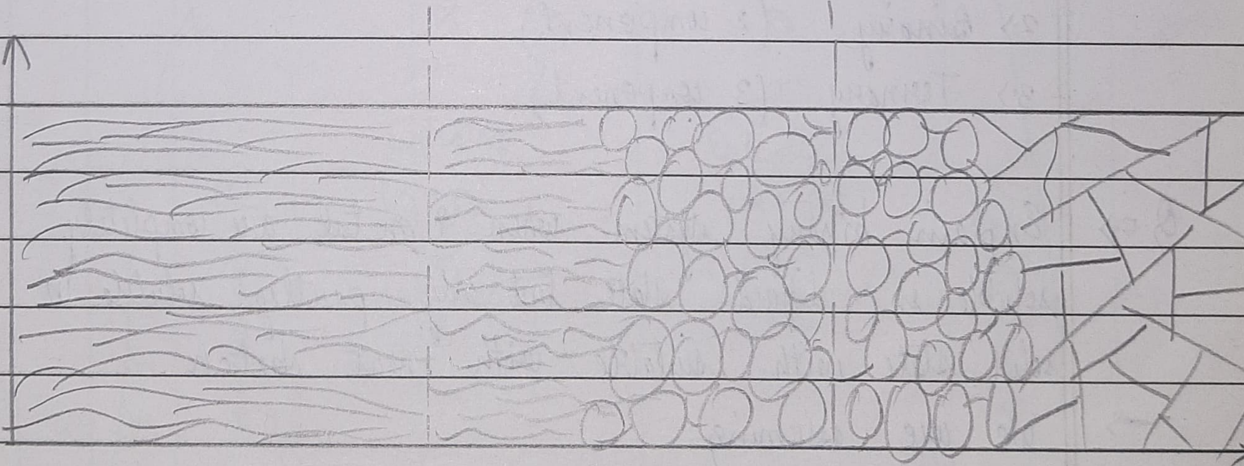
5) Recovery, Recrystallisation and grain growth

Recovery - Occurs below recrystallization temp^r, stresses in the highly deformed regions are relieved.

Recrystallization - Within a certain temp^r range, new equiaxed and strain-free grains are formed to replace older grains.

Grain Growth - Grains begin to grow in size and exceed the original grain size when temp^r is raised further.

~~6) Solid solution - It is.~~



6) Solid solution - It is a mixture of 2 crystalline solids that consist as a new crystalline, solid or crystal lattice. The substance may be soluble over a partial or even complete range of relative conc., producing of crystal.

7.) Equilibrium Diagram–
Constitutional Diagram
Phase Diagram

It enable the phase content of the alloys to be determined at any temperature and composition. They enable the phase transformation to be followed in heating and cooling the alloy under equilibrium conditions i.e when all processes in the given system are reversible.

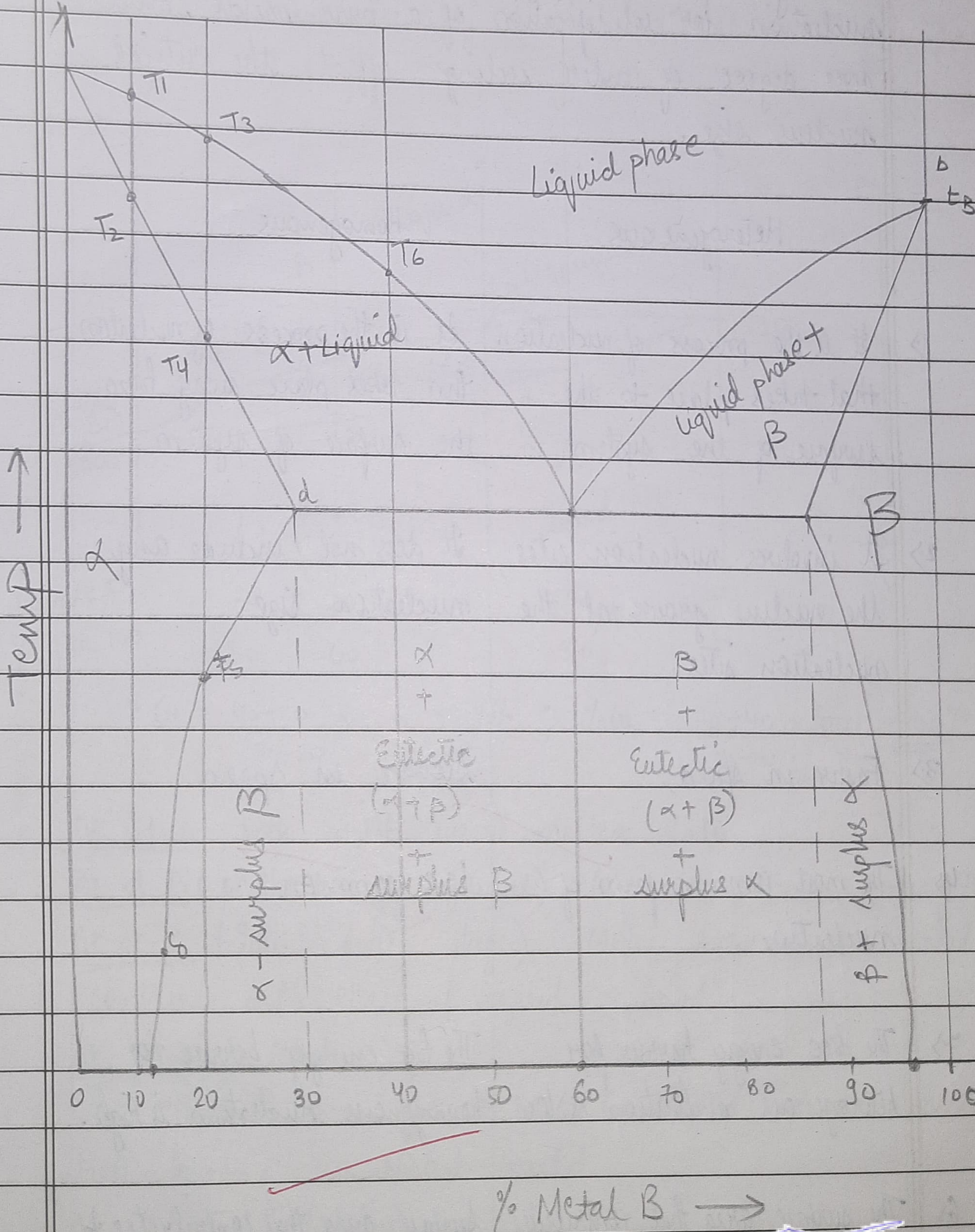
It is classified as –

1.) Unary (1 component)
2.) Binary (2 component)
3.) Ternary (3 component)

Q,5.) Explain binary system when 2 metal are completely soluble in liquid state but only partly soluble in solid state with suitable with neat sketch.

→ We are assuming
Metal A + Metal B

Metals are completely soluble in liquid state but partially soluble in solid state.



T1
T3
T2
Liquid phase
b
t_B
T6
T4
α + Liquid
liquid phase + β
d
β
α
Temp →
T5
α
+
Eutectic
(α + β)
+
surplus β
β
+
Eutectic
(α + β)
+
surplus α
α - surplus β
β + surplus α
0
10
20
30
40
50
60
70
80
90
100
% Metal B →

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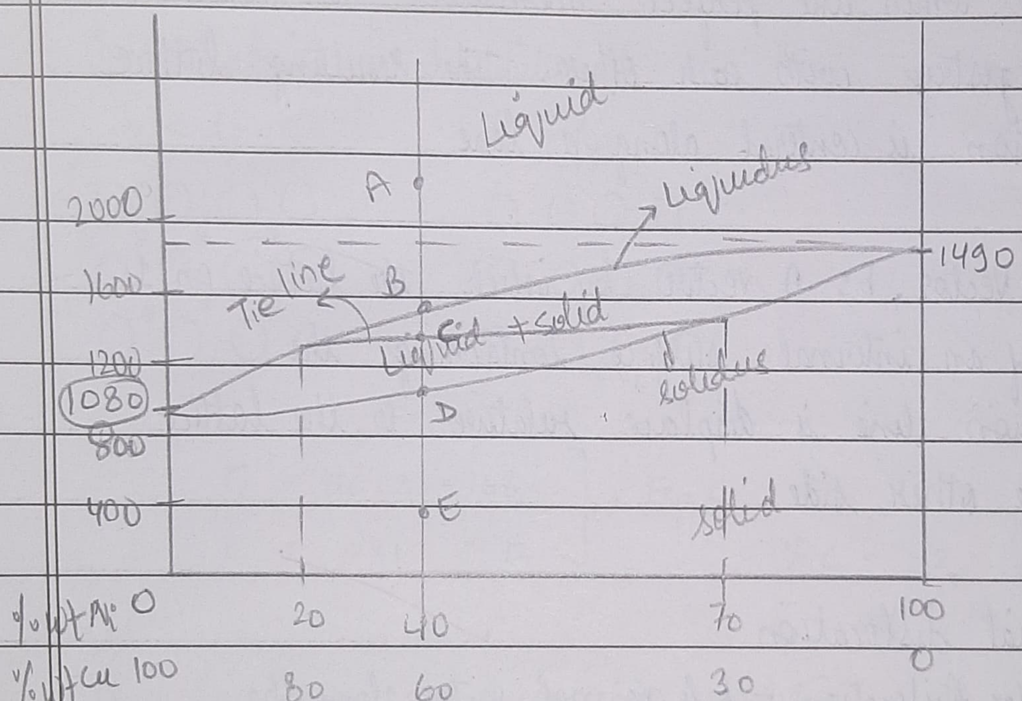
Q-6.) Distinguish b/w homogenous & heterogeneous nucleation for solidification of a pure metal. How does degree of under cooling affect the critical nucleus size.

Heterogeneous	Homogenous
1.) It is the process of nucleation that takes place to the surface of the system	It is the process of nucleation that takes place away from the surface of system.
2.) It involves nucleation sites, the nucleus grows at the nucleation sites.	It does not include any nucleation size.
3.) Faster in speed.	Slower in speed
4.) The most common form of nucleation.	Less common
5.) The free energy barrier for heterogenous nucleation is low.	The free energy barrier for homogenous nucleation is high.
6.) The surface area that contributes to the growth of nucleus is low.	Surface area that contributes to the growth of nucleus is high.

The greater the degree of undercooling of a liquid the smaller the critical radius of nuclei

Q-7) Draw an equilibrium diagram of binary system with limited solid state and in which solubility decreases with decrease in temperature, also explain it briefly.



$\% Cu = \frac{40-20}{70-20} \times 100 = 40\%$; $\% Cu = \frac{70-40}{70-20} \times 100 = 60\%$

liq — solid

At pt. A, both metals are at molten state.

At pt. B (on the line of Liquidus), Cu metal starts forming nuclei.

At pt. C (Intermediate stage), Metals ~~are in~~ semi-solid form contains both phase (liquid + solid)

At pt. D (solidus),

There is grain growth in Cu metal whereas nuclei starts forming in Nickel metal.

At pt. E (solidifies),

Metal solidifies completely.

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Q-8) Explain line dislocation & burger vector.

⇒

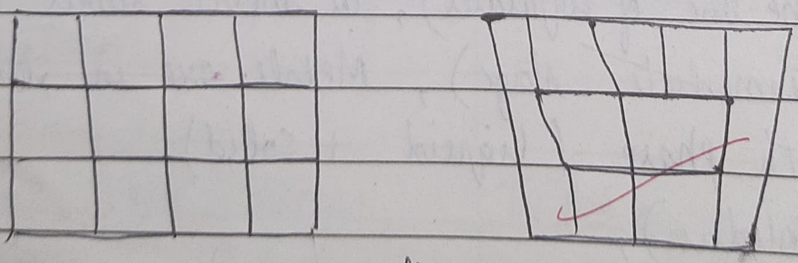
Line Dislocation - Boundary b/w 2 regions of a surface which are perfect themselves but are out of registry with each other. The resulting lattice distortion is centered along a line.

Burgers Vector, b: A vector by which the lattice on 1 side of an internal surface containing the dislocation line is displace relative to the lattice on the other side.

2 special dislocation

Edge Dislocation - b & normal vector along the dislocation line l are ⊥r.

Screw Dislocation - b & normal vector along the dislocation line l are ∥.



Edge Dislocation

20/11/2024