THEORY & OBJECTIVE

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MATERIAL SCIENCE

THEORY

1.1 INTRODUCTION

Two materials will combine together and form alloy when the conditions of Hune-Rothary Rules are satisfied.

Conditions:

(i) The difference in atomic radius should be less then 15%.

(ii) Valency of both the materials should be same.

(iii) Electronegativity and Electron affinity of both materials should be comparable.

(iv) Crystal Structures of both materials will be same.

1.2 PHASE DIAGRAM

Phase diagram is a plot on temperature composition space showing stability of various phases. In other words, it tells us what will be the melting point of alloy.

(P) = Number of Phase

(C) = Number of Components

(F) = Number of Degree of Freedom

$$C + 2 = F + P$$

If C = 1; Unitary phase diagram

Example: Carbon phase diagram

1.2.1 Binary Phase Diagram (C = 2)

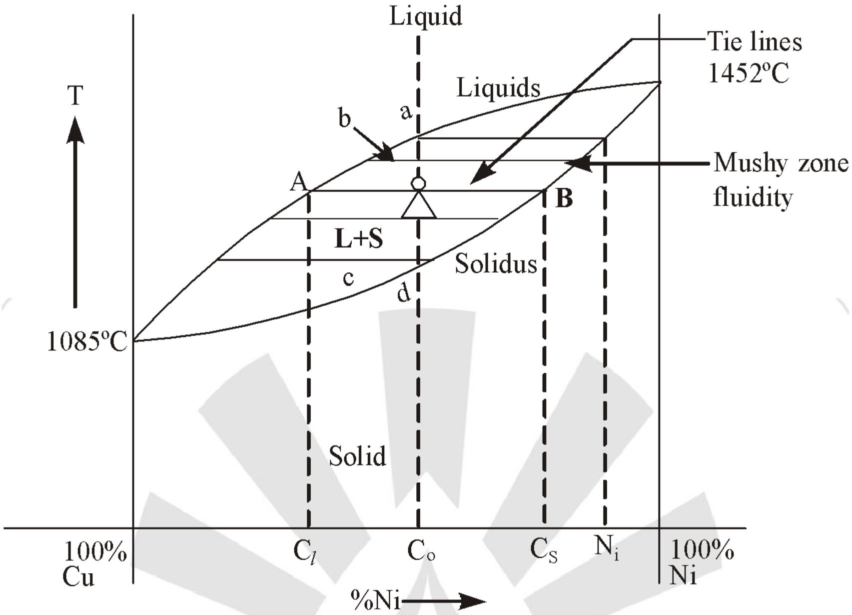
(a) *Cu-Ni Phase Diagram:*

Materials which are completely soluble in the liquid state as well as solid state.

The line which separates the Mushy zone with the liquid phase is called liquids and the line which separates the Mushy zone with the solid phase is called Solidus.

Larger is the mushy zone of material, lesser will be its fluidity and hence large variation will be there in the properties of alloys. Fluidity also increases by increasing the temperature but there is a limit in casting practice beyond which we cannot increase the temperature.

Higher the temperature rise, design becomes very complex, also at high temperature moisture disintegrate in H_2 and O_2 and as hydrogen gas is coming out, it creates large. Number of pin holes on the surface of casted part. These defect is called Pin Hole Porosity.



Cu-Ni Phase Diagram

$$m_l = \text{liquid}$$

$$m_s = \text{solid}$$

$$m_s + m_l = 1$$

$$m_s c_s + m_l c_l = c_0$$

$$(1 - m_l)c_s + m_l \cdot c_l = c_0$$

$$\therefore \quad c_s - c_s m_l + c_l . m_l = c_0$$

$$\therefore \quad m_l (c_l - c_s) = c_0 - c_s$$

$$\because \quad m_l = \frac{c_0 - c_s}{c_l - c_s} \text{ (lever Rule)}$$

$$m_s = 1 - \frac{c_0 + c_s}{c_l - c_s} = \frac{c_l - c_s - c_0 + c_s}{c_l - c_s}$$

$$\because \quad m_l = \frac{c_l - c_0}{c_l - c_s} \text{ (lever Rule)}$$

Upon slowly cooling the sample of copper and nickel along line "a-d", following microstructures changes will be occurred.

At point "a" entire microstructure will be in the liquid phase. As soon as the temperature decreases slightly below the liquids line, solid particle at the liquid region upon decreasing nucleate.

For the temperature from point b to c, following conclusions can be drawn by drawing a no. of tie lines

(i) Mass fractions of solid phase increases.

(ii) The moment solid nucleates, percentage of nickel in solid phase is very high and by decreasing the temperature, percentage of Nickel in solid phase is decreasing and approaching towards over all composition c_0.

At high temperature, phenomenon called diffusion appears in the material in which the atoms diffuses from higher to lower concentrations. It is solid so that at every 20°C increase in temperature, diffusion get doubles.

So nickel diffuses from centre to outward direction, making the entire composition homogeneous.

The moment temperature decreases slightly below the solidus line, entire sample converts into the solid phase. Each solidification front will have a particular arrangement of atoms and the region where two solidification front meets, there will be orientation mismatch of atoms called Grain Boundaries.

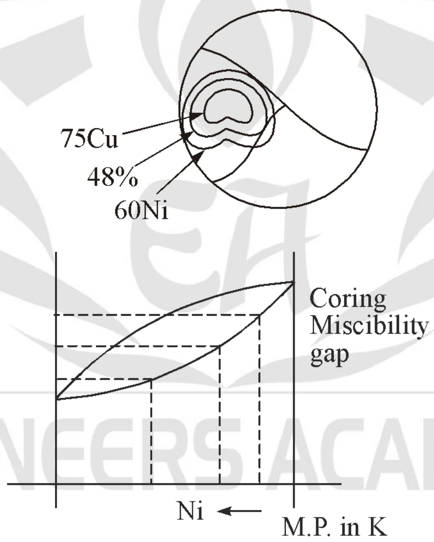
Bond length at the grain boundaries will be higher, larger the bond length, easily bond can break. That is why it is said that grain boundaries are at the high energy level. So atmospheric oxygen first attacks the grain boundaries atom and corrodes the materials. Finer is the grain structure, lesser will be the corrosion resistance of materials.

Generally to improve the corrosion resistance, chromium is added in the material, which after reacting with oxygen produces Chromium oxide which gets settle down at the grain boundaries, protecting the atoms from further oxidation.

(i) Generally in iron nickel is called austenite phase stabilizer.

(ii) Chromium is called ferrite phase stabilizer.

For Rapidly cooling



Cold working < 0.4 T_m

Warm working – 0.4 to 0.6 T_m

Hot working > 0.6 T_m

If the sample of copper and nickel is cooled rapidly. Since there is no sufficient time for diffusion to take place. There will be concentration gradient within the grain. At the grain boundaries, percentage of Nickel will be very low.

It can be observed in the phase diagram that lower is the percentage of Nickel, lower will be melting point of material. So upon hot working, the grain boundary material will melt out producing cracks, these leads to Brittle Fractures and the phenomenon is called Coring or Miscibility Gaps.

Note: *All the binary phase diagram are plotted at a particular pressure which is one of the degree's of freedom. So the modified gibb's phase rule can be written as:*

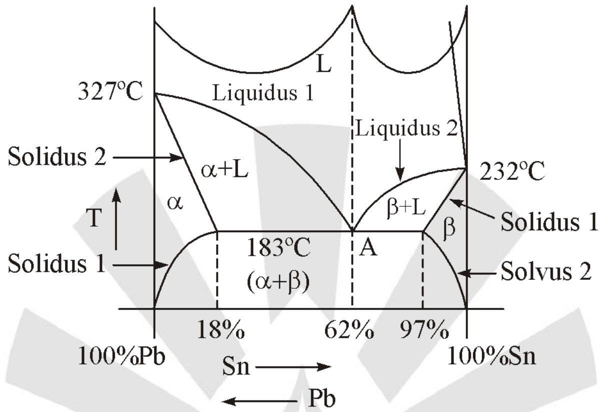
$$C + 2 - 1 = F - 1 + P$$

$$\Rightarrow \quad C + 1 = F + P$$

(b) ***Pb-Sn Phase Diagram:***

Materials which are completely soluble in the liquid state but partially soluble in the solid state.

Phase Diagram of Pb–Sn (Lead Tin) (Soldering Alloy)



Pb-Sn Phase Diagram

$$0.5\ T_m = 0.5\ (327 + 273) - 273$$

$$= 27°C \text{ (Melting point of lead)}$$

α = Phase is solid solubility of Sn (Tin) in Pb (lead) and

β = Phase is solid solubility of Pb in Sn.

Maximum solid solubility appears at 183°C and it decreases by decreasing the temperature. Any line on the phase diagram which separates a single solid phase with a mixture of solid phases. is called solidus

At point-A $\quad L \xrightleftharpoons[183°C]{62\%\ Sn} \alpha + \beta \quad$ Eutectic Reaction

$$C + 1 = F + P$$

$$2 + 1 = 0 + P$$

$$\therefore \quad P = 3$$

On such phase diagrams, there appears a point at which there is no Mushy zone and liquid directly converts into two different solids. It is called Eutectic Reaction. At Eutectic point three phases exist in equilibrium simultaneously.

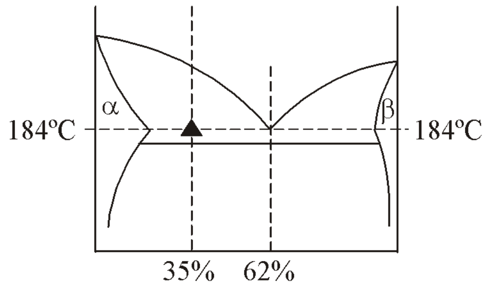
Example: Calculate the mass-fractions of phases present in an alloy of lead-Tin with 35% Sn and 62% Pb and at 184°C.

Solution: We know,

$$m_\alpha = \frac{62-35}{62-18} = \frac{27}{44} = 0.613$$

And

$$m_\beta = \frac{35-18}{62-18} = \frac{17}{44} = 0.386$$



Example: Calculate the mass and volume fraction of lead and Sn alloy with 35% Sn and 100°C. At this temperature. 10% Sn can be dissolved in Pb and 2% Pb can dissolve in Sn. Take density of Pb and Sn to be 10.25 g/cc. and 13.38 g/cc

Solution: 35% Sn at 100°C

$$m_\alpha = \frac{98.35}{98-10} = 0.715$$

And $$m_\beta = \frac{35-10}{98-10} = 0.285$$

$$\alpha = 10\%\ Sn + 90\%\ Pb$$

And $$\beta = 98\%\ Sn + 2\%\ Pb$$

$\therefore$ $$\frac{1}{\rho_\alpha} = \frac{0.1}{\rho_{Sn}} + \frac{0.9}{\rho_{Pb}}$$

And $$\frac{1}{\rho_\beta} = \frac{0.98}{\rho_{Sn}} + \frac{0.02}{\rho_{Pb}}$$

$$\rho_\alpha = 10.49 \text{ gm/'cc}$$

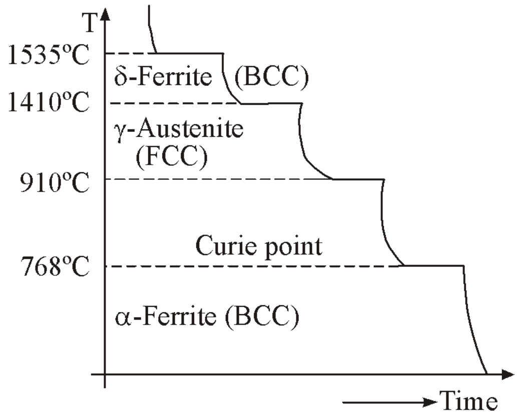
And $$\rho_\beta = 13.29 \text{ gm/cc}$$

$\therefore$ Volume fraction $$V_\alpha = \frac{\frac{m_\alpha}{\rho_\alpha}}{\frac{m_\alpha}{\rho_\alpha} + \frac{m_\beta}{\rho_\beta}} = 0.76$$

And $$V_\beta = 1 - V_\alpha = 0.24$$

1.3 Iron Carbon Phase Diagram

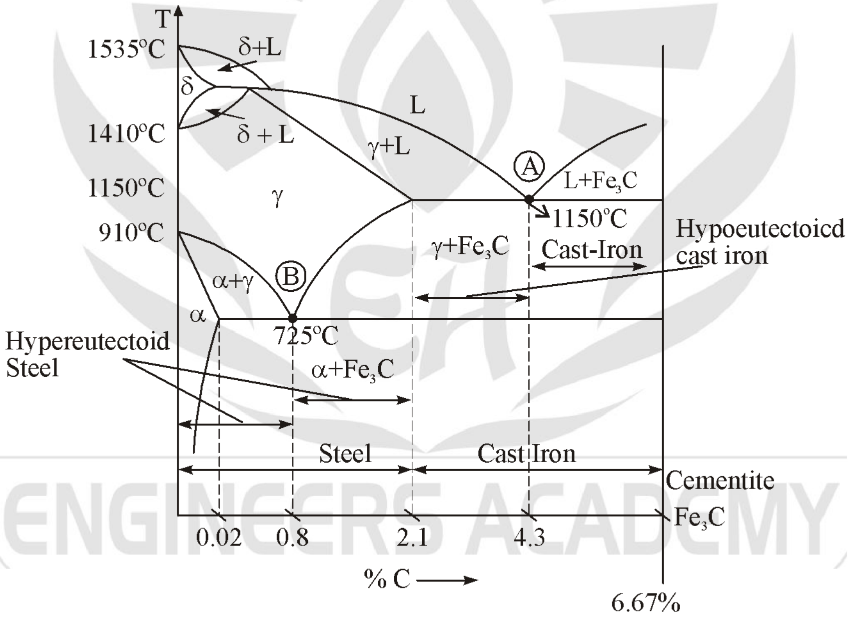
Generally latent heat transactions indicates the change of phase and it can be represented by a horizontal line on temperature time graph. But in case of iron at 768°C, there is no change of phase and only magnetic properties are disappearing. These temperature is called ***Curie Point.***



These characteristic of Iron due to which it exist in different phases at different temperature is called Allotropy.

1.3.1 Paramagnetic Materials

Are those in which electron are unpaired and such materials exhibit colour like alloys of copper. Di-Magnetic materials are those in which electrons are paired and such materials are colourless. But some materials such as iron which sometimes behave as paramagnetic and sometimes as Di-Magnetic, depending upon temperature, due to its unique characteristic are called as ***Ferro-Magnetic.***



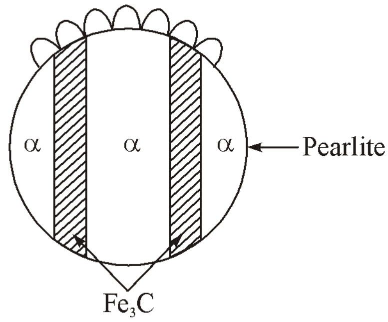
Fe-C Phase Diagram

$L \underset{4.3\%\,C}{\overset{1150°C}{\rightleftharpoons}} \gamma + Fe_3C$ (Ledeburite) — Eutectic Reaction

$\gamma \underset{0.8\%\,C}{\overset{725°C}{\rightleftharpoons}} \underset{0.02\%}{\alpha} + \underset{6.67\,\%}{Fe_3C}$ (Pearlite) — Eutectoid Reaction

$S + L \underset{0.18\%C}{\overset{1493°C}{\rightleftharpoons}} \gamma$ (Austenite) — Peritectic Reaction

Both are not phase of iron these are phase mixture of iron.



When one solid upon cooling converts into two different solids, these reaction is called Eutectoid reaction. Austenite is not stable below 725°C. So carbon diffuses from one interstitial side to another and forms alternate plate like structure of α and Fe_3C called pearlite. It all takes place by diffusion process.

Similarly eutectoid decomposition produces alternate plates of austenite and cementite and there microstructure ledeburite. Pearlite and Ledeburite are not phases, these are phase mixtures.

***Note:* Five phases of Iron:**

α– Ferrite, γ– Austenite, δ– Ferrite, Cementite, Martensite

*When there is a large difference in the melting point of two materials, peritectic reactions appears on such phase diagrams and there diagrams, are called **"Peritectic Phase Diagrams"**.*

***Peritectoid Reaction :** When two solid combine together to form a single solid (one component) is called peritectoid reaction*

$$S_1 + S_2 \xrightleftharpoons{\text{Cooling}} S_3$$

1.3.2 Classification of Steel

(a) Low Carbon Steel/Mild Steel :

Percentage of Carbon : 0 – 0.3%

(b) Medium Carbon Steel :

Percentage of Carbon : 0.3 – 0.7%

(c) High Carbon Steel :

Percentage of Carbon : > 0.7%

(d) Gray Cast Iron :

Cast iron of such composition in which carbon appears in free or flake form is called Gray Cast Iron. These materials is used in making machine beds, piston rings etc.

(e) White Cast Irons :

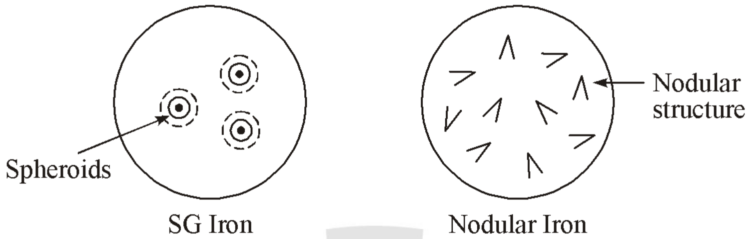
Cast iron of such composition in which entire carbon appears in the combined form is called white cast iron.

(f) Chilled Cast Iron :

Cast iron of such composition in which it will normally freezed as Gray but forced to appears as white are called chilled cast Iron (Sudden cooling). White and chilled cast irons are extremely brittle, and these materials are used to produce ***Ductile Cast Iron.***

(g) Ductile Cast Iron :

Chilled Cast Iron is heated to a temperature below 1150°C and then cooled slowly in the present of Magnesium or Cerium (Ce). Carbon diffuses towards the centre and produce spheroidal structure which are Ductile. Slightly higher cooling rates produces Nodular structure.



Note: *We cannot avoid sulphur in Iron, it is from nature.*

1.3.3 Effect of Sulphur and Mangnese in Iron

Whatever liquid and solid present in the nature impurity of sulphur cannot be avoided.

Sulphur in iron is a very dangerous impurity because after reacting with iron, it produces iron sulphide (FeS) which is having very low melting point.

So upon heating FeS melts out producing cracks at grain boundaries which leads to Brittle fracture. These phenomenon is called Hot shortness. To eliminate the ill effect of sulphur, Mangnese is added in the material. Mangnese capture sulphur, before sulphur captures iron and produces MnS (Magnese Sulphide).

MnS is not only having high melting point but also it is having low shear strength, which increases the machinability of material. Further addition of mangnese, increases the strength of materials and with 12% Mn materials becomes exceptionally strong called Hadfield steel, used in haeavy duty applications like Bulldozers etc.

1.3.4 Effect of Silicon on Steel

Steels are very difficult to cast because it undergoes excessive shrinkages during solidification. So steel is having a tendency to capture oxygen from surroundings. Addition of silicon and, absorbs these Oxygen and produces SiO_2 which settles down as sludge.

Note: *When deoxidization process of steel is complete it is called Killed Steel, but when the deoxydization is partial, it is called semi-killed steel.*

Effect of Silicon in Cast Iron

$$\text{C-equivalent} = \%C + \frac{1}{3}C\ \%Si + \%P = 4.3\ \%$$

$$3.3\ \%\ C + 3\%\ Si$$

1.3.5 Effect of Silicon and Phosphorous

Addition of silicon and phosphorus in iron, shifts the iron -carbon diagram towards left. So, graphite flakes in cast-iron appears at much lower percentage of carbon. Addition of silicon in liquid iron, discharges graphite in red hot condition, & since graphite is having lower density, it jumps over the surface of liquid iron and sparkles. These phenomenon is called KISH.

Elements	Gray C.I.	White C.I.
C	2.5 – 4	1.8 – 3.6
Si	1 – 3	0.5 – 1.9
Mn	0.4 – 1.0	0.25 – 0.8
S	0.05 – 0.25	0.06 – 0.2
P	0.05 – 1.0	0.06 – 0.18

1.3.6 Development of Micro-structure In Fe-C System

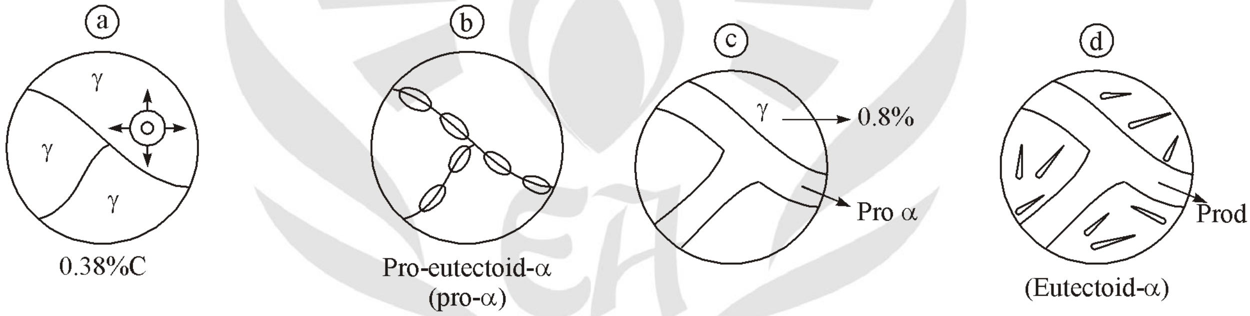
Upon cooling the sample of hypoeutectoid steel, with 0.35% C along line "a–d", following microstructural changes can be observed. At point "a", it is all austenite within the grain with 0.35% C. When the temperature decreases slightly below to point "b", Ferrite phase starts appearing in microstructure.

These ferrite which appears before eutectoid temperature is called hypereutectoid ferrite. Upon decreasing the temperature slowly from point "b–c" following conclusions can be made using lever rule.

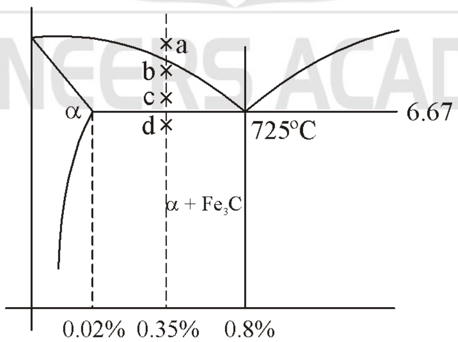
Mass fraction of pro-eutectoid ferrite increases.

Percentage of carbon in austenite within the grain increases and approaches towards the eutectoid composition.

Upon decreasing the temperature slightly below the eutectoid temperature, austenite within the grain converts into pearlite. Ferrite within the microstructure of pearlite is called Eutectoid Ferrite.



Development Of Micro-Structure



$$M_{\alpha} = \frac{6.67 - 0.8}{6.67 - 0.02} = 0.88$$

Example: Determine the mass fraction of pro-eutectoid ferrite, Eutectoid ferrite, total ferrite in steel sample having 0.35% C.

Solution: "b" Pro-eutectoid,

$$\Rightarrow \quad m_{Pro\text{-}\alpha} = 0.576$$

$$H_{Fe_3C} = 0.423$$

$$m_{Pro\text{-}\alpha} = \frac{0.8 - 0.35}{0.8 - 0.02} = 0.576$$

"d" $$m_{Total\text{-}\alpha} = \frac{6.67 - 0.35}{6.67 - 0.02} = 0.95$$

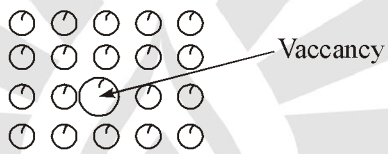
"c" $$m_{eutectoid\text{-}\alpha} = 0.95 - 0.57 = 0.38$$

1.4 Types of Defects

1.4.1 Point Defect

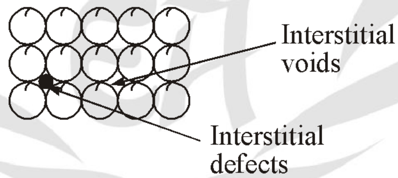
(a) ***Vaccancy Defects***

When one atom from the crystal structure is escaped this type of defect is called as vaccancy defect.



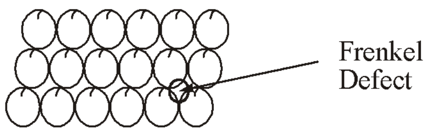
(b) ***Interstitial Defects***

When one extra atom occupied the interstitial voides in crystal structure this type of defect is called as interstitial defect.



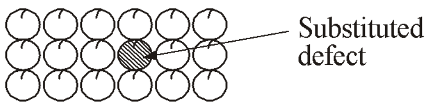
(c) ***Frenkel Defects***

When one cation or anion is found extra in crystal structure this type of defect is called as frenkel defect.



(d) ***Substituted Defects***

When one extra atom replaced the previous crystal structures atom this type of defect is called as substituted defect.



Example: Mo, V, Cr, α–iron

(c) Face Centred Cubic (FCC) :

Atoms are arranged at the corners and at the centre of each faces of the unit cell.

$$n = \frac{1}{8}\times 8+\frac{1}{2}\times 6$$

$$n = 1 + 3 = 4$$

Atomic packing factor = 0.74

Example: Ag, Cu, Pb, P, Au, Al, Co

(d) Hexagonal Closed Packing (HCP)

Atoms are arranged at the centre of only one set of faces in addition to the atoms at the corner of the unit cell.

$$n = \frac{1}{6}\times 12+\frac{1}{2}\times 2+3=6$$

Atomic packing factor = 0.74

Co-ordination number = 12

Example: Ti, Zn, Be, Mg

❑❑❑

PRACTICE SHEET

OBJECTIVE QUESTIONS

1. Fibre reinforce metallic composite can not used for
(a) Resisting corrosive wear
(b) Increased toughness
(c) Metal cutting
(d) All of the above

2. Cast iron contains carbon % age as
(a) 0.2 to 0.4 (b) 2 to 4
(c) 1 to 1.5 (d) None of these

3. Depth of steel hardness is increased by adding
(a) Cobalt (b) Tungsten
(c) Chromium (d) Manganese

4. Tensile strength of mild steels normally is in the range
(a) 150-180 MPa (b) 320-600 MPa
(c) 550-750 MPa (d) 650-1000 MPa

5. Carbon percentage in eutectoid steels is
(a) 0.5 (b) 0.8
(c) 0.65 (d) 1.4

6. Cast iron are classified as per
(a) Sulphur percentage (b) Iron percentage
(c) Tensile strength (d) Ident hardness

7. Monel metal consists of
(a) Nickel, lead and mangesium
(b) Zinc, Tin and lead
(c) Nickel, copper
(d) Carburizing

8. Find the process which is different from others.
(a) Nitirding
(b) Galvanizing
(c) Cyaniding
(d) Carburizing

9. German silver is an alloy of
(a) Silver and aluminium
(b) Nickel and silver
(c) Silver with tin
(d) Nickel, copper and zinc

10. Steel containing 0.8% carbon and 100% pearlite is known as
(a) Ferrite (b) Eutectoid
(c) Austenite (d) Cementite

11. Solder is an alloy of
(a) Tin and zinc
(b) Tin and lead
(c) Lead and zinc
(d) Tin and copper

12. Steels with coarse grains are
(a) Lighter (b) Denser
(c) Very tough (d) Less tough

13. Nodular iron has
(a) High melting point
(b) High tensile strength
(c) Low machinability
(d) All of these

14. Under microscope pearlite appears as
(a) White feathery (b) Finger print
(c) Light spots (d) Dark spots

15. High speed steel are basically
(a) Alloy steel
(b) Plain carbon steel
(c) Low carbon steel
(d) Medium carbon steel

16. Steel containing ferrite and pearlite is
(a) Soft (b) Brittle
(c) Ductile (d) Data insufficient

17. The major constituents of stellite are
(a) Cobalt, chromium and tungsten
(b) Zinc, lead and copper
(c) Nickel, copper and tin
(d) None of the above

18. The main component of any hardened steel is
(a) Carbon (b) Pearlite
(c) Martensite (d) Sorbite

19. Slow plastic deformation of metals under a constant value of stress is known as
(a) Plastic deformation
(b) Elastic deformation
(c) Creep
(d) Fatigue

20. Which of the following has hexagonal closed packed structure?
(a) Silicon (b) Germanium
(c) Aluminium (d) Zinc

21. The major defect responsible for the phenomenon of slip is called
(a) Fracture (b) Twinning
(c) Strain hardening (d) Dislocation

22. Recrystallization temperature is one at which
(a) Change of allotropic form takes place
(b) Crystals first start forming from molten metal when it is cooled
(c) New spherical crystals are formed from the old one when a strained metal is heated.
(d) None of the above

23. Engineering materials which are made up of more than one phase, with different mechanical properties, are known as
(a) Discontinuous (b) Plastic
(c) Heterogeneous (d) None of these

24. Which of the following constituents of steel is softest?
(a) Ferrite (b) Ledeburite
(c) Pearlite (d) Austenite

25. Which of the following type of materials are usually the most ductile?
(a) Body-centred cubic lattice
(b) Face-centred cubic lattice
(c) Hexagonal close-packed lattice
(d) Simple cubic lattice

26. Ductile fracture witnesses
(a) Major plastic deformation before crack propagation
(b) Faster crack propagation
(c) Nill deformation
(d) Noise accompanying the process

27. Pure iron is basically
(a) Austenite (b) Cementite
(c) Ferrite (d) Ferrite and cementite

28. The brittle fracture tendency increases by
(a) Increased temperature and increase strain rate
(b) Decreased temperature and increased strain rate
(c) Prior plastic deformation
(d) Decrease in triaxial stress

29. Ferromagnetic alpha iron exists in temperature range of
(a) Above 1539°C (b) 1300-1539°C
(c) 870-910°C (d) Below 723°C

30. Pearlite phase is consists of alternate layers of
(a) Ferrite and cementite
(b) Ferrite and ledeburite
(c) Cementite and bainite
(d) Bainite and troosite

31. Material property to absorb energy when deformed elastically and to return it when it is unloaded is known as
(a) Indent hardness
(b) Resilience
(c) Creep phenomenon
(d) Toughness

32. Paramagnetic alpha iron changes to gamma iron at
(a) Above 1539°C (b) 1040°C
(c) 910°C (d) 770°C

33. Addition of manganese to low carbon steels results in
(a) Making them tough
(b) Making them hard and tough
(c) Improve machinability
(d) None of the above

34. Capacity of a material to absorb energy in the plastic range is called
(a) Proof load (b) Resilience
(c) Creep (d) Toughness

35. Annealing of white cast iron produces
(a) Grey cast iron (b) Nodular cast iron
(c) Spheroidal cast iron (d) Malleable cast iron

36. Nickel in steel improves
(a) Cutting ability and decreases hardenability
(b) Ductility, tensile strength and toughness
(c) Improves wear resistance and toughness
(d) None of the above

37. Duralumin alloy contains aluminium and copper in the ratio of
(a) 94 % AL, 4% Cu
(b) 95 % AL, 5% Cu
(c) 87 % Al, 13% Cu
(d) 82 % Al, 10% Cu, 2% Ni

38. Delta iron are temperature range
(a) Upto 800°C
(b) Between 800°C and 1200°C
(c) 800°C to critical temperature
(d) Between 1400°C and 1530°C

39. Corrundum contains which of the following as majority ingredient?
(a) Fe_2O_3 (b) MgO
(c) Al_2O_3 (d) SiO_2

40. Hardenability of steel is the
(a) Depth of the hardened zone due to quenching
(b) Ability to withstand heat shock
(c) Resistance to wear and abrasion
(d) None of the above

41. Gamma iron exists in the temperature range
(a) 900°C and 1400°C
(b) 600°C and 850°C
(c) 1400°C and 1600°C
(d) 1600°C and 1800°C

42. Line imperfection is known as
(a) Edge dislocation (b) Schottky defect
(c) Misrum (d) Screw dislocation

43. Which of the following controls the properties of steel?
(a) Nickel (b) Carbon
(c) Vanadium (d) Chromium

44. Austempering process results in the formation of
(a) Troostite (b) Bainite
(c) Cementite (d) Martensitic

45. Which amongst following has zero temperature coefficient?
(a) Cobalt steel (b) Cast iron
(c) Invar steel (d) Hadfield steel

46. Which of the following is correct composition of babbitt metal?
(a) 84% Sn, 2% Cu, 6% Sb, 5% Al, 3% Mg.
(b) 87.75% Sn, 4% Cu, 8% Sb, 0.25% Bi.
(c) 80% Sn, 6% Cu, 5% Sb, 6% Al,
(d) 82% Sn, 4% Cu, 10% Sb, 4% Al,

47. Slowly cooled steel inside furnace develops which structure?
(a) Cementitie (b) Pearlite
(c) Martensite (d) Troosite

48. Which of the following is alloyed with high carbon tool steels to increase the resistance to shock?
(a) Nickel (b) Vanadium
(c) Carbon (d) Tungsten

49. Quenching of steel in water, forms
(a) Cementite (b) Pearlite
(c) Martensite (d) Troosite

50. Which of the following is most ductile material?
(a) Nickel (b) Mild steel
(c) Brass (d) Zinc

51. Quenching of steel in oil, form
(a) Cementite (b) Pearlite
(c) Martensite (d) Troosite

52. On rockwell 'C' scale, one rockwell number indicates penetration depth of
(a) 0.0080 of an inch
(b) 0.00080 of an inch
(c) 0.080 of an inch
(d) 0.000080 of an inch

53. Recrystallization temperature can be decreased by
(a) Working at high temperature
(b) Grain refinement
(c) Adding metals and non-metal
(d) None of the above

54. Which of the following counteracts the effect of sulphur?
(a) Manganese (b) Silicon
(c) Molybdenum (d) Boron

55. Atomic packing fraction is maximum for
(a) SSC (b) BCC
(c) MCP (d) FCC

56. Process in which steel is upto 40°C, below the lower critical temperature, held at that temperature for a time and then allowed to cool slowly in the furnace is called
(a) Annealing (b) Tempering
(c) Austempering (d) Case hardening

57. A bearing alloy must posses which of the following properties?
(a) High coefficient of friction
(b) Low compressive strength
(c) High resistance to corrosion
(d) All of these

58. Corrosion resistance of steels is increased by the addition of alloying elements like
(a) Cobalt and manganses
(b) Phosphorous
(c) Sulphur
(d) Nickel and chromium

59. Ball bearings are generally made of
(a) Cast iron
(b) Stainless steel
(c) Carbon chrome steel
(d) Plane carbon steel

60. Austenite is a solid solution of carbon in which of the following?
(a) Beta (b) Alpha
(c) Gamma (d) Delta

61. Which of the following has lowest melting point?
(a) High carbon steel
(b) Alloy steel
(c) Cast iron
(d) Pig iron

62. Presence of silicon in cast iron
(a) Makes the casting unsound
(b) Makes iron machinable
(c) promotes graphite
(d) Precipitates carbon

63. Which of the following is the property of ceramics?
(a) Malleability and plasticity
(b) Elasticity and ductility
(c) Brittleness and hardness
(d) High temper brittleness

64. Recrystallization temperature can be decreased by
(a) Grain refinement
(b) Working at low temperature
(c) Metal purification
(d) All of these

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ANSWER & EXPLANATIONS

1. *Ans. (c)*
2. *Ans. (b)*
3. *Ans. (d)*
4. *Ans. (b)*
5. *Ans. (b)*
6. *Ans. (c)*
7. *Ans. (c)*
8. *Ans. (b)*
9. *Ans. (d)*
10. *Ans. (b)*
11. *Ans. (b)*
12. *Ans. (d)*
13. *Ans. (b)*
14. *Ans. (b)*
15. *Ans. (a)*
16. *Ans. (a)*
17. *Ans. (a)*
18. *Ans. (c)*
19. *Ans. (c)*
20. *Ans. (d)*
21. *Ans. (d)*
22. *Ans. (c)*
23. *Ans. (c)*
24. *Ans. (a)*
25. *Ans. (b)*
26. *Ans. (a)*
27. *Ans. (c)*
28. *Ans. (b)*
29. *Ans. (d)*
30. *Ans. (a)*
31. *Ans. (b)*
32. *Ans. (c)*
33. *Ans. (b)*
34. *Ans. (d)*
35. *Ans. (d)*
36. *Ans. (b)*
37. *Ans. (a)*
38. *Ans. (d)*
39. *Ans. (c)*
40. *Ans. (a)*
41. *Ans. (a)*
42. *Ans. (a)*
43. *Ans. (b)*
44. *Ans. (b)*
45. *Ans. (c)*
46. *Ans. (b)*
47. *Ans. (b)*
48. *Ans. (b)*
49. *Ans. (c)*
50. *Ans. (b)*
51. *Ans. (d)*
52. *Ans. (b)*
53. *Ans. (b)*
54. *Ans. (a)*
55. *Ans. (d)*
56. *Ans. (b)*
57. *Ans. (c)*
58. *Ans. (a)*
59. *Ans. (c)*
60. *Ans. (c)*
61. *Ans. (c)*
62. *Ans. (b)*
63. *Ans. (c)*
64. *Ans. (d)*

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