Material Science

Two Material will combine togther and form alloy Only when the Conditions of Hume-Rothary rule satified.

Before Condition of Hume-Rothary apply crystal structure of Both material should be same.

(i) The differance in the atomic radius sould be less than 50%.

(ii) Valency of both the material should be same

(iii) Electronegativity and electron affinity of both the material should be comparable.

Phase diagram:- Phase diagram is a plot on temp Composition Space showing the stability of varies phase

In other words phase diagram tells us what will be the melting point of alloy.

Phase:- Physically distinct chemically homogeous and mechanically seprabally state of any matter is called ~~state~~. phase.

Component: No. of chamical formulas in the mixture of p

DOF:. No. of indepandent Variable require to define the state of any matter is called DOF.

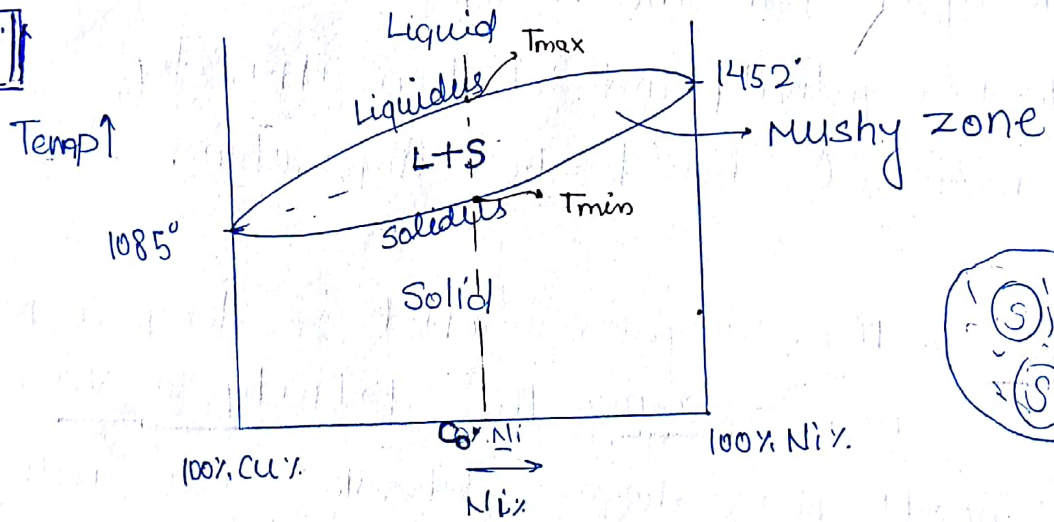
Mixture of diff phase will be in equ^m only when it follows Gibbs phase rule

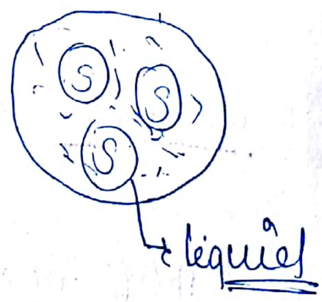
$$P+F = C+2$$

C = 1 unary phase diagram
C = 2 Binary phase diagram
C = 3 Ternary phase diagram

★ Binary phase diagram Type - 1 :- Materials which are completely soulible both in the liquid and solid state.

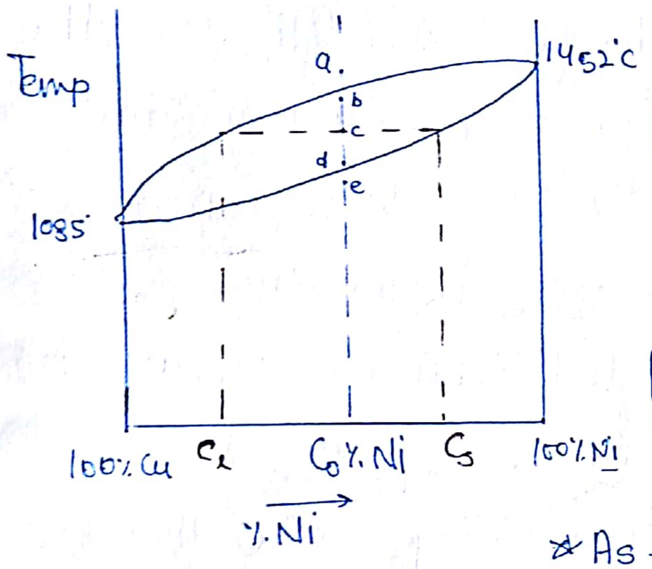
Cu-Ni

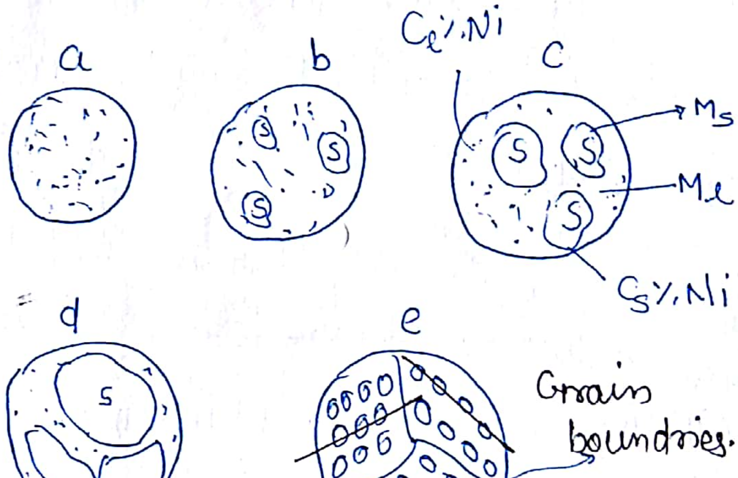




Cu & Ni both Combines togther and produces a single phase in solid state it is called solid soulibity. All the lines appearing on the phase diagram are the properties of alloy and can not be changed. There appear a region on such phase diagram where there is a mixture of liquid and solid called mushy zone.

larger is the extent of mushy zone more will be the variation in properties of that alloy. Any line on the phase diagram that seprate the mushy zone with liquid phase is called liquidus. Any line on the phase diagram that seprate mushy zone with solid phase is called Solidus. as it can be seen in the diagram that if mushy zone is appear in the alloy melting point will not be fixed there will a range of temp at which liquidification and solidification takes place.





* As temp. ↓ % Ni will also ↓

$$m_s C_s + m_l C_l = C_o$$

$$m_s + m_l = 1 \quad \text{(mass fraction)}$$

$$\boxed{m_s = \frac{C_o - C_l}{C_s - C_l}} \quad \text{lever rule}$$

C_o % → Ni

$(1-C_o)$ % → Cu

$$\boxed{m_l = \frac{C_s - C_o}{C_s - C_l}}$$

* lever rule can only be apply in a two phase region.

⇒ A sample of Cu - Ni with C_0 % Ni is Cooled along line a-e slowly. Point 'a' is above the liquids line so entire microstructure in the liquid phase The movement temp. of sample slowly decreases to point 'b' solid start nucleating in microstructure at thousands of places. up on the decreasing the temp from point 'b' to 'd' following conclusion can be drawn by using lever rule

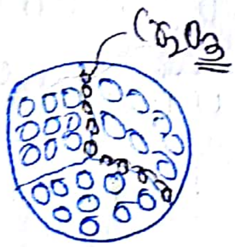
(i) As the temp. decreases mass fraction of solid phase keeps on increasing

(ii) The moment solid nucleated % of Ni in the solid is quite high upon decreasing the temp % of Ni in solid keeps on decreasing at approach towards the overall Composition C_0.

(iii) At high temp. phinomina called diffusion appear in the solid which tryies to homogenise the composit. It is said the every 20°c increase in temp. diffusion multiply by 2 (2x diffusion) so Ni will diffusion from to Center to outward direnction and make composition uniform throught. so within the solid phase composition of Cu & Ni will Uniform.

Eeach and every solidification form will have a perticular arrangment of atom. The moment temp. of the sample slightly decreases below the Solidus line different solidification fronts will fuse together and entire microstructure will convert into solid phase. The regions where different Solidification front are meeting there will be mismatch in the orientation of atom. These region of orientation mismatch are called grain boundaries

→

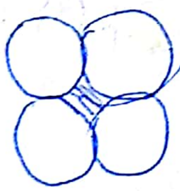


Fe 18-8 SS

18% Cr when it come in Contact with

8% Ni $O_2 \rightarrow Cr_2O_3$

↳ works phase stablizer



Interstitial voids

iron { Ni - Austonite phase stablizer

{ Cr - Ferrite phase

Super Alloy - material which only single grain boundary.

Whiskers:-

At the grain boundary since bond length is large so easily bond can break so atomspheric oxygen first attach the grain boundary and Corros it. thats why it is said that grain boundaries at are high energy level.

To increase Corrosion resistance of any material ~~Cromium~~ is added in it. Cr after reacting with oxygen produces ~~Cro~~ Cr_2O_3 (Chromium oxide) and it get accumulate grain boundary, protecting the gainboundary from the attach of other gases.

→ Ni is a phase stablizer. In Case of iron Ni is Austenite phase stablizer. and Cr is Ferrite phase stablizer.

→ To protect any material from gain boundary Corroson either forgion phase accumalate at grain boundary or the grain boundaries should complatly remove from material.

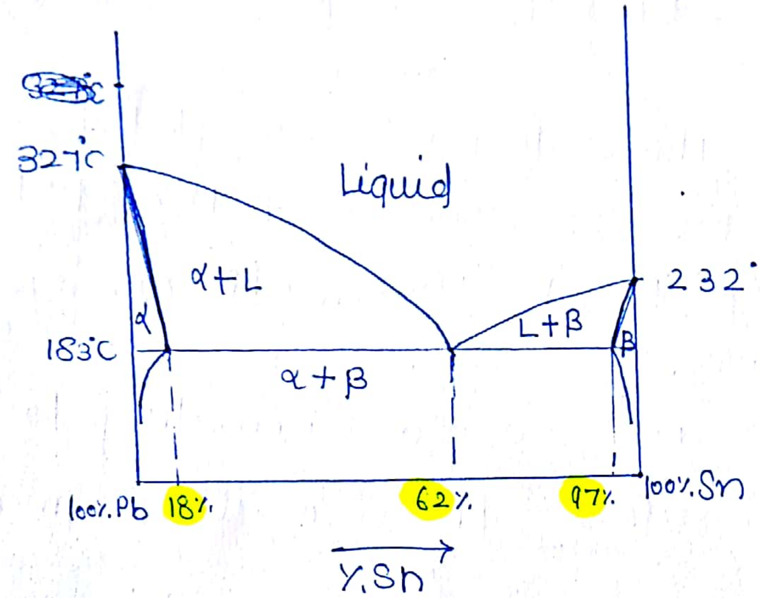
- The material where ther is no grain boundries are Called super alloy. ~~Super~~

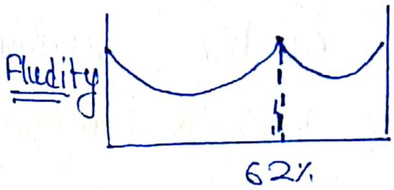
- Super alloys in thin section are Called whiskers

Binary phase diagram of Type-2 :-

Materials that are Complately Soluble in the liquid state but partially Soluble in the Solid state

Pb-Sn





⇒ α phase is solid solution of Sn in Pb and max. 18% tin (Sn) can be desolve in led (Pb) at 183°C. This solid solibility decreases by decreasing the temp.

⇒ β phase is solid solution of Pb in Sn and max, 3% led (Pb) can be desolve in tina at 183°C. This Solid Solibility decrease by decreasing the temp.

⇒ 183°, 62%Sn
L ⇌ α+β eutectic point (No mushy zone)

for Pb-Sn 183°C eutectic temp.
62% Sn eutectic Composition

* Eutectic reation
nice melting

it called invarient F = 0

$C+2 = F+P$ ⇒ at Patm

$C+2-1 = (F-1) + P$ ⇒ $C+1 = F' + P$

⇒ These reaction done on Patm and Patm have 1 DOF modifidy Gibbs rule for binary Eutectic system

$C+1 = F^{*} + P$

at eutectic point $F^{*} = 0$

$2+1 = P \Rightarrow P = 3$ (phase)

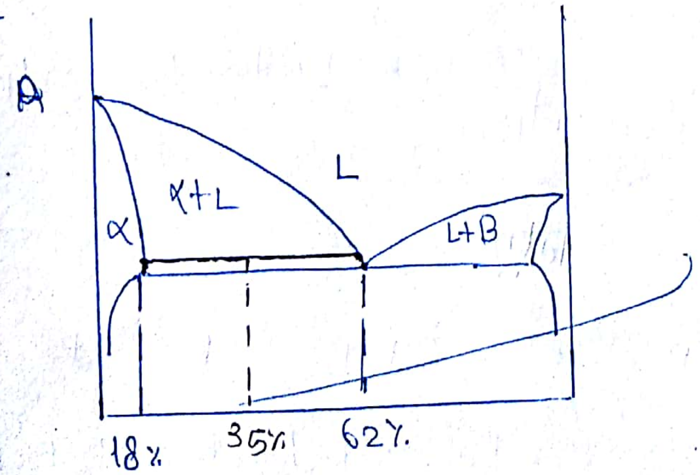
⇒ All the binary phase diagrams are ploted at atomspheric pressure but pressure is one of the DOF. So we have risticting 1 DOF this will change the Gibb's equation.

⇒ Invarient means DOF = 0 so according to modifidy Gibb's phase rule 3 phase will be in equilibrium at eutectic point.

⇒ The temp. at which Eutectic reaction appear is called eutectic temp. and composition at which eutection reation appear called eutectic composition.

Problem:- Calculate the mass fraction of phases present in a Pb-Sn alloy with 35 % Tin(Sn) and at 184°C

Soln

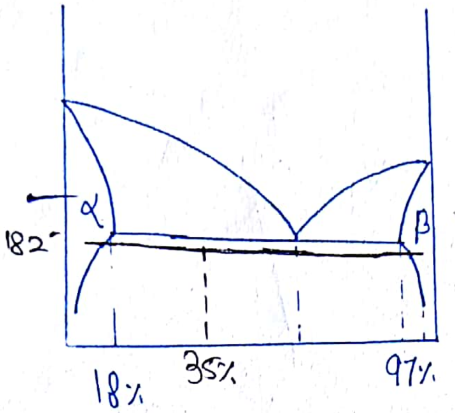


$m_{\alpha} = \frac{62-35}{62-18} = 0.61$

$m_{L} = \frac{35-18}{62-18} = 0.39$

Problem:- Calculate the mass fraction of the phase present in a Pb-Sn alloy 35% Tin(Sn) and at 182°c

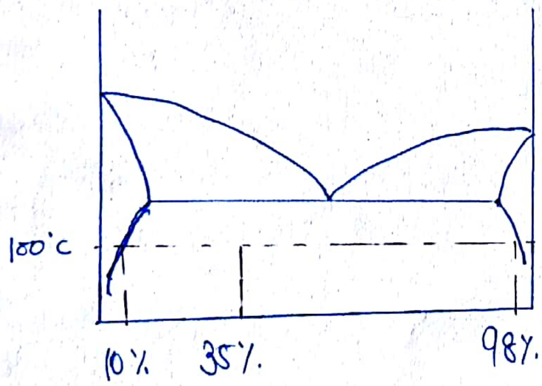
Sol^n



$$m_\alpha = \frac{97-35}{97-18} = 0.72$$

$$m_\beta = \frac{35-18}{97-18} = 0.22$$

Problem:- Calculate the mass and volume fraction of the phase present in Pb-Sn alloy with 35% Sn at 100°c. at this temp 10% Sn can desolve Pb completaly and 2% Pb desolve in Sn completaly density of Pb = 10.96 gm/cc & Sn = 13.28 g/cm



$$m_\alpha = \frac{98-35}{98-10} = 0.715$$

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

α → 10% Sn + 90% Pb

β → 2% Pb + 98% Sn

$\rho_{Pb} = 10.96$ g/cc

$\rho_{Sn} = 13.28$ g/cc

i.f A → ρ_A → 20%

B → ρ_B → 80%

$$\frac{1}{\rho} = \sum_{i=1}^{n} \frac{x_i}{\rho_A}$$

$$\boxed{\frac{1}{\rho} = \frac{0.2}{\rho_A} + \frac{0.8}{\rho_B}}$$

So

$$\frac{1}{\rho_\alpha} = \frac{0.1}{\rho_{Sn}} + \frac{0.9}{\rho_{Pb}} \quad -(1)$$

$$\frac{1}{\rho_\beta} = \frac{0.02}{\rho_{Pb}} + \frac{0.98}{\rho_{Sn}} \quad -(2)$$

$$\boxed{V_\alpha = \frac{m_\alpha/\rho_\alpha}{\frac{m_\alpha}{\rho_\alpha} + \frac{m_\beta}{\rho_\beta}}} \qquad V_\beta = 1 - V_\alpha$$

from eq (1)

$$\frac{1}{\rho_\alpha} = \frac{0.1}{13.28} + \frac{0.9}{10.96}$$

$$\rho_\alpha = 11.15$$

$$\frac{1}{\rho_\beta} = \frac{0.02}{10.96} + \frac{0.98}{13.28}$$

$$\rho_\beta = 13.22$$

$$V_\alpha = \frac{\frac{0.715}{11.15}}{\frac{0.715}{11.15} + \frac{0.285}{13.22}}$$

$$V_\alpha = 0.748 \qquad V_\beta = 0.252$$

Phase change

1. Crystal structure change &
2. Size of unit cell change.

These are dictated by

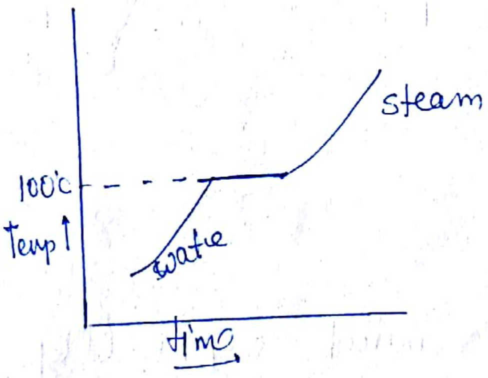
1. XRD machines
2. Electron microscope

SEM (Scanning) → Transmission EM (TEM)

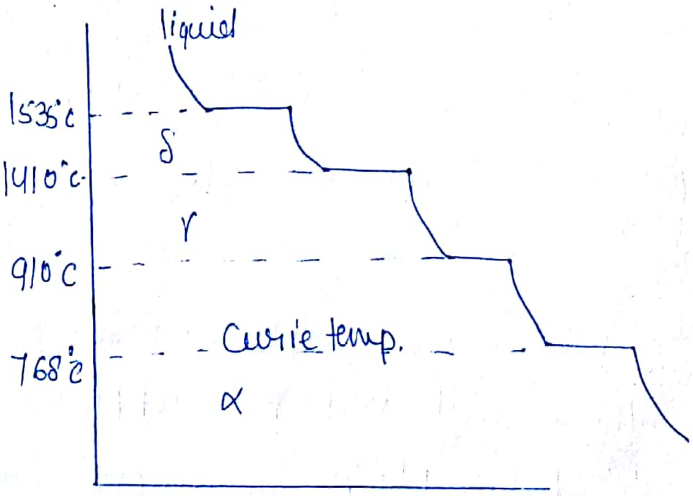
SEM:
- Surface topography
- type of fracture
  - Cleavages - Brittle
  - Dimple - cup & cone

Earlier when SEM & TEM not develope ~~state~~ Horizonal line dicteted the phase change (in temp Vs time graph)

For water



For Iron

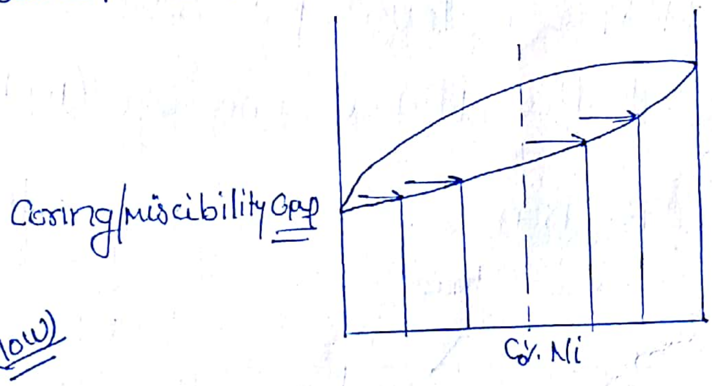


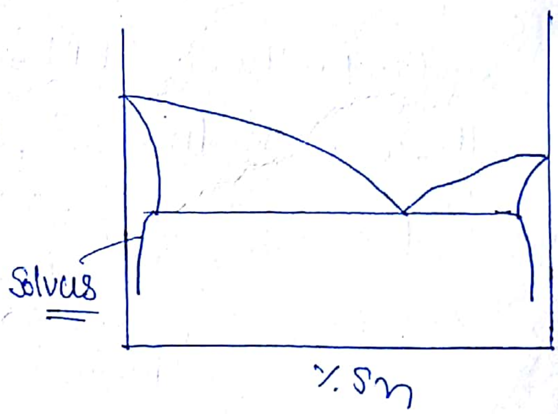
at 768°c no change in phase it change magnetic property

Whenever their is phase change in material either the crystal structure change or there is change in size of unit cell. Generally latent heat transaction indicate the phase change. But in case of iron at 768°C their is no change in the phase only magnetic propertie of material disappear this temp is called curie temp. The characteristic of iron due to ~~it~~ which it exist in diff phase at diff temp is called Alotropy.

05/08/16

⇒ ~~Eg~~ Any line on the phase daigram that seprates a single solid phase with a mixture of solid phase is called solvus.





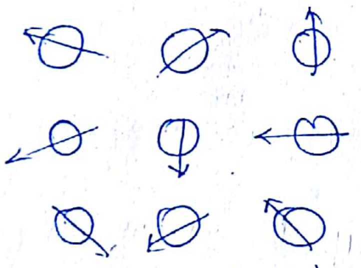
H ~~Hot work > 0.6 Tm~~

When the sample ~~oo~~ of Cu & Ni is cooled rapidally, there will not be sufficient time for the diffusion to take place so upon solidification of material there will be consantration gradient within the grain and at the grain boundary % Ni will be very low.

It can be seen in the Cu-Ni phase daigram that lower is the % of Ni, lower will be its melting point. So upon hot working the material grain boundary material will meltout producing crack this leads to brittle fracture and this phinomina is called coring/miscibility Gap

Materials

① Paramagnetic :-



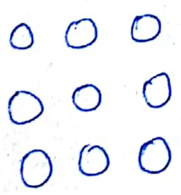
Brass ⇒ Cu-Zn

Bronze ⇒ Cu + (__) ↳other alloy

Paramagnetic are in random orientation

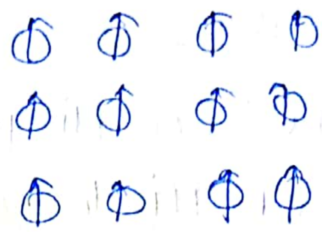
left hand side of the periodic table material are in paramagnetic in nature and there is no pairing of atoms and there magnetic dipole are randomly oriented such material exhibits colour like alloy of cuppor. (Co)

② Dimagnetic :- These material are present are on the RHS of periodic table and there is pairing of atom. There will no magnetic dipole.



③ Ferromagnetic :— Iron, Co, Ni are Ferromagnetic

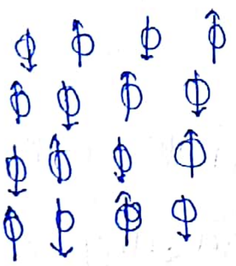
at room temp.



At room temp these material will have magnetic dipole only in one direction. These material are magnetic in nature.

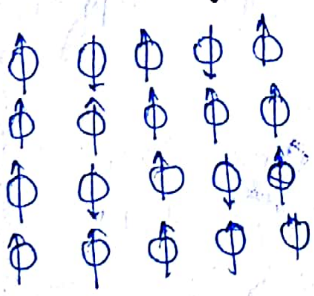
⇒ Iron is a such material which some time behave ~~Ferroma~~ paramagnetic and some time dimagnetic depanding upon the ~~temprature~~

④ Antiferro :- only chromium is Antoferro material.

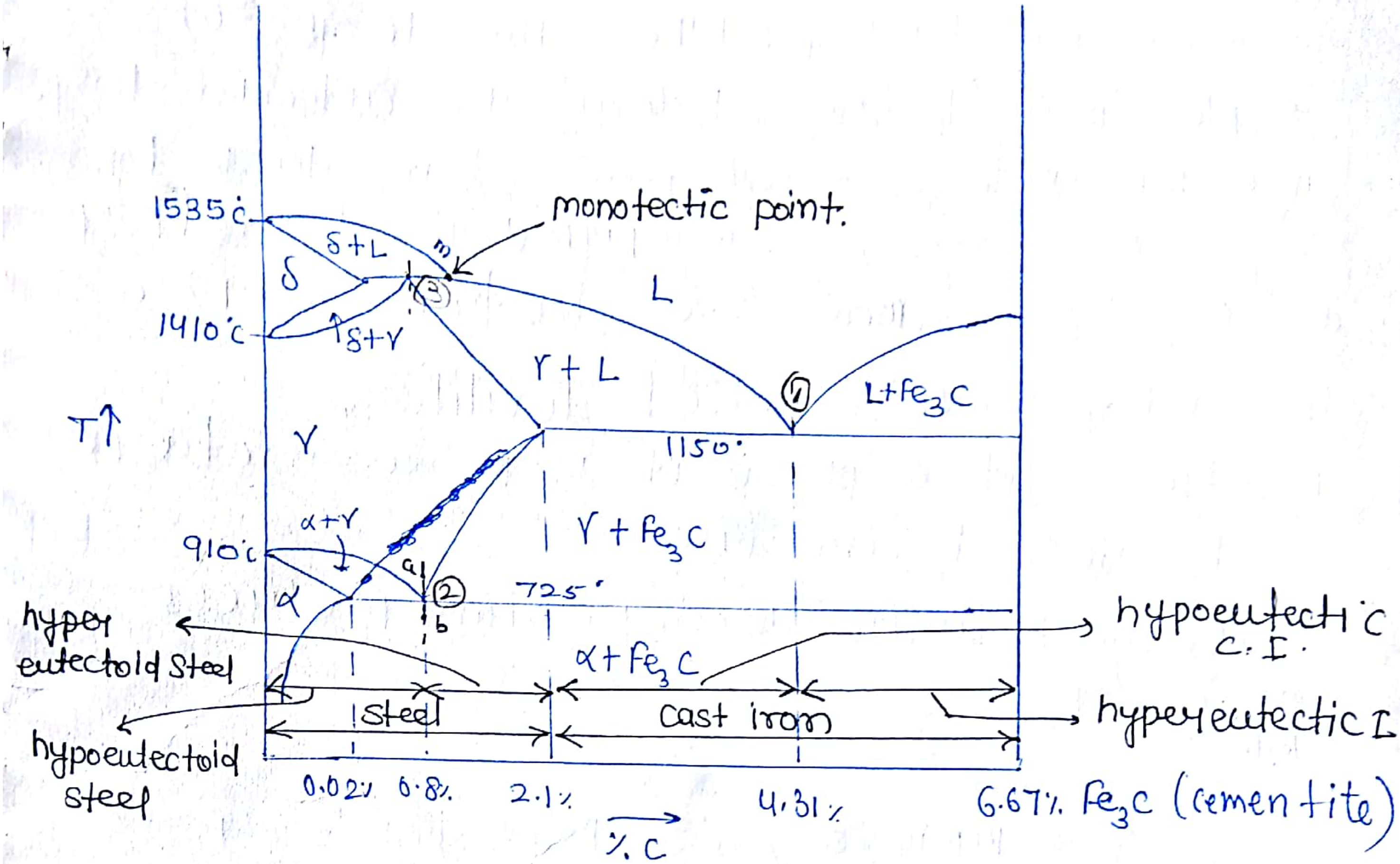


⇒ All the magnetic dipole moment are parallel but are in opposite direction eq. Cr

⑤ Ferrimagnetic :- Combination of Ferromagnetic & Antiferro magnetic. No material behave like this only compounds follow this characteristic, or this type of behaviour.



Fe-C phase diagram / Iron-cementite (Fe_3C) diagram.



α - Ferrite BCC

γ - Austenite FCC

δ - Ferrite BCC

Fe_3C - Orthorhombic

☆ max. ~~solid~~ soulibility of carbon in Fe is <u>6.67%</u>.

① $L \underset{4.31\%\,C}{\overset{1150°C}{\rightleftharpoons}} \gamma + Fe_3C$ → Ledburite

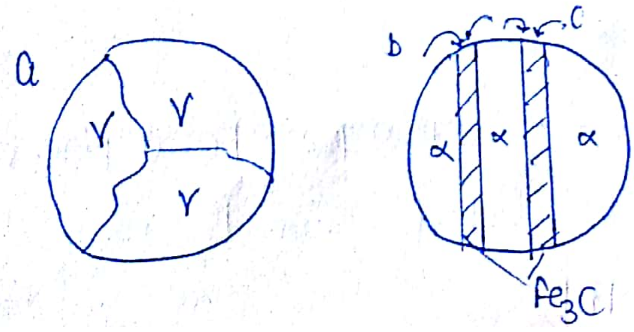
Eutectic Reaction

liquid → $solid_{\gamma}$ + $solid_{Fe_3C}$

② $\gamma \underset{0.8\%\,C}{\overset{725°C}{\rightleftharpoons}} \alpha + Fe_3C$ → Pearlite

Eutectoid Reaction

$solid_{\gamma}$ → $solid_{\alpha}$ + $solid_{Fe_3C}$



At 0.8%C at 726°c carbon is uniformaly distributed in the microstructure. When the temp. of sample slowly decreases below the eutecoid temp. since Austenite can not present in stable form. So carbon from one interstitial site to another and produce alternate like structure '$\alpha + Fe_3C$'

this microstructure called 'Pearlite'.

Pearlite is not a phase it is phase mixture of Ferrite and cementite.

Similarly Eutectic decompossion produces ~~Leede~~ ledeburite.

⇒ ③ $\delta + L \underset{0.18\%C}{\overset{1493°c}{\rightleftharpoons}}$ ✓ Peritectic Reaction

Solid + liquid ⟶ Solid

* When there is a large differance in the melting point of two material, the phase diagram of such alloy peritectic reaction appear..

⇒ I Fe-C daigram is such a ~~daigram~~ diagram where three invarient reaction appears simuntaneously.

* Point m is a monotectic point but it is not a invarient point. DOF = 2

Peritectoid Reaction :- it doen't appear on Fe-C phas dia

$S_1 + S_1 \underset{}{\overset{Cooling}{\rightleftharpoons}} S_3$ when two solid convert into one solid

carbon %		
0 – 2.1%	steel	hypoeutectoid (0–0.8); hypereutectoid (0.8–2.1)
2.1 – 6.67%	cast iron	hypo eutectic (2.1 → 4.3); hyper eutectic (4.3 – 6.67)

Steels

0 – 0.3% C, low carbon steel (Mild steel)

0.3 – 0.7% C. Medium carbon steel

> 0.7% C, High carbon steel

① Gray Cast Iron :— In pure iron carbon system when more then 6.67% C is added, a portion of C come out on the microstructure and appear in free or flake form. Such Cast irons are called Gray Cast iron. These material are used to manufacture machine bed. because Graphite pockets act like Vibration damper and hence absorbs vibration.

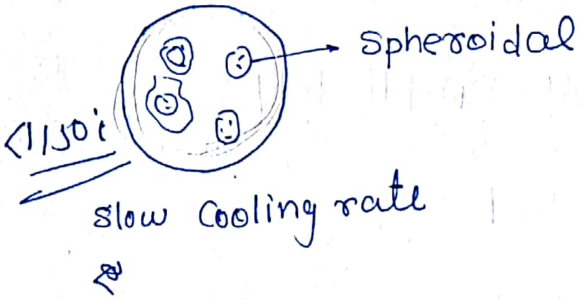
② White cast iron :- very hard and brittle.

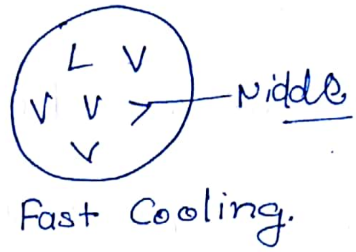
When a % of C is less than 6.67% entire amount of carbon will appear in Combined form and these material are called white cast iron.

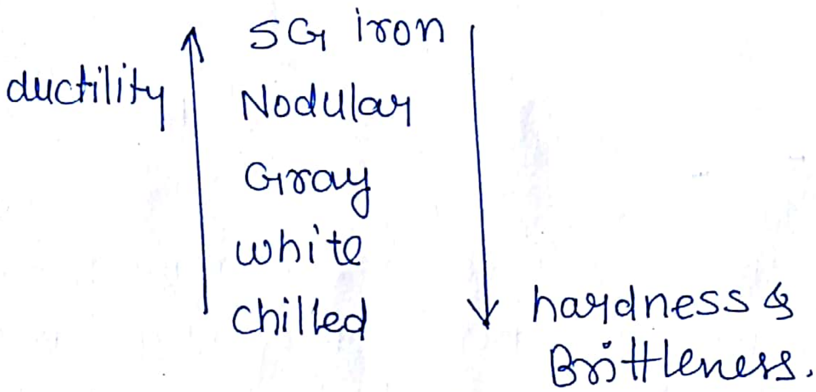
③ Chilled cast iron :- Cast iron of such composition in which normally it will friage as gray but forced to appear as void by rapid cooling is called Chilled C.I.

both white and chilled cast iron are brittle in nature so these material are not use directly in any engineering application. These material are used to make ductile cast iron.

④ Spheroidal Gray C.I (SG iron) ⑤ Nudular C.I.

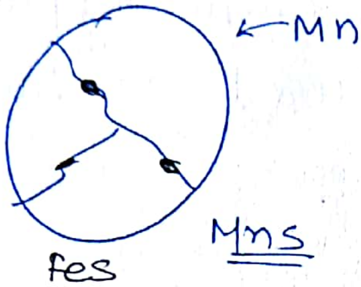






If the objective to produce ductile cast iron small amount of Mg, Ce (cerium) is added in the material. These material act like catalyst in the diffusion process of carbon. After producing chilled cast iron the material again heat to a temp <1150°c and than cooled extremely slowly in the furnace at thousand of places carbon will diffuse at the centre and produces spheroidal. This increase the overall ducticity of material if the Cooling rate are slightly Faster combined form of carbon appear in the niddle like form is Called Nodular Cast iron.

Effect of sulpher (s) and magnise(Mn)



12 % Mn (strong)

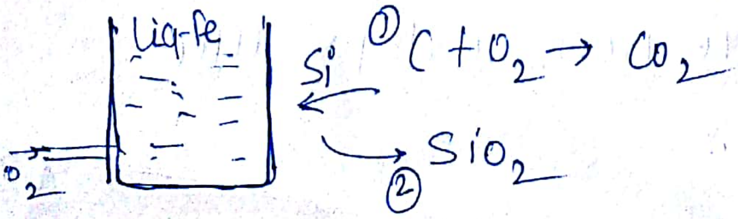
Whatever liquid & solid present in nature Impurity of sulpher cannot be avoided so Sulpher will present in iron also. Impurity of sulpher in iron is very dangrous because after reacting with iron it produces iron sulphide (fes) and it get accumulated at grain boundries.

Melting point of fes is very low so upon ~~what~~ warm forming of the material, fes will meltout producing & Cracks at grain bourdries thats lead to brittle fracture. this phinomina called hot shortness or sulpher-embrittlement.

To avoid the ill effect of sulpher small amount of manganese (Mn) is added in material. Mn capture sulpher before sulpher capture iron, and produce manganese sulphide (Mns).

Melting point of Mns is quite high so hot-Shortness phinomina will be gone.
Shear strength of Mns is low and this increases the machinability of material. Further addition of Mn increase strength of material and with <u>12%</u>, Mn Material become exceptionally become very strong <u>Hadfield steel used</u> in heavy duty applications like bulldozer.

To produce <u>steel</u> carbon has to be removed from material. so O_2 is injected in liquid Iron pond. O_2 after reacting with carbon present in liquid iron produces CO_2. So carbon is remove from material by converting into gas. since it is exothermic reaction liquid iron pond appears to boil and this phinomina is called steel ~~boiot~~ boil. When we stop the flow of O_2 there will be a tendency ind steel to capture O_2 a portion of oxygen (O_2). Silicon (si) is added in the liquid metal to remove this trapped oxygen (O_2) when O_2 is completly removed from material it is called skilled steel and when removal of O_2 is partial it is called semi skilled steel.



Carbon equivalent

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

eg:- ~~If~~ to produce 4.3 %

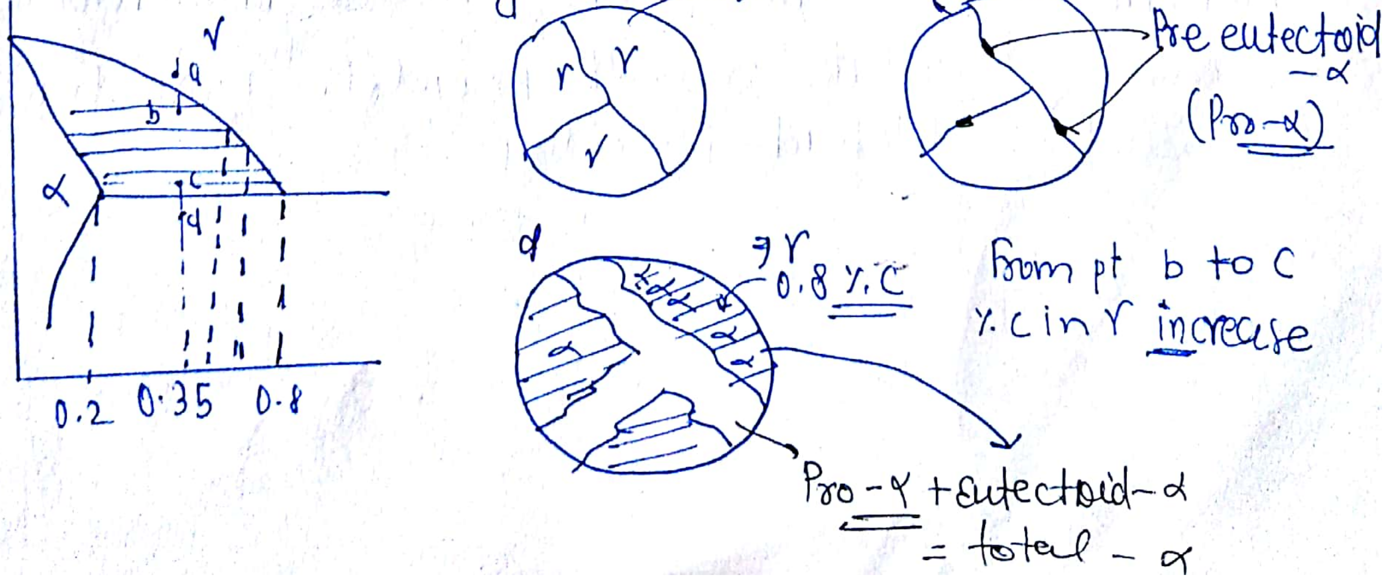
%C = 3.3 %
%Si = 3 %

So C-equivalent
$= 3.3 + \frac{1}{3}(3)$
$= 4.3\ \%C$

{ Gray cast iron
2.4 – 4 % }

By the addition of Si in liquid iron entire ~~iron~~ Fe-C diagram ~~it~~ shift towards left and Graphite formation appears at much lower % of C. So when Si is added in liquid iron Graphite will be discharge and since it is having lower density, due to bouncy force it come over the surface of liquid metal ~~at~~ and sparkles. this phinomina called kish.

Development of micro-structure in iron-carbon System:-



A sample of hypo eutectoid steel is cooled along line a-d and its changes in microstructure are observed. At point a entire microstructure is Austnite with carbon uniformally distributed in it. To moment temp slightly decreases to point b, Ferrite start appearing in the microstructure, This ferrite that appear before the eutectoid temp is called Pro-eutectoid ferrite and it get accumulate a grain boundries. Upon slowly decreasing the temp. from point b to c following conclusion can be drawn by using lever rule.

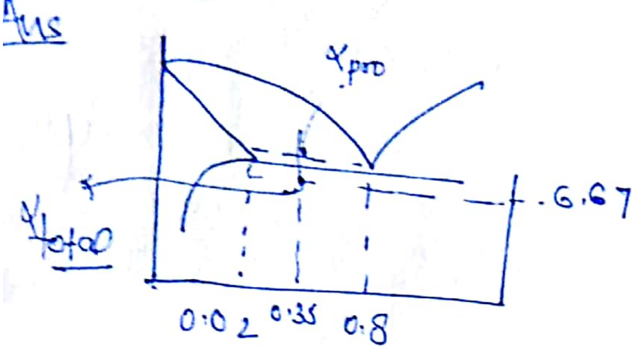
(i) upon decreasing the temp, mass fraction of pro-eutectoid ferrite (α) is increases -

(ii) % of carbon in austenite keeps on increasing and at point 'c' % c of carbon will be exactly equil to eutectoid composition.

iii) The moment temp. slightly decrease to point d austenite within the grain converse into ferrlite Amount of ferrite present ferralite microstructure is called eutectoid- ferrite (

Problem:- What is the % of proeutectoid ferrite, eutectoid ferrite and total ferrite in steel having 0.35 % carbon.

Ans



$$\alpha_{pro} = \frac{0.8 - 0.35}{0.8 - 0.2} = 0.577$$

$$\alpha_{total} = \frac{6.67 - 0.35}{6.67 - 0.02} = 0.95$$

So $Fe_3C = 1 - 0.95 = 0.5$

~~α eutectoid~~

eutectoid α → $0.95 - 0.57 = 0.38$