for sand casting : P+F = C+1

↓

only temp. vary

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CONSTITUTION OF ALLOYS

→ An alloy can be defined as a substance having metallic properties, composed of two or more no of elements out of which atleast one is a metal

→ A phase is defined as microscopically distinct, chemically homogeneous and mechanically separable part of a system.

→ No of phases in an alloy are found from Gibbs phase rule

$$P + F = C + 2$$

where,

P = No. of phases

F = Degree of freedom

C = No. of elements participating in alloy formation

2 = stands for any two variable out of 3 namely Temperature, Pressure, concentration.

BINARY ALLOYS (Made of two elements)

HOMOGENEOUS alloys (Single phase) → Hume Rothery's rule

- Solid solution
  - Substitutional
  - Interstitial
- Intermediate / metallic Compounds (e.g. Mg_2Pb, Mg_2Sn)
- Interstitial compounds
- Electron compounds (Gold, Ag, Fe, Ni + (Cd, Mg, Sn))

can not be expressed by a formula because solute concentration in solid soln does not remain constant.

solubility in FCC is more than BCC because void space is greater in FCC than BCC (void length)

Poly phase alloys (Mixtures)

Combination of solid solutions	Combination of compounds	Combination of solid sol^n + compound

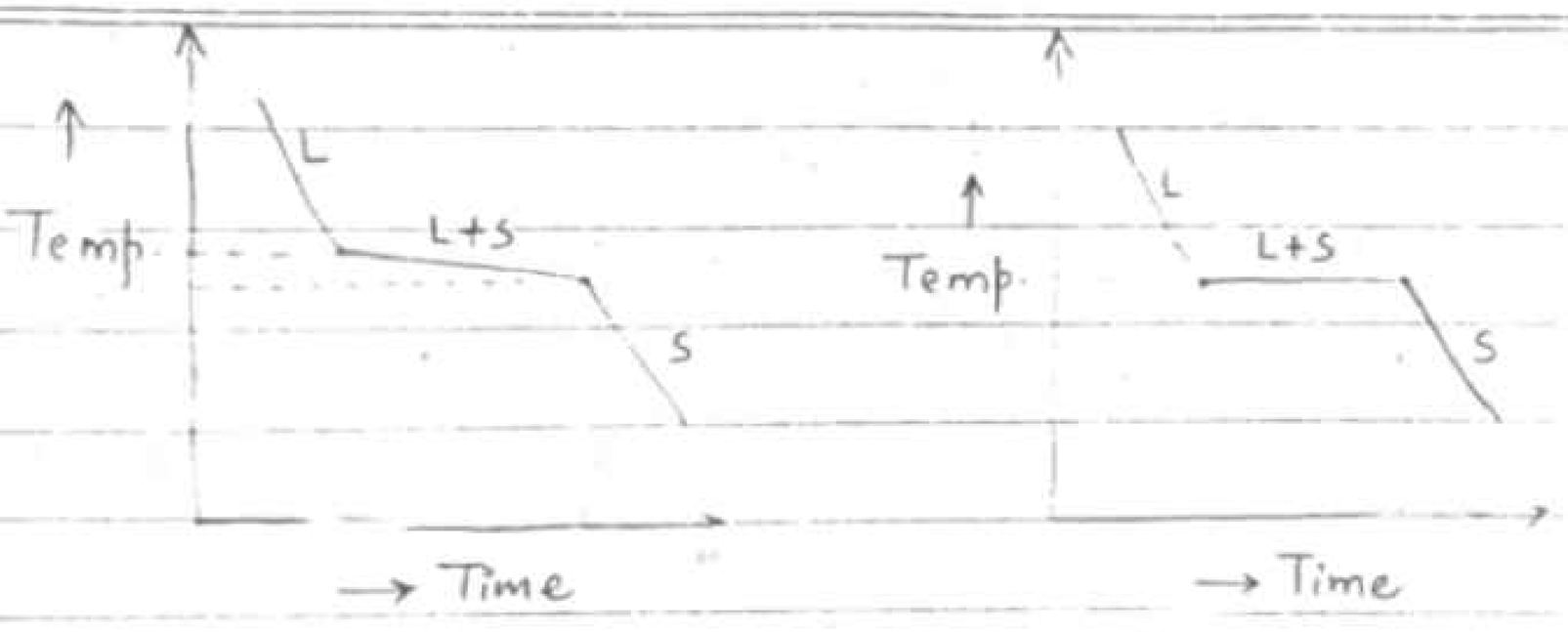
HUME ROTHERY RULE : (for solid sol^n)

1) Crystal structure factor :- crystal structure of both the elemen should be same.
2) Relative size factor :- The diff. in atomic radii should be less than 15 %
3) Chemical Affinity factor :- Smaller the chemical affinity b/w the two elements, greater will be the solubility.
4) Relative valancy factor :- Elements of lower valancy can dissolve a large amount of higher valancy elements of

- Intermetallic compounds are formed b/w chemically dissimilar metal.
- Interstitial compounds are formed b/w transition metal like tungsten, iron, titanium etc with oxygen, N_2, C, B, H_2 etc
- Electron compounds are formed b/w a group of alloys in whose case the ratio of valance e^- to no. of atoms participating in bond formation remain constant.

Strength → microstructure (grain structure)

Ductility / Brittleness → crystal structure



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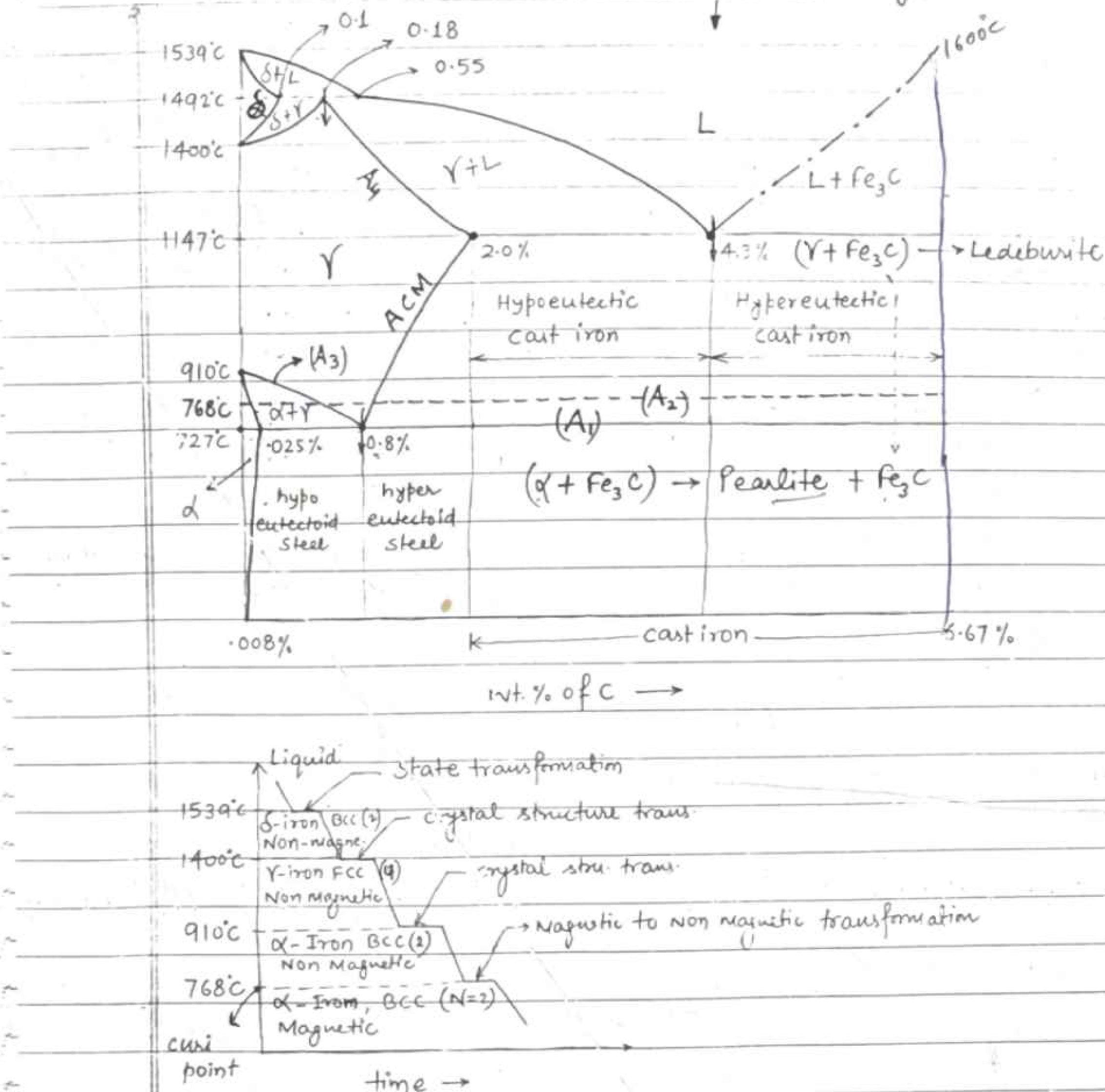
Iron - Iron Carbide Diagram



(COOLING CURVE OF PURE IRON)

As Temp ↑, magnetic dipoles of Iron get randomized, so they will cancel out their effect and become non magnetic.

classmate
Date
Page

δ → Ferrite

γ → Austenite

α → ~~cementite~~ ferrite

1.) δ- ferrite : It is an interstitial solid soln of carbon in δ iron which is of BCC structure with Nav = 2 and non magnetic in character

2) γ- Austenite : It is defined as an interstitial solid soln of C in γ iron which is of FCC structure with avg. no of atom 4 and non magnetic in char

3) α- ferrite : It is an interstitial solid soln of C in α iron which is of BCC structure with Nav = 2 and magnetic in character only up to 768°C

4.) Cementite (Fe_3C) It is an intermetallic compound of iron and carbon with a fixed carbon content of 6.67 in it.

INVARIANT REACTION :

1) Peritectic reaction (1492°C, 0.18 % C)

$$\delta + L \rightleftharpoons \gamma$$

$$(S_1) + L \rightleftharpoons (S_2)$$

2) Eutectic reaction (1147°C, 4.3 % C)

$$L \rightleftharpoons \underbrace{\gamma + Fe_3C}_{\text{Ledeburite}}$$

$$L \rightleftharpoons (S_2) + (S_3)$$

1) When liquid is cooled down, it formed two solids one is austenite (solid soln) and second cementite (a compound).

2) Ledebunite is defined as the eutectic mixture of ~~ferrite~~ austanite and cementite.
Ledebunite is defined as eutectic reaction product of liquid

3) Eutectoid reaction (727°C, 0.8% C):

$$\gamma \rightleftharpoons (\alpha + Fe_3C) \rightarrow \text{Pearlite}$$

Pearlite is defined as eutectoid mixture of ferrite and cementite. 'or' It is eutectoid decomposition product of austenite.

→ SOLUBILITIY OF Carbon in various phases :

1) Max^m C solubility in δ-ferrite phase is 0.01 %.
2) " " " " γ-austenite " " @ 2 %.
3) " " " " α-ferrite " " 0.025 %.
4) Room temp. solubility of C in α-ferrite is 0.008 %

→ Significance of some important line in diagrams :

A_1 → Pearlite → Austenite
A_2 → ferrite → Austenite
A_{CM} → Cementite → Austenite
A_4 →

→ A_1 line is called as lower critical temp. line. When

Eutectoid steels are heated to a temp. above A_1 line, pearlite transforms into austenite.

- A_2 line occurs at 768°C. It signifies the magnetic to non magenetic transformation on heating.

- A_3 line is known as upper critical temp. line for hypo eutectoid steel. It signifies the transfomation of ferite into austenite upon heating to a temp. aboven A_3 line.

- ACM line is known as upper critical temp. line for hyper eutectoid steel. This line signifies the transformation of cementite into austenite upon heating

- Mild steel gives a very mild steet response to heat treatment process. (100 % of C)

b/s cementite is in network form and simple but thermal cycle around A_1 of pearlite gives rise to spheroidal shape cementite (soften)

HEAT TREATMENT OF STEELS

1) Annealing
2) Normalising
3) Hardening
4) Surface hardening
   - Carburizing
   - Nitriding
   - Cyaniding

   } low 'c' steels

   - Induction hardening
   - Flame hardening

   } high 'c' steels

1) ANNEALING :

Steel sample is heated to completely austenitic range, held at the particular temp. for sufficiently long time for homogeneous austenitization to take place. It is then allowed to cool in the furnace itself. gradually.

This process results in development of uniformly coarse grain size on all surfaces and the resulting phase structure is pearlite (coarse).

Annealing result in relieving of internal stresses, recovering of ductility, increase of machinability, softening of material etc.

When it is applied to cold worked metal, the process is known as recrystallization annealing or stress relief annealing. The operating temp. in cold worked material case is less than A_1.

The oxidation of annealed surface can be prevented by circulating the inert gases in the furnace

BOX → CI → CI chips has high affinity towards air

(bright annealing) or by enclosing the steel sample in a box (box annealing)

2) NORMALISING :

Steel is heated to austenitic range and taken out of the furnace and allowed to cool in the open air. This process results in uniform grain structure and fine pearlitic phase structure in steel due to fast rate of cooling.

In normalising residual stress are not completely relieved (due to fast cooling), hence strength and hardness of normalised steel is always more than that of annealed steel.

Machinability of normalised steel is inferior to annealed steel.

3) HARDENING :

Steel is heated in the temp. range of 1100-1300°C and quenched in a quenching medium. This sudden cooling results in the transformation of austenite into martensite with the following characteristics -

- Martensitic transformation occurs at the speed of sound in the quenching medium.
- It occurs by a process of shear. (diffusionless process)
- Martensitic transformation does not depend upon time
- Martensitic transformation never goes to 100% completion at room temp. (ie retained austenite will be formed)

The following three methods can be applied for the elimination of retained austenite -

i) Sub zero cooling (This process transforms retained austenite into martensite)

ii) Plastic deformation of previously hardend component : It changes the austenite into martensite by shear distortion of lattice.

iii) High temp. tempring : transforms retained austenite into bainite and also relieves residual stresses caused by quenching.

∴ High temp. tempering is the only technique which ↑ the toughness of previously hardened components.

∴ A hardening process which employes interrupted quenching is known as Martempring. (2-3 stages). The objective of martempring is to prevent the occurance of quenched cracks and distortion of physical geometry.

∴ In austempering, the steel sample is heated to hardening temp. and quenched in a molten salt bath maintained at 550°C. Then it is allowed to cool gradually along with the salt bath. This process results in the development of tougher forms of steels than the commercial steel available.

∴ SURFACE HARDENING :

∴ CARBURISING : It denotes the process of ↑ carbon concentration on the surface, by heating steel in a carbaneous medium (pack carburising, liquid

Charcol
Na_2CO_3
Ethene

carburising, gas carburising)

→ Diffusion of C atoms into the steel surface makes the surface rich in carbon.

→ Carburising is always followed by hardening and quenching, in order to convert surface austenite into martensite. This process developed a hardness of 800 VPN but it takes a very long time.

b) NITRIDING : Steel is heated in the presence of ammonia gas at a temp of 55[illegible]°C. The ammonia gas dissociates into nitrogen and hydrogen atoms. These nitrogen atoms diffused into surface of steel and results in iron nitride formation.

→ Nitriding process can be completed quickly and hardness ↑ to 1000 - 1100 VPN. The nitrided surface will acquire very high brittleness and hence the life is less.

c) CYNAIDING: Steel is heated to a temp. of 800°C in molten cyanide salt bath. This process must be followed by quenching in water or oil to taken advantage of martensitic transformation.

Cynaided cases will have higher hardness than carburised cases but higher life than nitrided cases.

d) INDUCTION HARDENING Applicable to relatively small sized components made of high C steel.

One surface of steel is brought to red hot condition by

0 - 0.2% LCE
0.2-0.5% MCC
0.5-2% HCC

> Plain Carbon Steel

induction heating effect of a transformer carrying high frequency current. Once the surface becomes red hot, cold water sprays are ejected to convert the surface austenite into martensite.

FLAME HARDENING :

Large sized components (including M/c tool bed) are subjected to flame hardening technique. Steel sample is heated to 800-900°C by using the neutral flame of oxyacetelene torch. When the surface comes to red hot condition, only the surface is quenched to transform austenite into martensite.

Effects of Alloying Elements

- Soluble in ferrite
  - Solid solution ([illegible] either [illegible] and [illegible])
  - Ni, Cr, Mn, Mo, [illegible], Ti, [illegible], Si, [illegible]
- React with iron
  - intermetallic compounds (brittle)
  - Ni, Si, Al, Zr, V, Ti, W, Cr (to reduce)
- Effect on carbon
  - Carbide forming elements: Ti, Zr, V, Mn, Nb, W, Mo, Cr
  - Graphite forming elements: Si, Ni, Cu, Al
- React with oxygen
  - form inclusion
  - Si, Al, Mn, Cr, V, Ti
- Effect on critical temp.
  - Austenite stabilizers: $A_1\downarrow A_3\downarrow A_{cm}\downarrow A_4\uparrow$ — Ni, Mn, Cu, C, N
  - Ferrite Stabilizer: $A_1\uparrow A_2\uparrow A_{cm}\uparrow A$ — Ti, Mo, Cr, W, V, Si, Al

0-10% Low alloy steel

10% or more high alloy steel

Alloying Element	Effects
Sulphar	-> formation of iron sulphide which is hard & brittle -> Addⁿ of S results in hot cracking tendency in steel (HOTSHORTNESS) -> S ↑ Machinability
Phosphorous	-> Powerful solid solⁿ strengthener. ⇂↑ strength and hardness -> P ↑ Machinability -> P ↑ brittleness in steel. -> ⇂t induces (COLDSHORTNESS) in steel.
Silicon	-> ⇂t dissolves in ferrite. -> ⇂t is a stong deoxidiser. -> ⇂t is used to make magnetically soft material for use in transformers.
Manganese	-> ⇂t ↑ strength, hardness, toughness. -> ⇂t ↑ machinability of steel. -> ⇂t is used to produce extremely tough, wear resistant and non magnetic steel called as HADFIELD Mn Steel. -> ⇂t is an austenite stabilizer. -> ⇂t improves abrasion resistance
Nickel	-> ⇂t ↑ toughness without ↓ ductility -> ⇂t is an austenite stabilizer -> ⇂t ↑ corrosion resistance. -> ⇂t is used to produce alloys with zero coefficient of thermal expansion. (INVAR steel)

Chromium	It is a carbide former. It ↑ wear resistance. It ↑ corrosion resistance.
W, Mo, V	They are carbide forming element. They ↑ wear resistance They refine grain size.
Titanium	It is a strong carbide former. It ↑ strength and hardness. Refine grain size.
Aluminium	It is a powerful dioxidiser. It refines grain size It's a graphite forming element.

→ Ceramic - features & classification ←

- Glasses
  - Glasses
  - Glass Ceramic → crystalline (in oven)
- Refractories
  - fused clay
  - Acid Silica
  - Basic Silica
  - special → Resistance heating element, Crucible materials
- Cement
  - Portland cement, Lime, Plaster of paris
- clay products
  - structural clay products (Bricks, Tiles, Sewer pipes)
  - White-ware (Sanitary ware, Pottery, tableware, Porcelains)
- Abrasives (Diamond, Corundum, Emery (SiC), Garnet)
- Advanced Ceramic
  1. Si_3N_4 balls in bearing
  2. optical fibres
  3. Amorphous Silicon carbonitrides in MEMS