UNIT II CONSTITUTION OF ALLOYS AND PHASE DIAGRAMS

Introduction

- List the Major Types of MATERIALS
  - Metals
  - Ceramics
  - Polymers
  - Composites
  - Advanced materials

Introduction

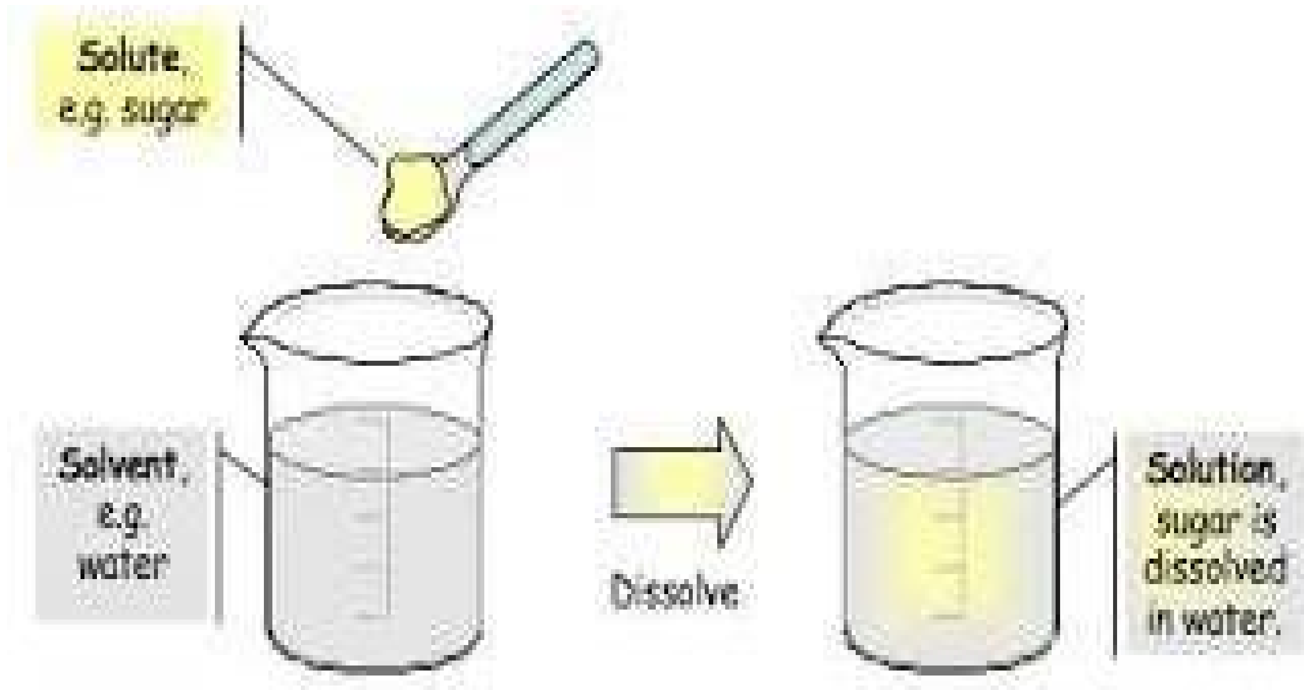
Alloys

- An alloy is a mixture of two or more metals or non metals
- The element which is present in the largest proportion is called the **base metal**, and all other elements present are called **alloying elements**

Solid Solutions

- **Solution**
  - A solution is a homogeneous mixture composed of two or more substances. In such a mixture, a solute is a substance dissolved in another substance, known as a solvent.
  - The solvent is a chemical substance and can be in a solid, liquid or gaseous state. Thus solution can exist in a gaseous, liquid or solid state.

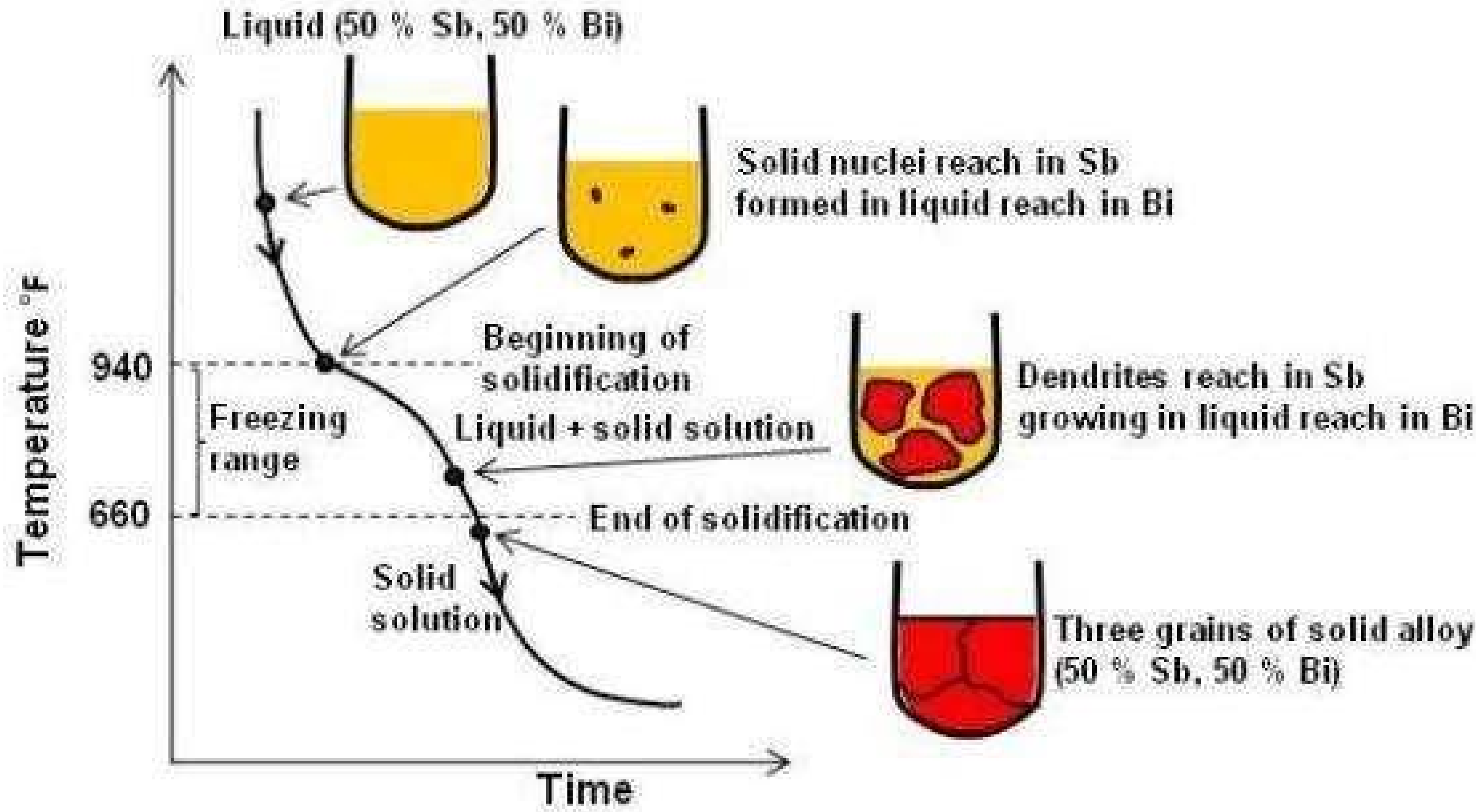
Solid Solutions



Solid Solutions

- A solid solution may be defined as a solid that consists of two or more elements atomically dispersed in a single-phase structure
- The amount of solute that may be dissolved by the solvent is generally a function of temperature (with pressure constant) and usually increases with increasing temperature

Solid Solutions



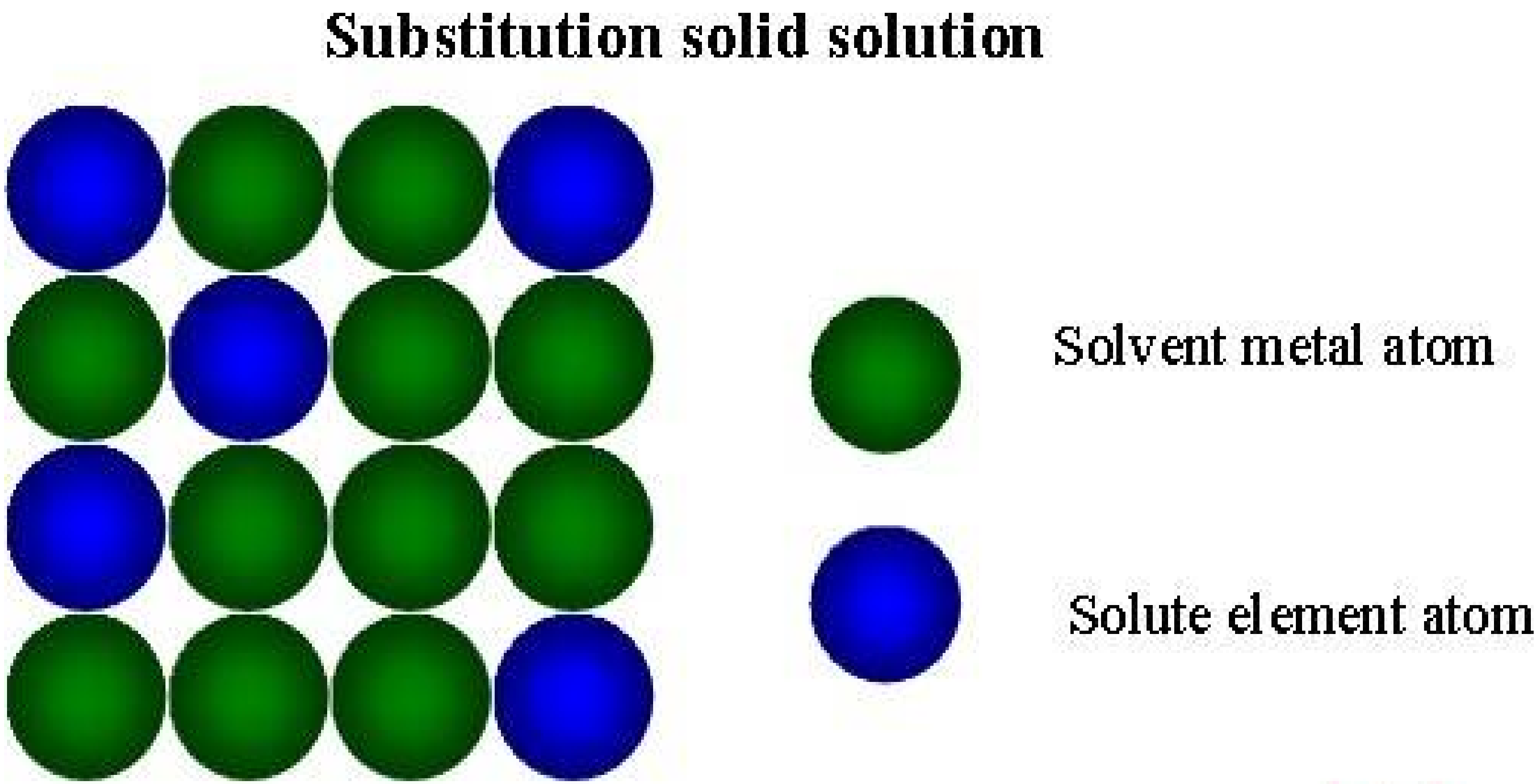
Cooling Curve for the solidification of 50 % antimony and 50 % bismuth alloy

(Cooling Curve for an Alloy)

Types of Solid Solutions

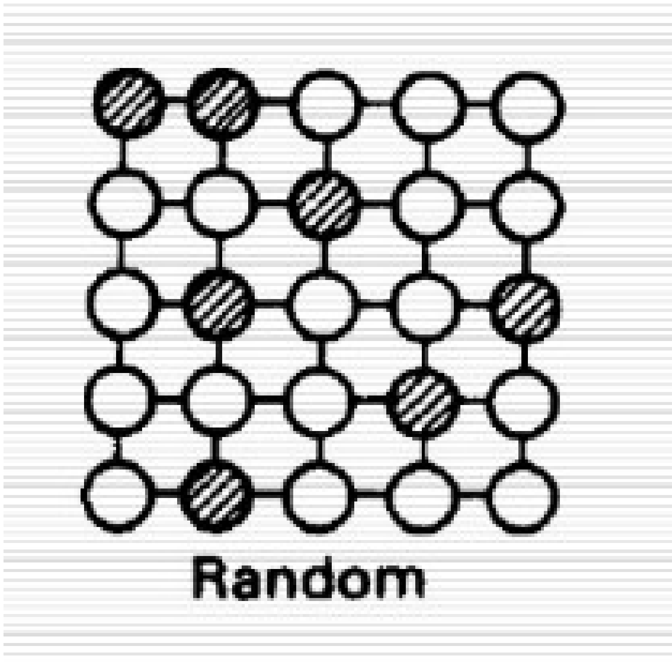
- Substitutional solid solutions
  - (i)Random
  - (ii)Ordered
- Interstitial solid solutions

Substitutional Solid Solutions



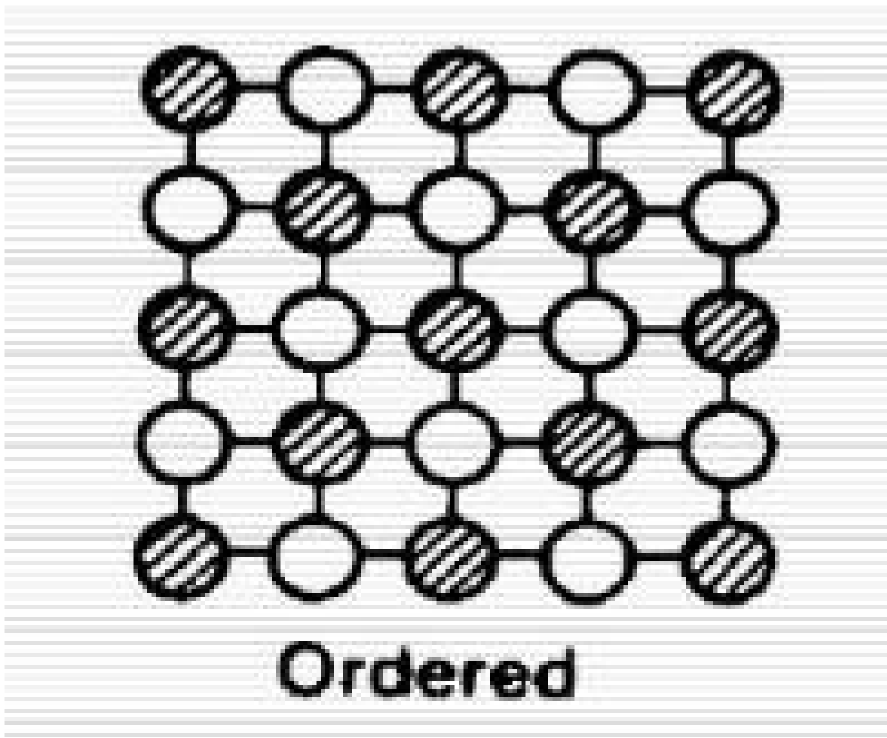
Random Substitutional Solid Solutions

- In the formation of a Substitutional solid solution, the solute atoms do not occupy any specific position but are distributed at random in lattice structure of the solvent. This alloy is said to be in a random or disordered condition.
- Examples: Copper-Zinc



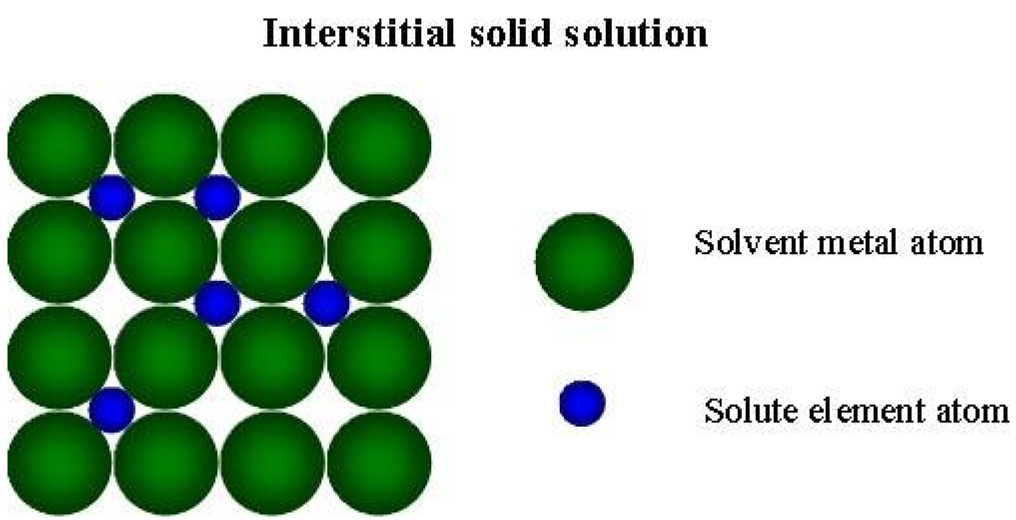
Ordered Substitutional Solid Solutions

- If the solute and solvent atoms take up some preferred position, then the solution is called ordered Substitutional solid solution.
- Examples: Gold-Copper



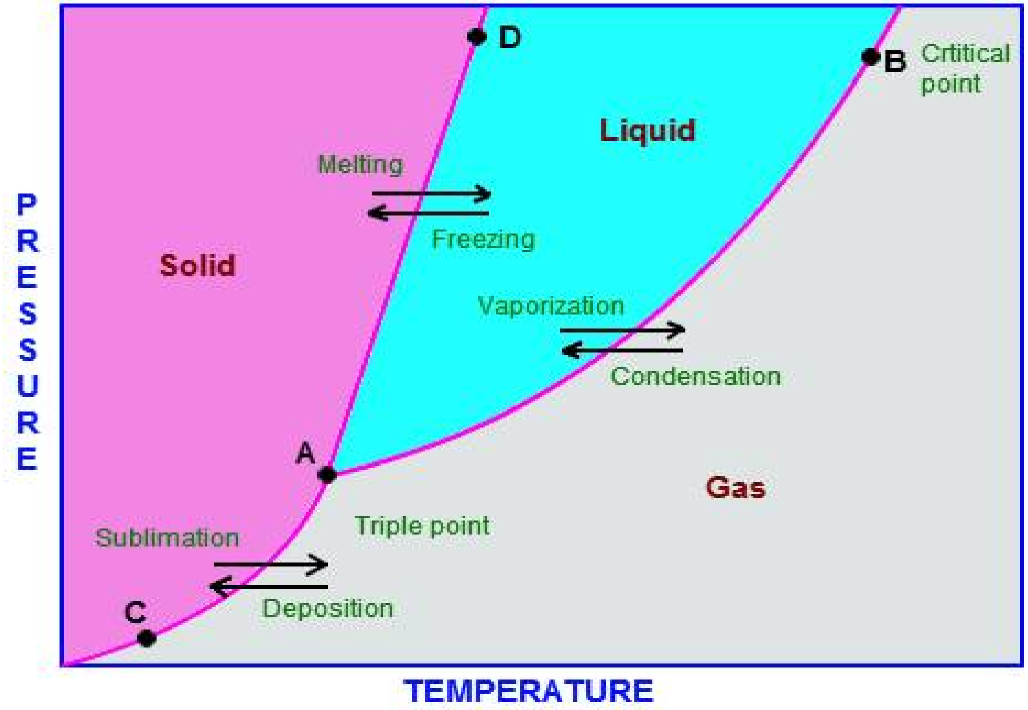
Interstitial Solid Solutions

- In interstitial solid solution, the solute atoms fit into the space between the solvent or parent atoms. These spaces or voids are called interstices.
- Interstitial solid solution can form only when one atom is much larger than another.
- Examples: Iron- Carbon



Phase diagrams

- It is the graphical representations of what phases are present in a materials system at various temperatures, pressures and compositions
- It is also known as equilibrium diagrams (or) constitutional diagrams



Phase

- Phase can be defined as a physically distinct and chemically homogeneous portion of a system that has a particular chemical composition and structure
- **Examples:** Water in liquid or vapor state is single phase. Ice floating on water is an example two phase system.

Single Phase

- Three forms of water – ice, water , water vapour

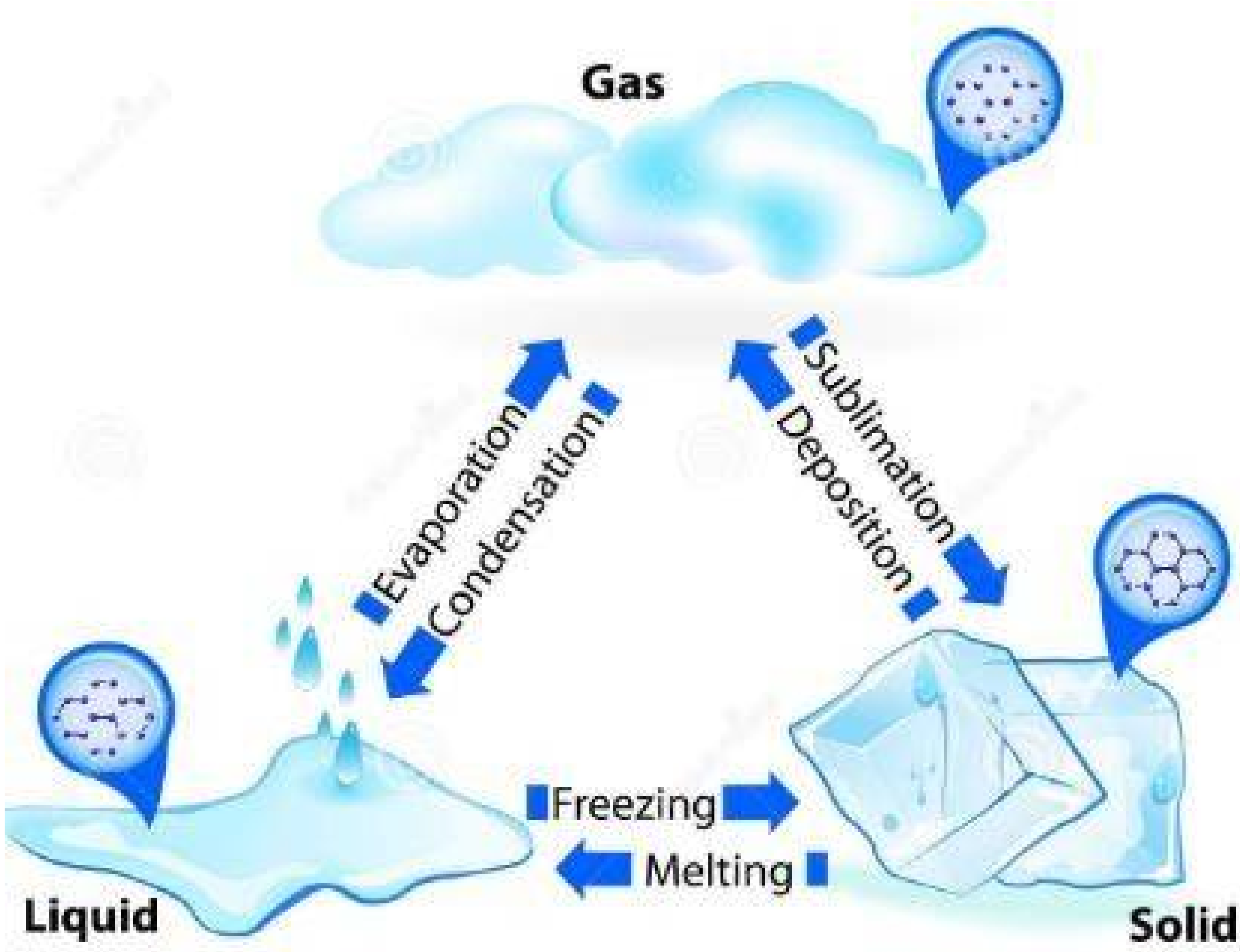
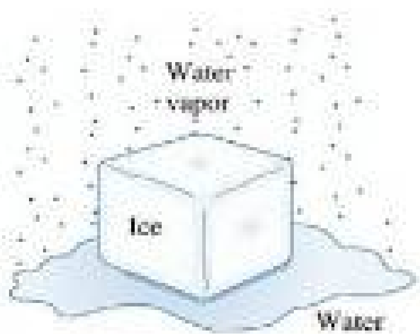


Illustration of phases

Illustration of phases and solubility



(a)

(a) The three forms of water – gas, liquid, and solid – are each a phase.

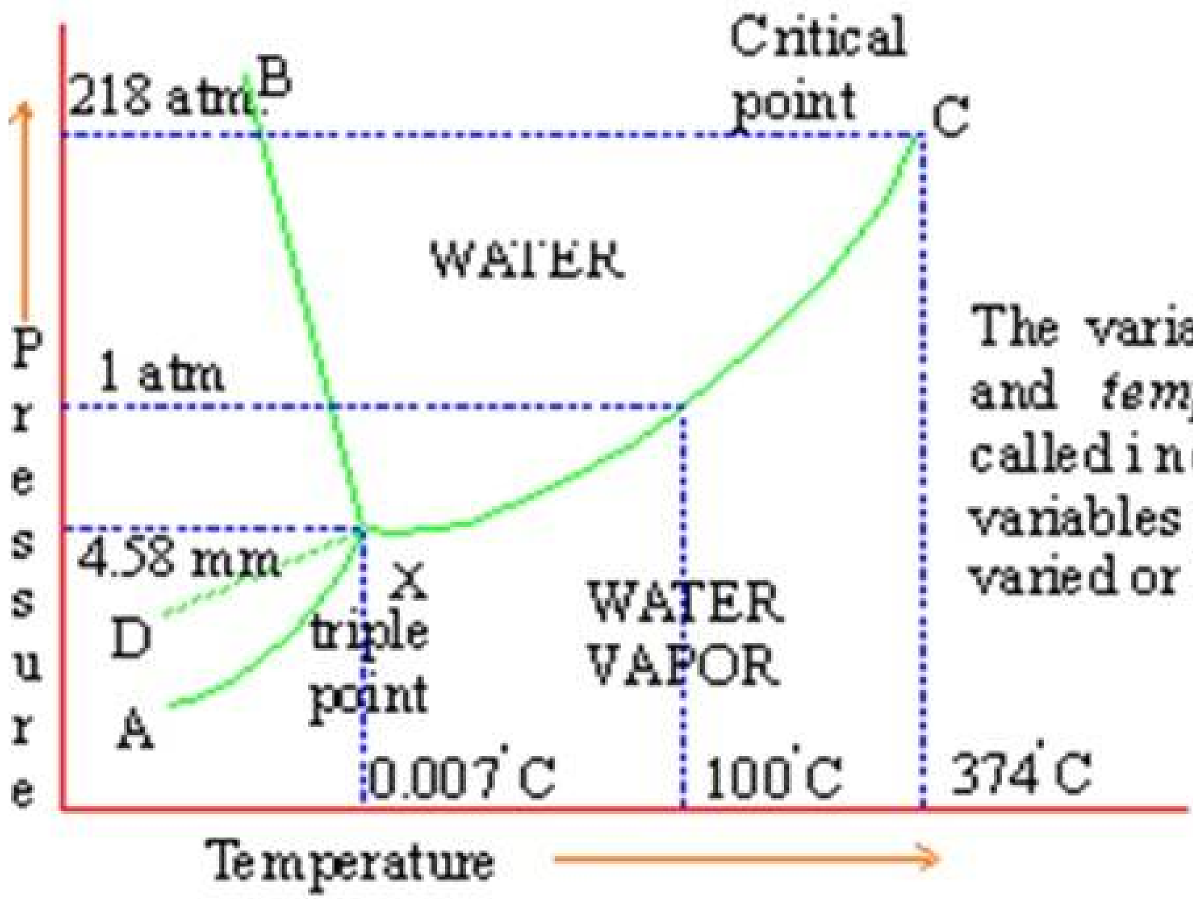
(c)

(d)

(c) Salt and water have limited solubility.

(d) Oil and water have virtually no solubility.

Phase diagram of a pure substance (one component phase diagram)



The variables *pressure* and *temperature* are called independent variables and can be varied or held constant.

Phase diagram of water (not to scale)

Gibb's phase rule

- The number of phases present in any alloy depends upon the number of elements of which is alloy is composed

$$F= C-P+2$$

Where,

F= Degrees of freedom of system or number of variables (temp, pressure, or composition etc) that may be changed independently without altering the equilibrium

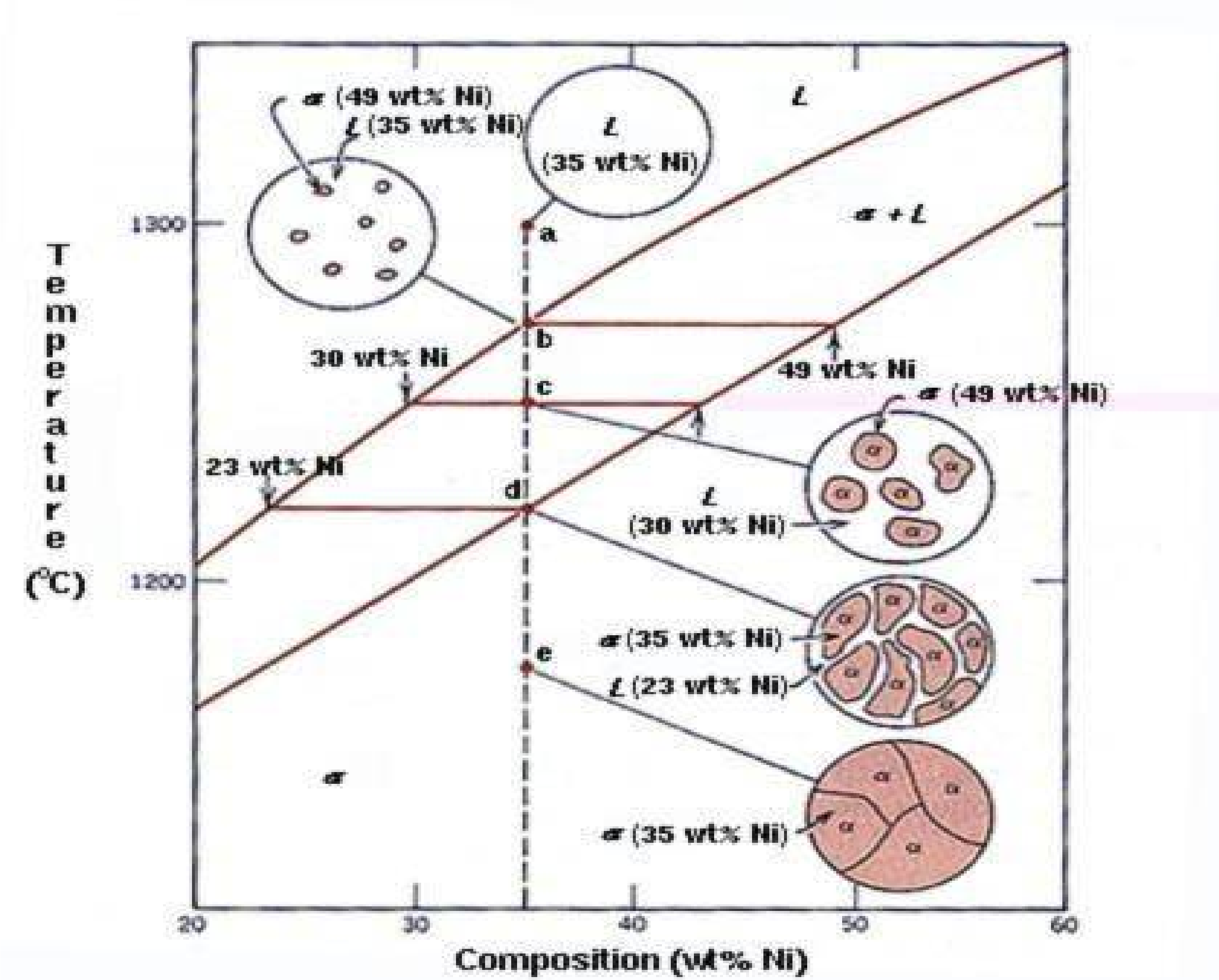
C= No. of components

P= Number phases present in the system

Isomorphous binary Phase diagrams

- Example:
  - Copper-Nickel (Cu-Ni) System
  - Antimony- Bismuth (Sb- Bi) System
  - Gold – Silver (Au-Ag) System
  - Chromium – Molybdenum (Cr- Mo) System

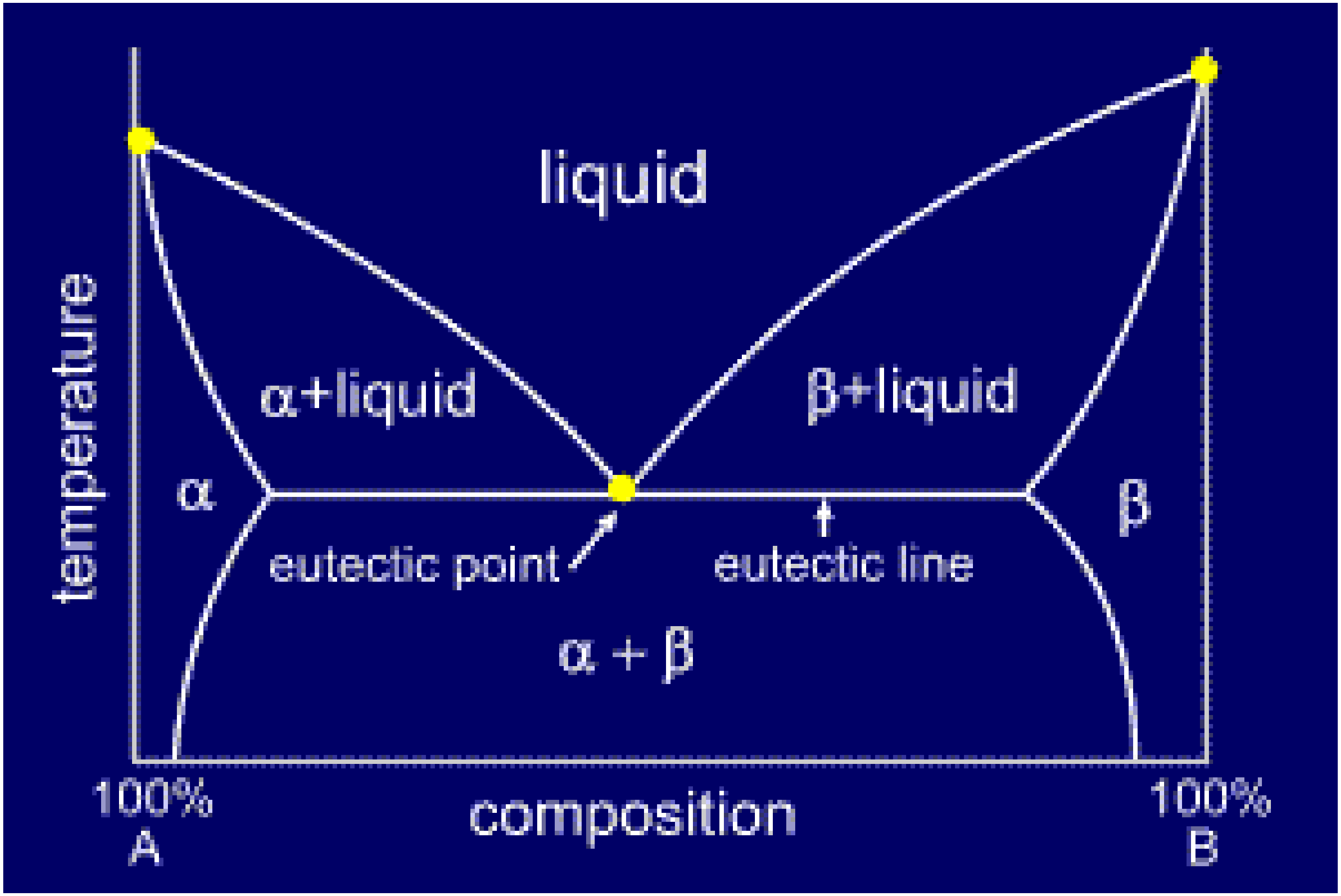
Isomorphous binary Phase diagrams



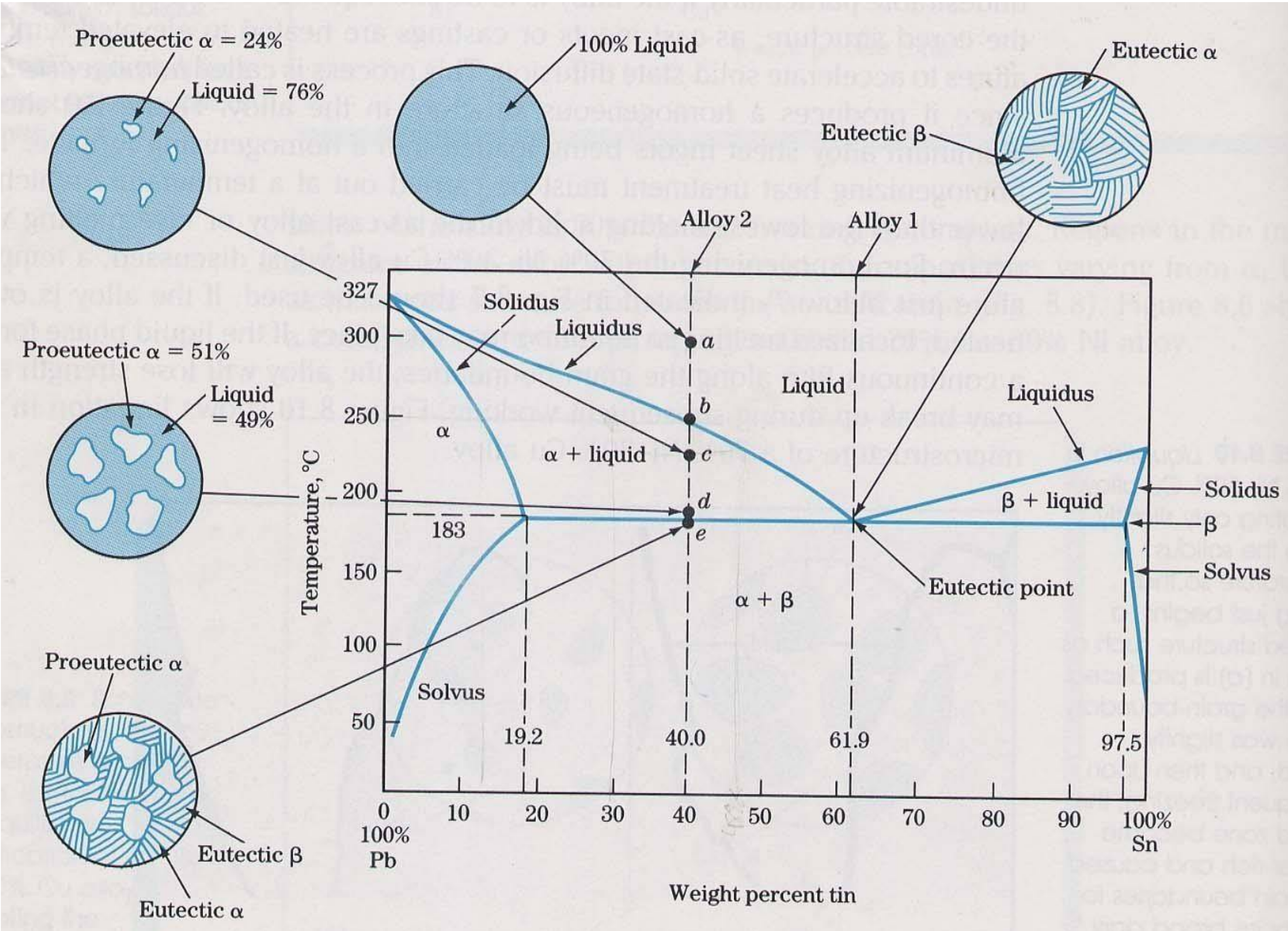
Phase diagram for partial solid solubility

- Each element is soluble in the other element up to certain limit or saturation point. The value of this limit is a function of temperature
- If the two metals A and B are not completely soluble through all ranges in composition, then second phase will form at grain boundaries.
- Examples:
  - Copper- Silver (Cu-Ag) System
  - Lead- pin (Pb-Sn) System
  - Aluminium – Copper (Al-Cu) System

Phase diagram for partial solid solubility



Phase diagram for partial solid solubility – Lead(Pb)-Tin(Sn)

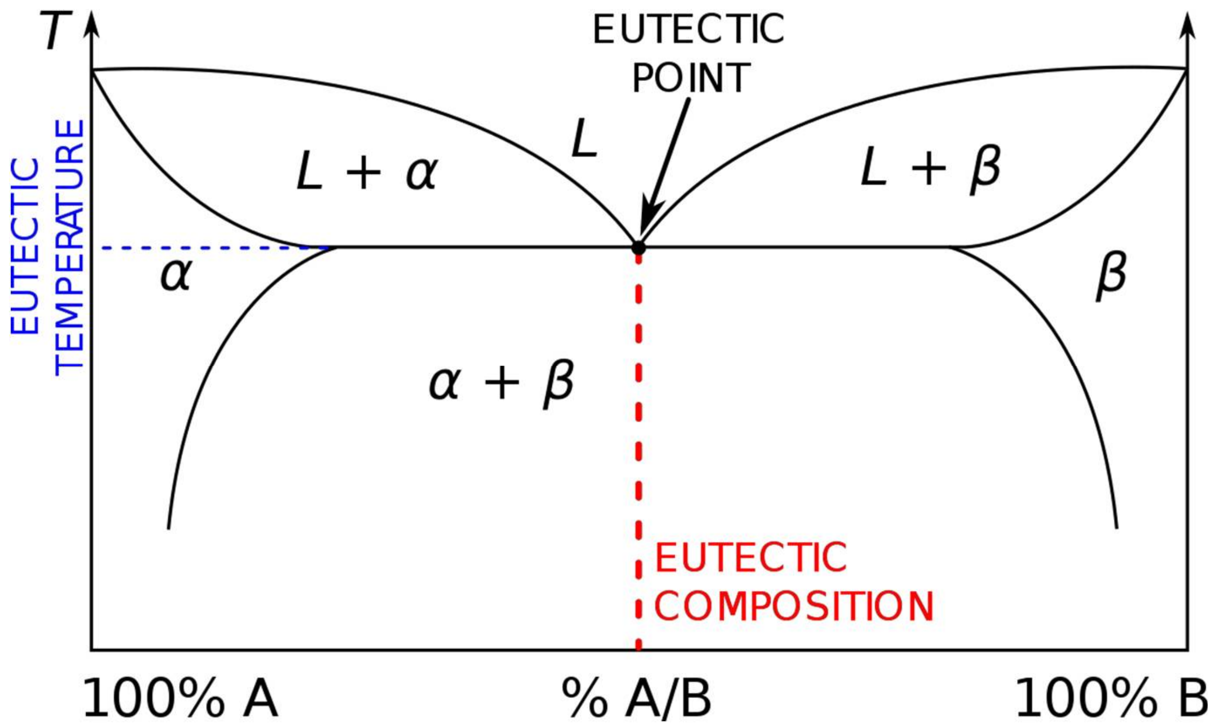


Phase diagram for partial solid solubility

- Six phase regions/fields are found in the diagram
- α solid solution phase
- β solid solution phase
- α solid + liquid phase
- β solid + liquid phase
- α + β Solid Solution phase
- Liquid phase

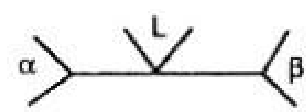
[Eutectic - Greek work – Easily melted]

Eutectic Reaction

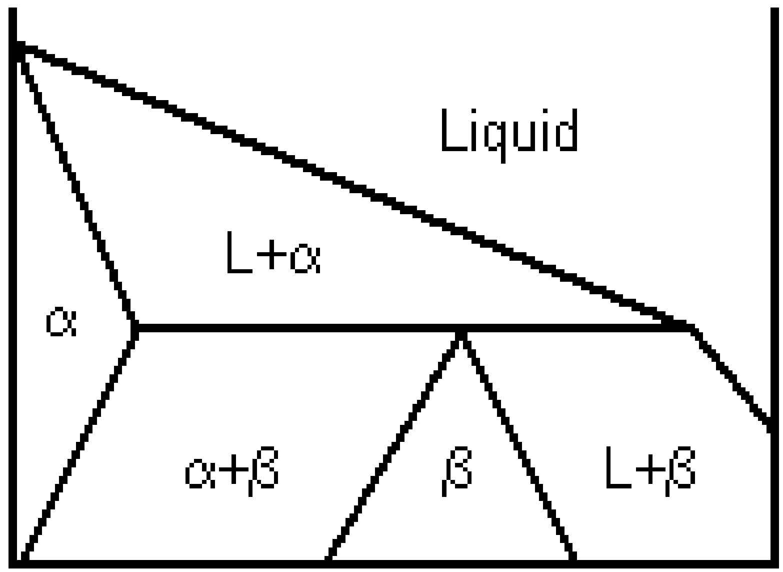


- Liquid $\underset{\text{Heating}}{\overset{\text{Cooling}}{\rightleftharpoons}}$ Solid 1 + Solid 2

Phase diagram Characteristics



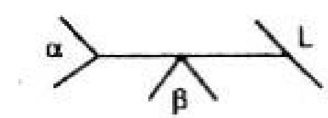
Peritectic Reaction



- **Examples:** Iron-carbon system

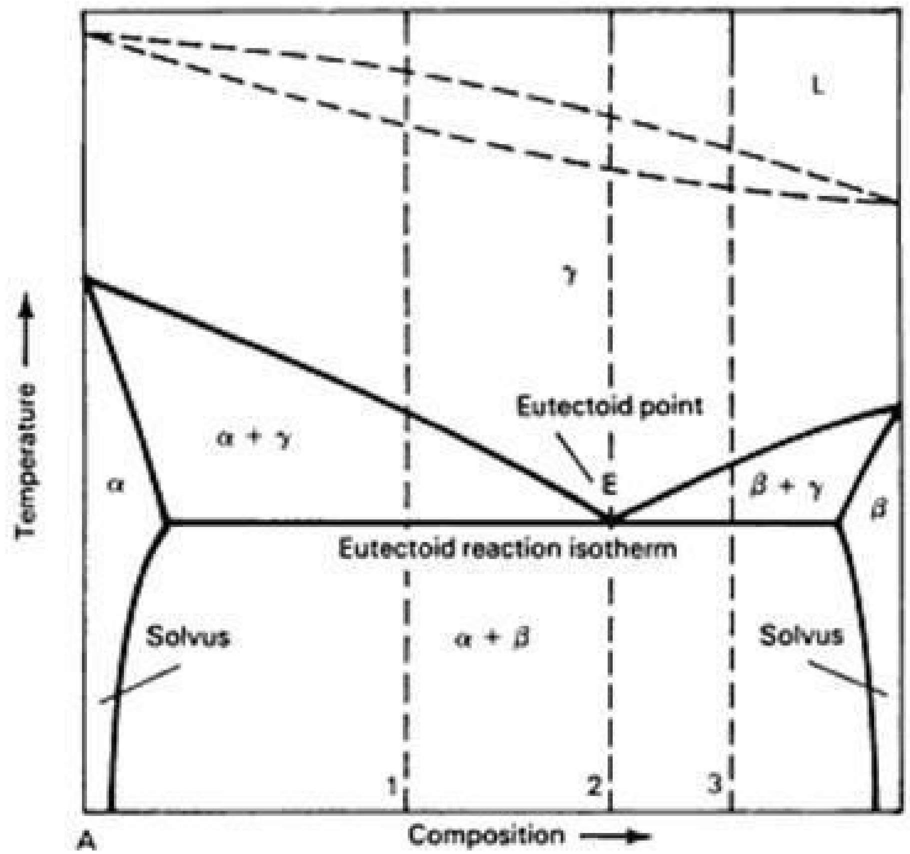
- Liquid+ Solid 1 $\underset{\text{Heating}}{\overset{\text{Cooling}}{\rightleftarrows}}$ Solid 2

Phase diagram Characteristics



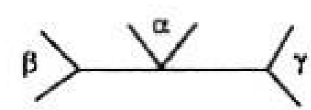
Eutectoid Reaction

- **Ex:** Cu-Al,
- Al-Mn,
- Cu-Zn



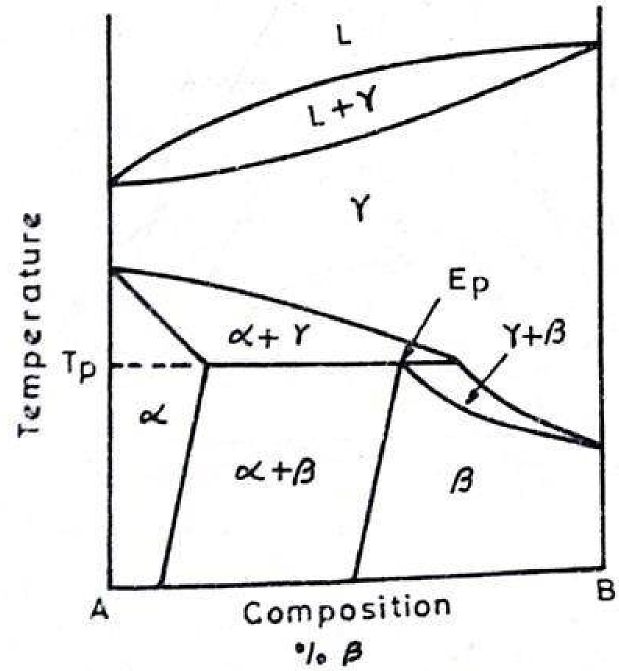
- Solid 1 $\underset{\text{Heating}}{\overset{\text{Cooling}}{\rightleftarrows}}$ Solid 2 + Solid 3

Phase diagram Characteristics



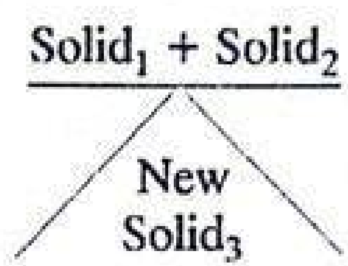
Peritectoid Reaction

- **Ex:** Ni-Zn,
- Cu-Sn,



A peritectoid diagram.

$$\text{Solid}_1 + \text{Solid}_2 \underset{\text{Heating}}{\overset{\text{Cooling}}{\rightleftharpoons}} \text{New Solid}_3$$

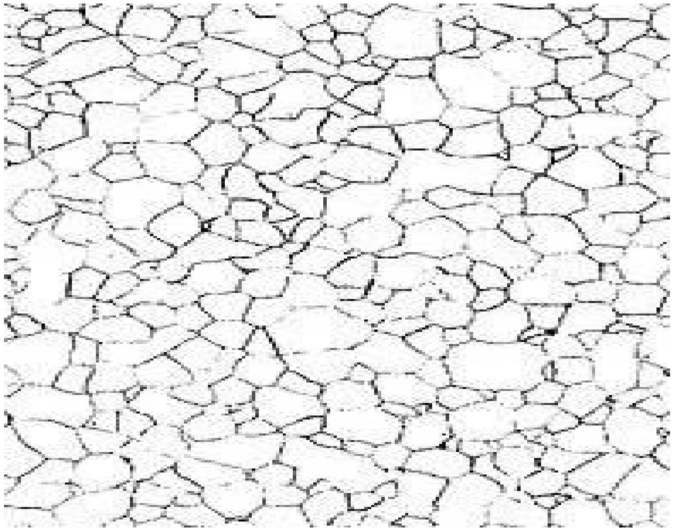


Micro-Constituents of Iron-Carbon alloys

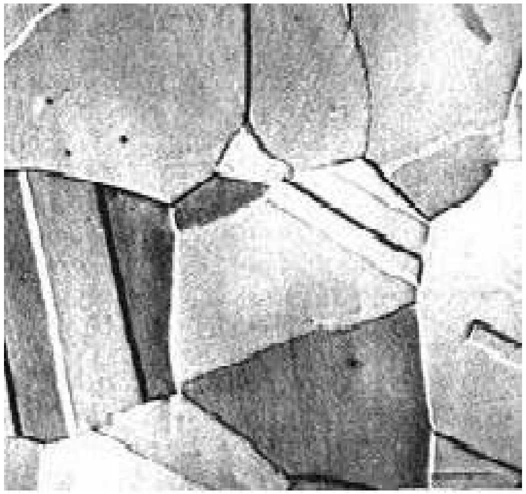
1) Ferrite (or α- iron)
2) Austenite (or γ- Iron)
3) Cementite (Fe_3C)
4) Pearlite (α- Iron + Fe_3C)
5) Ledeburite (γ- Iron + Fe_3C)
6) Martensite
7) Troosite
8) Sorbite
9) Bainite

Micro-Constituents of Iron-Carbon alloys

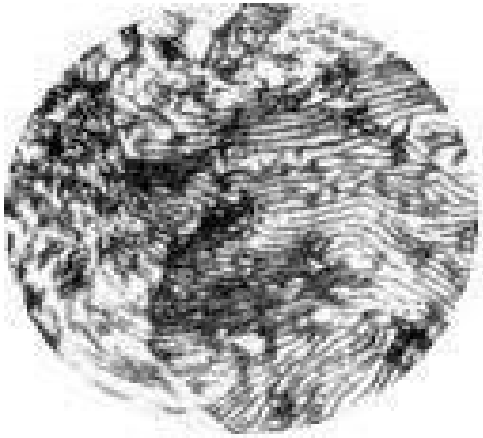
FERRITE



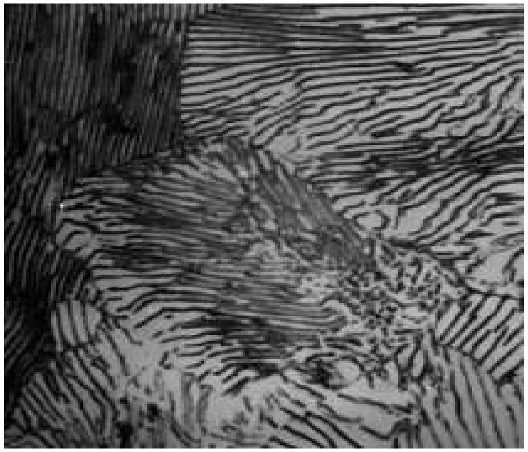
AUSTENITE



CEMENTITE



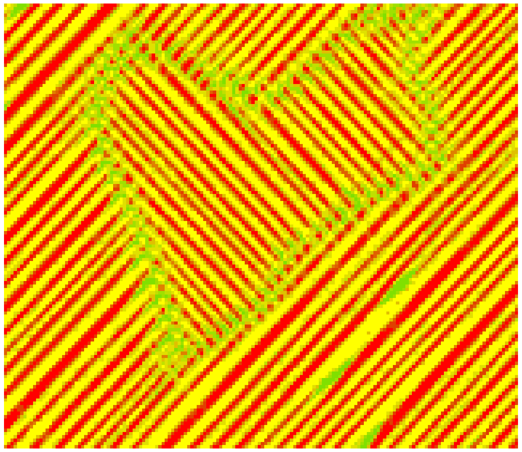
PEARLITE



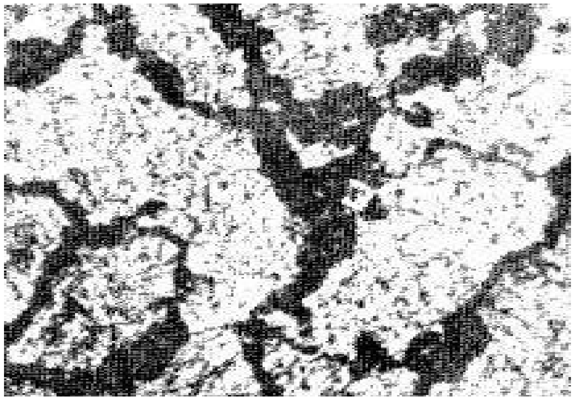
Micro-Constituents of Iron-Carbon alloys

Ledeburite

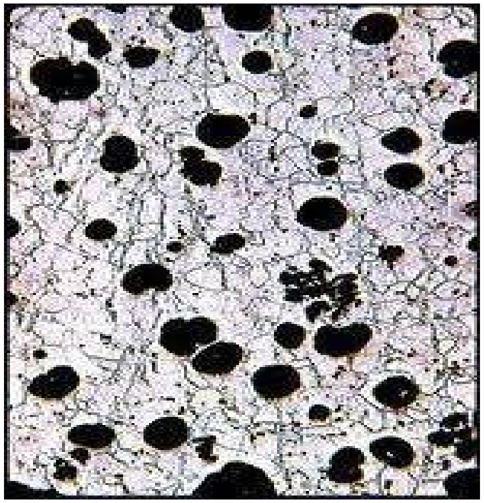
Martensite



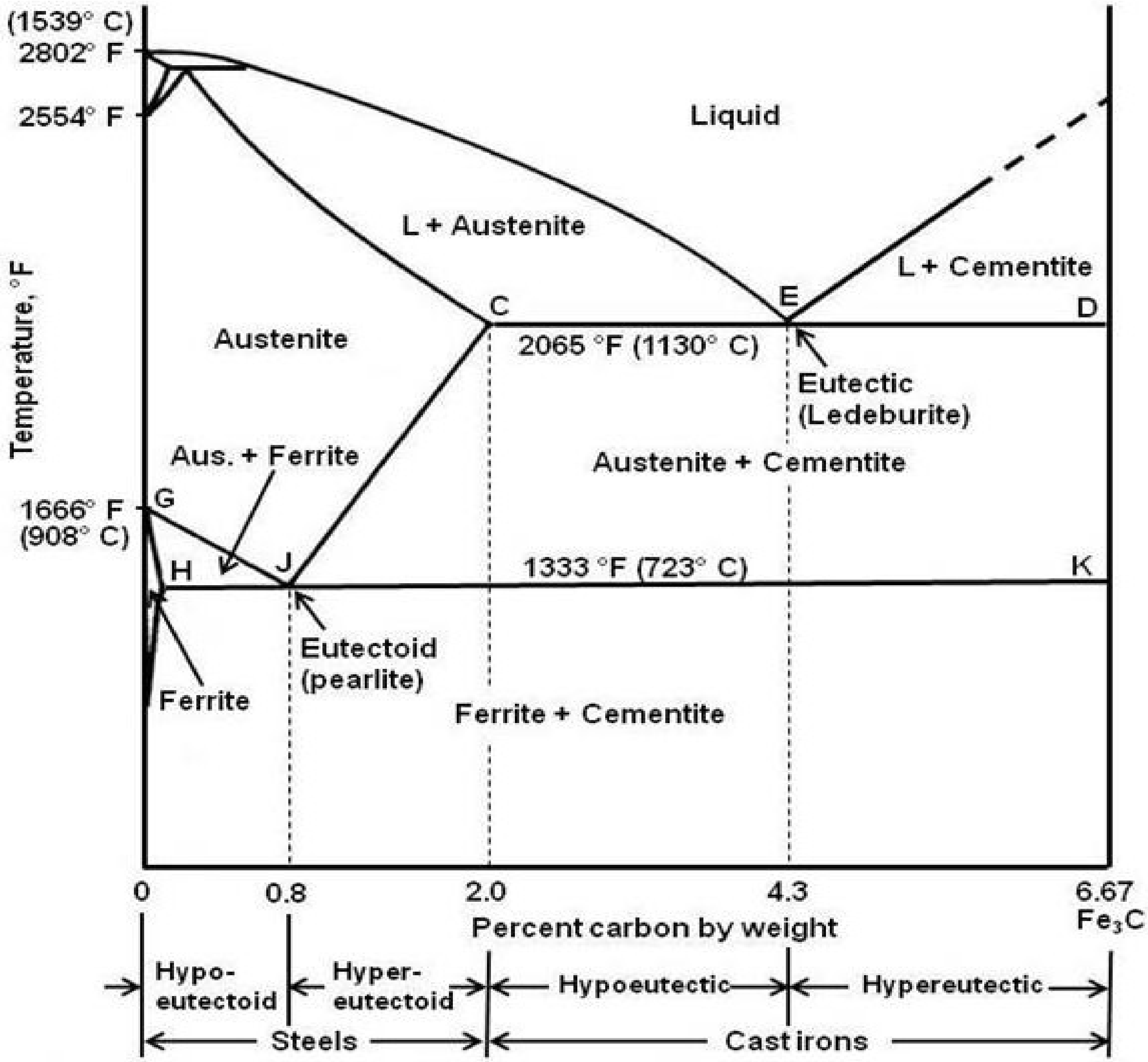
TROOSTITE



SORBITE



BAINITE



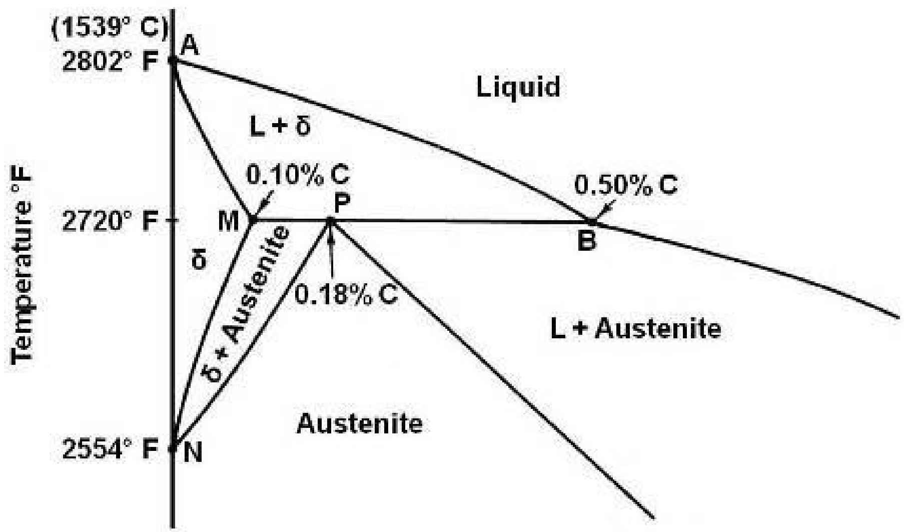
The iron-iron carbide equilibrium diagram labeled with common names

Iron – iron carbide Equilibrium diagram

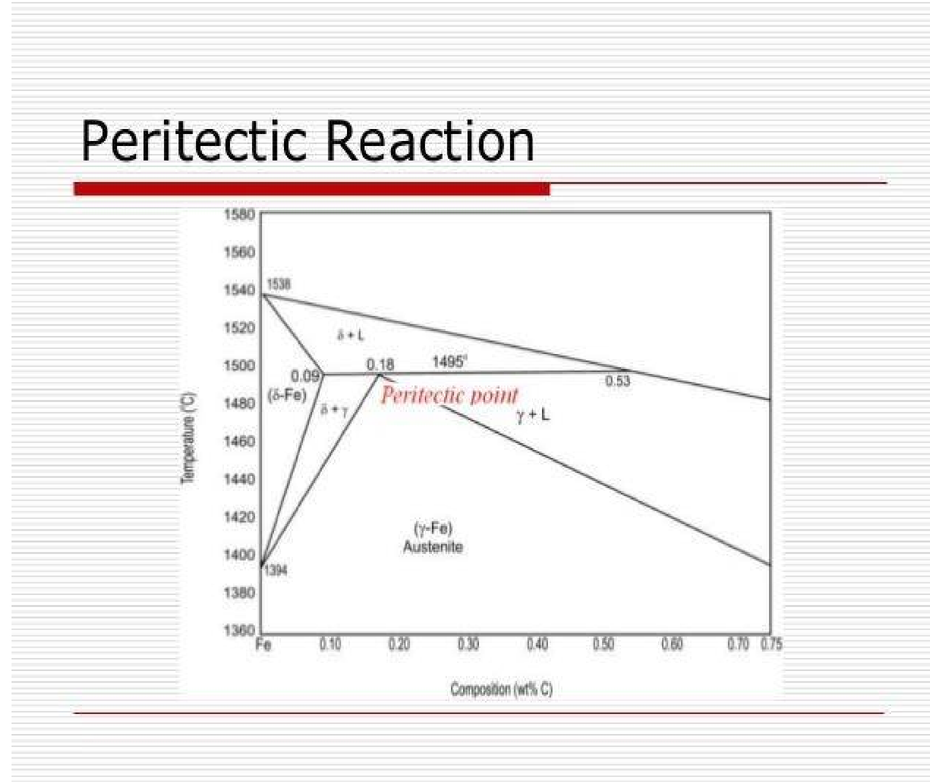
- Pure iron exists in three allotropic forms before it melts
  - α – Iron
  - δ– Iron
  - γ – Iron
- Stables at temperatures up to 908°C **(α- Iron) –BCC**
- Stables between 908°C and 1388°C **(γ – Iron)-FCC**
- Stables between 1388°C and 1539°C(Melting Point). **(δ – Iron) -FCC**

Invariant reactions in the Fe-Fe_3C Phase Diagram

Peritectic reaction



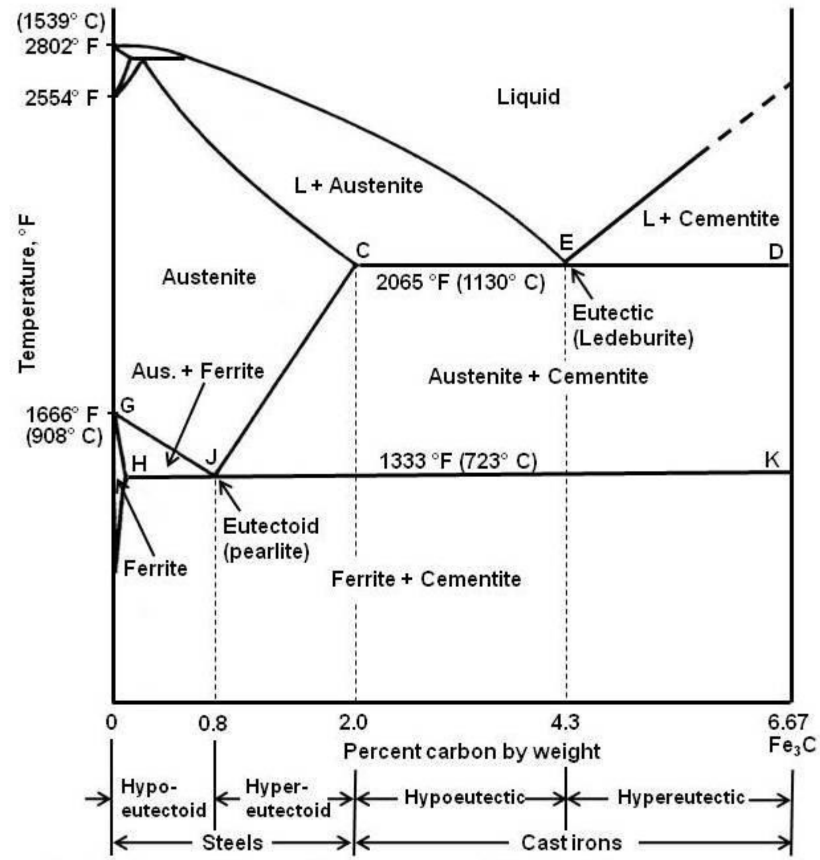
The delta region of the iron-iron carbide diagram



$$\text{Liquid (0.53\%C)} + \delta \text{ Ferrite (0.09\%C)} \underset{}{\overset{1495°C}{\rightleftharpoons}} \gamma \text{ Austenite (0.17\% C)}$$

Invariant reactions in the Fe-Fe_3C Phase Diagram

- **Eutectic reaction**

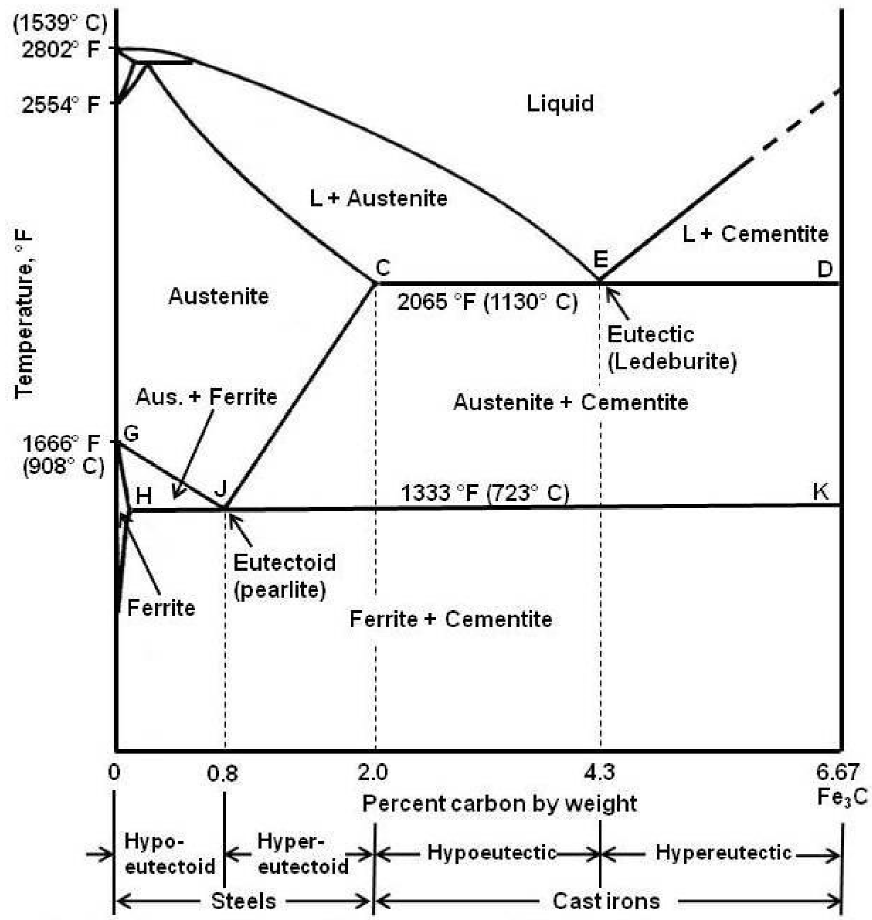


The iron-iron carbide equilibrium diagram labeled with common names

$$\text{Liquid (4.3\%C)} \underset{}{\overset{1148°C}{\rightleftharpoons}} \gamma\text{Austenite(0.09\%C)} + Fe_3C\text{(6.67\%C)}$$

Invariant reactions in the Fe-Fe_3C Phase Diagram

- **Eutectoid reaction**



The iron-iron carbide equilibrium diagram labeled with common names

$$\gamma \text{Austenite}(0.8\%C) \underset{}{\overset{723°C}{\rightleftharpoons}} \alpha \text{ Ferrite } (0.02\%C) + Fe_3C(6.67\%C)$$

Steels

- Steels are alloys of iron and carbon .
- However steels contain other elements like silicon, manganese, sulphur, phosphorus, nickel etc.

- ***<u>Classification of steels:</u>***
- 1. Plain carbon steels.
    - (i) Low carbon steels
    - (ii) Medium carbon steels
    - (iii) High Carbon steels
- 2. Alloy Steels
    - (i) Low alloy steels
    - (ii) High alloy steels

Low carbon Steels
(Carbon- Less than 0.25%)

- **Characteristics:**

✓ Its Relatively soft week

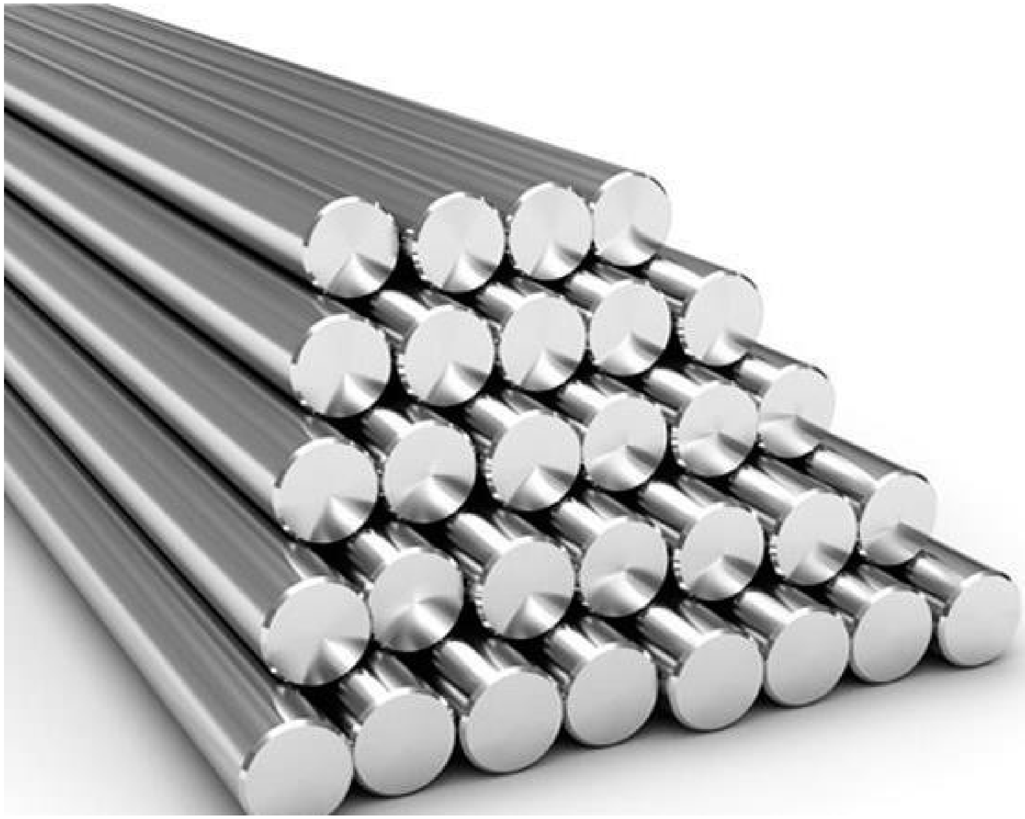
✓ The possess formability and Weldability

Medium carbon Steels
(Carbon- 0.25% to 0.60%)

- **Applications:**
- ✓ Railway wheels
- ✓ Railway tracks
- ✓ Gears
- ✓ Cranks shafts

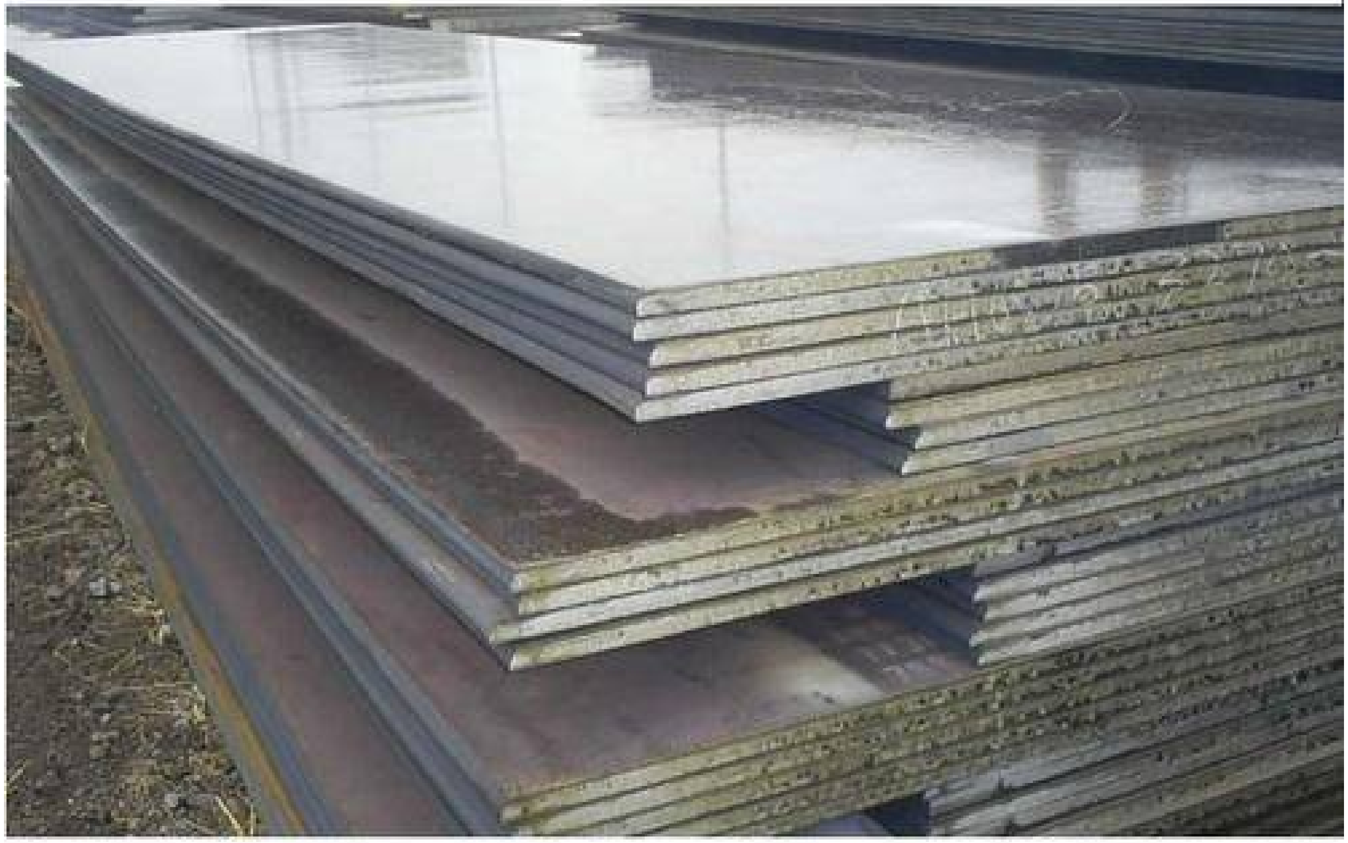
Alloy Steels

- Any steels other than carbon steels
- The steels products manual defines alloy steels as that exceed one or more of the following limits



Low Alloy Steels

1) AISI Steels
2) HSLA Steels



High Alloy Steels

1) Tool and die Steels
2) Stainless Steels

Cast Irons

- Carbon – Greater than 2% carbon
- Its also Contain small amounts of silicon, sulphur, manganese and phosphorous

- **Features of cast iron**

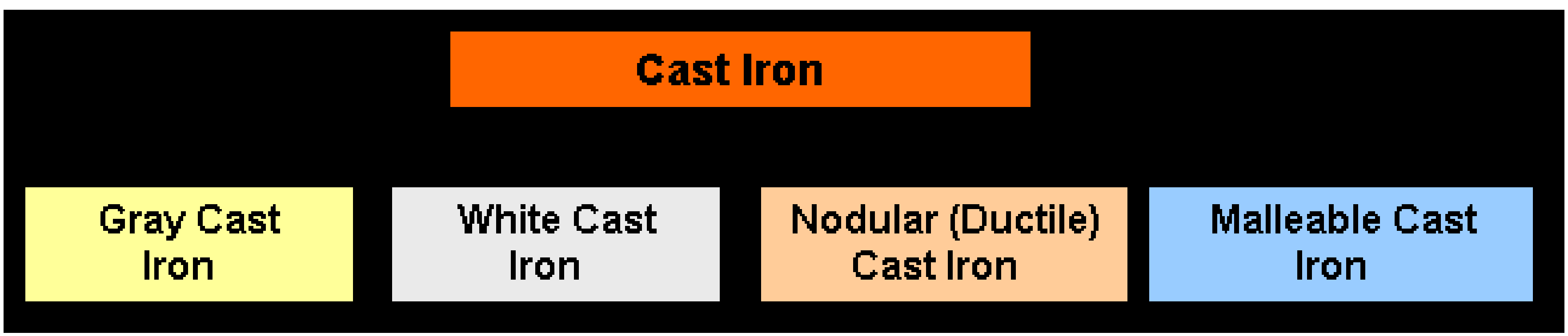
✓ Least expensive . Plentiful resources next to aluminium

✓ Good mechanical rigidity and good strength under compression

✓ Good machinability can be achieved

Composition of Cast Irons

- Carbon -3.0 to 4.0%
- Silicon- 1.0 to 3.0%
- Manganese – 0.5 to 1.0%
- Sulphur- upto 0.1%
- Phosphorus – upto 1.0%



Cast Irons