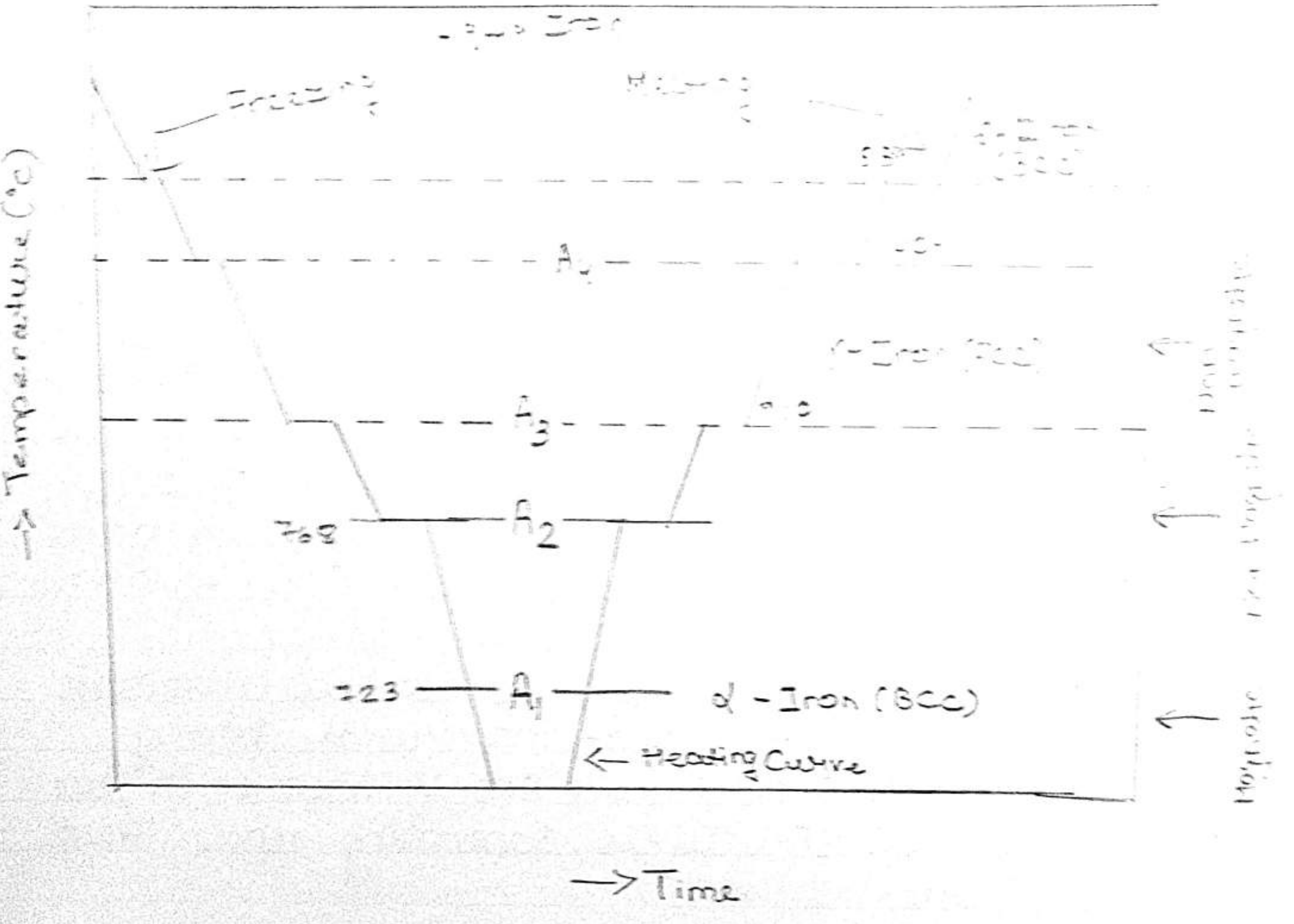
Practical - 3

⇒ To illustrate allotropy of Iron

The existence of the same metal in two or more crystalline form is called "allotropy or "polymorp- -hism" and the metal in which such changes occur is known as "allotropic". The process of change of crystal lattice with temperature is called an "allo- -tropic" or "polymorphic transformation" of the metal. In this type of transformation the atoms of a crystalline solid form a new crystal lattice by converting from one crystalline form to another.

Iron is an allotropic metal. It has two allotropic modifications, α- and δ- iron with body centered cubic structures, and γ- iron with face centered cubic structures, depending upon the temperature.

The "Fig" shows the cooling curve of pure iron which is plotted by allowing the molten iron to cool slowly in an insulated crucible.

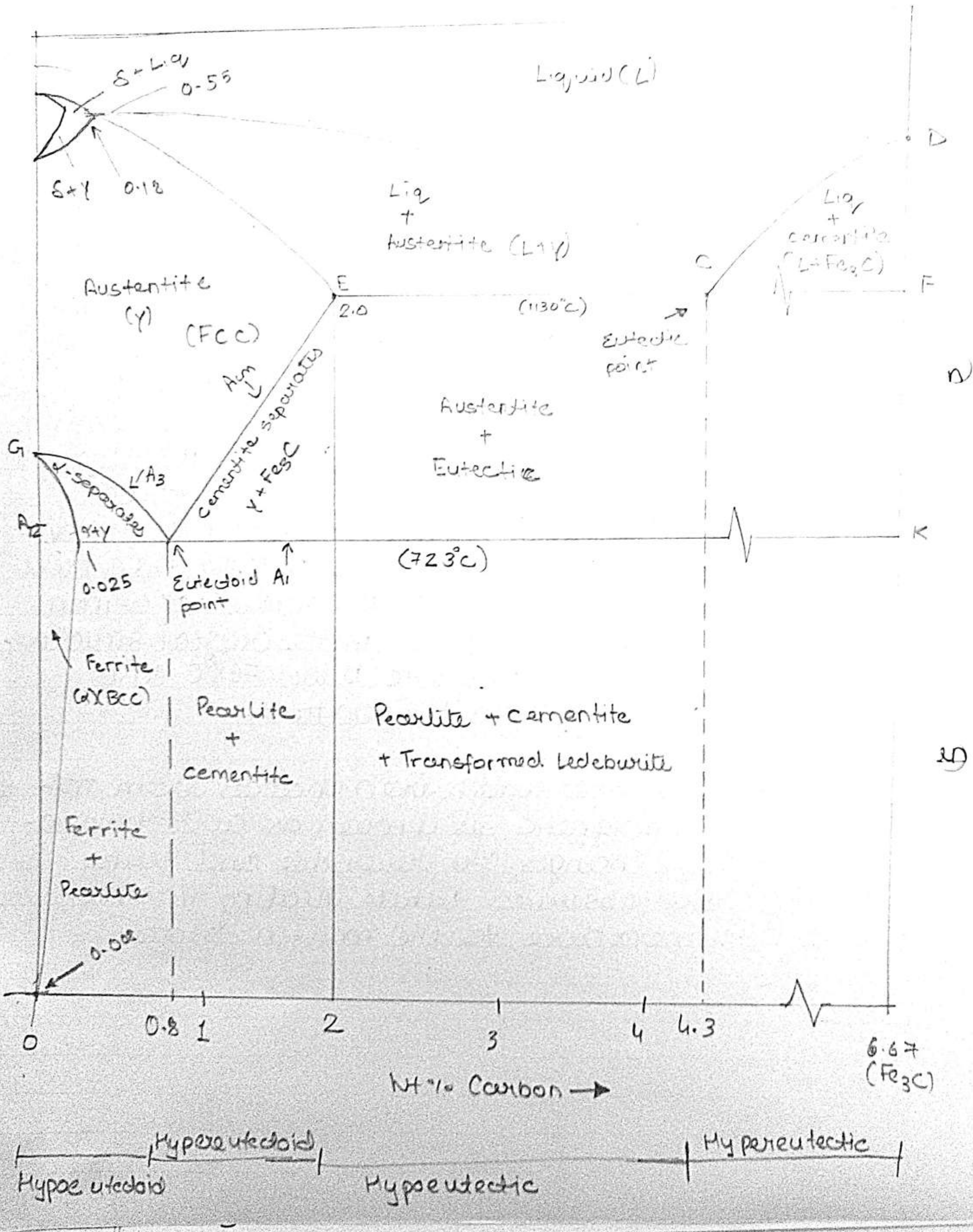


→ Temperature (°C)
A_3
768
A_2
723
A_1
α - Iron (BCC)
← Heating Curve
→ Time

At temperature above 1539°C, iron is in liquid form. At 1539°C iron starts freezing. When iron first solidifies at 1539°C, it solidifies with BCC structures with lattice constant $a = 2.93 A^0$ and it is known as delta iron (δ-Fe). On cooling further at 1404°C the atom rearrange themselves into FCC structures with lattice constant $a = 3.63 A^0$ and it is known as γ-iron. It is non-magnetic.

Another phase change occurs on further cooling to 910°C. Where non-magnetic gamma iron changes to non-magnetic BCC structure with lattice constant $a = 2.886 A^0$ and it is known as α-iron. Finally, when the temperature reaches 768°C, there is a change in the magnetic behaviour of α-iron and no-change takes place in the crystal structure. The α-iron becomes magnetic below 768°C and remains so upto room temperature.

This temperature at which iron changes from non-magnetic to magnetic is known as curie temperature. These changes are reversible and same changes are observed while heating from room temperature to the molten state.


Liquid (L)
δ + Liq
0.55
δ + γ
0.18
Liq + Austentite (L+γ)
Liq + cementite (L+Fe₃C)
D
C
F
E
2.0
(1130°C)
Eutectic point
Austentite (γ)
(FCC)
Acm
cementite separates
γ + Fe₃C
Austentite + Eutectic
G
α-separates
A₃
A₂
α+γ
K
(723°C)
0.025
Eutectoid point
A₁
Ferrite (α)(BCC)
Pearlite + cementite
Pearlite + cementite + Transformed Ledeburite
Ferrite + Pearlite
0.008
0
0.8
1
2
3
4
4.3
6.67 (Fe₃C)
Wt % Carbon →
Hypoeutectoid
Hypereutectoid
Hypoeutectic
Hypereutectic

⇒ Invariant reactions in $Fe-Fe_3C$ diagram

The existence of various phases in iron-carbon phase diagram is due to phase transformation which take place in iron-carbon alloy at different temperature and compositions.

(a) Peritectic reaction occurs when the alloy containing 0.18% carbon, liquid and delta iron transform on cooling into austentite at 1493°C.

$$\delta\text{-Iron} + \text{Liq} \underset{}{\overset{1493°C}{\rightleftharpoons}} \text{Austentite}$$

δ	L	γ
0.09	0.55	0.18
BCC	–	FCC

(b) Eutectic reaction occurs when liquid alloy containing 3.3% carbon transform on cooling austentite and cementite at 1130°C. The eutectic mixture is known as ledeburite. However this mixture is generally not seen in the micro-structure at room temperature since austentite is not stable at temp below 723°C are called hypoeutectic cast irons whereas those with more than 3.3% carbon are called hypereutectic cast irons.

$$\text{Liquid} \overset{1130°C}{\rightleftharpoons} \underbrace{\text{Austentite} + \text{Cementite}}_{\text{Eutectic Mixture}}$$

L	2	6.67
4.3	FCC	Orthorhombic

(C) Euctectoid reaction takes place when austenite containing 0·8% carbon decomposes on cooling into ferrite and cementite at 723°C. The eutectoid mixture formed is called pearlite.

$$\text{Austenite} \underset{}{\overset{723^\circ C}{\rightleftharpoons}} \underbrace{\text{Ferrite} + \text{Cementite}}_{\text{Eutectoid Mixture (Pearlite)}}$$

γ	α +	Fe_3C
0·8	0·025	6·67
FCC	BCC	Orthorhombic

This alloy of 0·8% carbon is known as eutectoid steel and it consist of pearlite at room temperature. The steels with less than 0·8% carbon are known as hypoeutectoid steels and their microstructures show grains of ferrite plus pearlite.

The cementite is brittle and therefore presence of free cementite at grain boundaries drastically reduces the mechanical properties like tensile, strength and impact strength of the steel.

$F = C - P + 1$ $\quad C = 2$ (Fe & Fe_3C)

$= 2 - 3 + 1$ $\quad P = 3$ $\begin{cases} \text{Peritectic} \rightarrow \delta, L, \gamma \\ \text{Eutectic} \rightarrow L, \gamma, Fe_3C \\ \text{Eutectoid} \rightarrow \gamma, \alpha, Fe_3C \end{cases}$

$= 0$

⇒ Different phases in phase diagram

Iron - Carbon phase diagram can be understood by knowing the presence of various phases in different phase regions of the diagram, their relative properties, as well as various tempera-tures and compositions at which phase transfor-mations takes place. The iron-carbon phase diagram shows constituents such as Ferrite, Austentite, Cementite, Pearlite & ledeburite.

(1) Ferrite: It is practically pure iron containing only 0.008% carbon at room temperature. It is a solid solution of carbon in α-iron. The name "ferrite" comes from the latin word "ferrum" which means iron. Therefore it is also called α-iron.. The solubility of carbon increases with temperature and reaches to 0.0025% at 723°C
The Ferrite grains are polygonal and of regular shape & size.

(2) Austentite: It is a solid solution of carbon in γ iron for carbon steel. For alloy steel austentite can be considered as solid solution of carbon and alloying elements γ-iron. Carbon is present as interstitial solid solution whereas alloying elements like Mn, Ni, Cr etc. form substitutional solid ~~solut~~ solution with iron. Carbon is present as interstitial solid sol^n

of iron. and Austenite is non-magnetic and norm-
-ally not stable at room temperature.
Austenite has a FCC structure.

(3) Cementite: It is a compound of iron and carbon, known chemically as iron carbide having the approximate chemical formula Fe_3C. It has orthorhombic crystal structure. It is a hard and brittle compound. Cementite is a magnetic phase at room temperature and becomes paramagnetic above 210°C. The steel with high amount of cementite has high hardness and so can be used for cutting tools

(4) Pearlite: It is intimate mixture of ferrite and cementite. It has a lamellar structure and consists of alternate plates of cementite and ferrite. Pearlite is the product of austenite decomposition by an eutectoid rxn at 0.8% carbon & at 723°C. Pearlite has the highest tensile strength amongst all room temp phases of iron-carbon phase diagram.

(5) Ledeburite: It is the eutectic mixture of austentite and cementite. It is formed at 1130°C and 3.3% carbon. Below 723°C, austentite of ledeburite transform to pearlite giving it a characteristic appearance under microscope.