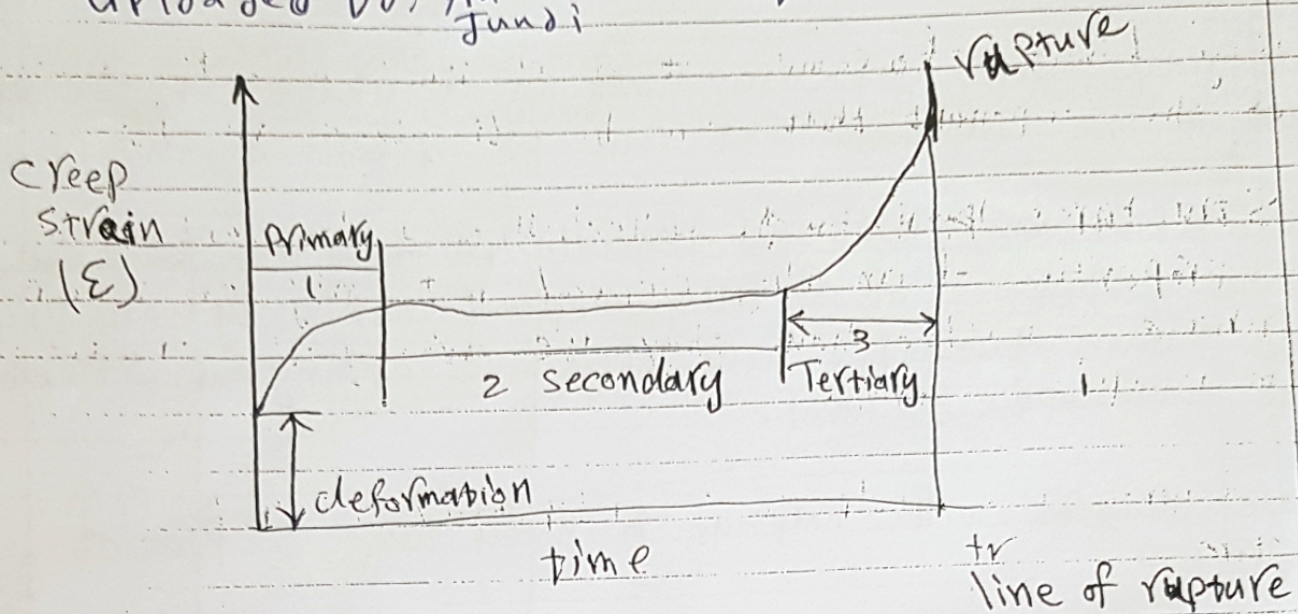




- ① Instantaneous deformation: mainly elastic
- ② Primary / transient creep: slope strain (ϵ) vs time decrease with time
- ③ Secondary / steady-state creep: Rate of straining is constant
- ④ Tertiary: Rapidly acceleration strain rate up to failure

Ch 9 & 10

Components Chemically Recognizable Species (Fe & C, Steel, H₂O)

Phases: a portion of a system that has uniform physical and chemical characteristics. And they are separated from each other by definite phase boundaries.

Single phase system is called homogeneous
System in two or more phase are mixtures heterogeneous

Solubility Limits

Solvent: host or major component in solution

Solute: minor component

Solubility Limit of a component in a phase

Solubility Limit of a component in a phase is the maximum amount of the component that can be dissolved in it.

* Micro Structures
* The properties of an alloy depend not only on proportion of the phase but also how they are arranged structurally at the microscopic level.

* Phase diagram will help us to understand & predict microstructure

* Equilibrium and Metastable States

* A system is at equilibrium if at constant temperature, pressure and composition the system is stable (not changing) with time.

* Equilibrium is the state that is achieved given sufficient time. But the time to achieve equilibrium may be very long. The state along the path to the equilibrium may appear to be stable. This is called a metastable.

* Phase Diagrams

* A phase diagram: graphical representation of combinations of Temp, pressure, composition or other variables.

* Phase diagrams show what phases exist at equilibrium and what phase transformations we can expect when we change one of the parameters of the system (T , P , C_{com})

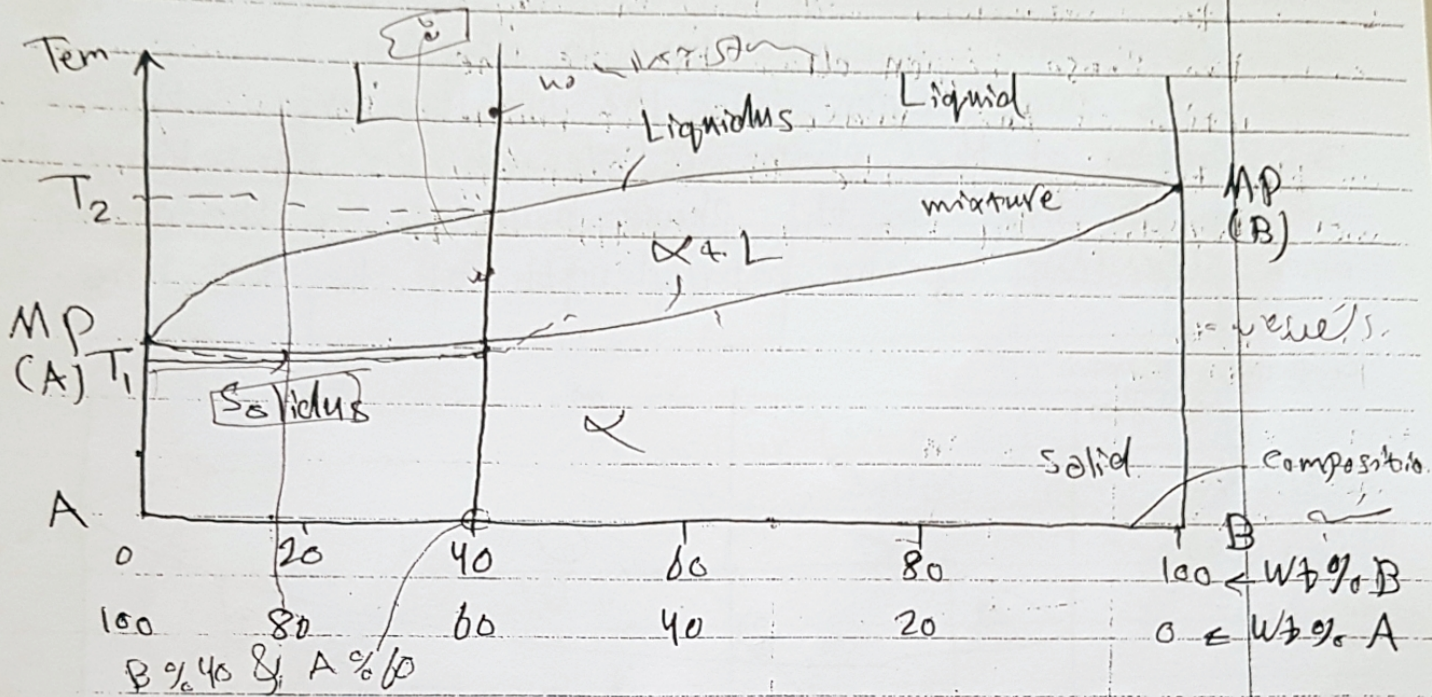
liquidus



لو انا عايز تدرج MA و MA

Binary Isomorphous Systems

Isomorphous Systems complete solid solubility of the two components



MP: Melting Point

Wt%: weight percent

If: $T > T_2 \rightarrow L$ Liquids have no microstructure 100% liquid
 $T_1 < T < T_2 \rightarrow \alpha + L$ L has microstructure
 $T < T_1 \rightarrow \alpha$ 100% Solid

Interpretation of phase diagrams

for a given temp and composition we can use phase diagram to determine:

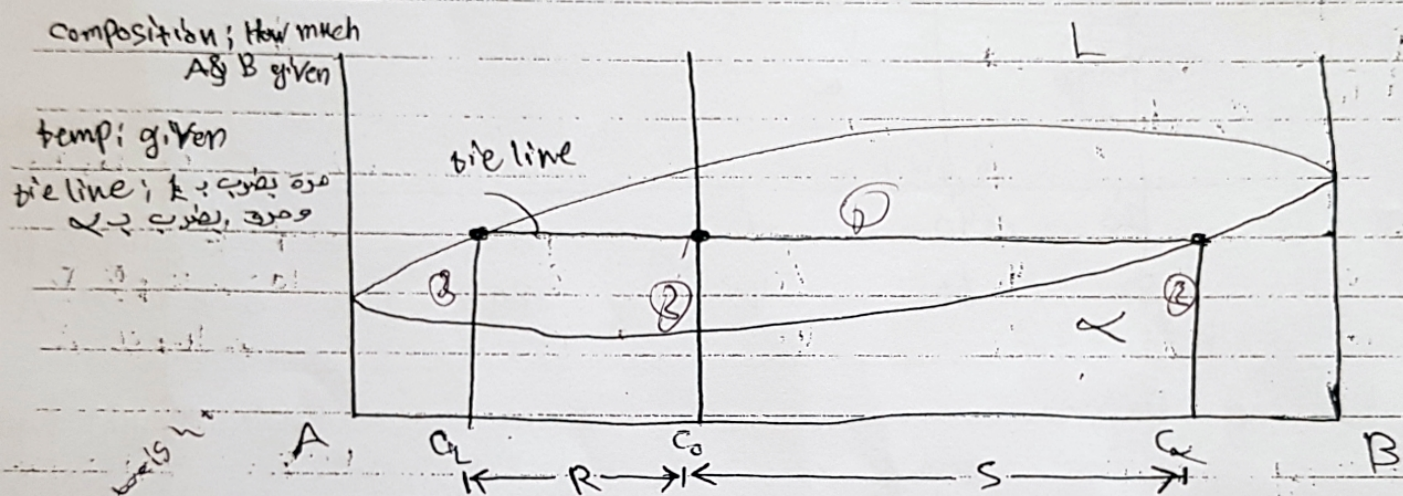
- 1) phases that are present.
- 2) composition of the phase.
- 3) Relative fractions of the phase.

كيس في الماي

* Lever Rule:

Finding of phases in a two phase Region.

1. Locate composition and temp in diagram.
2. In two phase region draw the tie line or isotherm.
3. Fraction of the phase is determined by taking the length of the tie line to the phase boundary for the other phase and dividing by the total length of the tie line.



$$W_L = \frac{S}{R+S} = \frac{C_\alpha - C_0}{C_\alpha - C_L}$$

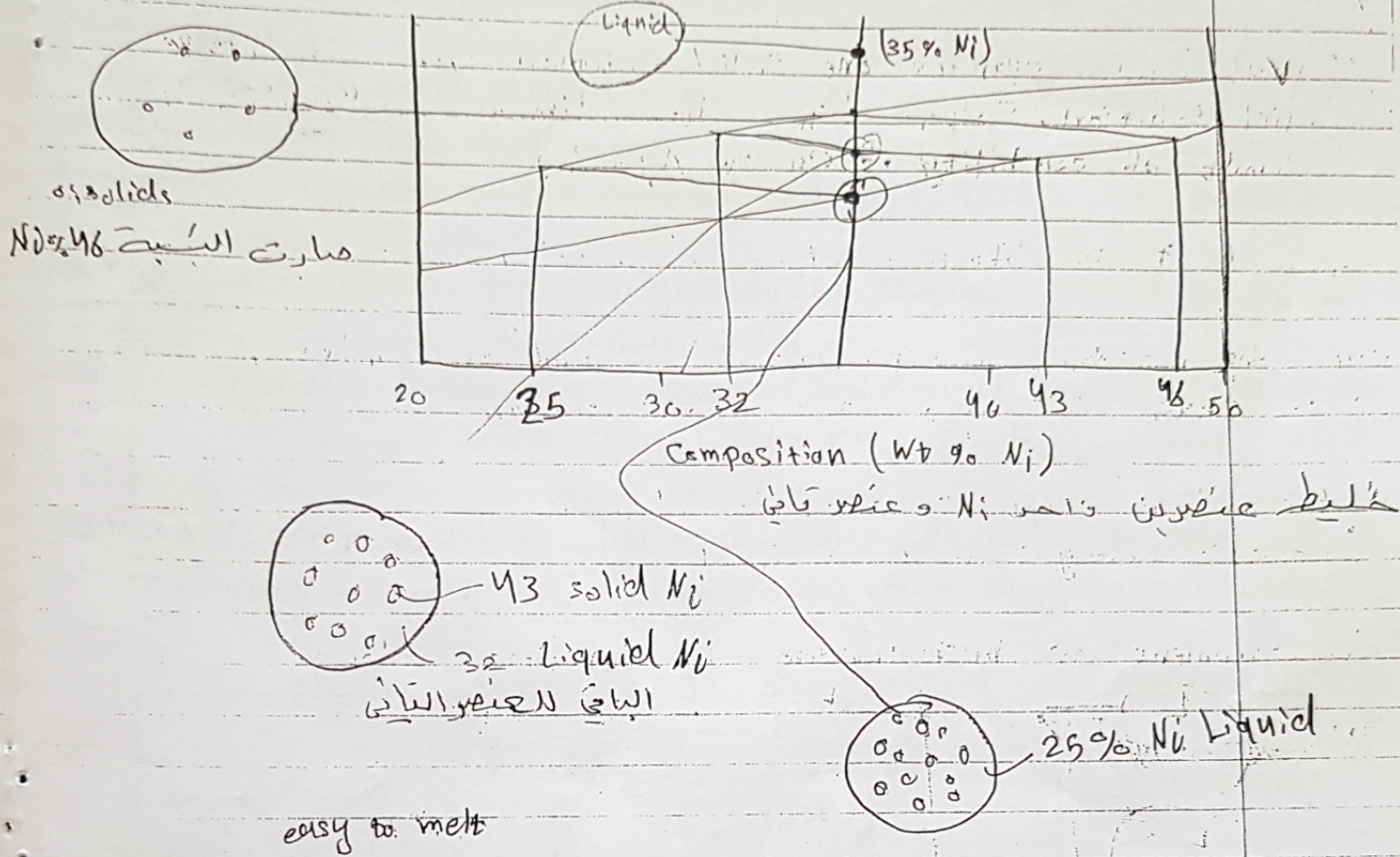
$$W_\alpha = \frac{R}{R+S} = \frac{C_0 - C_L}{C_\alpha - C_L}$$

$$W_L + W_\alpha = 1$$

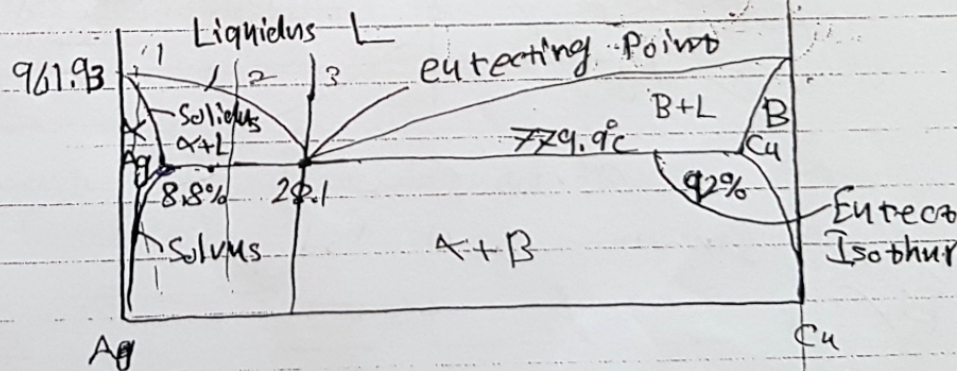
$$W_\alpha C_\alpha + W_L C_L = C_0$$

Call sub, Scale etc

* Development of Microstructure in Isomorphous Equilibrium



* Binary Eutectic Systems Alloys with limited Solubility



- ① L
↓
α+L
↓
α+β
- ② L
↓
α+L
↓
α+β
- ③ L
↓
α+L
↓
α+β

37

α & solid of Ag

eutectic point $\rightarrow$ α (L) $\rightarrow$ β (L) $\rightarrow$ hyper right

Two phase Region: $\alpha + L$, $\beta + L$, $\alpha + \beta$

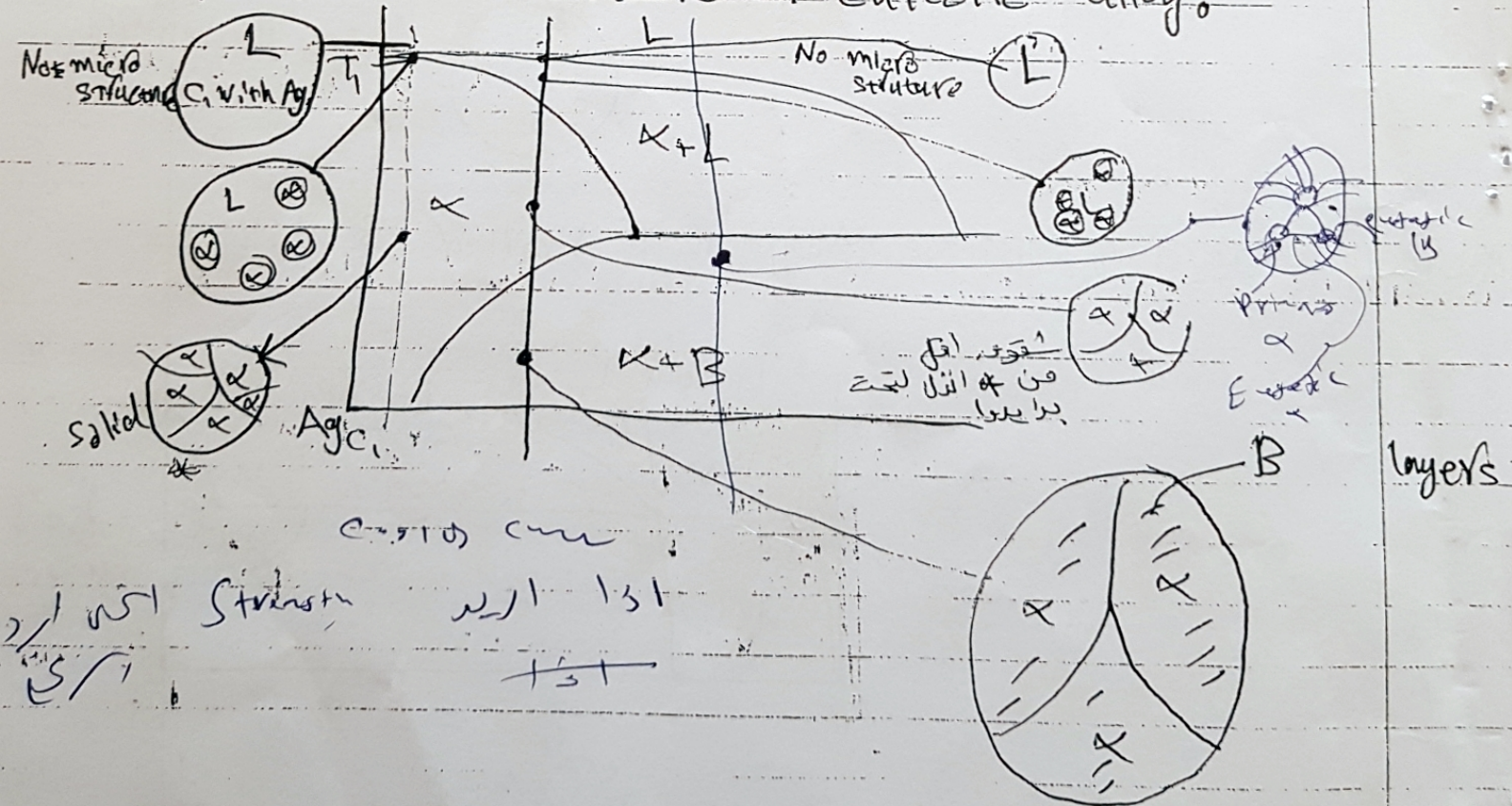
Solvus Line: Separates one solid solution from a mixture of solid solution. Solvus Line shows limit of solubility
 Limit of solubility of Cu in Ag = 8.8

from L to two different solids $\rightarrow$ (Eutectic Point) Eutectic Reaction

* Eutectic Reaction: Transition between liquid and mixture of two solid phase $\alpha + \beta$ at eutectic concentration C_e

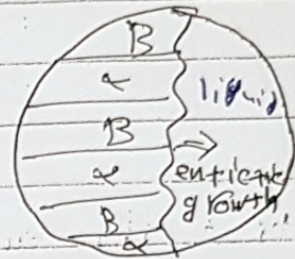
* the melting point of eutectic alloy is lower than that of the components
 (eutectic = easy to melt in Greek)

* Development of microstructure in eutectic alloy:

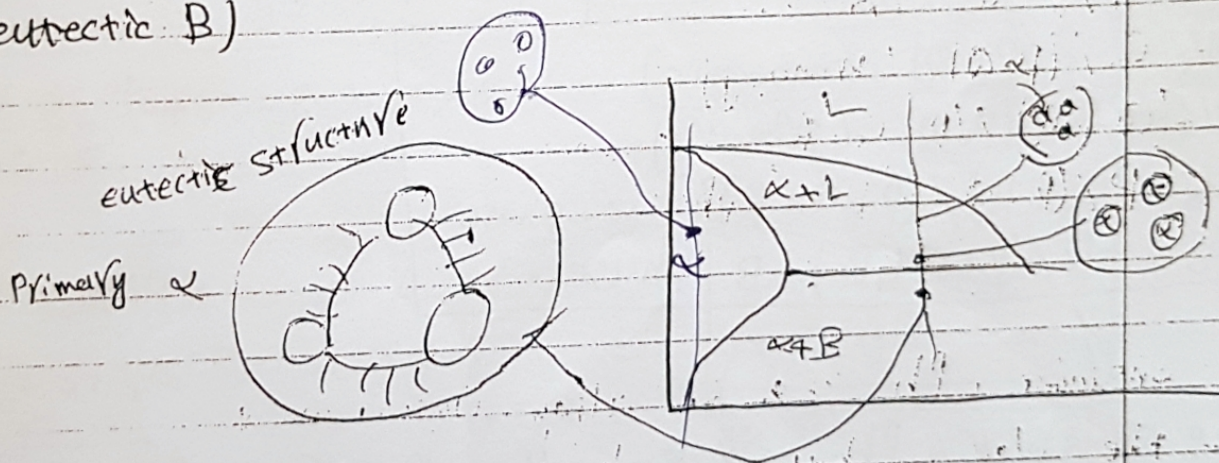


Development of microstructures in eutectic alloy

- Composition of α and B phases are very different eutectic
- Reaction involves redistribution of Pb and Sn atoms (slide 22)
- by atomic diffusion. This simultaneous formation of α and B phases result in a layered (lamellar) microstructure this is called eutectic structure

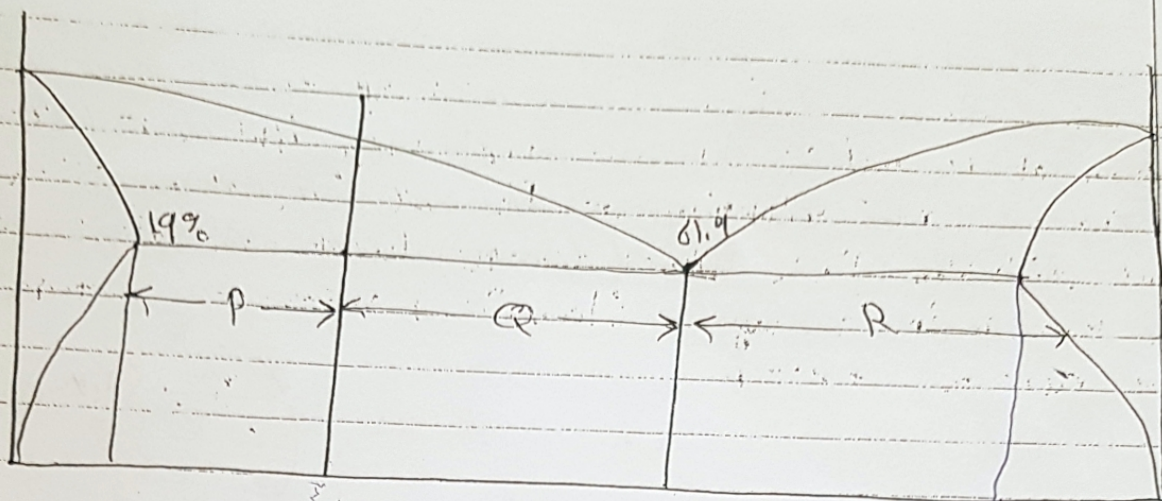


Primary α phase is ~~formed~~ ^{formed} in $\alpha+L$ region and eutectic structure that includes layers of α and B phase (eutectic α and eutectic B)



microconstituents: element of microstructure having a distinctive structure

Eutectic microconstituent forms from Liquid having eutectic structure (61.9% wt Sn) (slide 27)



We can treat the eutectic as a ~~separate~~ separate phase and apply Lever rule to find relative fractions of primary α (19% Sn) and eutectic structure (61.9 wt% Sn)

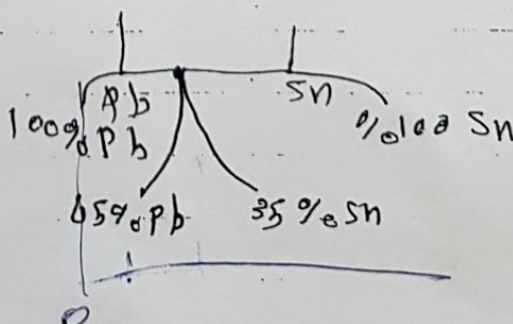
$$\begin{aligned}
 W_e &= P / (P + Q) \quad (\text{eutectic}) \\
 W_\alpha &= Q / (P + Q) \quad (\text{primary}) \\
 W_\alpha &= (Q + R) / (P + Q + R) \quad \alpha\text{-phase} \\
 W_B &= P / (P + Q + R) \quad B\text{-phase}
 \end{aligned}$$

Ex: Consider a Pb - 35% Sn alloy. Determine:

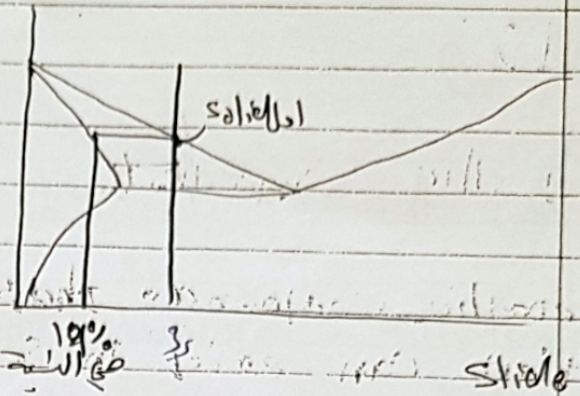
- if the alloy is hypo or hyper eutectic
- the composition of the first solid to form during solidification
- the amount and composition at each phase at 184°C
- the amount and composition at each phase at 182°C
- the amount and composition of each microconstituent at 182°C
- the amount and composition of each phase at 25°C

35% Pb Sn

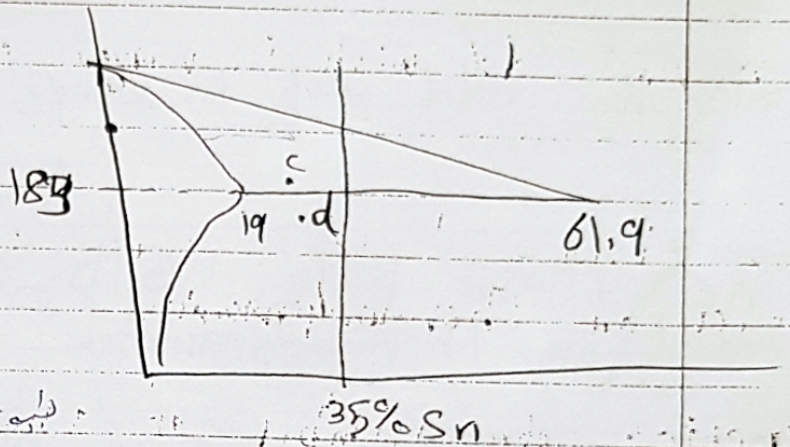
Q. hypo eutectic alloy



b) 14% Sn



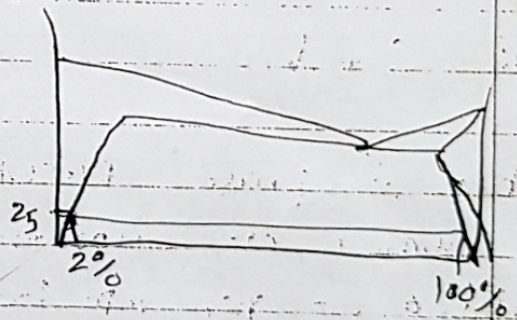
c) $\% \alpha = \frac{61.9 - 35}{61.9 - 19} \times 100\% = 63\%$
 $\% L = 37\%$



d) $\alpha = 19\% \text{ Sn}$, $B = 97.5\% \text{ Sn}$
 $\% \alpha = \frac{97.5 - 35}{97.5 - 19} \times 100\% = 80\%$, $\Rightarrow \% B = 20$

e) Primary $\alpha = 19\% \text{ Sn} \Rightarrow \alpha = 63\%$
 eutectic = $61.9\% \text{ Sn} = 37\%$

f) $\alpha = 2\% \text{ Sn}$, $B = 100\% \text{ Sn}$
 $\% \alpha = \frac{100 - 35}{100 - 2} \times 100\% = 66\%$, $B = 34\%$



Ch 10:

Intermetallic compounds

Intermetallic compounds that have precise chemical composition can exist in some systems.

Stoic & Non stoic with in range to Non

* The Phase Rule (Gibbs phase Rule) :

* Based on Thermodynamics

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* Predicts the number of phase that will coexist with a system at equilibrium.

$$P + F = C + N$$

P: Number of phases present.

C: The number of components.

N: Number of noncompositional variable.

N: 1 or 2 for Temp & Pressure.

N: 1 if $P = \text{constant}$ OR $T = \text{constant}$.

F: Number of degrees of freedom.

Number of external controllable variables (T, P, composition) which can be changed independently.

Ex 8

A: $P=1$

$C=2$

$N=1$

Compositional (wt%) C

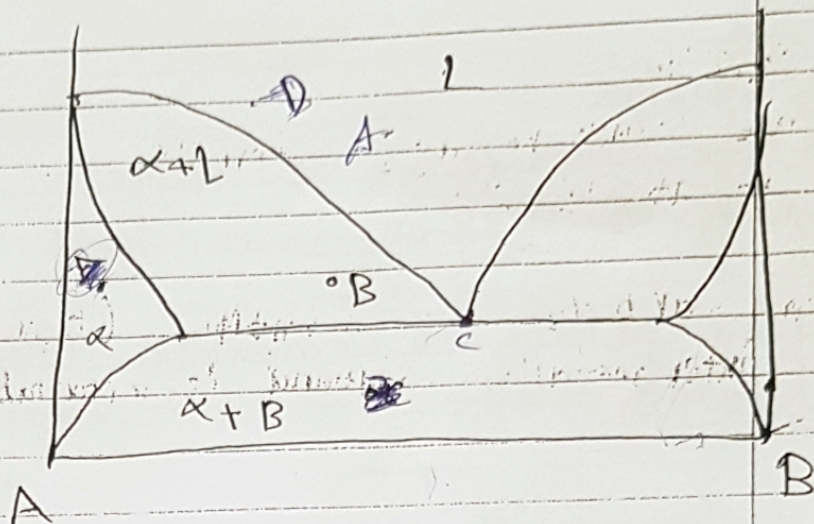
$P+F=C+N$

$1+f=3$

$f=2$

B: $f=1$

C: $f=0$ at compo



A: $C=2$

$P=1$

$N=1$

$f=2$

to completely describe the character of the alloy, you must describe 2 phases

you can change 2 variables without changing the state of phase in equilibrium

~~Ch 7: Iron-Iron Carbide (Fe-Fe₃C)~~

Iron-Iron Carbide (Fe-Fe₃C)

In their simplest form steels are alloys of Iron (Fe) & Carbon (C)

① α -ferrite - Solid Solution of C in BCC (Fe)

* Stable form of Iron at Room Temp

* max Solubility of C is 0.025 wt%

* Transforms to FCC γ -austenite at 912°C

② γ -austenite - Solid Solution of C in FCC (Fe)

* max Solubility of C is 2 wt%

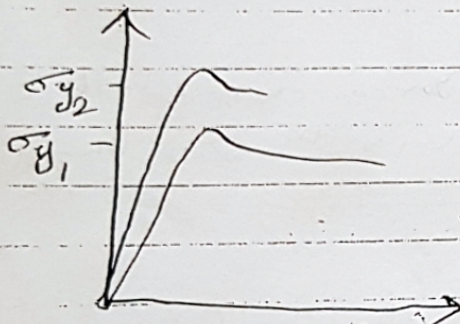
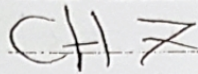
* transform to BCC δ -ferrite at 1395°C

Is not stable below the eutectoid Temp (727°C) unless cooled rapidly.

③ δ -Ferrite

- * Same structure as α -ferrite.
- Melts at 1538°C

* Iron Carbide or Cementite (Fe_3C)
This intermetallic compound is metastable



زيادة في قوة من خلال
منطقة التصلب σ_y Stress Hardening

بعد ما نخلص rolling بعد في Stress حتى لما أبعده بالحرارة يتخلص منها
ال Stress هو $\frac{F}{A}$ يرفع درجة الحرارة فيتمدد ويتزايد A ويتقلد ال stress لحرارة يتم
Release stress

هو تعامل مع التصلب بدون استخدام الحرارة (في مثلها الخرافة)
Cold Work: heat treatment بعد Cold Work تتخلص من Stress معين مثلاً

Annealing: عند 60% من melting point بعد في كبير بطريقه فيتمدد في ما يدي
Forging: annealing

Anisotropic (اليد 4.6) ال forging ال سطح يزداد الشد من الداخل

الكلب اكد بعد 1 CH3

Control of Annealing:

(A) Recrystallization Temp.

- ① Recryst. Temp. decreases when ↑ Cold work increase. لا يزيد C.W. بل يقل
- ② A small original cold work grain size reduces the recrystallization Temp. by providing more sites ثقل حراري أقل thickness



- ③ Increasing the annealing time reduces the recryst. temp. transition sites أكثر فالحرارة تستغل أسرع بالتالي يبدى حرارة أقل وفي الغاز يزيد الوقت
- ④ Higher melting point alloys have higher recryst. temp.

(B) Recrystallised Grain Size

Annealing temperature or annealing time reduces the grain size