

* Materials science.

CH.1

* Materials types

1. Metals (Fe "pure Iron", Al, Mg)

Fe + C "Alloy".

2. Plastic (polymers).

3. Composite material (wood)

4. Ceramics

5. Advanced materials.

→ self-Reading - Semi conductors.

- Biomaterials.

- Nano-materials.

* Properties

1. Mechanical properties "strength, Ductility, hardness".

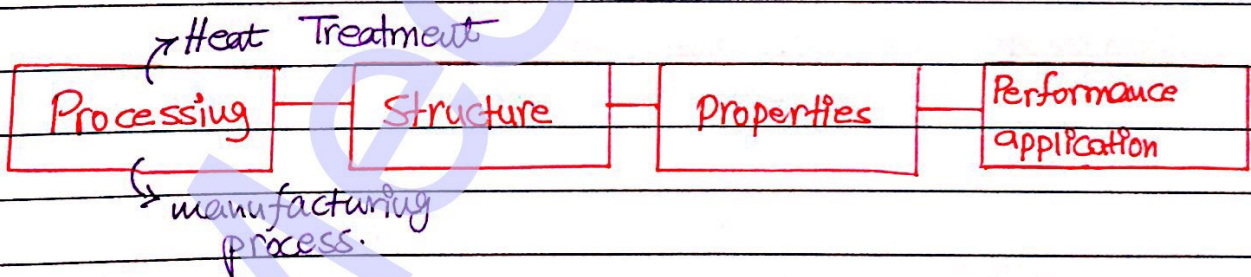
2. Thermal properties

3. Electrical

4. Chemical "Deteriorative"

5. Physical "Optical" → "Density, weight, color".

6. Magnetic



* Identify → Al (how) *

Diagram

* very light + cheap

* not shiny

* melting point 660.3°C

* no sparks

* Not magnetic

* easy to scratch

* doesn't rust.

Assignment B Requirements of making a Basketball

1. Leather } * set of requirements
2. Rubber } according to the above diagram.

→ Example for each type of materials "tables ch.1".

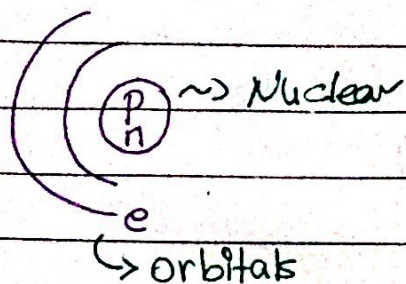
Yahya Alhayek

Scanned by CamScanner

* CH. 2:

* Atom + Structure

→ Periodic table bonding.

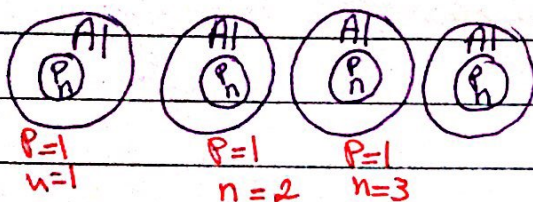


* $P = +ve$ (1.6×10^{-19})

* $n = \text{Neutral}$

* $e = -ve$

Al : metal



* Isotopes

* Isotopes are atoms for the same element which has the same no. of protons and diff. no. of neutrons.

Isotopes / Isotopes

* weight of electrons "Negligible".

* atomic mass = mass of $(e + p + n)$

$$= (\text{mass of each proton} \times \text{\# No. of protons}) +$$

It differs → (mass of each $n \times$ \# No. of neutrons.)
(Isotopes)

→ atomic weight.

* Atomic mass $\Rightarrow$ weighted avg. for Isotopes $\Rightarrow$ atomic weight
[g/mol]

* mole of atoms = Avogadro's number
 $= (1 \times \text{mole})$.

* CH.2 *

atomic mass : $[g/mol]$

atomic number = # No. of protons = # No. of electrons.

** Quantum mechanics "Electron configuration"

* 4-quantum numbers?

1. Shells: K L M N $\rightarrow$ 1, 2, 3, 4 ---

2. SubShells: s p d

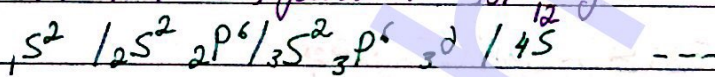
3. from low Energy $\rightarrow$ to high Energy.

4. Orientation of configuration.


$$\begin{array}{r} 5P^{(10)} \\ (2) \overline{5P^{(6)}} \\ \overline{5^{(2)}} \end{array}$$

* ex. 8

* Electron configuration for Mg:



#Valance electrons 8

الكرخفان الحمار الأسي

Periodic Table 8

	1	2	3	4	5	6	7	8
Electron Negativity ↑	H	Mg	Al	C		O	F	Nobel gases
(+)								
↓								
↓	(F)							

* $(1, 2, 3, 4) \sim (e^-, \bar{\nu}_e)$

* $(5, 6, 7) \sim (\bar{e} | \bar{a})$

$\xrightarrow{+}$ Electron negativity.

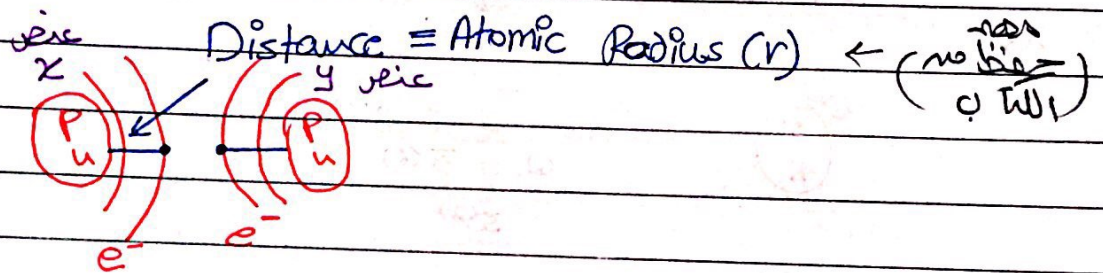
* توزيع الألفوفان في الجدول التالي كما عدد الألفوفان
الكميات الأخيرة

* **Electron Negativity**: tendency of the metal to acquire electrons.

تزداد (left to right) وبتناقص (Bottom to top) (0.7 → 4)
 تزداد

* **Bonding types**

- Primary
 - Ionic
 - Covalent
 - Metallic
- Secondary
 - Van der Waals
 - Hydrogen



1. attractive Force

2. Repulsive Force

1. **Ionic Bond**

NaCl

(واحد فقط واحد بسيط)

1. It involves electron transfer.



MS+ المسافة في الجزيء / الجزيء

tendency

2. High difference in electron-negativity.

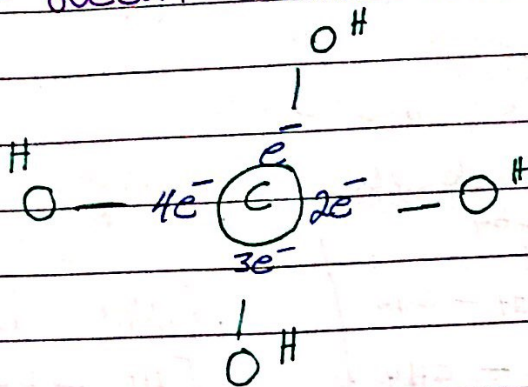
* Primary bondings stronger than secondary bonding.

3. Examples, characteristics. From Book.

Yahya Alhayek

2. Covalent bond:

1. It doesn't involve electron transfer.



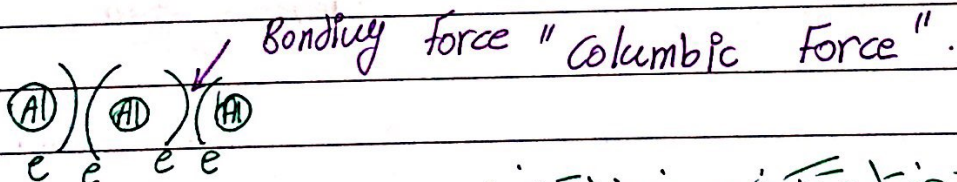
2. Examples, characteristics.

3. Low diff. in electron negativity.

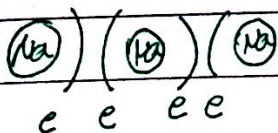
$$\% \text{ Ionic character} = 1 - \exp^{-0.25(\chi_A - \chi_B)^2}$$

→ χ Electron Negativity.
AIB 8 Elements; (H₂O for ex.).

3. Metallic [1, 2, 3 groups], (الفلزات فقط).



* للفلزات فقط. وتكون بين ذراتها
* *beinmet*



* Covalent → Directional.

* Metallic, Ionic → Non-directional.

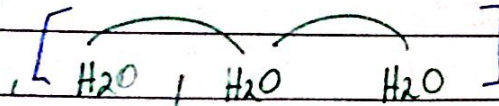
* Secondary Bonding

1. van der Waals

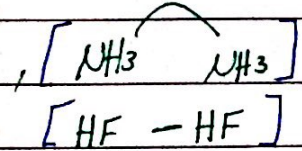
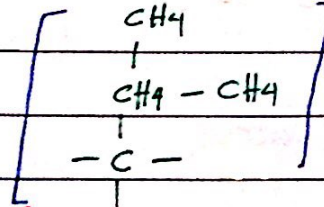
القوة بين الجزيئات الضعيفة



→ covalent



Between molecules. → $(H-N-F)$

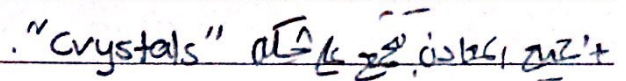


Dipoles

attractive & Repulsive Force.

Bonding Force "Coulombic Force".

Fig 2.8 - 8th Edition.



"Solidification"

* liquid

Solid *

1. * Crystal & atomic arrangement. "Metals"

→ crystal structure. $\leadsto$ "crystalline material"

2* NO-crystal & Random Packing. "Polymers, Plastics"
↳ Isomorphous.

* lattice & crystal "Atomic arrangement" in 3D. جایگاه اتمی - ذرات
 ↳ Unit cell & Building Block "repetitive unit". لattice جزیء
 in a lattice.

(Structural Systems)

Cube ملاک و سبب اختلاف

١- اختلاف توزيع الزلازل في الـ

Packing of crystals

~> Dense = regular "crystalline structure".

~> Non-dense = random. "Amorphous structure".

Table (3-2) "خواص ذرات و جاذبه"

1. Cubic.

2. Hexagonal.

3 - Crystals structures

1. FCC

2. BCC

3. HCP

* characteristics = ?!

BCC $\left\{ \begin{array}{l} \rightarrow \text{corner atoms} \\ \rightarrow \text{Body atoms} \end{array} \right.$ without face atom.

* Face atoms share $(\frac{1}{2})$ atom for each face.

BCC Body centered cube

* atoms $\left[\begin{array}{l} \text{corner atoms} + \text{body} \\ \text{"Internal"} \end{array} \right. + \text{Face}$

$$\text{BCC} = 8 \times \frac{1}{8} + 1 = 2 \text{ atoms}$$

$\rightarrow 8 \text{ corners; share } (\frac{1}{8})$

* coordination no. = no. of touching atoms.

* APF & Atomic packing factor

$\rightarrow$ total volume = volume of the atoms + volume of vacancies.

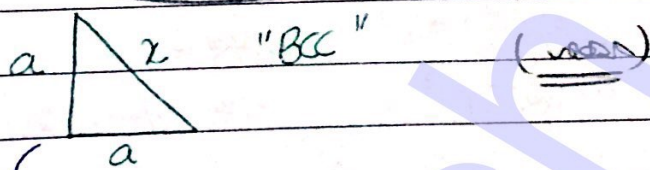
$$\sim \text{APF} = \frac{\text{Volume of the atoms}}{\text{volume of the unit cell}} \Rightarrow \frac{\left(\frac{4}{3} \pi r^3 \right) + 2 \text{ atoms}}{= \text{atoms} + \text{vacancies.}}$$

$$\begin{aligned} a \times b \times c &= \\ \rightarrow a = b = c &\Rightarrow (a^3) \\ \text{Cube} & \end{aligned}$$

no. of atoms in the unit cell.

$$\ast \text{APF}_{\text{BCC}} = \frac{2 \times \frac{4}{3} \pi r^3}{a^3}$$

	BCC	FCC	HCP
# of atoms	2	4	6
coordination No.	8	12	12
APF	0.68 (68%)	0.74 (74%)	0.74
a & R Relation	$a = \frac{4R}{\sqrt{3}}$	$a = 2\sqrt{2}r$	X
Example	Cr	Al	Mg



$$a^2 + a^2 = x^2$$

$$x = \sqrt{2}a$$

* another one

$$(\sqrt{2}a)^2 + a^2 = (4R)^2$$

$$\rightarrow \left(a = \frac{4R}{\sqrt{3}}\right)$$

$$\ast \text{APF} = \frac{2 \times \frac{4}{3} \pi r^3}{a^3} = \frac{2 \times \frac{4}{3} \pi r^3}{\left(\frac{4R}{\sqrt{3}}\right)^3} = 0.68 = 68\%$$

* APF $\neq 1$ (1) no. of atoms in unit cell

* FCC Face-centered cubic.

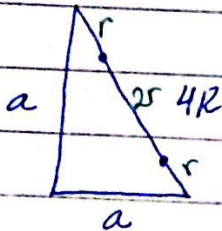
* of atoms = corner + Face + body = 0

$$\text{FCC} = (8 \times \frac{1}{8}) + (6 \times \frac{1}{2}) = 4$$

~> coordination Number => youtube "it needs imagination".

* APF for FCC = $\frac{\text{Volume of the atoms}}{\text{Volume of unit-cell}}$

** Relation between a & R



$$\begin{aligned} a^2 + a^2 &= (4R)^2 \\ \Rightarrow a &= 2\sqrt{2}R \end{aligned}$$

$$\text{APF} = \frac{(4) \left(\frac{4}{3}\right) \pi R^3}{a^3} = \frac{(4) \left(\frac{4}{3}\right) \pi R^3}{(2\sqrt{2}R)^3} = 0.74 = 74\%$$

26% vacancies

* HCP Hexagonal closed-Packed.

* of atoms = body + corner + Face

$$3 + (2)(6)\left(\frac{1}{6}\right) + 2\left(\frac{1}{2}\right) = 6 \text{ atoms}$$

=> Table (3.1) ndp

Yahya Alhayek

* Polymorphism allotropy

- * change of crystal structure with temperature & Pressure; for ex
- * Iron + Titanium has.

* Theoretical density . دال جال

$$\rho = \frac{m}{V} = \left[\frac{g}{cm^3} \right] = \frac{nA}{V_c N_A} \quad \text{Fcc, Bcc, Hcp}$$

- * n = no. of atoms per unitcell (2, 4 or 6)
- * A = Atomic mass $\Rightarrow [g/mol]$
- * V_c = volume of the unitcell (a^3)
- * N_A = Avogadro's number 'conversion'.

$$1 \text{ m} \Rightarrow 10^9 \text{ u}$$

$$1 \text{ m} \Rightarrow 10^2 \text{ cm}$$

$$1 \text{ cm} \Rightarrow 10^7 \text{ u}$$

$\Rightarrow$ Density of copper

$$\rho = \frac{(4) \overset{\text{atom}}{(63.5)} \frac{g}{mol}}{a^3 (6.023) (10^{23}) \frac{\text{atom}}{mol}}$$

$$= \frac{(4)(63.5)}{(252 (0.128) (10^{-7})^3 (6.023 \times 10^{23}))} = 8.8 \text{ g/cm}^3$$

From nano to cm ($\times 10^{-7}$)

* Crystallographic 8

Directions

x	y	z	
a	b	c	, a=b=c=1 assumption.
(1/2)	1	0	$\Rightarrow$ no projection on z-direction
1	2	0	(Reduction).

خروجی از این محاسبات

$\Rightarrow$ Direction $[1, 2, 0]$

Planes

$\Rightarrow$ where does it intersect

x	y	z	
∞ لا تقاطع	1	$(\frac{1}{2})$	$\Rightarrow$ Intersects.
0	1	2	$\Rightarrow$ قطع
1	Reduction		$(0 \ 1 \ 2)$ plane

از این محاسبات خروجی

* Stacking sequence 8

FCC ; HCP

→ APF = 0.74

Coordination number = 12

* Stacking sequences

→ (repeated 3-layers) "FCC" ; (ABCABC---)

→ (repeated every 2-layers) "HCP" ; (ABAB---)

[* Anisotropy: Directionality of properties. (depends on direction).
* Isotropy: The properties are Independent from directions.

* x-ray diffractions

~> To examine the type of crystal structure (FCC, BCC)

↳ optical microscope. ✗

↳ x-ray diffraction. ✓

technique

→ 18 wave length.

→ A: Amplitude ~ (مساحة).

* Diffraction conditions

• يجب ان يكون المسار A مساويا للمسار B

• المسار A والمسار B

* Diffraction $\Rightarrow A + A = 2A$
تداخل

* Subtraction $\Rightarrow A - A = 0$
الغاء

تداخل
غير متساو

$$\sim n\lambda = \overline{SQ} + \overline{QT}$$

' n = diffraction order " Integer No. "

$$n\lambda = d_{hkl} \sin\theta + d_{hkl} \sin\theta$$

↳ Amplitude المساحة

$$= 2d_{hkl} \sin\theta$$

$$d_{hkl} =$$

$$\frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

المساحة
المساحة

or write it in terms of
(r). , FCC BCC .

~> Scattering Event

atoms

فترات التداخل

$$\sim \theta \equiv \text{angle}$$

~> $2\theta \equiv$ diffraction angle.

~> Indices of the plane or miller Indices
or (H K L) Indices. (the same)

x-ray waves analysis

1. BCC: The sum of the Indices ($h+k+l$) must equal an even number.
2. FCC: all of the indices must be Even or Odd (h, k, l).

Case study

Prove the above "2-assumptions" of FCC & BCC.

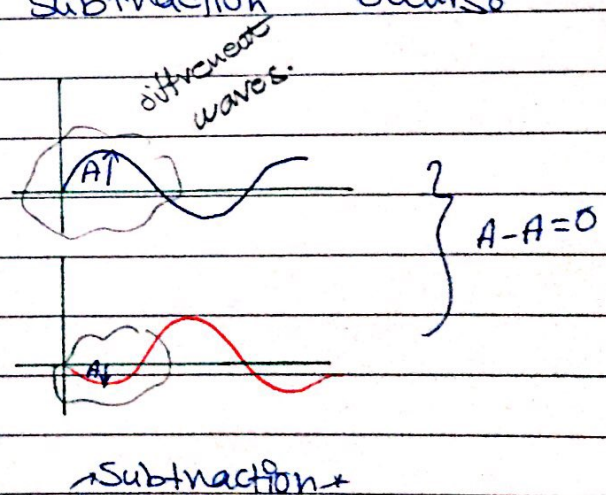
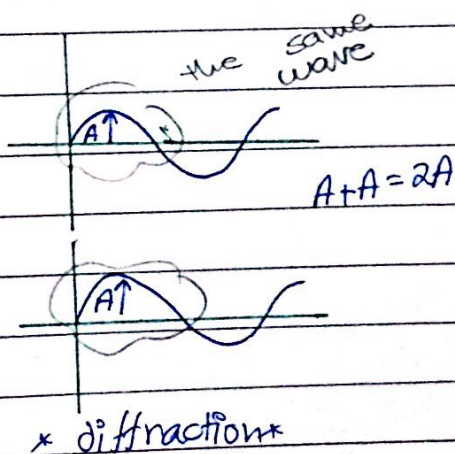
→ dead line 8 27-12-2016 / bonus 5 marks.

⇒ Expected question

Draw the diffraction Pattern!! ($A, 2\theta$)

Amplitude $\leftarrow$ x-axis $\rightarrow$ diffraction angle y-axis.

how diffraction and subtraction occurs



* Prob. 3.62 8

metal

BCC

diffraction angle (321) at 27°
plane
hkl

$$\sim n=1, \lambda = 0.071 \text{ nm}$$

$$1. d = ?!$$

$$2. \text{atomic radius} = ?!$$

$$* a = \frac{4R}{\sqrt{3}}$$

$$n\lambda = 2d_{hkl} \sin \theta$$

$$2\theta = 27^\circ$$

$$\theta = 13.5^\circ$$

$$1. d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

$$\sim (1)(0.071)(10^{-9}) = 2 d_{hkl} \sin(13.5^\circ)$$

$$\therefore d_{hkl} = 1.52 \times 10^{-10}$$

$$\sim (1.52)(10^{-10}) = \frac{a}{\sqrt{9+4+1}}$$

$$a = 5.689 \times 10^{-10}$$

$$2. R = 2.464 \times 10^{-10} \text{ m}$$

* Prob. 3.64 8

 α -Iron

diffraction pattern

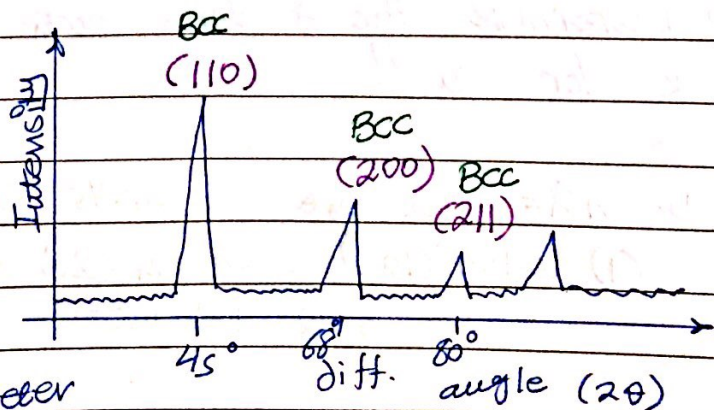
$$\lambda = 0.154 \text{ nm}$$

$$d = ?!$$

$$a = ?!$$

lattice parameter

$$\sim n=1$$



$$n\lambda = 2d \sin \theta$$

$$2\theta = 45 \Rightarrow \theta = 22.5^\circ$$

$$(1)(0.154)(10^{-9}) = 2d \sin(22.5)$$

$$1. d_{hkl} = 2.0121 \times 10^{-10}$$

$$d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

* for $n=1$

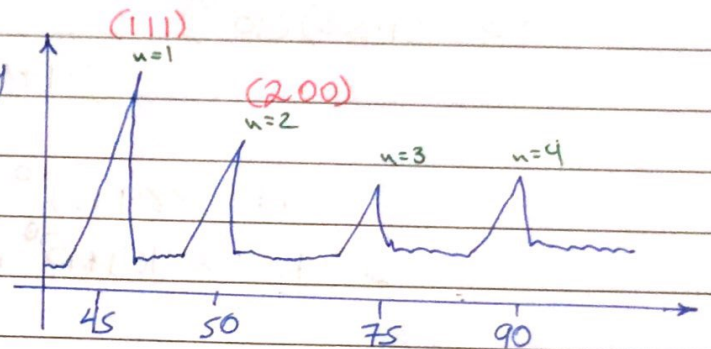
$$2.0121 \times 10^{-10} \times \sqrt{1^2 + 1^2 + 0^2} = a$$

$$2a = 2.85 \times 10^{-10} \text{ m}$$

* prob. 3.668

First four peaks of x-ray diffraction for Cu (FCC)

$$\lambda = 0.154 \text{ nm}$$



a. Index the peaks?!

b. Determine the d for each peak?!

c. R for Cu?!

$$n\lambda = 2d \sin \theta$$

$$2\theta = 45 \Rightarrow \theta = 22.5^\circ$$

$$(1)(0.154)(10^{-9}) = 2d \sin(22.5)$$

$$d = 2.0121 \times 10^{-10}$$

$$d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

$$\Rightarrow (2.0121)(10^{-10}) \times \sqrt{1^2 + 1^2 + 1^2} = a$$

$$a = 3.49 \times 10^{-10}$$

$$a = 2\sqrt{2} r$$

$$r = 1.232 \times 10^{-10} \text{ m}$$

Imperfections in solids. $\begin{matrix} \rightarrow \text{FCC} \\ \rightarrow \text{BCC} \\ \rightarrow \text{HCP} \end{matrix}$

* Why we make alloys?!

→ to achieve the required mechanical properties.

* Crystalline defects = Imperfections = Lattice irregularity.

1. Point

2. Line

3. Plane

4. Volume $\equiv$ lattice

* Types of Imperfections.

1. Point

2. Line

3. Area

- a. Vacancy: atomic site but is not occupied by an atom.
 b. Interstitial: not an atomic site but is occupied by an atom.
 c. Impurities

(os ~) * Distortion of planes yielded by the imperfections.

$$N_v = N \exp\left(-\frac{Q_v}{kT}\right)$$

N_v : Number of vacancies
 N : total no. of atomic sites
 Q_v : activation energy
 k : Boltzmann's constant
 T : in Kelvin = $^{\circ}\text{C} + 273^{\circ}$

"given"

→ no. of allowable vacancies for certain sites at certain temperature.
 Just below the melting (T)

* Ex 8

(مسألة) الجواب

$$\Rightarrow V = 1 \text{ m}^3, \rho = 8.4 \text{ g/cm}^3, A_{\text{Cu}} = 63.5 \text{ g/mol}, Q_e = 0.9e \text{ e}^-/\text{atoms}$$

$$T = 1273^\circ \text{K}, N_A = 6.02 \times 10^{23} \text{ atoms/mole}, k = 8.62 \times 10^{-5}$$

$$* \rho = \frac{nA}{V_e \text{ Avo.}}$$

$$1 \text{ m} \rightarrow 10^2 \text{ cm.}$$

$$1 \text{ m}^3 \rightarrow 10^6 \text{ cm}^3.$$

$$n = \frac{\rho V_e \text{ Avo.}}{A}$$

Yahya Alhayek

* Imperfections

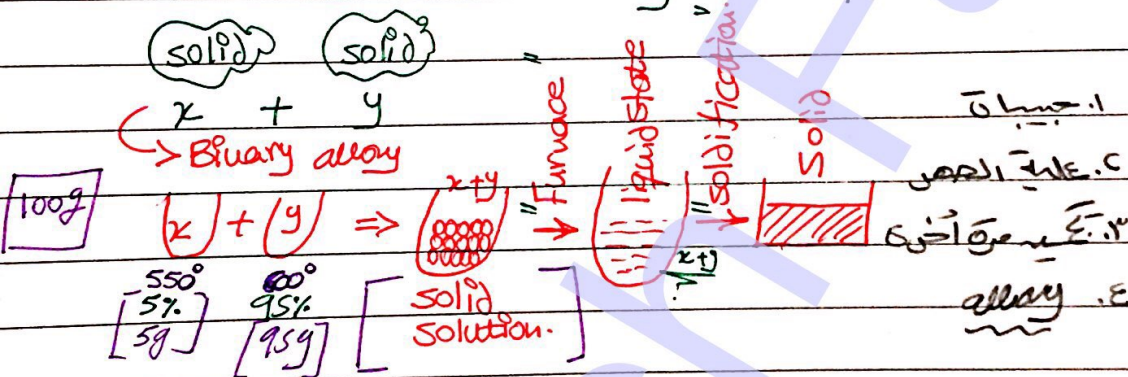
1. Point $\begin{cases} \rightarrow \text{vacancy} \\ \rightarrow \text{Self-Interstitial} \\ \rightarrow \text{Impurities} \end{cases}$
2. Line

3. Plane/Area
Volume.

** Impurities + alloying: $\rightarrow$ (المزيج)

$$x + \frac{y}{100} \rightarrow 10\% \rightarrow 20\%$$

* alloying $\Rightarrow$ solubility (الذوبان).
related directly to Temperature.



(ex.) $\rightarrow$ (610°C) $\rightarrow$ (المزيج) $\rightarrow$ (المزيج)

$\rightarrow$ x host material (المزيج).

* atoms of y go to vacancies of element x.

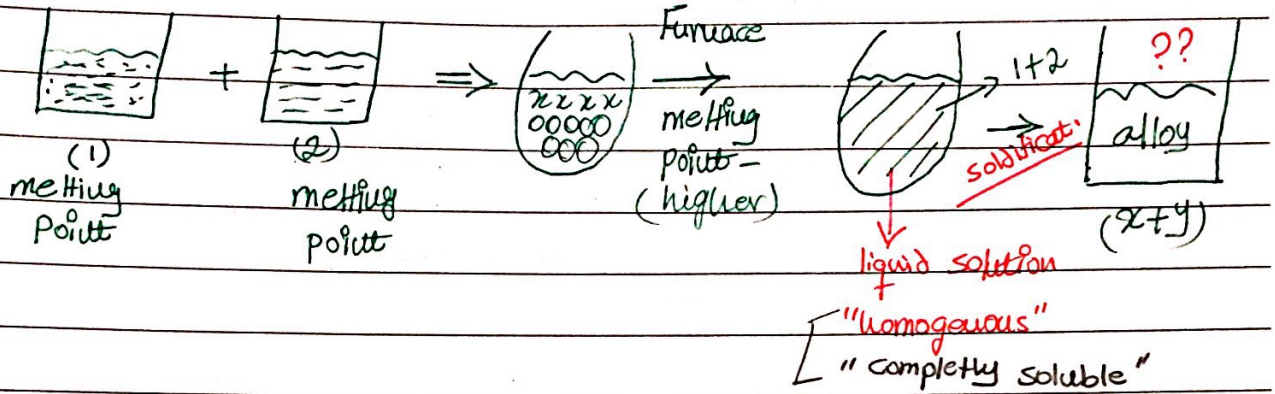
* solubility in liquid state $\Rightarrow$ complete.

* (المزيج) $\rightarrow$ (المزيج)
المزيج
المزيج

2- Elements or more.
 * Impurities "Binary alloys"

alloying

(solubility $\rightarrow$ solidification)



1. Solubility in liquid state is complete.

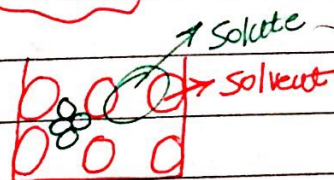
2. Solubility in solid state is 8

- Solubility Effects & Conditions
1. Crystal structure.
 2. atomic radius.
 3. Electronegativity.
 4. Valence electrons.

1. Complete.
2. Partial.
3. Insoluble.

Solute

Solvent



"host atoms"
 higher concentration.

* Solute *
 * Vacancy *
 * Missing atom *

* Identification of solubility

1. The same crystal structure "Bcc, Bcc" ; "Fcc, Fcc"

2. Atomic Radiuses approximately the same (0.127) (0.125) 0.001 nm difference

check it = ?

3. (c/c)
4. (c/c) or (host larger than solute).

* Partial
 * Insoluble $\leftarrow$ alloy $\rightarrow$ 2 phases +

* weight Percent, $C \equiv$ Composition

(نسبة وجود العناصر)

$$C_1 = \frac{m_1}{m_1 + m_2} \times 100\% \quad / \quad C_i = \frac{m_i}{m_i + m_{i+1} + m_n \dots}$$

(First mass) $\leftarrow$

$$= \frac{m}{\text{total mass}}$$

$$n = \frac{\text{mass}}{\text{Molar mass}} \equiv \text{No. of moles.}$$

$$= \frac{58}{55.5 \text{ g/mol}} = 1 \text{ moles}$$

* (2) Dislocations - Linear Defects. (1-D)

Types

25.10.2016

1. Edge

2. Screw

3. Mixed

* Burger Vector & Distance between 2-planes.

* Edge Dislocation line and burger vector $\perp$.

* Screw Dislocation line and burger vector $\parallel$.

* Mixed.

* Term of dislocations (dark lines) in titanium alloy

↳ Electro-Microscope:

"Transmission"

* Dislocation causes.

* Burger vector must be the same for all planes in the unit cell.

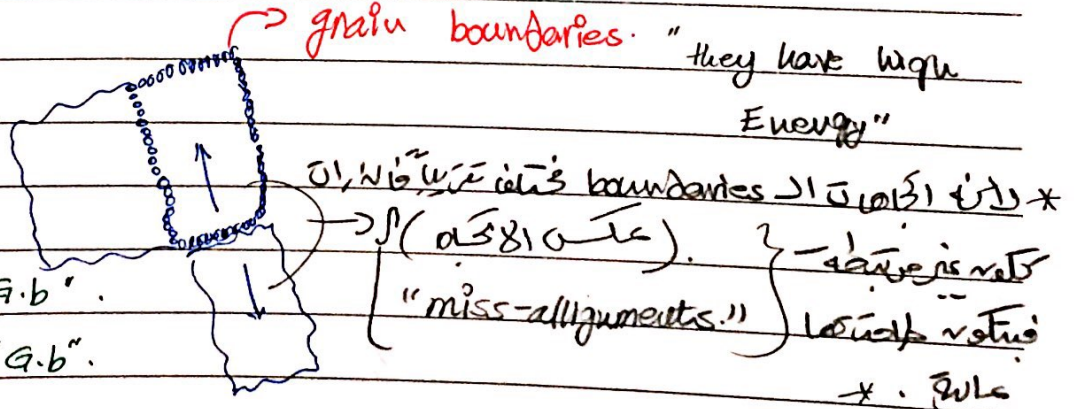
(3) - Interfacial defects "Surface defects".

1. External surfaces.
2. Grain boundaries.
3. Twin boundaries.

(1.) Surface atoms have high energy, because it doesn't bond with other atoms, so it will shrink into the surface.

(2.) Difference in solidification orientation.

- high angle "G.b".
- Small angle "G.b".



↳ tilt boundary & twist boundary. Small angles

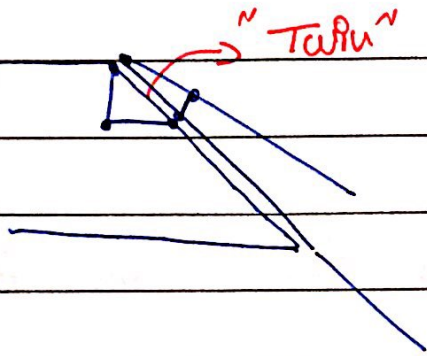
Important "mid"

⇒ Case-study: why tilt boundary related to edge dis. and twist boundary related to screw dis.?

* Deadline: 25-11-2016

"P15"

(3.) Twin boundaries



(annealing)

- Heat treatment $\rightarrow$ annealing
- Mechanical load.
- Shear Force.

* Mirror

* Annealing.

* Mechanical Force.

* Volume "lattice defects" 8

1. Cracks

2. Pores

3. Vibration

(نقصات الشبكة).

* Types of microscopes + microscopes examination + Grain size calculation.

~> direction + phase + Volume ; Defects => "Transmission electron microscope + Scanning electron microscope".

~> "Optical microscope" (depends on light) -> Surface (grains) only

* Optical microscope 8 depends on light "Electricity".

1. Reflection. (انعكاس)

2. Transmission.

1. انعكاس الضوء على السطح
2. انتقال الضوء (المرور)
Mirror surface 8 انتقال الضوء (المرور)
(Eye-lens) 8 انتقال الضوء

1. إعداد السطح المرآة

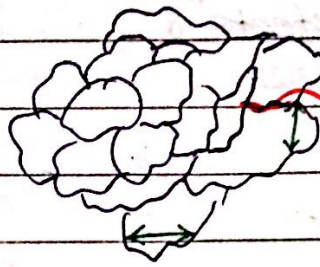
1. إعداد السطح المرآة

2. إعداد السطح المرآة

3. إعداد السطح المرآة

~> using "Diamond paste or Al₂O₃".

(Irregular
Shape)



← * Grain *

→ grain boundary.

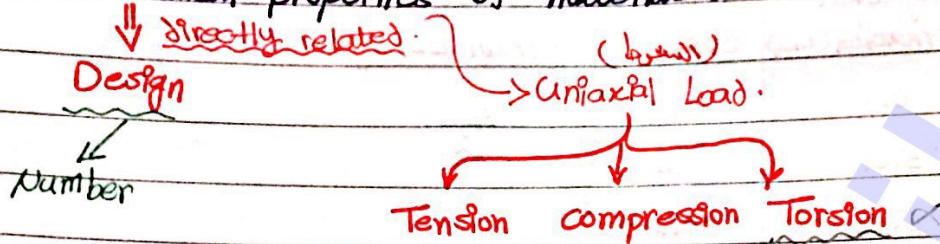
* avg grain size (μm), (nm)⁸, "we take avg. since it is not regular shape."

1. ASTM

2. Intercept method

(Intercept)
] self-Reading "d"

* Mechanical properties of materials



* I have to know the maximum stress that the specimen can hold before fracture to prevent "Failure".

* UTM = Uniaxial tensile testing.

* material geometries

→ mild steel.

* geometries

1. Circle.

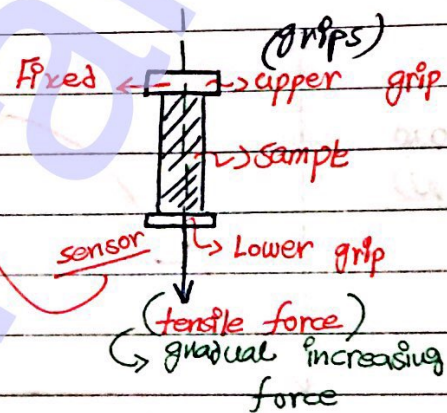
→ $A = \pi r^2$, height

2. Sheet.

$A = \text{width} \times \text{thickness}$,
height.



→ specimen



→ Fluct

to gain good stress concentration.

→ gage length.

* Grips types

1. Flat, for flat shapes like (Sheet)
2. V-Shape, for cylinders.

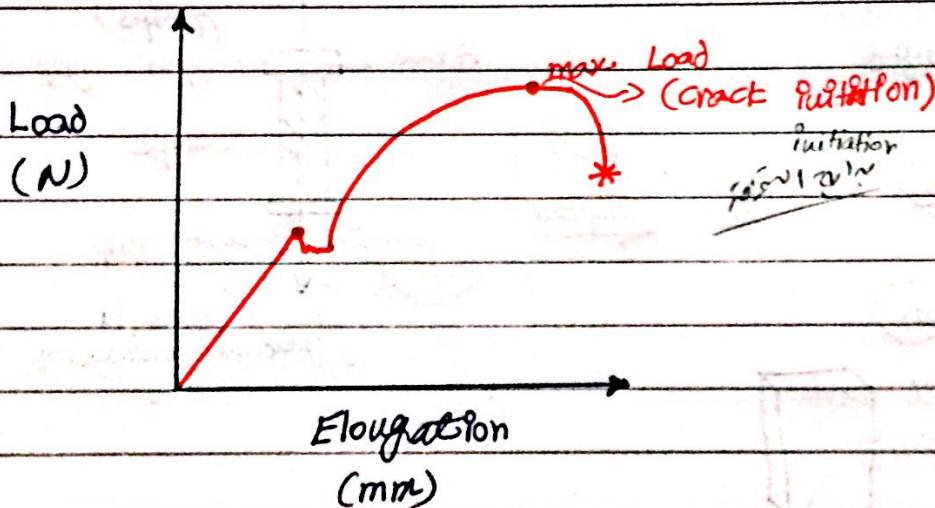
⇒ max. capacity for machines must be considered.

we use diff. machine for plastic since capacity differs.

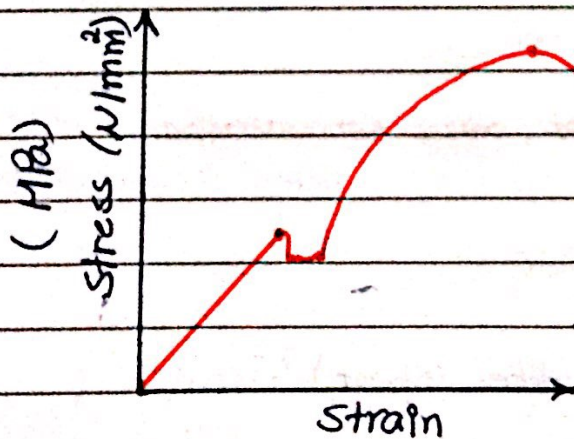
* $L_0 = 5 \text{ mm}$

Load (N)	Elongation deformation (mm)	Stress (MPa)	strain ($\Delta L / L_0$)
F_1 0	0	F_1 / A_0	$(\frac{\Delta L}{L_0})$
F_2 1	5.01	F_2 / A_0	
F_3 2	5.06	F_3 / A_0	
...	5.08	...	
4	5.2	...	

First yielding
→ deformation



* (Load - deflection) curve *



* (L-d) curve as

Same as
(σ, ϵ) curve.

but with
different scale.

$\sim A_0$: Cross-sectional Area. } Initial.
 $\sim L_0$: Gage Length.

* UTM $\equiv$ Universal testing machine.

$\sim$ [capacity, cross-head velocity] must be considered.

* Elastic Region

1. Turn-on $\rightarrow$ yield Point.
2. Small $\rightarrow$ Small elongation and strain.
3. The sample retains its dimensions upon removing of the Load.
4. Linear relationship between stress and strain.

$$\sim y = ax + b$$

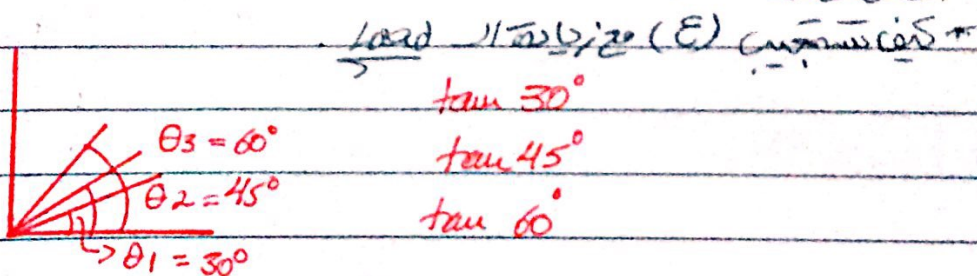
$\downarrow$ slope $\downarrow$ Intercept = 0

$$y = \tau, x = \epsilon$$

$$y \Rightarrow (\tau = a \epsilon) \quad ; \quad a = \frac{\Delta \tau}{\Delta \epsilon} = \tan \theta$$

$$* \tau = E \epsilon$$

$\hookrightarrow$ modulus of Elasticity $\equiv$ stiffness.



$$5. E = \tan \theta = \frac{\Delta \tau}{\Delta \epsilon} \equiv \text{Modulus of elasticity} \equiv \text{Stiffness.}$$

$$6. \text{Modulus of Resilience} = \frac{1}{2} E_y \cdot \tau_y \equiv \text{Area under the curve.}$$

$(\tau = E \epsilon)$ Hook's law "valid in elastic region only".

$$= \frac{1}{2} \epsilon_y \sigma_y$$

$$= \frac{1}{2} \epsilon_y E \epsilon_y$$

$$= \frac{1}{2} \frac{\sigma_y}{E} \sigma_y$$

$$\sim MR = \frac{1}{2} \sigma_y \epsilon_y$$

$$= [MPa]$$

$$MPa = \frac{\text{Joule} \rightarrow \text{Energy} = F \cdot d}{mm^3}$$

$$= \frac{F \cdot mm}{mm^3} = \left(\frac{F}{mm^2} \right) = [MPa]$$

* Stiffness

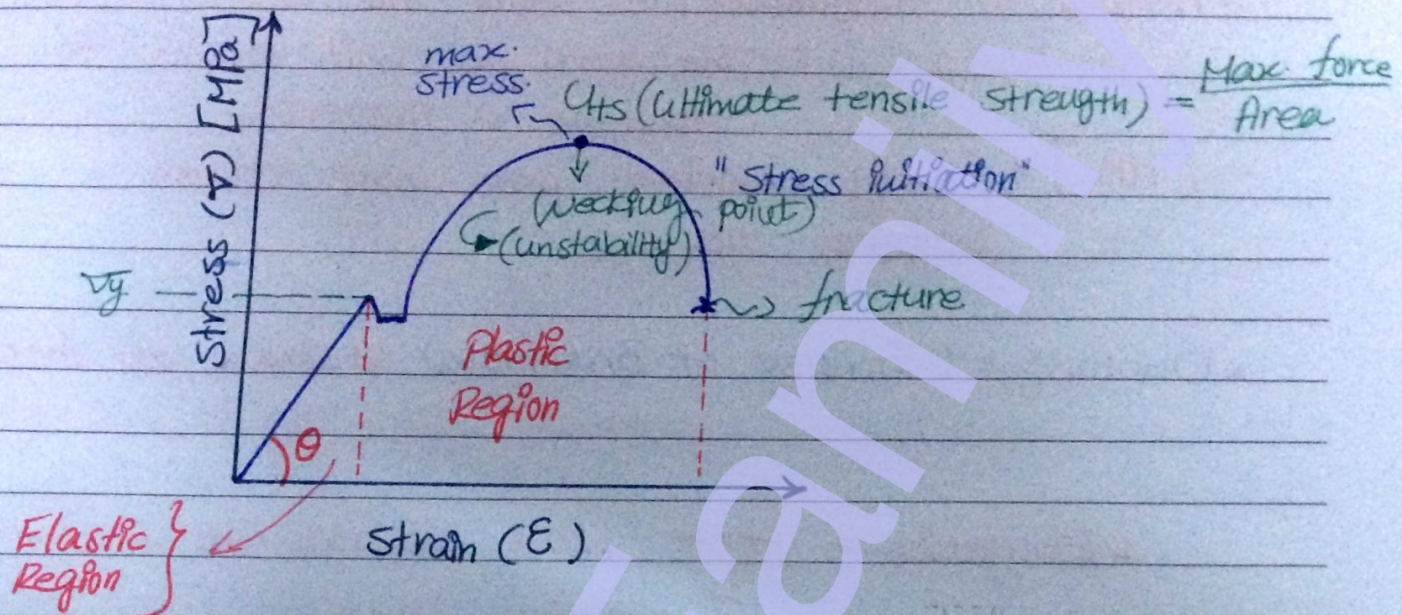
* Resilience

→ is absorbed energy per unit volume without distortion.

* Modulus of Resilience = the amount of energy that a unit volume of the material can absorb within the elastic region without fracture.

* Stiffness Resistance to deformation.

* Mechanical behavior

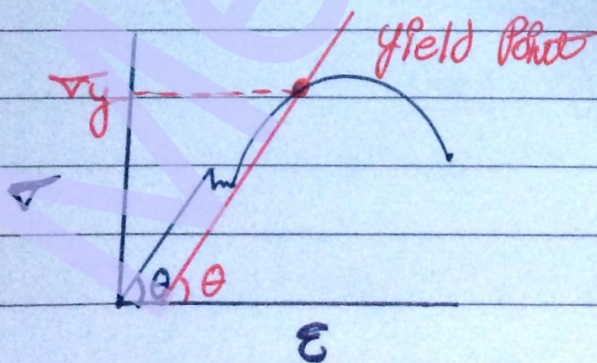


$$1. \epsilon_{\text{longitudinal}} = \frac{\Delta L}{L_0}$$

$$\epsilon_{\text{lateral}} = \frac{\Delta D}{D_0}$$

* Poisson's Ratio $\nu = \left| \frac{\epsilon_{\text{lateral}}}{\epsilon_{\text{long.}}} \right|$

2. Yield Point θ = Prot stress, Prot strain.
 → offset by 0.002 parallel to the elastic region.



* Modulus of toughness & Area under the whole curve.

= The work per unit volume to fracture a material.

[MPa] & Energy absorbed per unit volume before fracture.

* Ductility = (Inverse of Brittleness) $\equiv$ strain at fracture.
(strain) $\frac{L_f - L_0}{L_0} \times 100\%$

* Elongation = $\frac{L_f - L_0}{L_0} \times 100\% \equiv$ strain at fracture

* Reduction in area = $\frac{A_0 - A_f}{A_0} \times 100\%$

* $\underset{L_0}{5\text{ mm}} \Rightarrow \underset{L_f}{15\text{ mm}}$

* $\underset{L_0}{5\text{ mm}} \Rightarrow \underset{L_f}{5.5\text{ mm}}$

13.11.2016

- * Engineering stress-strain $\Rightarrow$ Relative to original (L_0, A_0)
- * True stress-strain $\Rightarrow$ Relative to current (A_c, L_c) or A_f

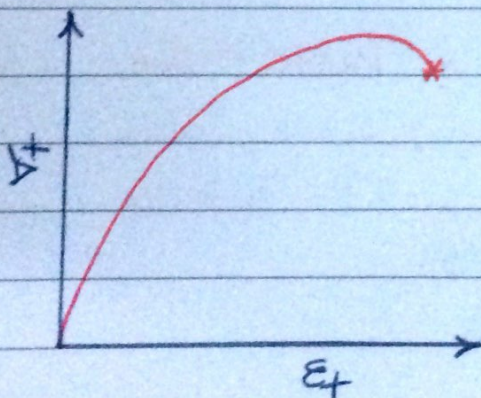
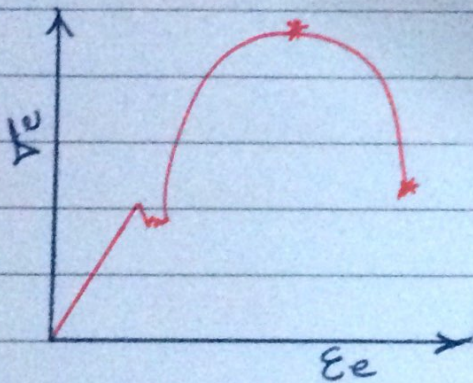
* True stress $\Rightarrow \sigma_T = \frac{F}{A_c}$ or A_f

* True strain $\Rightarrow \epsilon_T = \ln\left(\frac{L_c}{L_0}\right) = \ln\left(\frac{L_f}{L_0}\right)$
current. Instability.

* Volume remains constant

$$A_0 \cdot L_0 = A_c \cdot L_c = A_f \cdot L_f$$

$$\rightarrow A_c = \frac{A_0 \cdot L_0}{L_c}$$



$\sigma = K \epsilon^n$
Strength coefficient [MPa] Strain hardening exponent.

Load $\rightarrow$ σ $\rightarrow$ ϵ

قوة $\rightarrow$ σ $\rightarrow$ ϵ
 Load $\rightarrow$ σ $\rightarrow$ ϵ

(Design) $\rightarrow$ σ $\rightarrow$ ϵ

Yahya Alhayek

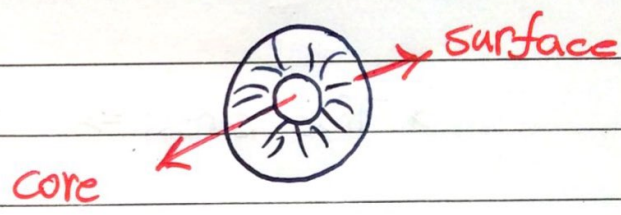
Scanned by CamScanner

* Hardness Mechanical property for the surface of specimen only.

* Scratch → Indentation test.

10 → Diamond

0 → Talc Powder.



* Scratch test ability of the material to resist scratches. ≡ "surface property".

15. 11. 2016

- 10 - Diamond
- steel
- Al, Mg
- Polymers
- 0 -

* Indentation test → Rockwell
→ Brinell
→ Vickers

* Table 6.5 *

الصلابة والحرادة	(مقياس جبر)
الصلابة الكوب	* الصلابة الكوب
الصلابة (لا)	مقياس لوكس

* Indenter testing tool itself.

* Indentation الأثر على الصلابة

ability of the material to resist plastic deformation on the surface.

(Indenter) و (thickness of mat.)
 Self-Reading.

* 6.11-12 not included.
Design.

* the test can't be applied on the edges.] self-Reading.
* thickness specification.

$$* HB = \frac{2P \rightarrow \text{load (kgf)}}{\pi D (D - \sqrt{D^2 - d^2})}$$

(Hardness Brinell no.) $\rightarrow$ Indenter diameter $\rightarrow$ Indentation diameter.

* القوانين للتقوية فيك وليس
فيك

$$\left[\frac{\text{kg}}{\text{mm}^2} \right] = (\text{no.}) HB \text{ at } (F)$$

* ex. 8 $\equiv$ (50) HB at (100) kgf.

hardness $\rightarrow$ Indentation $\rightarrow$ (load) $\rightarrow$ * * * * *

* Rockwell hardness test 8 "Most common test"
 $\rightarrow$ with 3 scales $\rightarrow$ Because it's so easy to be applied & perform.
A B C

* Figure 6.18 :
 $\rightarrow$ Several hardness scales comparison.
(Knoop, Brinell, Rockwell, Mohs --) .

* Suggested Problems 8

6-7, 10, 11, 24, 26, 30, 38, 39, 47, 48 for midterm
57, 54

* CH. 9

27.11.2016

* Phase Diagram *

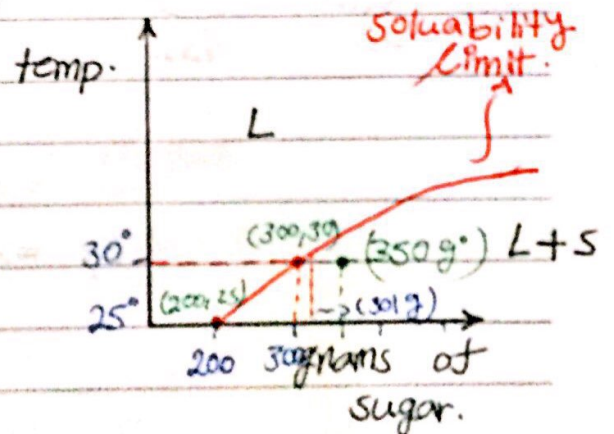
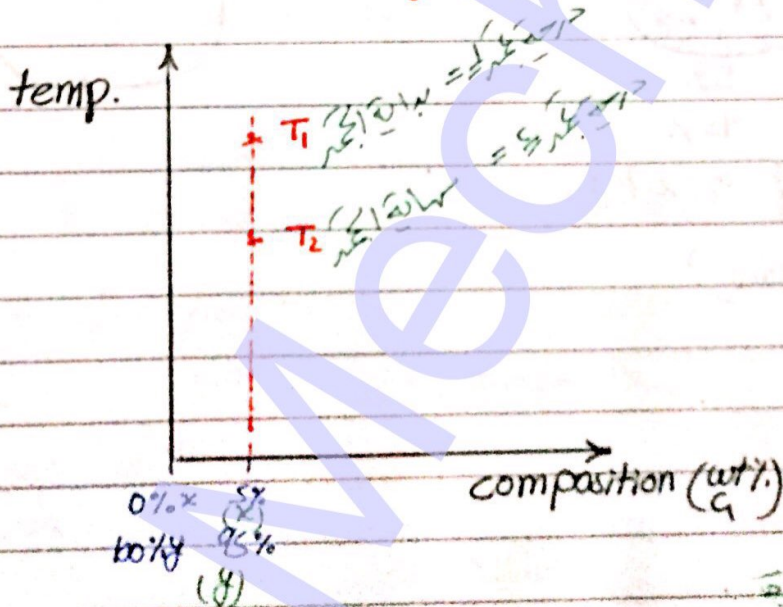
↳ Solid.] for metals only.
↳ liquid.

metal (furnace)
x → 350°C melting point. ✓
"solid" (State) → solidification point.

→ 350°C (350°C)
 (350°C)
 (350°C)

(Binary) 350°C ← → 400°C
* alloy ⇒ x + y → $\begin{pmatrix} x & y & x \\ x & y & x \\ y & x & y \end{pmatrix}$
5% 95%
(C₁) (C₂) (410°C) solubility.

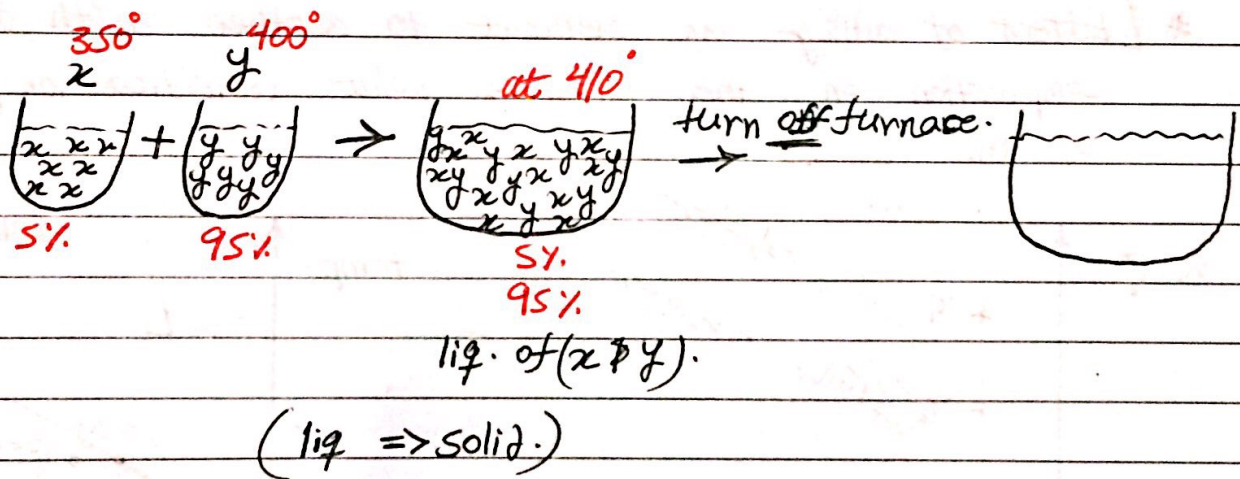
* [Effect of adding an element to another with diff. composition on the melting point (solidification point) of the alloy].



* Solubility Limit & coordinates relates between composition and Temperature. (Comp., Temp.)

* Metals *

Phase Diagram	Solubility "Solid"	Solubility "liquid"
(Isomorphous)	Comp.	Comp.
(Partial.)	Partial	comp. ذائب في سائل
(Eutectic)	Insoluble	Comp. "no castable alloy" (لا يمكن صبها)

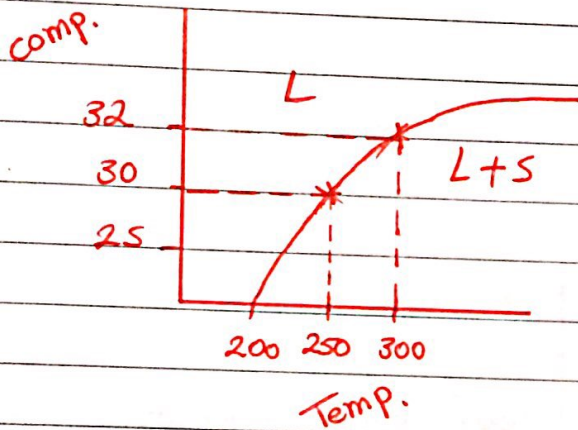


4-12-2016

Phase Diagrams

→ Effect of adding one metal to another "Composition" on the melting point.
freezing
Solidification.

Solubility (comp., temp.).



(220°) (330°)

$x + y$

→ $x + y$ "alloy" → Furnace



Powder



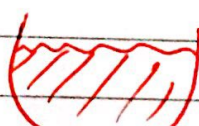
Powder

"5g" + (95g) = 100g.

$C_1 = 5\%$

$C_2 = 95\%$

wt %
composition %



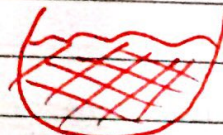
liq. solution.
($x + y$)

5%, 95%

(350°)



(liq. state)



(solid state).

Solubility

Solid

Liquid

Iso-morphous

Comp.

Comp.

→ 330 → 349 (30s)

→ (349) → (348) (30s)

Partial

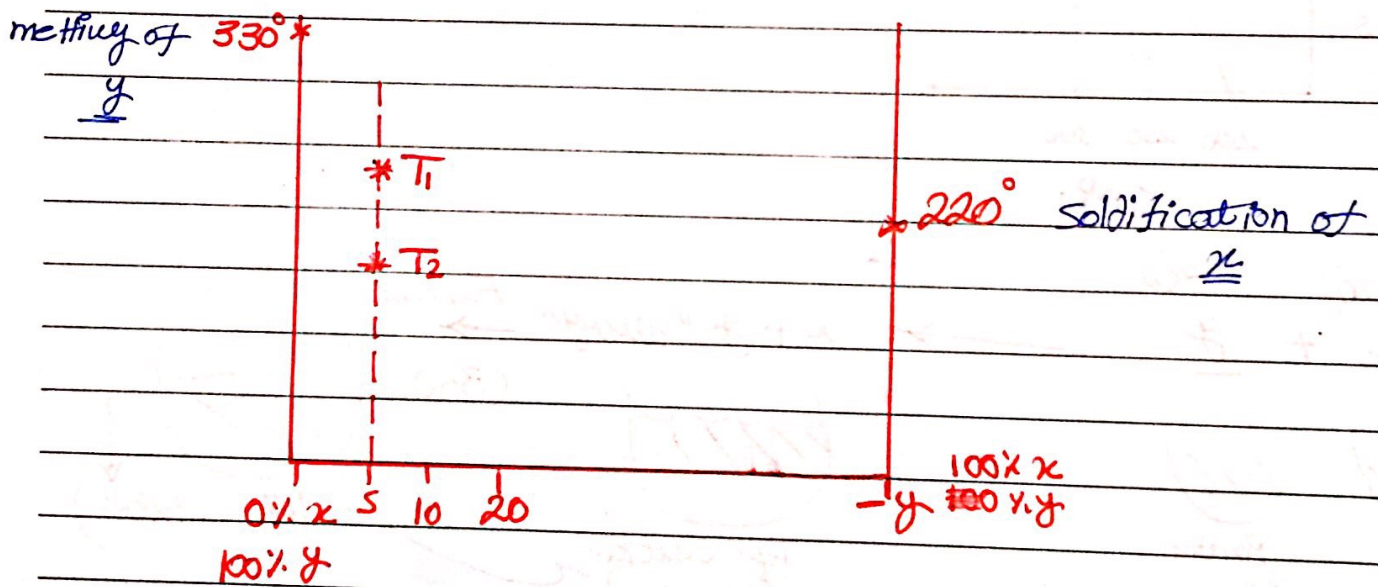
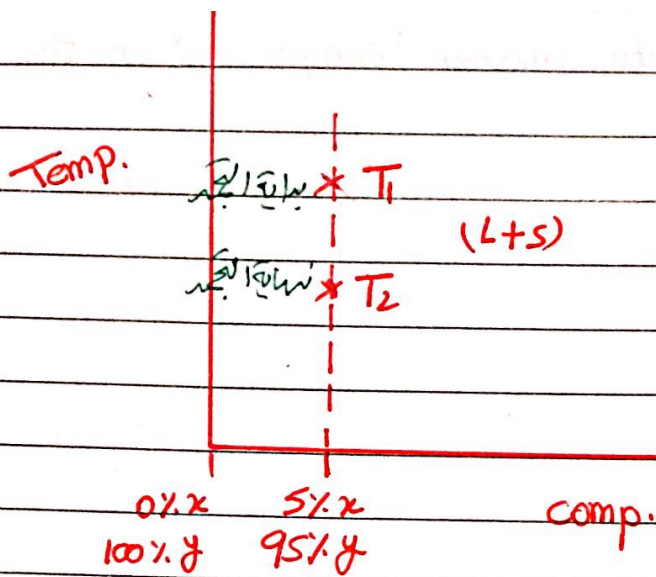
partial

Comp.

Eutectic

Insoluble

Comp.

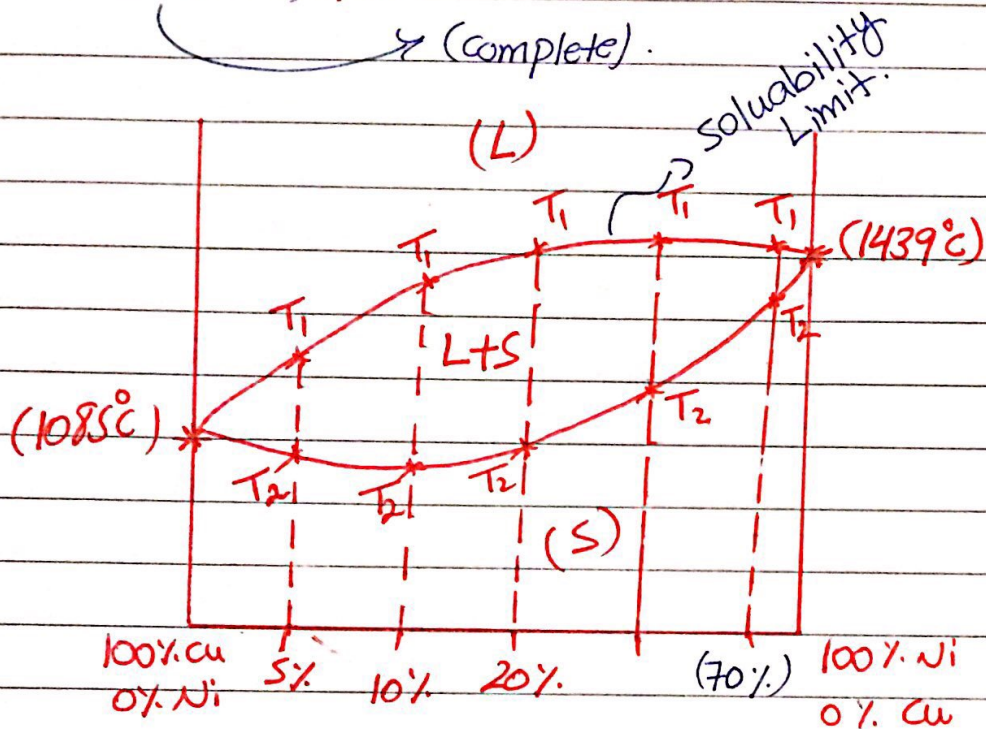


* least no. of samples to draw the phase diagram is 5 samples, with different compositions of both alloys.

* Ni (1439°C) FCC, $\Delta R \leq 15\%$

* Cu (1085°C) FCC

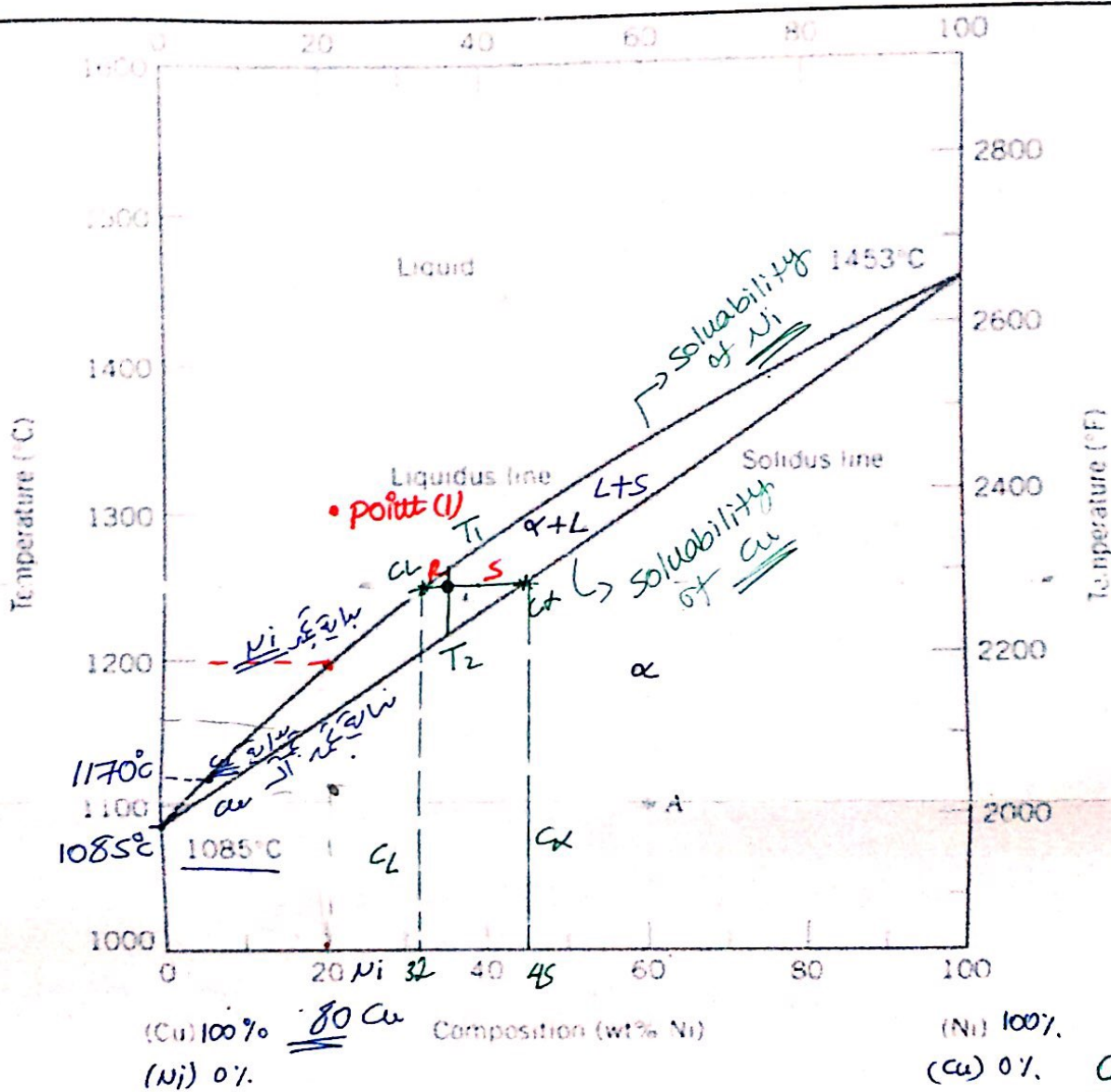
(complete)



Yahya Alhayek

* Binary alloy *

"Isomorphous"



$n_{L+S} \equiv$ of Both (Ni) & (Cu).

→ 58 solid
(α, β, γ) indicates to solid.

$\Rightarrow (20\% Ni)$ at $1300^\circ C$

(1) phase present?!

(2) phase composition?

$C_L = 20\%_{Ni}$, $80\%_{Cu}$ "homogeneous"
liquid sol.

c) liquid composition.

(3) phase amount?

phase diagram: $w_L + w_S = 1$ } $w_S = 0$
 $w_L = 100\%$ } $w_L = 100\%$ Scanned by
 are in the liquid region:

(Ni) 100%
(Cu) 0% Co (given)

③ 40% Ni ; 1250°C

(1) $L + S$
(tie line) $\rightarrow$ liq. $C_L = 32\%$

(2) 40% Ni }
60% Cu } sol. $G = 45$

(3) $C_A W_A + C_L W_L = 100\%$
 $W_A + W_L = 100\%$

(4)

(S)

(6)

(4) at what temperature the alloy will begin solidify?

1200°C

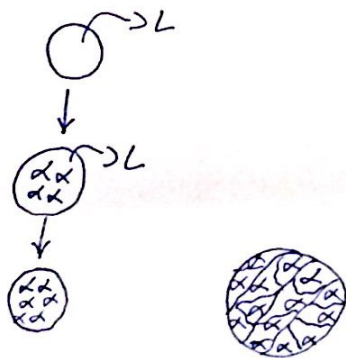
→ which will solidify first?
Ni

(5) at which temperature the alloy will be completely solid?

at (1170°C) not 100% exact
around 1170°C or 1150°C

(6) Draw a microstructure?

التركيب المجهري
alloy.



* what is the effect of adding (Ni to Cu) on melting points?!

→ زيادة (Ni) في (Cu) تؤدي إلى ارتفاع درجة انصهاره وخفض نقطة انصهاره (نقطة انصهاره) والعلامة.

(Isomorphous) → دائماً حسب درجة انصهاره only.

(2)

* 20% (Ni) at 1100°C

(1) solid (α)

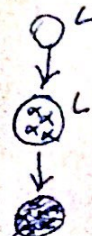
(2) $\alpha = 20\% \text{ Ni}$

(3) $w_\alpha = 100\% = 1$, $w_L = 0$

(4) 1200°C Ni

(5) 1170°C

(6)



11-12-2016

* 40% Ni at 1250°C

(3) $C_X W_X + C_L W_L = C_0$

$W_X + W_L = 100\%$

$\leadsto W_X = \frac{C_0 - C_L}{C_X - C_L}$

$\leadsto W_L = 1 - W_X = \frac{C_X - C_0}{C_X - C_L}$

* $W_X = \frac{0.40 - 0.32}{0.45 - 0.32} = 61\% \approx 0.61$

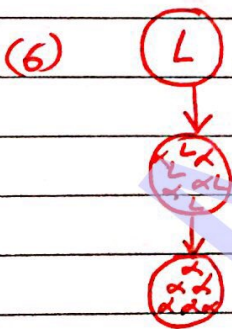
* $W_L = 39\% (0.39)$

} Labor Rule ; $W_X = \frac{R}{R+S}$
(R) نقس النسبة

$W_L = \frac{S}{R+S}$
(S) نقس النسبة

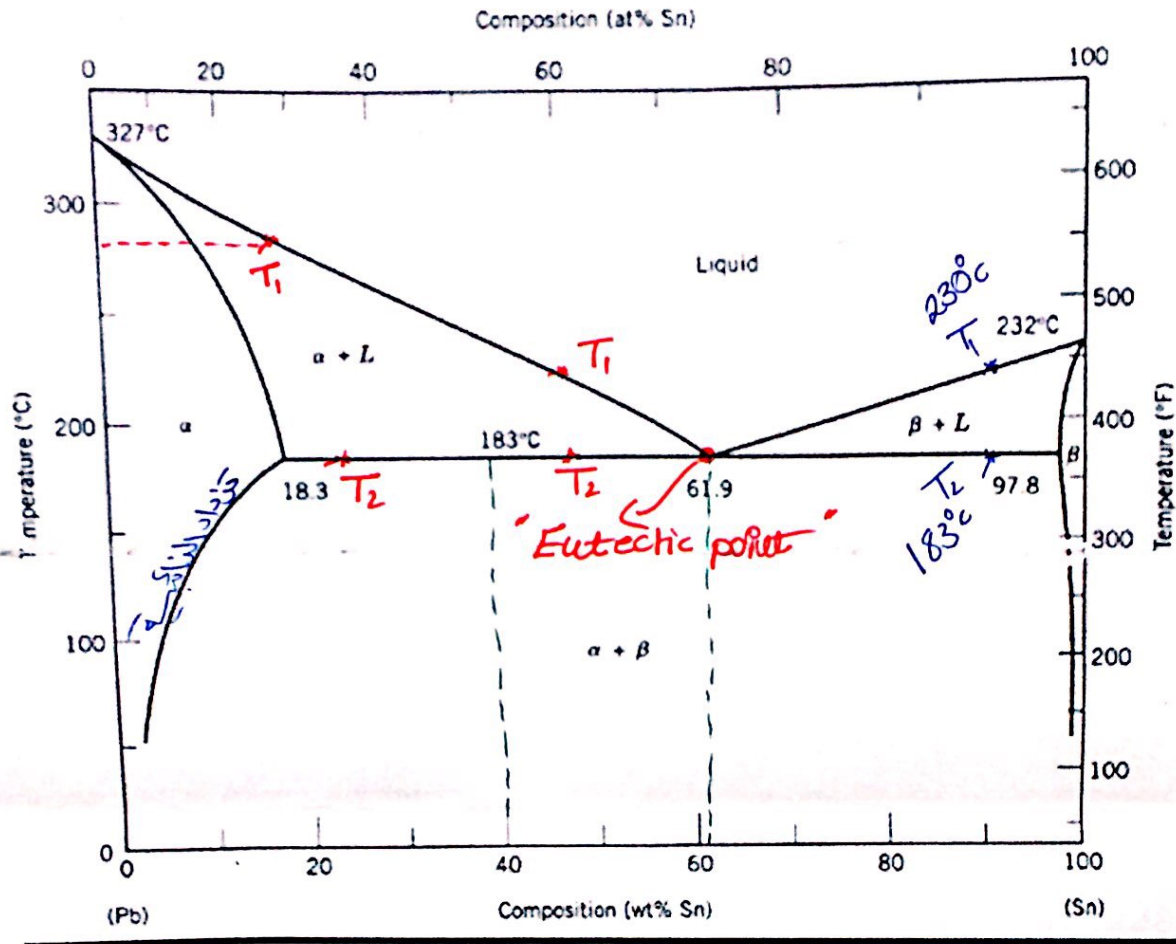
(4) 1280°C

(5) 1230°C



* Section (9.8), volume part "not included".

* Partial phase diagram *

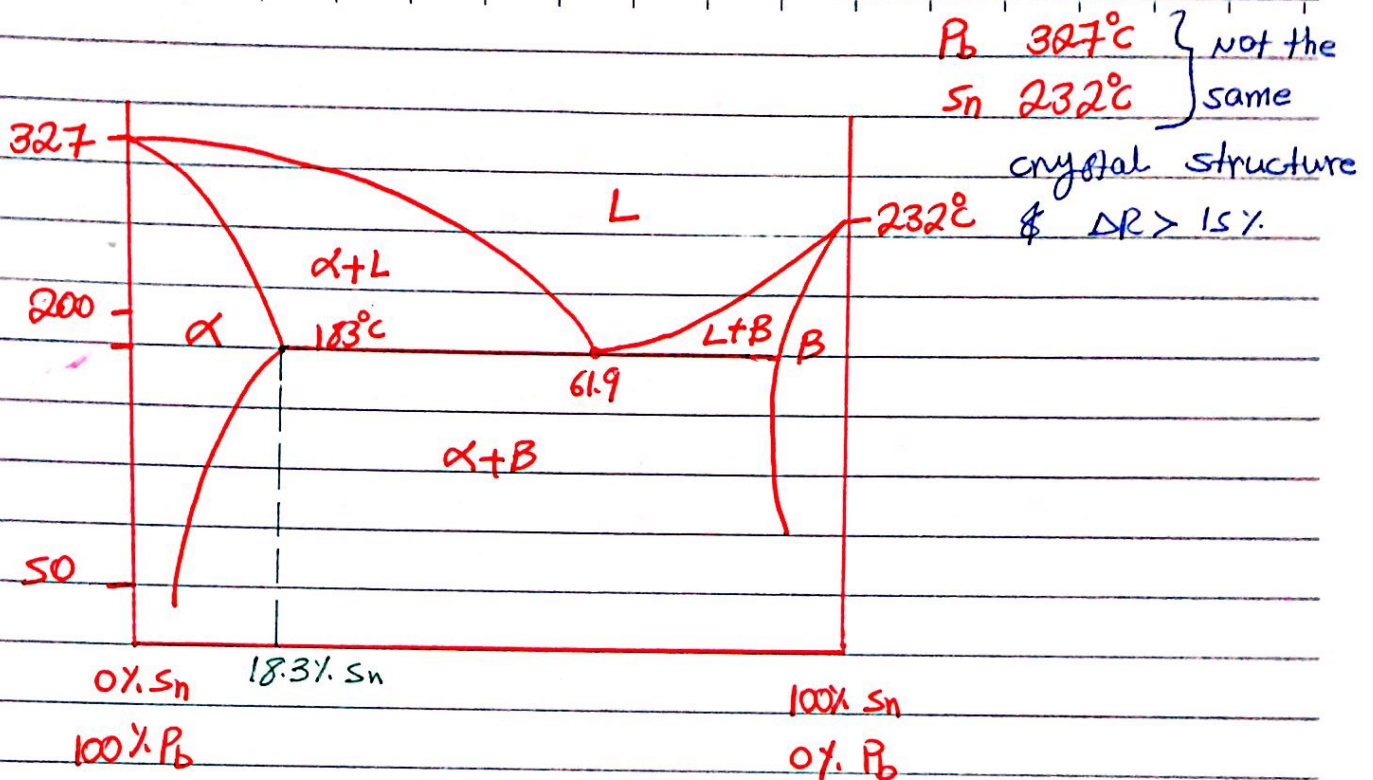


* إضافة (Sn) إلى (Pb) يؤدي إلى تغير حالة 183°C

* إضافة (Sn) (61%) إلى (Pb) (38.1%) يؤدي إلى تغير حالة 183°C

$\sim$ at region Pb $\Rightarrow$ Pb "أولاً"
 $\sim$ " " Sn $\Rightarrow$ Sn "أولاً"

* Eutectic point $\Rightarrow$ when alloy is converted from liquid to $(\alpha + \beta)$ at (composition, temperature) (61.9% Sn, 183°C)



* 350° $\equiv$ furnace temperature.

350 $\sim$ 349 "5 sec"

349 $\sim$ 348 "4.7 sec"

$\Rightarrow \alpha$ = solid solution; rich in Pb; solubility "Partial".

solute $\nearrow$ solvent

Sn
(sol) (sol)

Pb

max. min.

$\sim$ max. solubility of Sn in Pb = 18.3% at 183°C.

$\sim$ min. solubility of Sn in Pb = 0.1% Sn at 50°C

$\Rightarrow \beta$ = solid solution; rich in Sn; Partial.

solute solvent

Pb

Sn

$\sim$ max solubility of Pb in Sn = 2.2% at 183°C.

$\sim$ min. solubility of Pb in Sn = 0.1% at 50°C

* $L \rightarrow \alpha + \beta$

40% Sn; Just below the eutectic point.

* what is the phase present? double phase $\alpha + \beta$

* what is the phase composition?

$$C_{\alpha} = 18.3\% \text{ Sn}$$

$$C_{\beta} = 97.8\% \text{ Sn}$$

* what is the phase amount?

$$w_{\alpha} + w_{\beta} = 1$$

$$\sim w_{\alpha} = \frac{S}{R+S} = \frac{97.8 - 40}{97.8 - 18.3}$$

$$= 73\%$$

$$\sim w_{\beta} = 100\% - 73\% = 27\%$$

* Microstructure?



* at what temp. the alloy will begin to solidify?
230°C

* at what temp. the alloy will be complete solid?
183°C

$\sim$ Pb will solidify first.

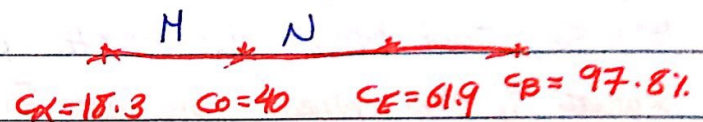
* $L \rightarrow \alpha + \beta$



very homogenous.
camellian.

} (phase $\rightarrow \alpha + \beta$)
liq. + solid

* what is the eutectic phase amount? (weight of eutectic).



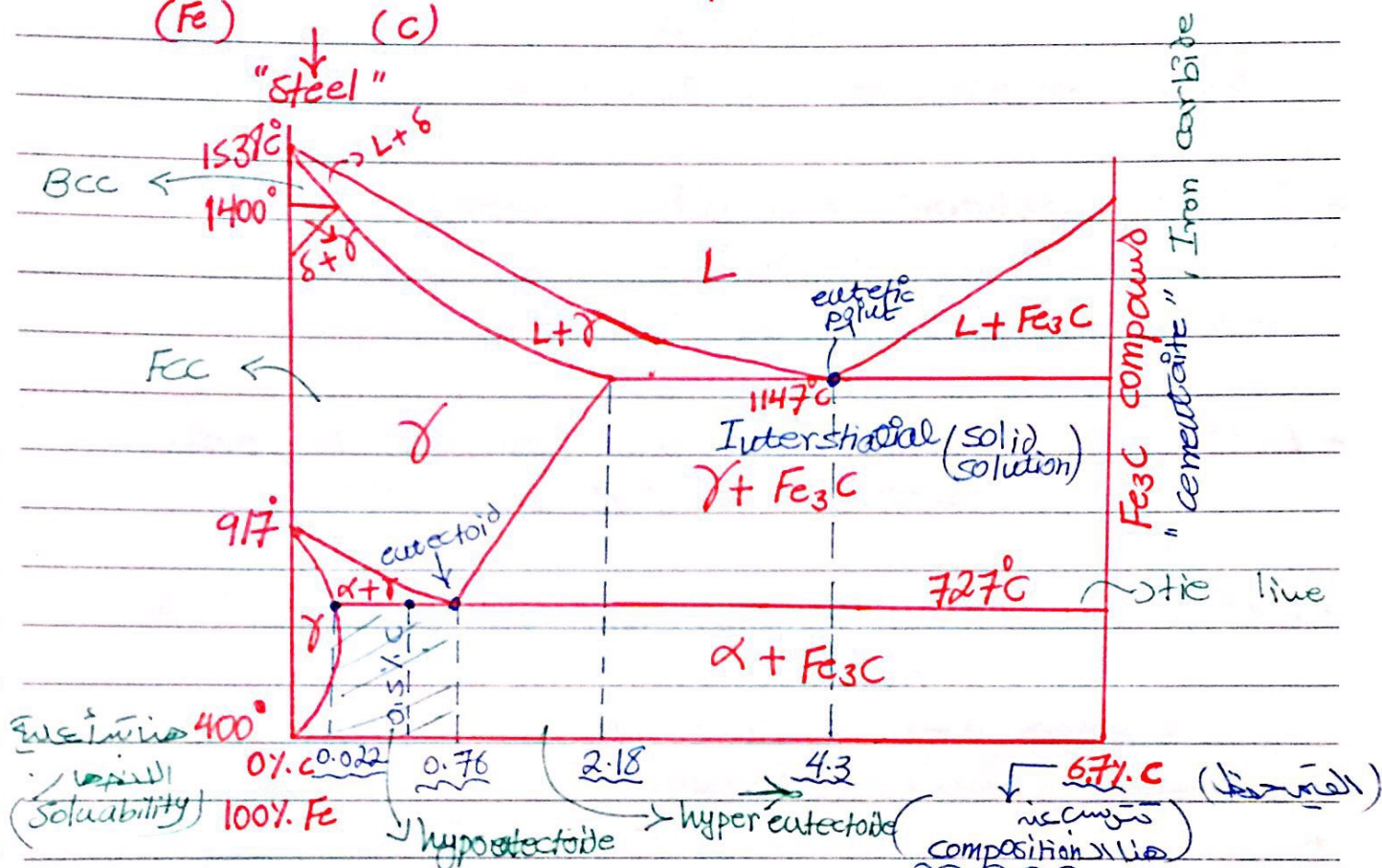
$$w_X + w_E =$$

$$w_X = \frac{N}{M+N}, \quad w_E = \frac{M}{M+N}$$

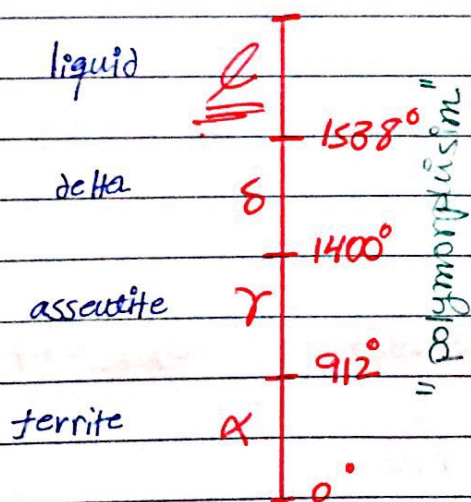
* Eutectic composition?

* at eutectic point: محل تبلور * لا

* Iron $\rightarrow$ Carbon $\rightarrow$ partial phase.
(Fe) (C)



* إذا كانت نسبة الكربون أكبر من 0.76% (brittle) و أقل من 0.022% (Solubility) 100% Fe



; (α , γ , δ) for solid solution.

* at 0.76% pure pearlite.

Layers of ($\text{Fe}_3\text{C} + \alpha$)

* إذا كانت نسبة الكربون أكبر من 0.76% و أقل من 0.022% (Solubility) 100% Fe

* Depending on solubility condition.

* α "solid solution": Solute C
Solvent Fe

$\rightarrow$ max. solubility of C in Iron (α) is 0.022 at 727°C.

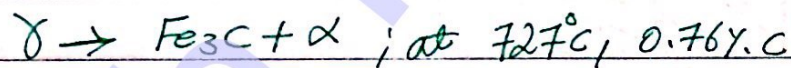
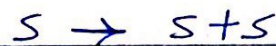
* δ "solid solution": Rich in (Fe), Solute C; solvent Fe

$\rightarrow$ max. 2.18% C at 1147°C

$\rightarrow$ maximum solubility $\rightarrow$ 1147°C $\rightarrow$ Fe₃C

* **Eutectic point**: transformation from liquid (to) two solids
 $L \rightarrow \delta + \text{Fe}_3\text{C}$; at 1147°C, 4.3% C

* **Eutectoid**: transformation from solid (to) two solids.



* 0.5% C at just below the eutectoid.

1. phase present?

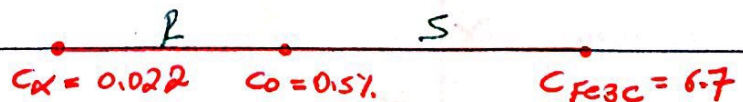


2. phase composition? by tie line which is already exist.

$$C_\alpha = 0.022\% \text{ C}$$

$$C_{\text{Fe}_3\text{C}} = 6.7\% \text{ C}$$

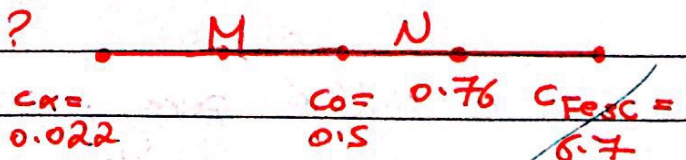
3. phase amount?



$$w_\alpha = \frac{S}{R+S}$$

$$w_{\text{Fe}_3\text{C}} = \frac{R}{R+S}$$

4. Phase amount of pearlite?



$$M = C_0 - C_\alpha$$

$$N = C_{\text{pearlite}} - C_0$$

$$* w_p = \frac{M}{N+M} = 6.5\%$$

* Steel



$\text{Fe} + \text{C}$



0.0 ---- 2.14% C

* low carbon steel

* high " steel

* Medium " steel

* 0.022 $\rightarrow$ 0.76 "hypoeutectoid"

* 0.76 < "hypereutectoid"

Suggested problems

9-11, 15, 17, 18 150, 51 "8th edition".

Iron Carbon diagram.

* Final Exam expected questions:

- * Iron-carbon phase diagram. (7 marks)
- * Materials types and examples.
- * Bonding types.
- * FCC, BCC structures and their relations.
- * Dislocations types and Imperfections.
- * Strength and hardness (ch.6)
- * Draw a (partial, Isomorphous) phase diagram.
- * Iron-carbon phase diagram (Labeling) & all values must be known by you.

المعادلة (ch.6) & (proof) - $\sigma = \sigma_0 + K \epsilon^n$
flow curve equation.)

The End
Best of luck.