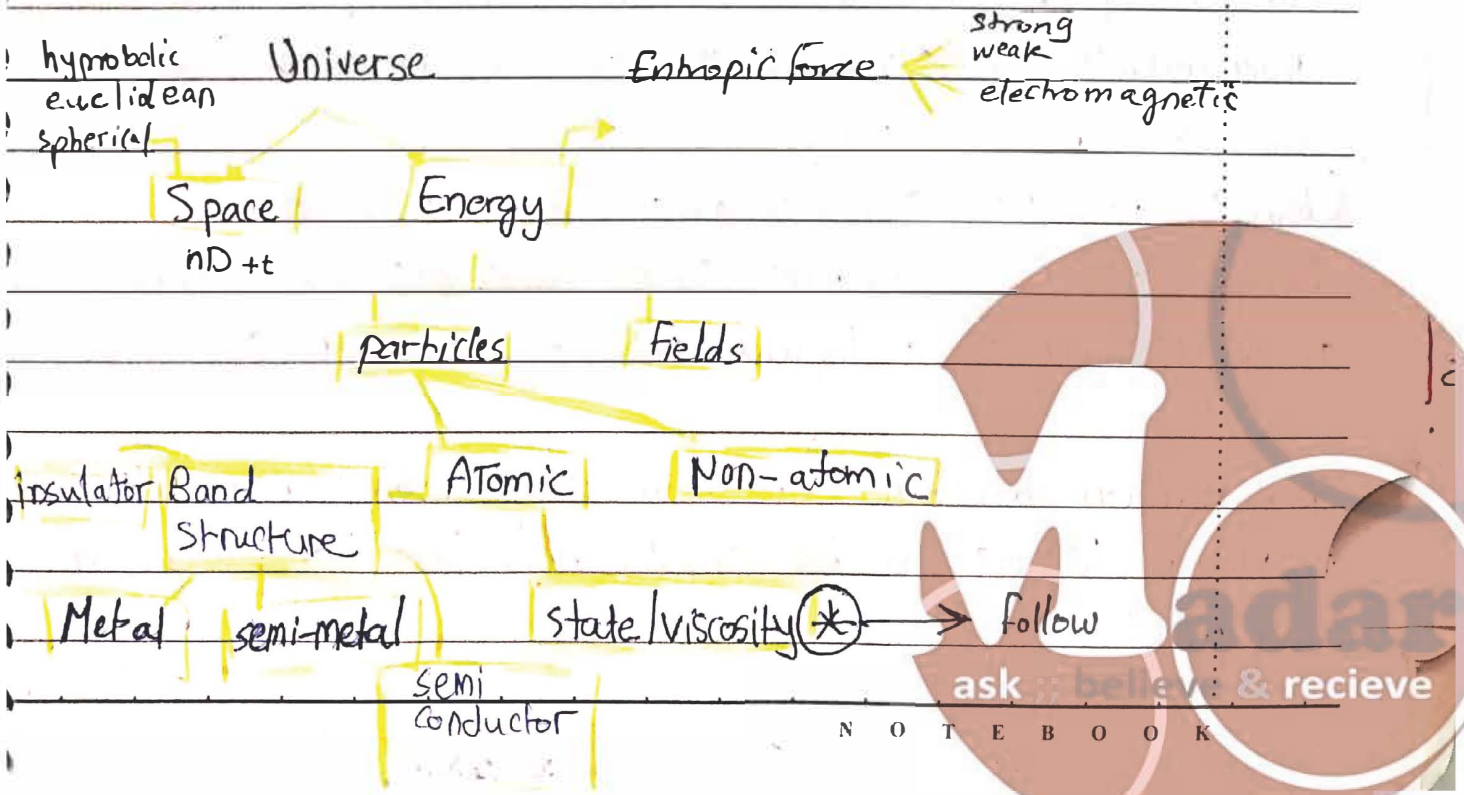
MATERIALS SCIENCE

Dr.Deeb Abu Fara

Object Introduction Date No.

What are the kind of question that a student ~~would ask~~?

* Why is glass brittle, while copper is ductile? What is mean by a ductile material?
* If we take two rods, one of Al and one of steel. Why is it easier to bend the Al rod as compared to the steel rod?
* How can I change properties like hardness, without changing the composition (say of 0.8% C steel?)
* Why is glass transparent, while any typical metal is opaque?
* Usually, good thermal conductors are also good electrical conductors. Why is this so?
* Why does Iron corrode easily, while Al does not (or does not seem to?)
* Why is wire of copper conducting, while piece of brick or wood non-conducting?



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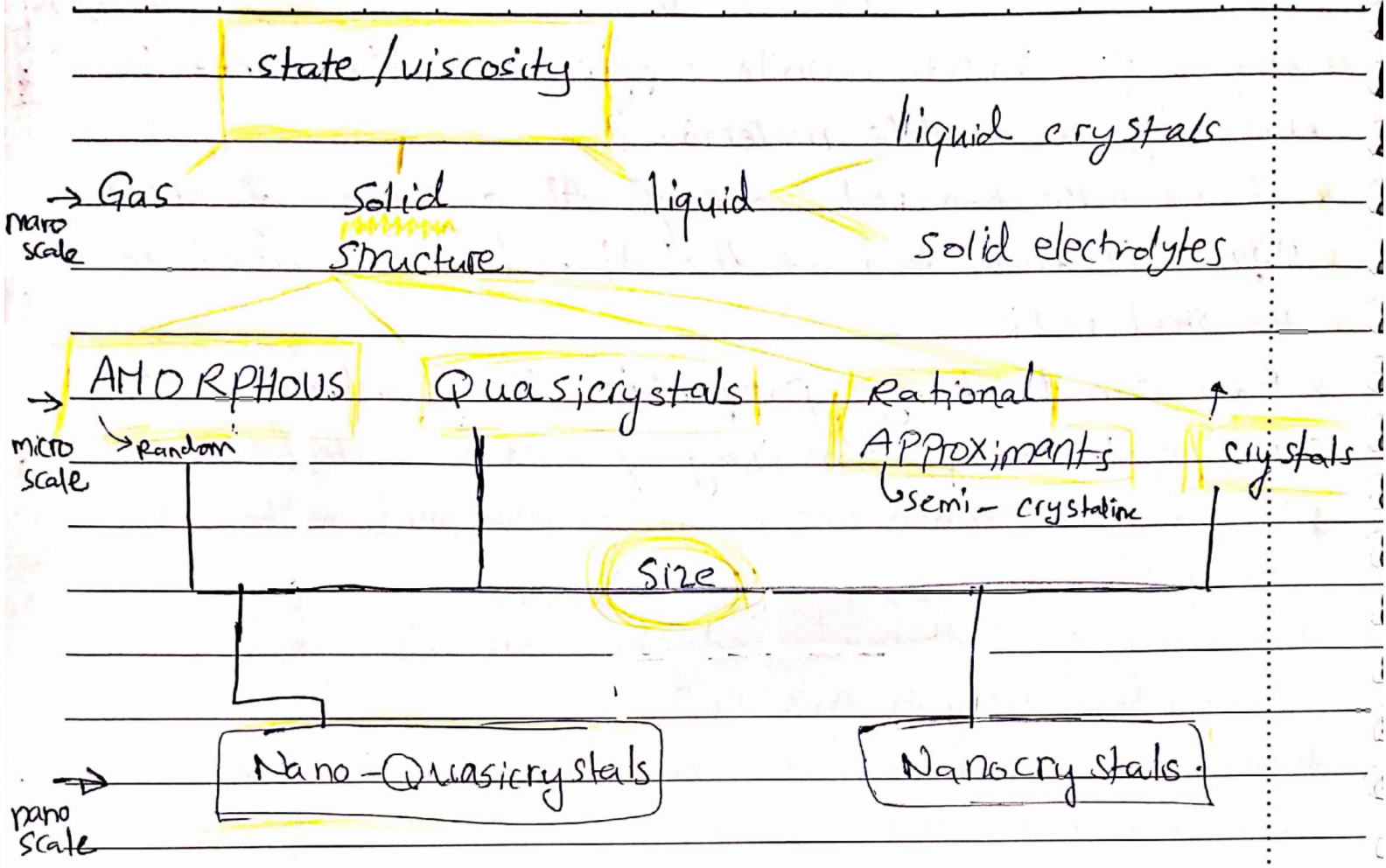

* based on state (phase) a given material can be Gas, Liquid or solid (Based on thermodynmic variables) Intermediate / coexistent states are also possible (i.e clear demarcations can get blurred).
(Kinetic variables can also affect how a material behaves: e.g at high rates some materials may behave as solids and as a liquid at low strain rates).

* based on structure (arrangement of atoms / molecules / ions) materials can be crystalline, Quasi crystalline or Amorphous.

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Intermediate states (say between crystalline and amorphous, i.e. partly crystalline) are also possible. Polymers are often partly crystalline.

* liquid crystals ("in some sense") are between liquids and crystals.

* Atoms ≡ building units of the microstructure in all materials ? NO

* NOT all, some materials ⇒ building units ≡ molecule like polymers.

* Solid Electrolytes ≡ fast ion conductors
≡ superionic conductors
are also between crystals and liquids.
These materials have a sublattice which is 'molten' and the ions in this sublattice are highly mobile
These materials are similar to liquid electrolytes in this sense.

* Based on Band structure, we can classify materials into Metals, Semi-metals, Semi-conductors and Insulators.

* Based on the size of the entity in question we can Nanocrystals, Nanoquasicrystals etc

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One way of classification does not interfere with another.

* From a State perspective we could have a liquid, which is a metal from the band structure/conductivity perspective

→ Hg is liquid metal at room temp.

* Or we could have a metal (band structure viewpoint) which is amorphous (structural viewpoint (atomic ordering))

→ Zr Ti Cu Ni Be bulk metalic glass.

* Or we could have a ferromagnetic material (from spontaneous spin alignment point of view – a physical property), which is amorphous (e.g) (structural viewpoint)

→ amorphous : Co – Au alloys are ferromagnetic

Common type of materials

- Metals
- Ceramics and glasses
- Polymers
- Hybrids (composites)

* let us consider the common types of Engineering Materials.

* These are Metals, ceramics, Polymers, and

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various types of [Composites] of these.

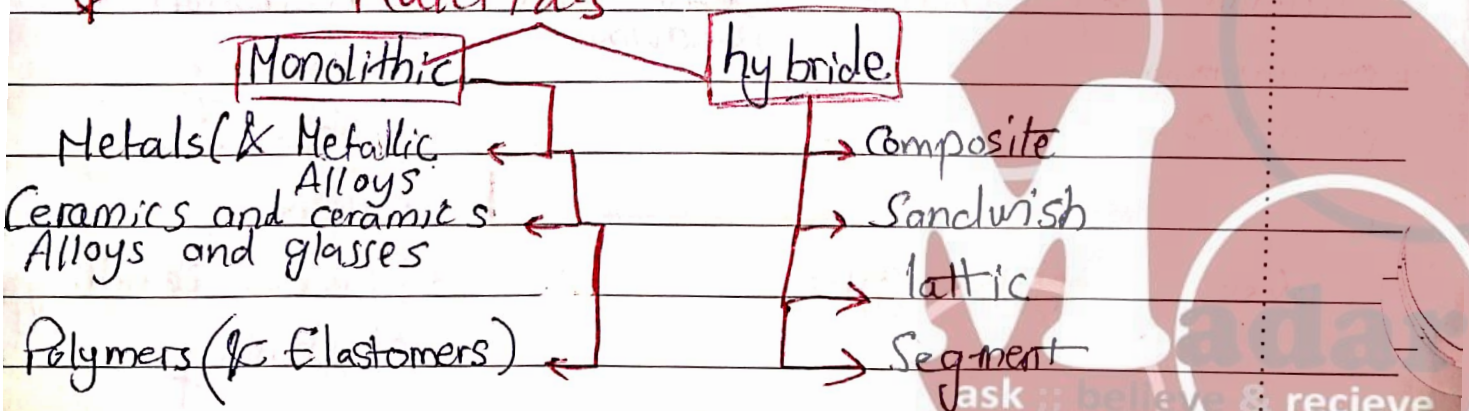
* A composite is a combination of two or more material which gives a certain benefit to at least one property.
* Hybrid : is a superset of composites.
* The type of atomic entities (ion, molecule etc.) differ from one class to another, which in turn gives each class a broad 'flavour' of properties
* composites ≡ polymer alloys
* Metal ≡ alloys
* classical polymers are not strong in mechanical point of view.
* polymer (↓ρ) (lightness) inforced material into the polymers we get the mechanical strength
* Biomaterials :

Source of material → bio
→ natural
→ non-bio source.

what is the application?

* bio material ≡ bio degradable → environmental point of view

* Materials



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Composite: have two (or more) solid components, usually one is a matrix and other is a reinforcement

Sandwish structure: have a material on the surface (one or more sides) of core material 

lattice: typically a combination of material and space (eg metallic or cermaic foams, aerogels, etc)

Segmented: are divided in 1D, 2D, or 3D (may consist of one or more materials).

* Hybrids are designed to improve certain properties of monolithic materials.

* Classification of composites:
  * Based on the matrix: metal-matrix, ceramic matrix, polymer matrix
  * Based on the morphology of the reinforcement: particle reinforced, fiber reiforced

*

Material Science and Engineering

- Physical
  - * Structure
  - * physical properties
- Mechanical
  - * Deformation Behaviour
- Electro-chemical
  - * corrosion
- Technological
  - * Extractive
  - * Casting
  - * Metal forming
  - * welding
  - * Powder Metallurgy
  - * Machining

Science of Metallurgy

chapter I and II

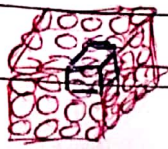
ما كلهم الدكتور و الكلام

اي قبل ما دقوس عليه الدكتور

Subject Date No.

Crystal Structure: → not the actual case

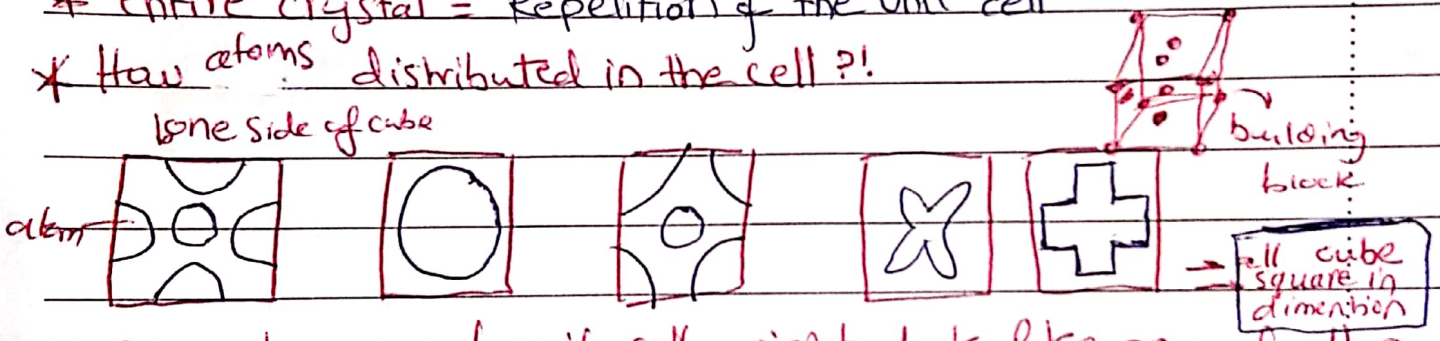
* Atoms = hard spheres with well-defined radii
* In this hard sphere model → shortest distance between two like atoms = one diameter (center)
* Crystalline structure = lattice of points at atom/sphere centers



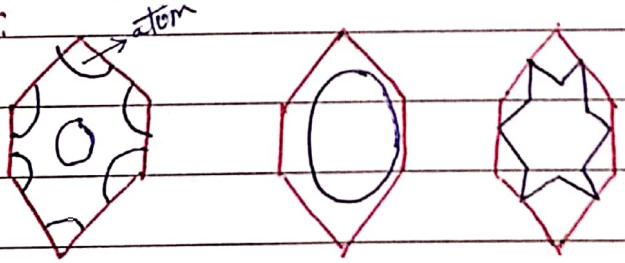
unit cell → crystalline

Unit cell: not talking about atoms

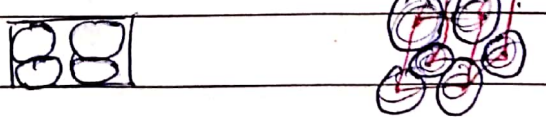
* unit cell = smallest structural unit or building block
* entire crystal = Repetition of the unit cell
* How atoms distributed in the cell ?!



* One hexagonal unit cell might look like any of the following:



* The most common types of the unit cells are:
  1. The simple cubic (SC)



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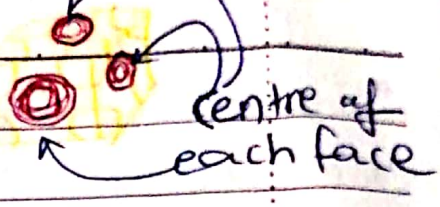
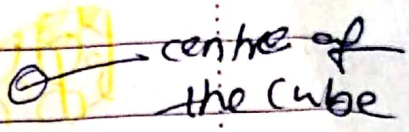
2. The faced centered cubic (FCC)
or cubic close packed (CCP)

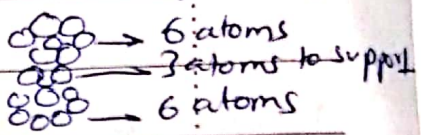


3. The body-centered cubic (BCC)



4. The hexagonal closed packed (HCP)

↳ consist of 3 layers

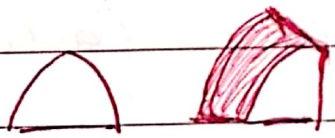


Unit cell: smallest building unit
How the atom arrange in the unit cell?

Simple cubic Metal:
atoms are identical
most = spherical
Metals thus tend to
adopt relatively simple structure
The simplest = simple cube

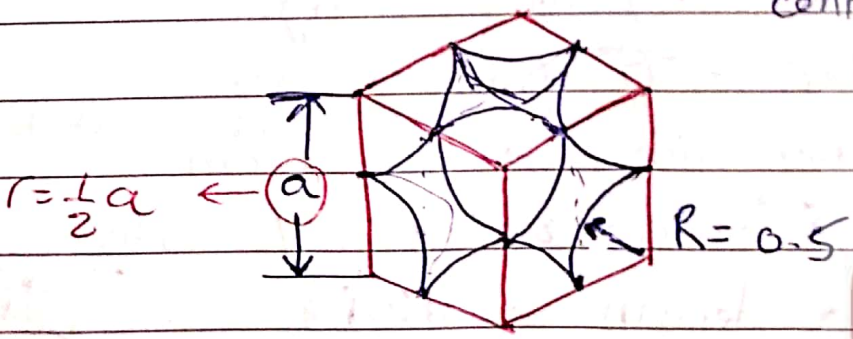
→ Rare = ↓↓ packing density → polonume
→ Only [Po] has this structure
→ Close-packed directions are cube edges

↳ distance between two centers
≡ distance between another centers of atoms.



1/8 of volume.
↳ halfe of the half of th hafe

Properties: each unit cell w.r.t atoms
contains 8 x 1/8 = 1 atom/unit



Closed-packed directions

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→ the maximum number of atoms that touch this atom

Coordination number = 6 atoms

Number of atoms per unit cell: = 8 corners x 1/8
= 1 atoms

In 3-D the packing efficiency is given unitcell's by:

P.E = (volume of spheres) / (volume of cell)

for a simple cubic lattice, this is:

volume of sphere $= 1/8 * 8 * \frac{4}{3} * \frac{22}{7} * (0.5a)^3$

volume of cell $= (a)^3$

$\therefore P.E = \frac{88}{168} = 0.523$

↑ P.E ↑ solid ...

solid atoms of unit cell → 0.4 not filled with atoms

* ... unitcell ... atoms ... *

qualitative ...

P.E ... ← factors ← quantitative *

face centred cubic (FCC) : or cubic close" Packed (CCP)

* Atoms touch each other along face diagonals.

NOTE: All atoms are identical.

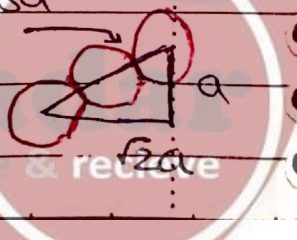
* Example: Al, Cu, Au, Pb, Ni, Pt, Ag

* coordination number = 12 atoms. how come? 12 atoms adjust to each atom

* Number of atoms per unit cell:

= 6 face x 1/2 + 8 corners * 1/8 = 4

⇒ the cube edge length a = $4R/\sqrt{3}$



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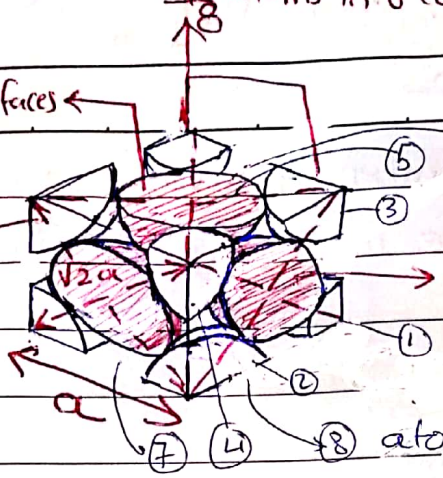


but 4 atoms remain to touch the atom directly from building block beside it

In 3-D the packing efficiency is given by:

PE = (volume of spheres) / (volume of cell)

For a face centered cubic lattice, this is:

volume of sphere $= 4 \times \frac{4}{3} \times \frac{22}{7} \times \left(\frac{\sqrt{2}a}{4}\right)^3$

volume of cell $= (a)^3$

$\therefore$ P.E. $= \frac{995.6}{1344} = 0.7405$

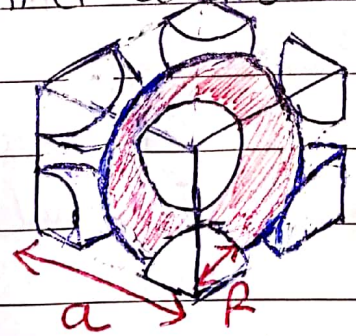
* Body centered Cubic Structure (BCC)

- The hard spheres touch one another along cube diagonal
- The coordination number, CN = 8.
- Number of atoms per unit cell, n = 2

1 center atom shared by no other cells : $1 \times 1 = 1$

8 corner atoms shared by eight cells : $8 \times 1/8 = 1$

Corner and center atoms are equivalent.



volume of sphere $= 2 \times \frac{4}{3} \times \frac{22}{7} \times \left(\frac{\sqrt{3}a}{4}\right)^3$

volume of cell $= (a)^3$

P.E $= \frac{914.5}{1344} = 0.6805$

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the higher coordination number and packing efficiency mean that this lattice uses space more efficiently than simple cube.

Density Computations:

Since the entire crystal can be generated by the repetition of the unit cell, the density of a crystalline material.

$$\text{Density} = \rho = \frac{\text{Mass of Atoms in unit cell}}{\text{Total volume of unit cell}} = \frac{nA}{V_C N_A}$$

Where:

n = number of atoms/unit cell

A = atomic weight

V_C = volume of unit cell = a^3 for cubic

N_A = Avogadro's number = 6.023×10^{23} atms/mol

Theoretical Density, ρ

Ex: Cr (BCC) : $A = 52.00$ g/mol

$R = 0.125$ nm

$n = 2$

$$a = \frac{4R}{\sqrt{3}} = 0.2887 \text{ nm}$$

$$\rho = \frac{2 \text{ atoms/unit cell} * 52.00 \text{ g/mol}}{a^3 \text{ volume/unit cell} * 6.023 \times 10^{23} \text{ atoms/mol}}$$

$\rho_{theoretical} = 7.18$ g/cm^3

$\rho_{actual} = 7.19$ g/cm^3

Subject (الجزء -> الجزء مباشرة) Date 6 July No

Chapter III

Outline

- How do atoms arrange themselves to form solids?
- Types of solids.
  1. Single crystal
  2. Polycrystalline
  3. Amorphous
- Crystal structures → * Related to Metals
  1. Simple cubic
  2. Face-centered cubic
  3. Hexagonal close-packed
  4. Body-Centered cubic
- Closed packed crystal structures
- Density computations

(سيبدأ تكوين الجزء من هنا)

* Crystalline lattices slid: (the lattice) = array of the building block unit

book → different Pages → each page → many lines.

lines ← different ← word

word → building Block unit

(Each word Contains different letters) → atoms

≡

smallest thing ≡ is the atom → many atoms will creat building block → many building blocks ≡ chain → many chains will creat a lattice → these lattices ≡ structure crystalline

⇓

what is the anatomy of crystalline?

NOTEBOOK

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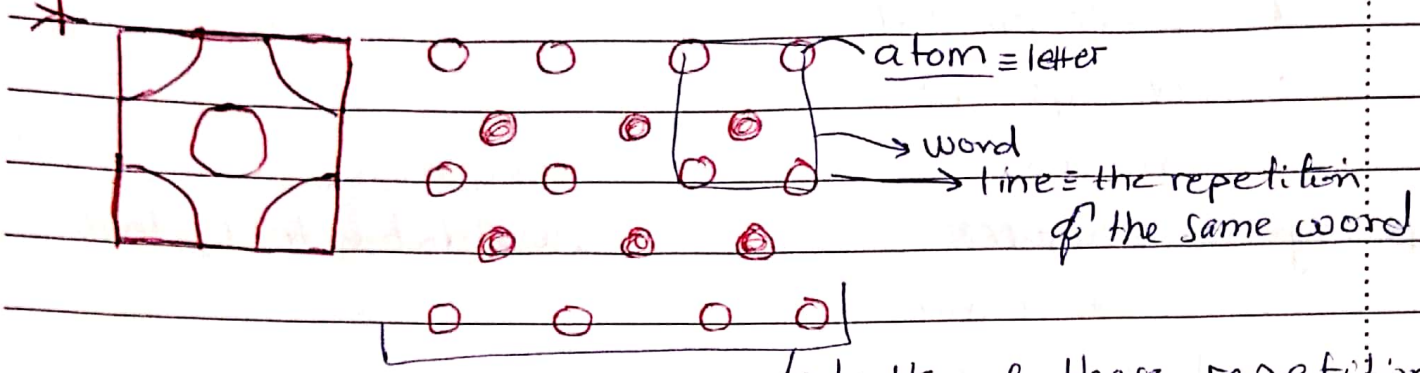
What is repeating? building blocks "word"
but the repetition = lattice



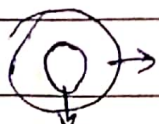
* Metallic crystal structures slide:

▷ Metals tend to be densely packed? Why?

a cubic with a dimention of (10 cm) made of metal (let's say Iron) is heavier than similar cube made of wood with same dimention, Why? (The packing) the atoms they are closely packed in metals compared with the atoms when they distribute within the wood structure.

* Metalic bonding is not directional? →

if an atom needs to share another atom in order to be stable that should'nt be done with only spesific atom.



→ It selects proper e⁻ to be stable

So there is a lot of varities for the atoms to be stable from the neighbour electron this not directional

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*Nearest neighbor distances tend to be small in order to lower bond energy ?!

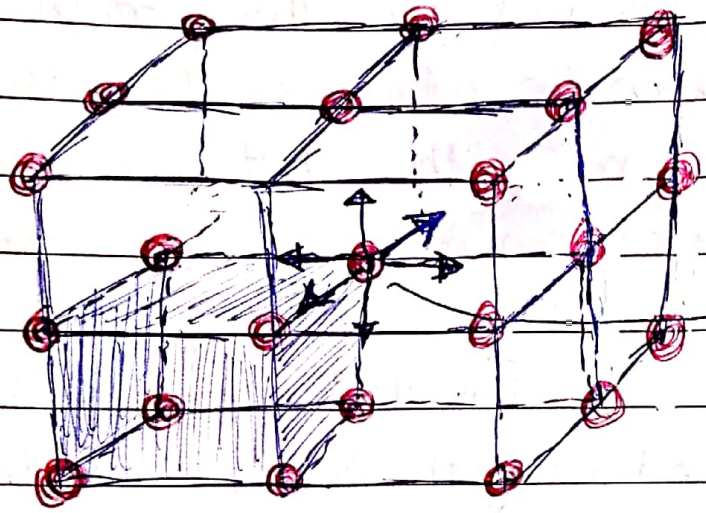
need minimum bonding energy, for metal, the atoms stand away from each other with a minimum bonding energy, ex: for simple cube is the distance between the centre and the other centre without any voidage or space between the atoms, so the distance D or 2r, othe crystalline more than that

+ The atomic bonding in metals is non-directional ⇒ no restriction on numbers or positions of nearest neighbour atoms

atom can at single moment be using this electron to be stable, but in another moment it will not using the same e⁻ from the other atom.

Subject Ch III, Dr. Yousef Date 8th july No.

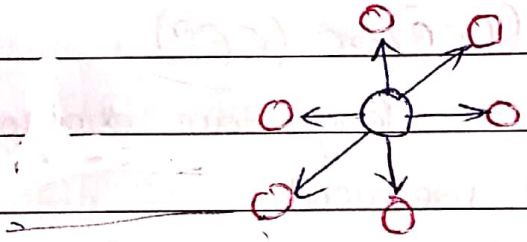
* Coordination number = 6 atoms for simple cube?
But Why?



* Big Cube owns 8 small cubes

* Coordination?
→ select atom in the middle

This atom will be indirect contacts with 6 atoms



* coordination number faced centered Cube
* we have two building blocks.

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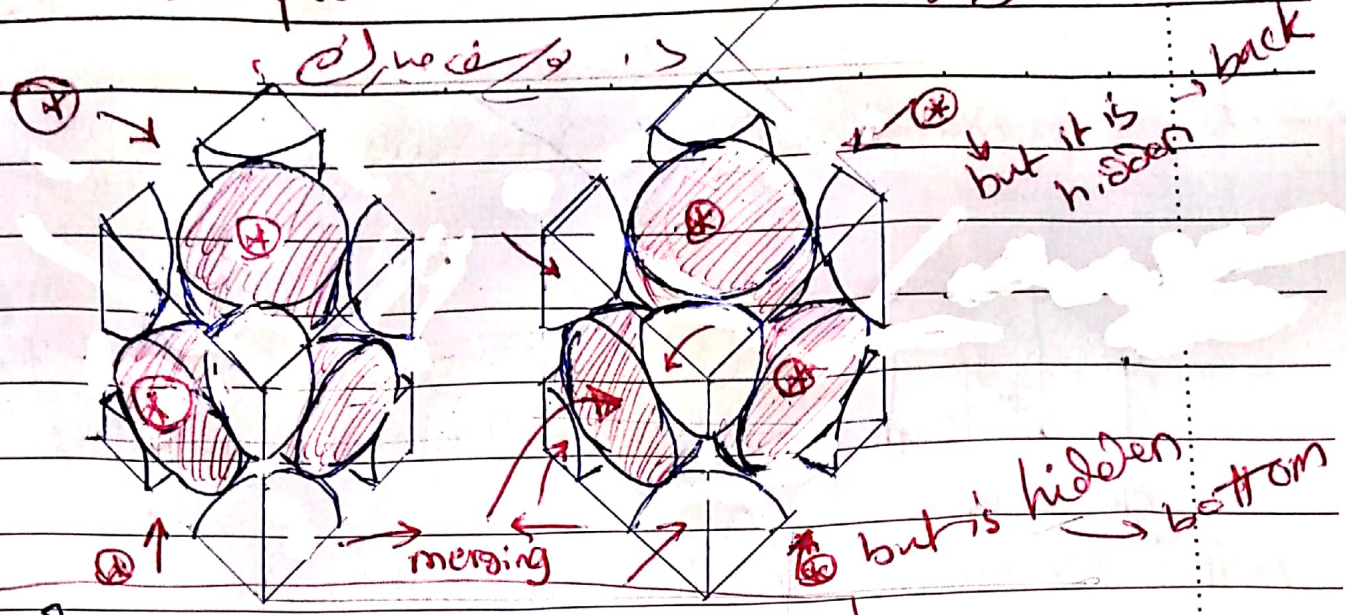

AMROXIPATE DRAWING

we want to merge these building blocks together just to how many atoms touch the red atom.

✓ Atoms in the edges (4)

✓ Atoms behind ⊛ (4) atom from first block
(4) atom from Second block

because it is one atom but each half belong to different building block.

= 12

* R.E (FCC): (12) atoms exist → building block is more dense.

(how many atoms we have within the building block

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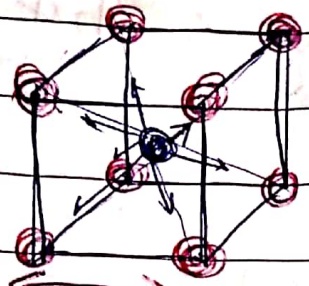
Body centered cubic structure :

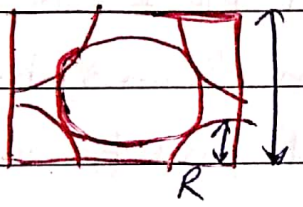


(8) → coordinat → direct touch atom
→ 2 atoms equivalent

NOTE: No longer 2r between centers.
unlike simple cube.

(Ex) From Periodic Table: Cr, W, Fe(α), Tantalum, Molybdenum.

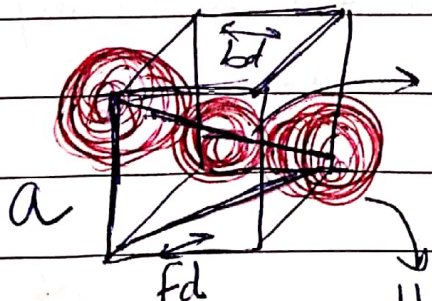
(*) Volume of building block



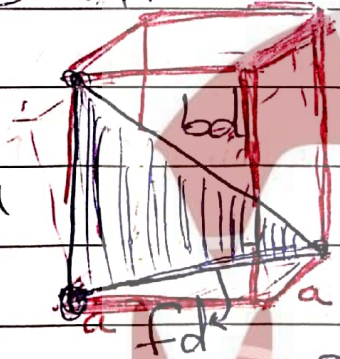
* challenge: we don't know distance
It's a^3, but no, we need
(a in term of r) or Vice versa

↓

* we do pythagoras twice after choosing diagonal (meaning) of building block



bd



three atoms are in direct content

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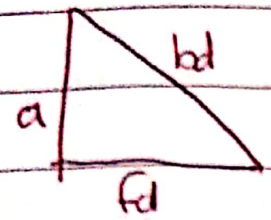
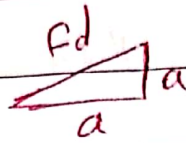


It is equal (4r)
→ 3 atoms in direct contact

$(bd^2) = a^2 + fd^2 \Rightarrow (bd^2) = a^2 + 2a^2$

we want to calculat it in terms of a



So; $bd = \sqrt{3}\,a = 4r \rightarrow r = \frac{\sqrt{3}\,a}{4}$

Volume of sphere $= 2 \times \frac{4}{3} \times \frac{22}{7} \times \left(\frac{\sqrt{3}\,a}{4}\right)^3$

Volume of cell $= (a)^3$

If you put it in term of (a)
you must put in term of a, too
to cancel each other

$\therefore PE = \frac{914.5}{1344} = 0.6805$

* forth Structure :

(Hexagonal Close - packed crystal structure)

Example: Cd, Mg, Zn, Ti. have this cryptal structure

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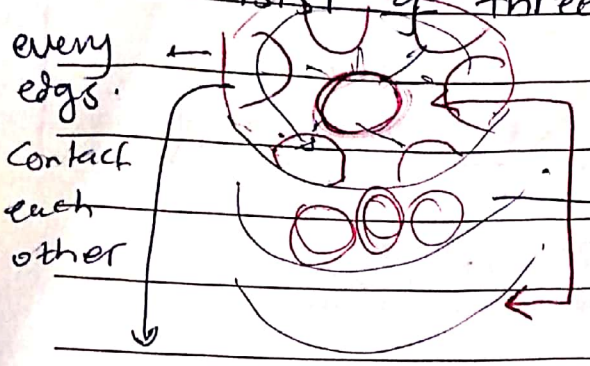
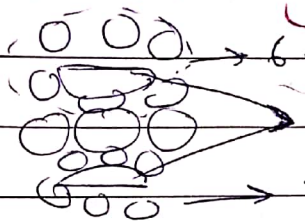
* consist of three layers.



similarity
→ three atoms → Complete atoms in the building block because they are hidden

In direct content with the middle one

How many atoms within the building block?

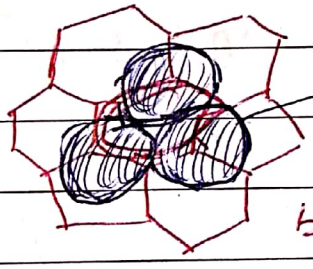


→ 6 edges → $\frac{1}{6} \times 6 = 1$

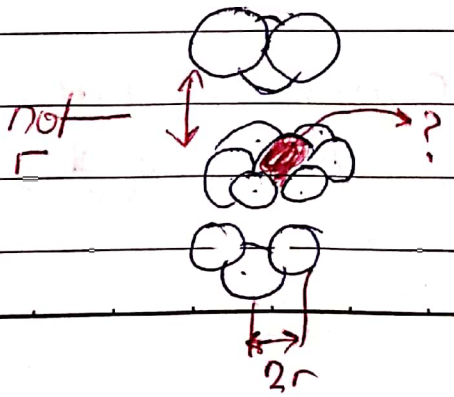
$\frac{1}{2} + \frac{1}{2} = 1$ + 3 in middle layer

→ 6 edges → $\frac{1}{6} \times 6 = 1$

6 atoms total equivalent in hexagonal structure, which is the max.



Coordination: (12)



→ different building block

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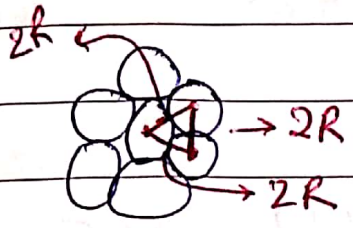
two dimention

between one atom and the other one = a → dimention I

between the layer and another one = c → dimention

▷ Radious → value of a → value of c from (Rahb)

→ Area of hexagon * height



→ 6 equal triangles with equal edges

→ Area of one tringle * 6 = Area of hexagonal

* Density computations:

(كثافة, density) →

- Atomic weight
- Density
- Crystalline structure
- Atomic radions

To calculate the density assume you have one building unite

(Mass of this volume / volume itself) (kg/m³)

Subject CHP III Date 8th July No.

Dr. Yousef

theoritical: نظري

in order to calculate volume, you have to the volume of building block unit if it is a cube $= (a^3)$

body centered cube not the same as simple cubic
↳ we should know the relation between a and r in all cases

ex: Cr → actual from table 7.19 BCC

bulk density

Densities of Materials classes:

Polymers are (light) unlike metals → metalic bonds

↳ covalent bond

↓ P.E ↓

↓ P.E ↑

To inhance mechanical properties of polymers:

Metal + (Graphits / Ceramics / semicond) + polymers

↓

Composites

variation of densities between the light metal and the heavier ones :

		Density	Atomic Radius
Al	→ fcc	2.71	0.143
Copper	→ fcc	8.94	0.128 ↓ less atomic Radius

↓ R the more atoms you can add to the cubic structure hence you can increase the density

* Crystals as Building blocks (slide)

Why do we prefer to use one [single crystall structure]

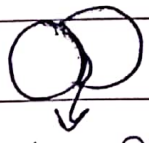
because this kind of structure is very strong

diamond is very stronger (not metal) but its properties like single crystal structure play great role.

+ Polycrystalline materials:

↓

Grain boundary



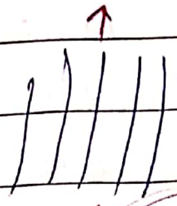
boundary = weak

clearity بيوزع على

Subject ↓ ch III — Date 9th July No.

* random → random → not specific direction (internal)
* orientation → most of them in the same direction

* apply force in specific direction

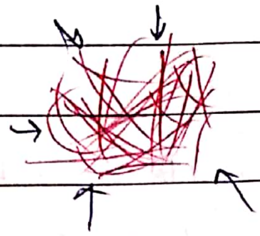


* this shape stronger in longitude direction than another (p.c) resistance

(37) ص ٤ل ثي

* properties not uniform

Prefer



→ strong wherever we apply force

* orientation → melting sample → Cooling under controlled cooling → isothermal cooling
→ تبريد سريع
↓
item fabrication
↓
سخين
↓
شد في اتجاهات متعددة → orientation المطلوب

* ↑ grain bounders → Small crystalls → weak crystall

* Isotropic structure have resistant in all direction
↓
* Random distribution
* ∞ grain bounders
* similar properties in all direction

bject Chp ### Date 9th July No.

random = isotropic properties = similar resistances

* atoms directly connected stronger than atoms between them separation → need force to separate

* Isotropic → ↓↓ cost

* Carbon — graphite

↓

not the same properties

↓

polymorphism of carbon

↓

Completly different structure

Subject chapter III Date 9 July No.

* Crystallographic Points, Directions and plans

+ linear density: stbl divided by a distance
+ planer : divided by an area
density = ____ (volumetric)
Volum

density = ____ (planer)
Area

density ____ = (linear)
distance

* Points : Atoms → budding unit

+ vector : origin

* plane → rule →

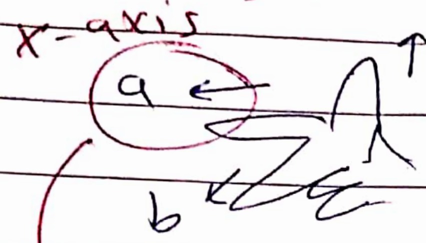
(length, width, height) (3) (4) hexagonal
cubical
rectangular →

Symmetry → faces

* Sign = bar → Right hand rule

Subject
Date July 9th No.

~~Right hand~~



→ direction does not change from one unit building block

لف

counter clock wise على y-axis
ه بيطلع على ال c

+Z تبقى → bar Z لما تبقى
عكس اتجاه ال right hand rule

* geometry → 6 faces → ~~without~~ regardless the angels 90 / 80 } ما بتفرق

Parallel ليكونوا faces أهم اشي

No: .....

Date: 13th - 2020 - July

Type of Imperfections:

- Point
- line
- Area
- Bulk

Point:

Vacancy
self - interstitials → stress حول

* extra soldification

* Mechanical stress = residual stress =
  ⇒ dislocation, fracture

مثلاً: molten material
say It is a molten (AL)

⇒ mold + Cooling

slow

fast

why; slow cooling is better?

mechanical strength ↑ → No thermal residual stress or internal stress.

why is this?

slow; freezing, soldification → There is no heat transfer or heat to do dissipation.
or there is not any entropy to dissipate

↑ internal stress = structure becomes weaker

ex: molding: فكان اللحام هو أضعف مكان!

* we can apply fast cooling in case we aim to specific properties

brittle ↑ energy stress.
↓
That is why glass easy to crack

* to strengthen glass?

نسخن الزجاج على (80) درجة مثلاً لعدة أيام
وبعدين بيسيب كل internal energy
internal stress
dissipated → heat Transfer
↓
Soldification

* اي مادة فيها اجهاد خارجي ≡ مادة ضعيفة
اي ← external force ← كسر اسهل.

* imperfection → strength → chang properties internally

* imperfection → modification → under controlled condition

مثال Carbon steel : strong

* imperfection → point, line, Area, bulk
↓
dislocation

⊕ solid solution → alloyes مهمة

compatibility, with stronger mechanical strength
↓
metal dissolution

Internal Stress ← كتلة العملية مش لازم هاي
→ داخل المادة

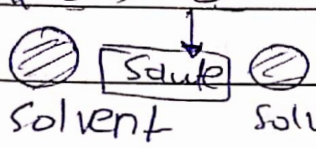
* ↑ valancy ( ) ↑ solubility

Al^{+3} > Ag^{+1} → ... solubility

* steel → non-homogenous

* Substitutional solid solution

solvent ...



+ Dislocations: linear defects

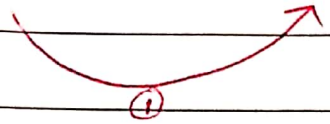
imperfection → dislocation

... → defects

ubject Mechanical Properties Date 19th July No.

elastic : property in which enable the material to get back to its original state when load is removed

(slid no. 3) 1. Initial 2. small load 3. Unload

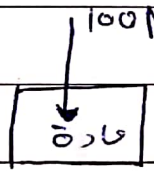


① and ② same behaviour ≡ linear elastic

* deformation has range ↗ elastic ↘ plastic

* Stress : represents the load apply to the material

* Stress ≡ ปริมาณ pressure



→ Doesnot give any information about what the kind of effect is going to happen

↓

more usefull term to know what happen to material ≡ N/A

load / A

Force → applied to material ①

→ applied to material ②

↓

Stress F/A ← (A) ปริมาณ → ใส่

↓

Area

How does (A) affect the material?

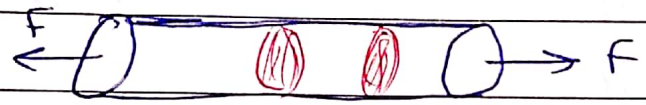
perpinducular ↓ tensic stress

Parallel ↓ shear stress

+ Torsion → rotating shaft

Shear → Area يؤثر على ≡ Torque

* simple tension:



A تتغير

$$\sigma = \frac{f}{A_o}$$

A_o → instant Area but for → dynamic analysis

static we use original Area.

∴ instant Area → each time has a cross section.

→

+ Compression:

$$\sigma = -\frac{f}{A_o}$$

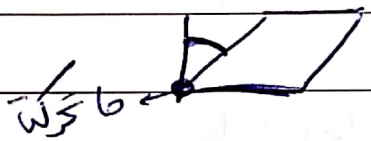
to show that number indicats compression not elongation

App for compression

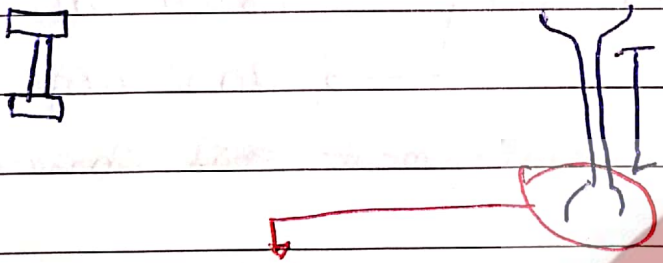
* Bi-axial tension ←O→ (↓ ↑)
* hydrostatic (Compression) ثلاثي الأبعاد

20th - July:

* Strain: deformation in the material
* difference in force ≡ tension strain
* $\varepsilon_L = \frac{\delta_L}{W_o}$ ← dimension decrease
  direction of deformation
* shear strain ≡ slippage in the shape

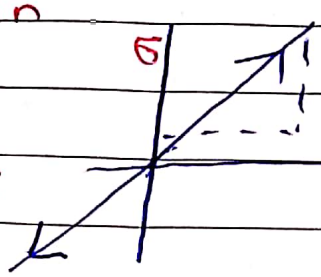


* Tesil stress test ? ASTM وغيرها standards



* why is this? to be held by the clap of the machine
  we apply force in gage length with small range
  [bone]
* why is it shapped like that? because if we apply force, we can avoid [end error] ← clap ما يلتقط

* slid (no. 11) : the relation between stress and strain



$\sigma = \frac{E}{\downarrow} \varepsilon$] linear

Modulus of elasticity → slope in elastic period

* slid (no. 12) :

tensil strain and lateral strain

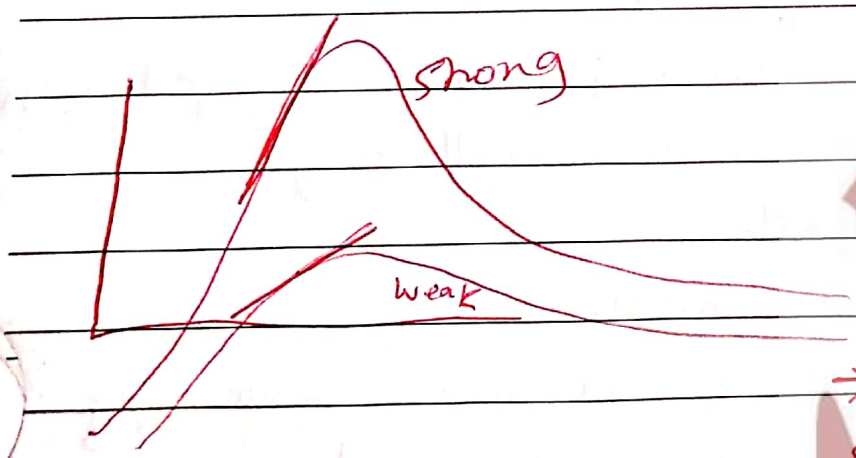
$$\nu = -\frac{\varepsilon_{lateral}}{\varepsilon} = -\frac{\delta_L}{w_0}$$

ν : poisson's ratio

* the relation between tensile strain and lateral strain is an indication to:

① If the material → isotropic / anisotropic

② molecules arrangement



* equilibrium interatomic separation r_0

→ on an atomic scale, macroscopic elastic strain is showed

as small changes in the interatomic spacing and the stretching of interatomic bonds

∴ magnitude of modulus of elasticity is a measure of the resistance to separation of adjacent atoms

Values of the modulus of elasticity for ceramic are about the same as for metals.
for polymers, they are lower

(slid no. 14):

$\tau = G\gamma$

τ → shear stress, γ → shear strain

{ Relationship between shear stress and shear strain for elastic deformation

* $P = -K\frac{\Delta V}{V_0}$ → volume strain

* $G = \frac{E}{2(1+\nu)}$ → elastic modulus

G → Shear modulus

bulk modulus ← $K = \frac{E}{3(1-2\nu)}$ → elastic modulus

* Bulk modulus K:

a modulus based on volume rather than angle or a deflection

* (slid no 16): modulus و stress و strain أي شي تابع الي ترتبط dimensionless

Hooke's law + definition of stress:

$\Rightarrow$ $\delta = \frac{P L_0}{A_0 E}$

P → force

L_0 → original length

E → elastic modulus

δ → deflection intension

22th July

* yeild strength: σ_y: at which the material starts to yeild deformation

* نقطة الوضع نتيجة ال load
* deformation = permenant
* Design = NOT TO REACH

* a Material → testing → knowing yeild → Application
* Application = Safety margin
* Mechanical structure, we suppose to apply load on, below the strength.

* (slid no. 19) Yield strength: comparison

* yield strength depends on the kind of material
* (treatment) بتختلف المادة بتغيرها حسب التصنيع (yield strength)
  ↳ Steel annealed Yield strength > Steel cold drawn

* Yeild strength for metals > yield strength of polymers in general

* annealed ≡ معالجة حرارياً

* What is annealing?
  we put the material on oven for several days with about (80 - 100) °C
  ↓ so
  ✓ Releasing for residual stress or thermal stress.

  ✓ giving energy to structure → rearrangment to atoms

* releasing residual stress ← بنزيل بطريقة ما ← بقلل الـ

* stress (in general) أي مادة فيها stress ضعيفة من مادة ما فيها stress

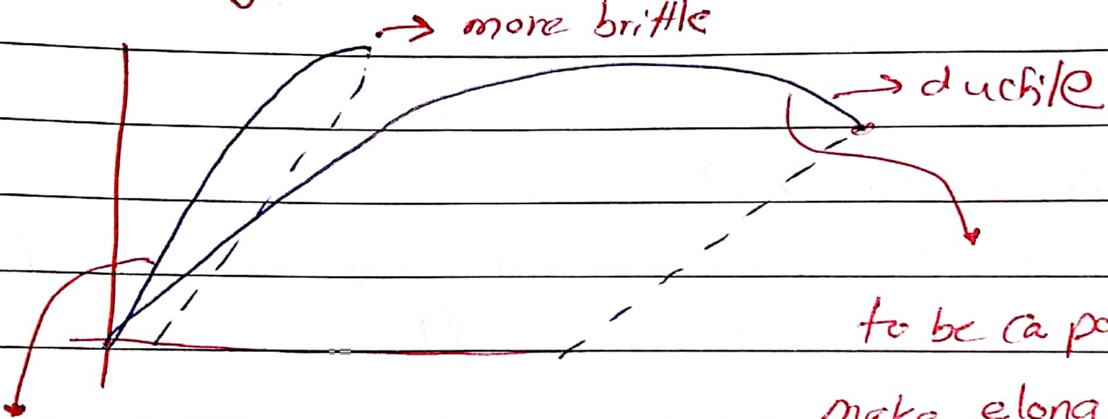
* quenched and tempered = special case

* very small crystalline and very brittle = ↑↑↑ tensile strength but not ductile

↑ brittness ↑ strength على حساب ductility

* maximum stress > yield : noticeable necking
* maximum tensile strength → differe from material to another → حسب fabrication or processing condition

* Ductility (slide no. 22) ← tensile



to be capable to make elongation before reaching breakage

استحمل strength أكبر يعني أستطالة أقل

* Depend on the required App, we consider any of each ductile / brittle is better

Toughness :

مثال: Steel و Al لما أقارن بين

↓

Same Volume

↓

Affecting of a force

يعني مادة تستحمل حتى لو tensile أقل القوة المؤثرة عليها بصير فيها elongation من دون ما تتكسر

taughness (slide no. 23)

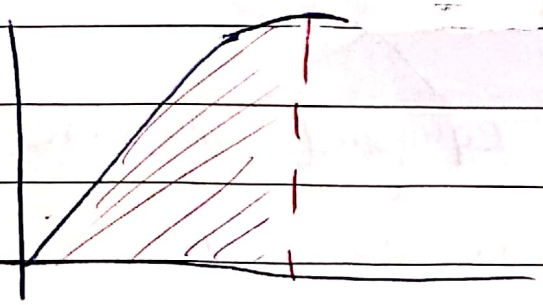
* ↑ brittleness ↑ Tensile strength ↓↓↓ toughness
  why

* How much the materile is toughness depends on how much it could store energy before breakage
  ≡ the ability to absorbe energy without breaking

* Robber toughness >> steel toughness
* steel ≡ deformation ≡ permenant change
  robber ≡ deformation ≡ not permenant change
* ceramic < robber , and glass too.
  less tough

↑ ductile ↑ toughness / ↑ brittle ↓ toughness

Resilience, Ability Store enegy without deformation



* Hardness: (surface property) مقاومة السطح لأي نوع من deformation

* Tensile Strength ↑↑

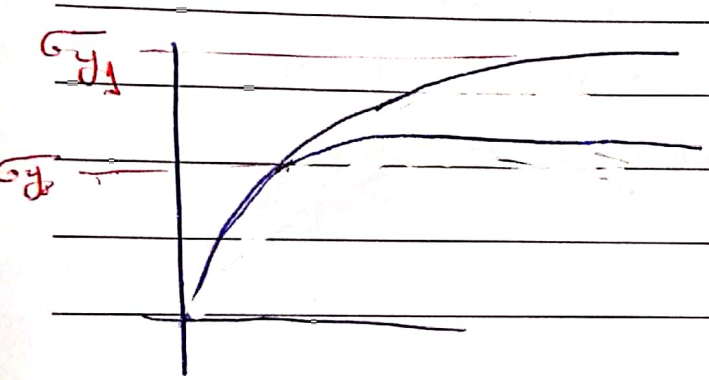
Surface scratch ↙

↓

not hard but it is shong

* Differences of hardness = explanbion: structure or how atoms arrangement

* Hardening (slide no. 30):



heat treatment ≡ ↑↑ Tensit strength

Ductility ↓↓ ↑↑

* how can I modify mechanical property? ↑hardness ≡ heat treatment

* Shong material → surface hardness ↑↑

equipment machine

Cutting Rocks Shaft ← force

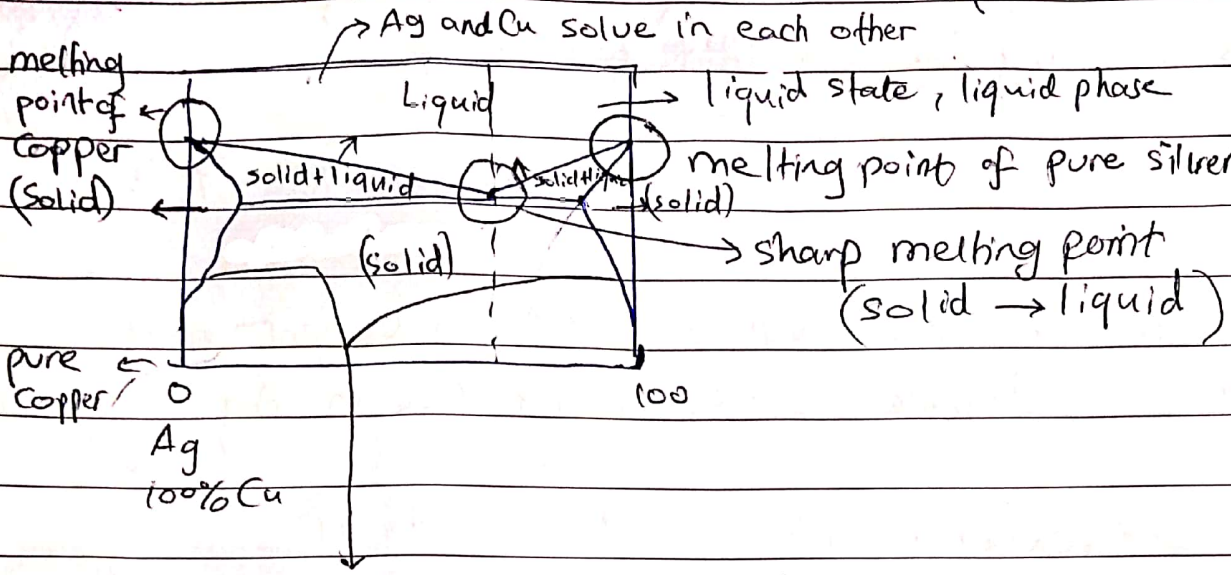
* material → deformation تحدد اي نوع
↓ يتحمل اقصى
working limits
working stresses
↓
allowable shess > 1 → Safety factor

Subject 11th Aug 2020 Date No.

Ch7, slides 33 →

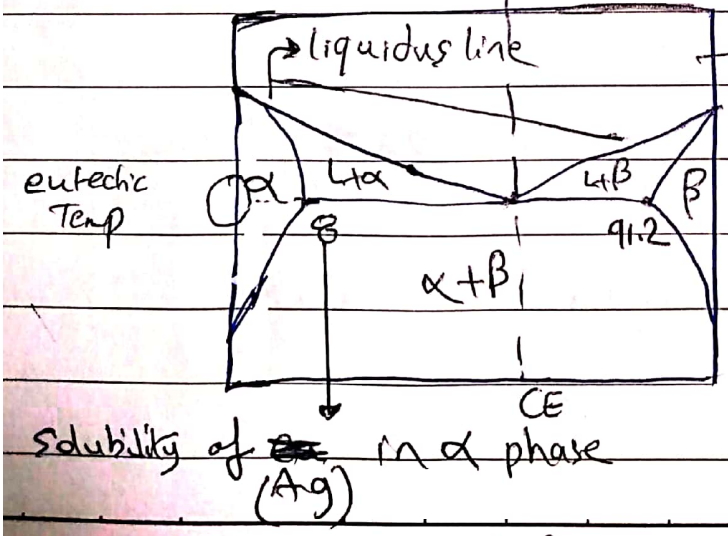
* Slide # 33: Binary Eutectic System:

* limited solubility → (Cu - Ag) → because they are not compatable



th. lines should intercept the x-axis not Y-axis, but not obvious because of magnification

* Another composition at which we have sharp melting Temp.? meaning that transfer from solid → liquid or from liquid → solid when doing solidification ?



71.9 Ag in Cu we have an alloy = 779 a

single state, single phase

β → single → phase / state

α

β+α → solid state but double phase

L+α → two state, two phase

β+L →

Solubility of (Ag) in α phase

≡ max. value is 8% only if we exceed 8% → tranfer to another Phase

α or β
↓
not pure solid, the difference between them is the composition

α → mainly Cu with littly amoont of Ag

β → mainly Ag with little amount of Cu

* The max. solubility the Cu in Ag = 100 − 91.2
= 8.8

we can dissolve up to 8% Ag in copper and we can dissolve up to 8.8% Cu in Ag

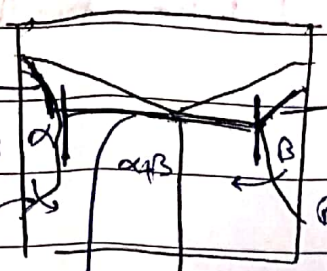
* if we exceed either %8.8 Cu in Ag or
%8 Ag in Cu
⇒ we will create new mixture of the materials exist
(α + β)

* 778 °C, once we exceed this limit the alloy of (Cu-Ag) will directly convert to liquid

* we can't apply lever rule in pure phase

L+α
L+β
α+β
} we can apply lever rule

#34



fraction line ≡ solidus

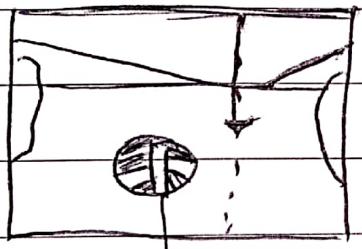
fraction line = solidus
it separates (liquid + solid) and (solid)

we can't call it a solidus line

this line called ≡ eutectic isotherm

* the tranformation from solid to another solid ≡ solvus line

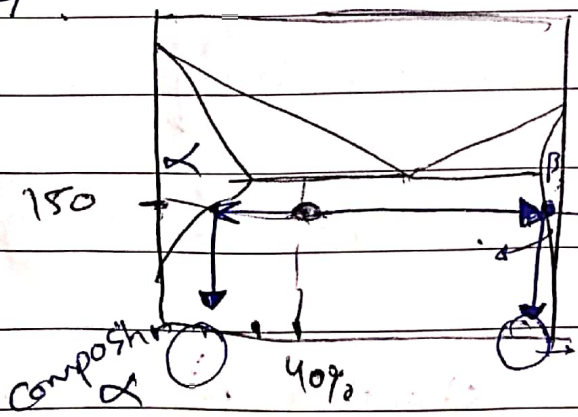
#35:



once, we cross the eutectic line we observe eutectic structure formation

eutectic structure

#37:



to attain the composition apply the lever rule

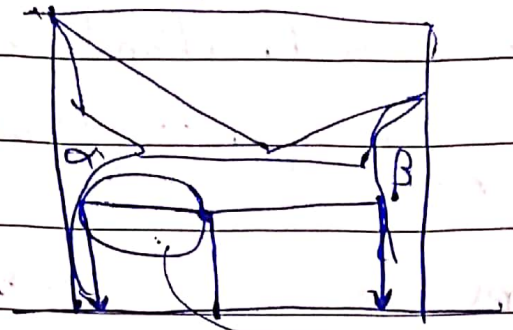
composition α

composition β phase

one state with two phases

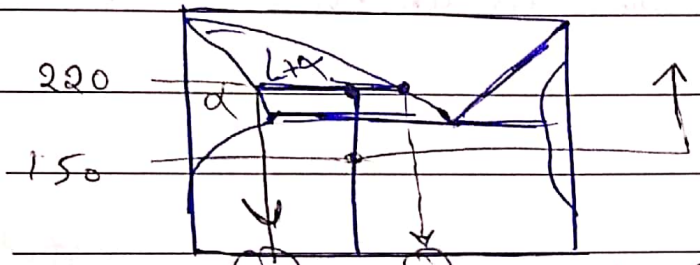
to determin β : we should take to the other side

β



$\beta = \frac{}{\text{total}}$

#38:



add 1 composition because of melting

composition Sn in liquid

composition Sn in α phase

Sn: 11% → 17% why weight fraction in α increases?

Because β melting before α

Composition β ↓ α ↑

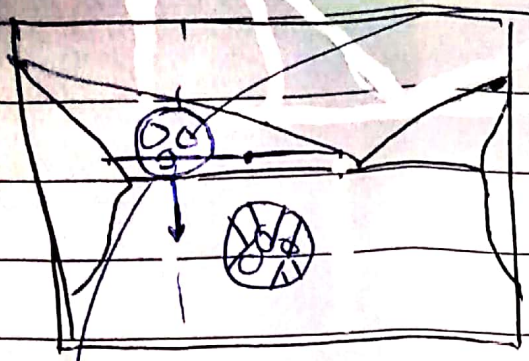
melting point β < melting point α

#39:

→ liquidus line : starting (α) creation

mixture of lead and Sn

#43



pred → ⊛ or . → created before crossing eutectic line

⊛ tie line on point 1 high fraction of liquid

α + (L) → will turn to Eutectic once it crosses the eutectic line

* Calculate the pre-α composition?

Apply lever rule just above the eutectic line

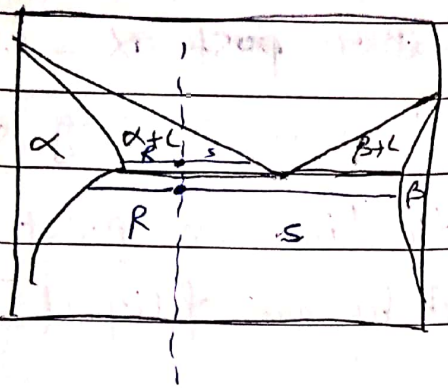
$w\%\alpha : \frac{61.9 - 40}{61.9 - 18.3}$ $\quad \%\,liquid = \frac{40 - 18.3}{61.9 - 18.3}$

(post-α) ..... → 0.73 − 0.50 = 0.23

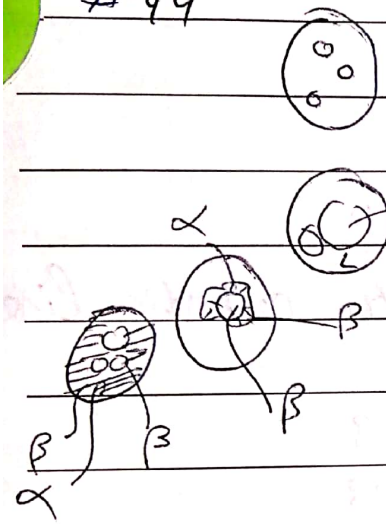
↓ before eutectic

Subject 12 - Aug - 2020 Date No.

#43



#44



How many β? 2 types

post β or pre-β? which stronger?

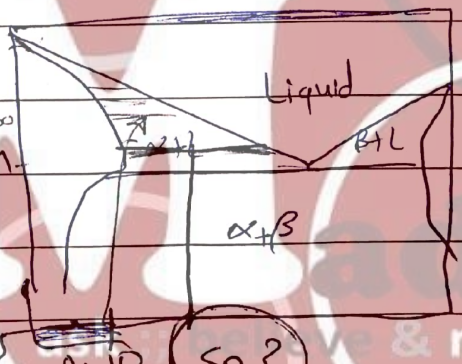
pre-β ↑ melting Temperature ↑

#46

for 10% wt Sn, 90 wt% Pb alloy:

(1). liquid-solid Area

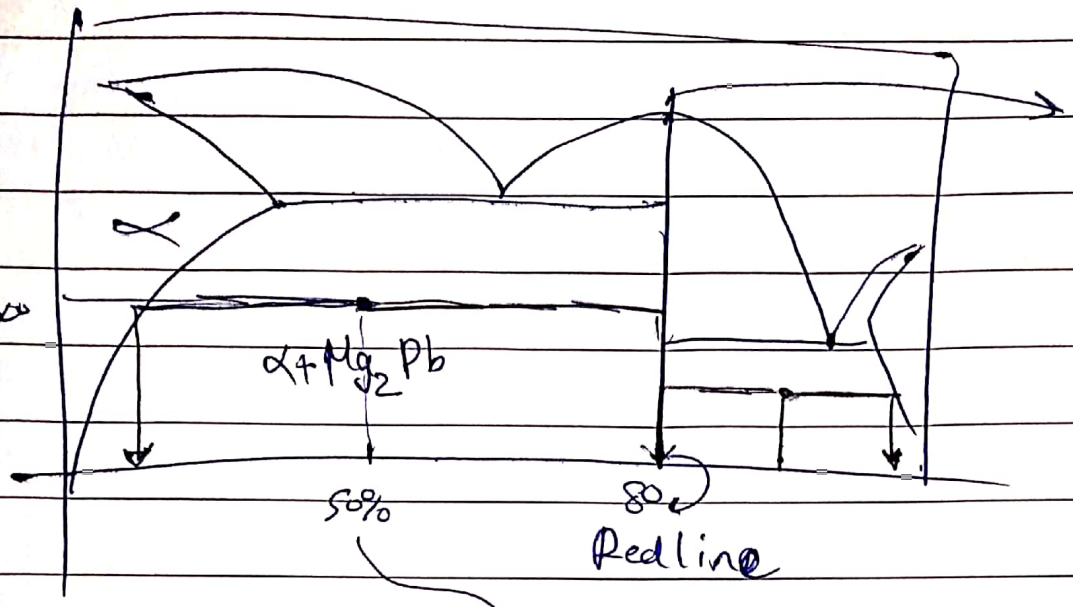
→ trail & error to attain left arm ≡ right arm



(2) (liquid - Solid) Area → separat two equal segments

(%Sn - 10%) →

* 48 : Mg_2Pb always exists in solid state



Two different phase diagrams but merge together

* Rever Rule
State → solid
weight % → extend line to solvus line and red line

* NO way to creat a structure contains both α & β

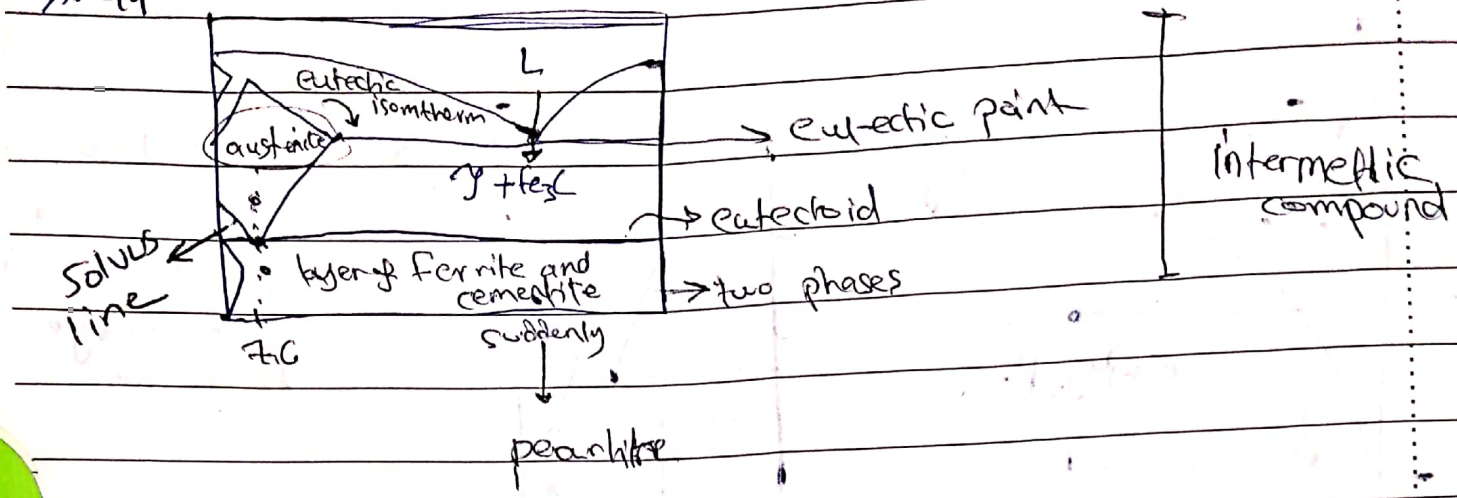
* Iron Carbon (fe-C) very important Diagram
Iron as pure → not heavy use → ductile like gold

ductile / steel / cast
BCC → fCC → Carbon ~~subs~~ intershtial rather than substitution

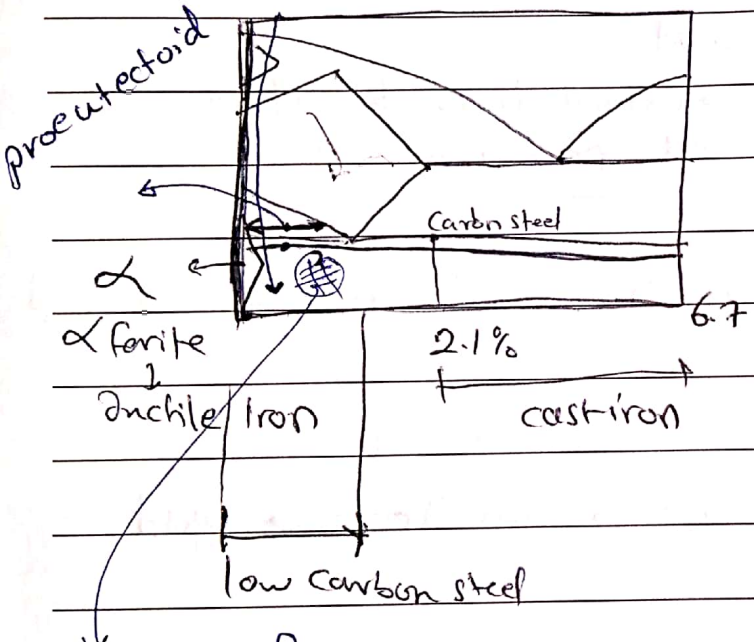
* limited solubility of C in iron because of radious of C
* Tmax 6.7% = solubility
* most Steel → austerite region

Subject Date No.

#49



#50:



* austenite → pearlite once you cross eutectoid line

* pearlite: ferrite and cementite

* above eutectoid line ≡ hypoeutectoid
below

% α - 76 C ω .51

pre-α ferite

post-α → ferite from austenite

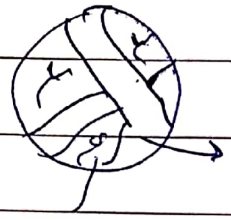
* There are post-α, post-α ? apply composition above and below the eutectoid line

Max. weight fraction of α above eutectoid and below

* ~~total~~ ferrite below - ferrite above = post ferrite

* $Fe_3C \rightarrow \frac{R}{S+R} \rightarrow$ cementite

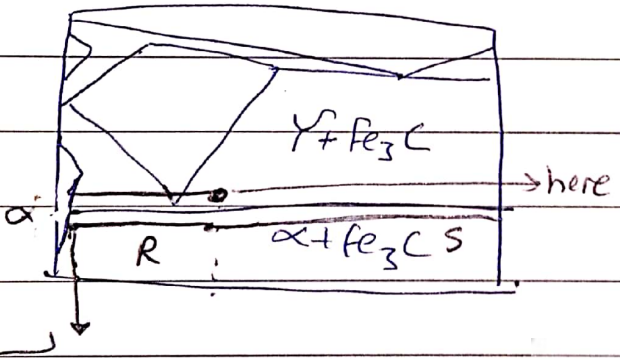
* Hypereutectoid steel: 1 α phase
2 cementite phases
above, below



Fe_3C (cementite)

austenite → after crossing eutectoid → pearlite
(ferrite cementite)

* Maximum cementite can be created just above eutechide line



$\% \text{ ferrite} = \frac{S}{R+S}$

$\% \text{ cementite} = \frac{R}{S+R}$

* 5.6% C in Iron for an example:
structure obtains after eutectoid line → has 3 types of cementit