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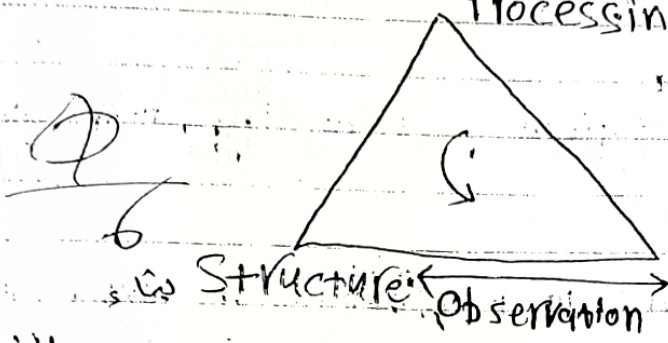
Material Science & Engineering

Material Science: is the Investigation of the Relationship among Processing, structure, Properties & performance



Properties: are the way the material response to the environment & external forces.

Mechanical Properties: are response to mechanical forces

Ch2

Atoms: nucleus (P+N) + e

Charges: electrons (-), protons (+) 1.6×10^{-19} Coulmbs

Atomic Mass: mass of (P) + mass of (N)

Proton & Neutron have the same mass $\Rightarrow 1.67 \times 10^{-27}$ Kg

e: 9.11×10^{-31} Kg

a.m.u (Atomic Mass Unit): is often used to express atomic. 1 amu is defined as 1/12 of the atomic mass of the common isotops of carbon

atomic weight = weighted average of atomic masses

A.W carbon = 12.011 amu

Moles: is the amount of matter that has a mass in gram equal to the atomic mass in amu (A mole of carbon has a
if 12 grams).

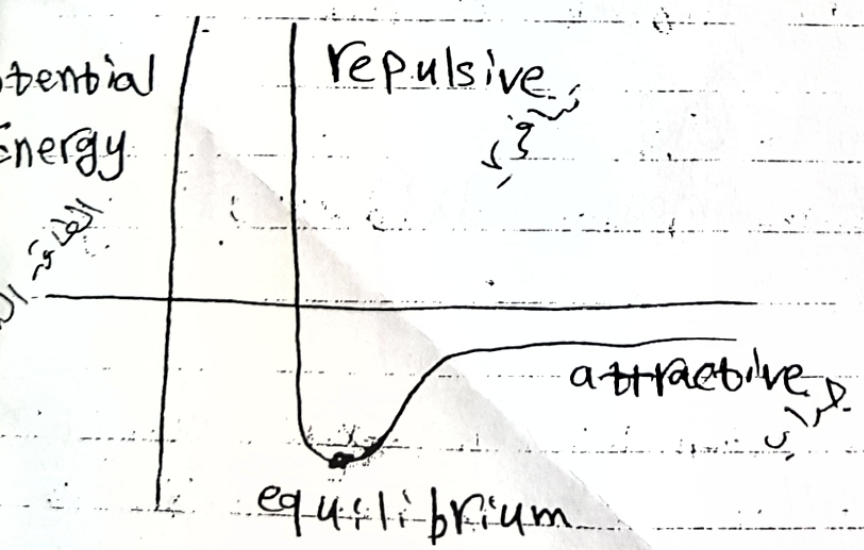
number of atoms in a mole is called Avogadro's number = 6

Paul: exclusion principle
only one electron can have a given set of the four qu
numbers.

Valeance electrons: Electrons that occupy the outer mo
filled shell (they are responsible for bonding)

Electro negativity: a measure of how willing atoms a
accept electrons.

Bonding Energies & forces:



Electron Volt: the energy lost/gained by an electron when it is taken through a potential difference of one volt.

$E = q \times V$

$q = 1.6 \times 10^{-19}$ Coulomb

$V = 1$ Volt

$1\ eV = 1.6 \times 10^{-19}\ J$

Types of Bonding:

I) Primary bonding: electrons are transferred or shared.
Strong (100 - 1000) (KJ/mol) or 1 - 10 ev/atm

① Ionic: Strong Coulmb interaction among negative atoms (have an extra e^- each) & positive atoms (lost an e^-): Na^+Cl^-

② Covalent: electrons are shared between the molecules to saturate the valency (H_2)

③ Metallic: atoms are ionized losing some electrons from the valency bond

II) Secondary bonding: no e^- transferred or shared.
Interaction of atomic/molecular dipoles
Weak < 100 KJ/mol

Ionic:
Mutual ionization occurs by electron transfer
Ion: charged atom
Anion: − Cation: +

Ions are attracted by strong coulombs interaction, (Bidirectional (Ions may be attracted to an another in any direction)

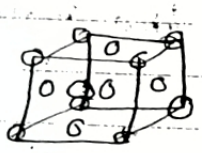
* Covalent Bondings:
- Electrons are shared between molecules formation.
- Cooperative sharing of valence electrons can be described by orbital overlap.

- Highly directional in the direction of greatest orbital overlap

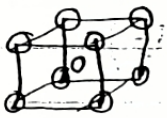
* Metallic Bonding:
- Valence electrons are detached from atoms and spread in electron sea that glues the ions together.
- nondirectional

Chapter 3:

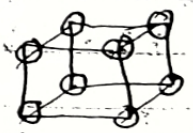
Lattice: is a collection of points which called lattice points



Face center



Body center



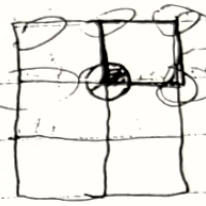
simple cubic

* Types of Solids:
1. Crystal material: atoms self-organize in a periodic array.
2. Single crystal: atoms are in a repeating or periodic array over the entire extent of the material.
3. Polycrystalline material: comprised of many small crystals of grains

*Crystal Structure:
Consider the following:
- atoms as being hard spheres with well-defined radii.
- The shortest distance between two like atoms is one diameter.

Unit Cell (uc): is the smallest structural unit or building block that can describe the crystal structure. (Repetition of the unit cell generates the entire crystal.

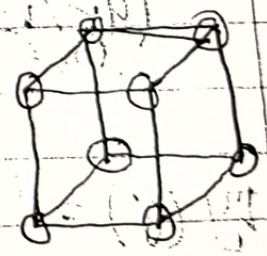
2D: ال uc الوحدة بتساهم بـ $\frac{1}{4}$ من الدائرة
3D: الكرة = $\frac{1}{8}$ = ... = ... uc ال



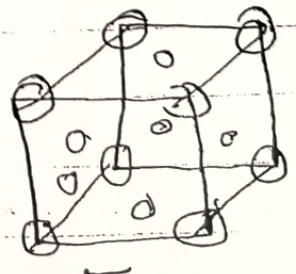
* For each unit cell in 2-D there is only $\frac{1}{4}$ of an atom at each corner.
* At each corner in 2D we will always draw full ~~circuit~~ circle to represent atom.
* it is understood that only the fraction of the atom that is contai inside the UC contributes to the total of atoms $\frac{1}{4}$ atom

Lattice Parameter: describes the size & shape of the U

$$\left(\frac{\text{Lattice Point}}{\text{Corner}}\right)\left(\frac{\text{Corners}}{\text{Cell}}\right) = \frac{\text{Lattice Point}}{\text{Cell}}$$


SC

$$\frac{1}{8} \times \frac{8}{1} = 1$$

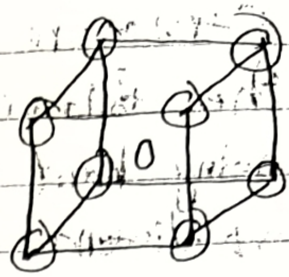

F.C.

$$\underbrace{\frac{1}{8} \times 8}_{\text{عدد الزوايا}} + \underbrace{6}_{\text{عدد الوجه}} \times \underbrace{\frac{1}{2}}_{\text{مساهمة كل وجه}} = 4$$

1

$\frac{1}{8} \times 8 + (1) \times (1) = 2$

Lattice point ← العدد ال...
كاملة
بتيجي مع المكعب جاهزة



B.C.

اللاتس بوينت بتعبرلي عن عدد الاماكن او المواقع اللي بتسمح فيها للذرات

* Hexagonal Close - Packed (HCP):

* HCP is one more common structure of metalic crystal.
* Six atoms from regular hexagon surrounding one atom in center. Another plane is situated half way up unit cell. (C-axis)

* Packing Factor = $\frac{\text{(number of atoms/cell) (Volume of each atom)}}{\text{Volume of unit cell}}$

P.F.: is the fraction of space occupied by an atom.

P.F: FCC:

Lattice Point من معادلة

$$P.F. = \frac{(4)\,(4/3)\,\pi r^3}{(4r/\sqrt{2})^3} = 0.74$$

$(a_0)^3$

ممكن يطلع P

* Density (ρ) = $\frac{\text{(atom/cell) (atomic mass)}}{\text{(Volume of u.c.) (Avogadro)}}$

Ex: Calculate the atomic radius in cm for the following
a) BCC metal units $a_o = 0.3294$ nm and one atom per lattice Point
b) Fcc " " $a_o = 4.0862$ Å

Perfect: one atom per lattice point

(a) $r = \frac{\sqrt{3}\, a_o}{4} = 0.1426\ nm = 1.426 \times 10^{-8}$ cm

(b) $r = \frac{\sqrt{2}\, a_o}{4} = 1.4447\ Å = 1.4447 \times 10^{-8}$ cm

Ex: Determine the crystal structures for the following: (6)
(a) a metal with $a_o = 4.9489\ Å$, $r = 1.75\ Å$
(b) " " $a_o = 0.42906$ nm, $r = 0.1859$ nm
(a) by ratio between a & r ⇒ fcc
(b) BCC

Ex: ρ for an element which has the BCC structure is $0.855\ g/cm^3$, A.W = 39.09 g/mol. Calculate
① lattic parameter
② r.

$$0.855 = \frac{(2)(39.09)}{(a_o)^3 (6.023 \times 10^{23})}$$

① $a_o = 5.3335 \times 10^{-8}$ cm
② $r = 2.3103 \times 10^{-8}$ cm

Ex: a metal having a cubic structure $\rho = 2.6\ g/cm^3$, A.W = 87.32 g
$a = 6.0849\ Å$. Determine crystal structure

Fcc

x = 4

Coordinate #: is the # of atoms touching a particular

A metal has a hexagonal structure with $a_o = 0.4548\ nm$ and $c_o = 1.186\ nm$, $\rho = 9.808\ g/cm^3$, $AW = 208.98\ g/mol$

Determine:

① the Volume of U.C.

② How many atoms are in each U.C.

$$V_{hex} = a_o^2 c_o \cos 30 = 0.21226\ nm^3 = 2.1226 \times 10^{-22}\ cm^3$$

$$\rho = \frac{(\text{atoms})(AW)}{(\text{Volume})(\text{Avog})} \Rightarrow \text{atoms} = \rho(\text{Vol})(\text{Avog})$$

Ex: A metal has an orthorhombic structure with $a_o = 0.$ $b_o = 0.45186\ nm$ and $c_o = 0.7557\ nm$, $r = 0.1218\ nm$, $\rho = 5.904$ $AW = 69.72\ g/mol$

Determine:

Ⓐ # of atoms in each U.C

Ⓑ P.F

$$V_{orthorhombic} = a_o b_o c_o = 1.560 \times 10^{-22}\ cm^3$$

Ⓒ $\rho \Rightarrow$ #atoms = 8

Ⓑ $$P.F = \frac{(\#\text{atom/cell})(\text{Volume})}{(\text{Volume})(\text{Avog.})} = \frac{(8)(69.72)}{(1.560 \times 10^{-22})(6.023 \times 10^{23})}$$

Ⓑ $$P.F = \frac{(\#\text{atom/cell})(\text{Volume of each mass})}{\text{Volume of unit cell}} = \frac{8\ (4\pi/3)(0.1218\ nm^3)}{0.1560\ nm^3}$$

Exp Above 882°C, a metal (titanium) has a BCC structure, with $a_o = 0.332$ nm. below this temperature, the metal has a H.C.P structure with $a = 0.2978$ nm & $c = 0.4735$ nm. Determine the Percent Volume change when BCC metal transforms to HCP. Is this contraction or expansion?

HCP more ductile of BCC

$V_{BCC} = 0.03859\ nm^3 = a_o^3$

$V_{H.C.P} = 0.03637\ nm^3$

$\Delta V = V_2 - V_1$

$= V_{H.C.P} - V_{BCC}$

$\Delta V = \frac{V_{H.C.P} - V_{BCC}}{V_{BCC}} \times 100\% = -0.6\%$

$\Rightarrow$ Contraction

الإشارة السالبة تعني تقلص

Contraction = (-)

Exp: α-metal has a cubic structure with $a_o = 0.8931$ nm & $\rho = 7.4\ g/cm^3$

B-metal has different cubic structure with $a_o = 0.6326$ nm, $\rho = 7.26\ g/cm^3$, $A_w = 54.938\ g/mol$, $r = 0.112$ nm

Determine the % Volume change from α metal to B metal.

تغيير الـ Structure يقدر يغير عدد الـ atoms في الـ cubic

① $7.4 = \frac{(x)(54.958)}{(.8931 \times 10^{-7}\ cm)^3 (6.023 \times 10^{23})} \Rightarrow x = 58$ atom/cell

② $x = 20$

$\Delta V = \frac{\left(\frac{58}{20}\right) \text{Volume}_{(B)} - \text{Volume}_{(\alpha)}}{\text{Volume}_{\alpha}}$

correction factor $= \frac{58}{20}$

$= +3.05\%$ (Expansion)

*A typical paper cup weighs 0.54 g and consist of BCC Iron

Calculate:

ⓐ # of u.c ⓑ $a_o = 2.866 \times 10^{-8}\ cm$, $\rho = 7.882\ g/cm^3$, find # of atoms

Solution: a) # of u.c $= \frac{W}{\rho \times V} = 3.185 \times 10^{21}$ cell

b) $\# = 6.37 \times 10^{21}$ atoms

Planar (ρ) = # atoms per face / area of face

planar P.F = area of atoms surface / area of face = $\frac{\pi r^2}{a_0^2}$

Repeat distance: the distance between Lattice point along the direction.

* FCC [110]

If we start 0,0,0 Location, the next lattice point is at the center (1/2, 1/2, 0)

∴ the distance between lattice point is an half of the dia

$\frac{1}{2}\sqrt{2}\,a_0$

Interstitial Sites:

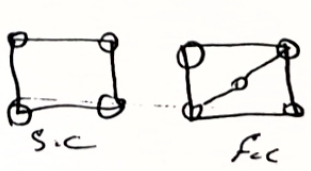
In all crystal structures, there are small holes between the usual atoms into which smaller atom may placed.

* Polymorphism and Allotropy:

* Some materials may exist in more than one crystal structu
* If the material is an element solid, it is called allotropy.
an example of allotropy is carbon which can exist as diamond, graphite.

Anisotropy:

Different directions in a crystal have a different packing
for example, atoms along the edges of fcc u.c. are more separated along the face diagonal. this causes Ainstropy in the

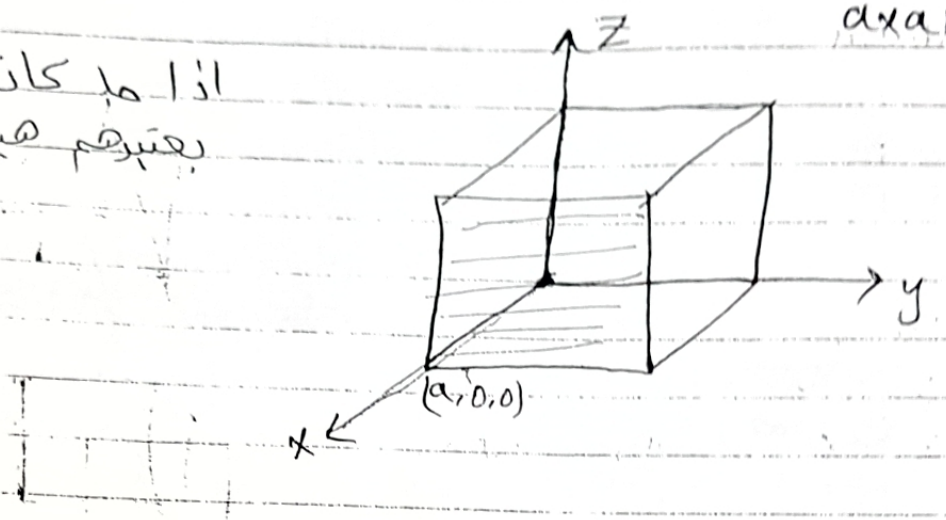


Miller Indices:

The orientation of a surface or crystal plans may be defined by considering how plane intersects the main crystallographics axes of the solid

axaxa

اذا ما كان محدد المحاور بعضهم هيك



Steps:

1) Identify the intercepts on x, y, z.

Intercepts
(a, ∞, ∞)

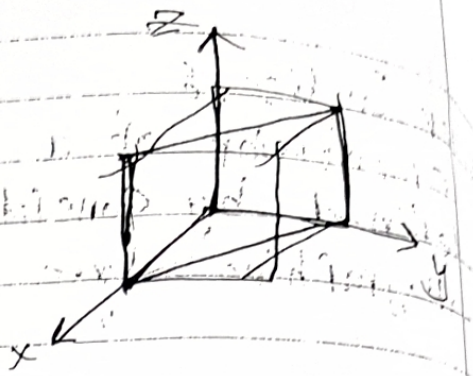
2) ~~Specified~~ Specify the intercepts in fractional coordinate point (x, y, z) ÷ axbxc

Fractional Co. (x/a, y/b, c/z)
(a/a, ∞/a, ∞/a)
1, ∞, ∞

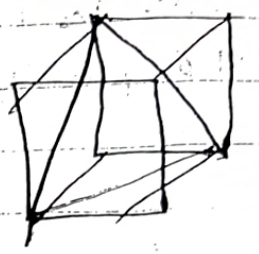
3) Take the reciprical (مقلوب) of the fractional intercepts coordinates.
(1, 0, 0)

Inter. a, a, ∞
F.co. 1, 1, ∞
M.I (1, 1, 0)

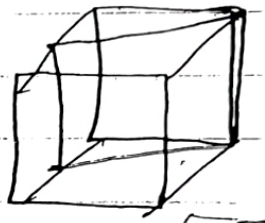
to know crystal graphic orientation



Inter. a, a, a
F.co. 1, 1, 1
M.I: 1, 1, 1



Inter. $\frac{1}{2}a$, a, ∞
F.co: $\frac{1}{2}$, 1, ∞
M.I: 2, 1, 0



* Bragg's Laws:

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

*this law explains why the faces of crystals appear to reflect x-ray beam at certain angle (θ). where:
d: is the distance between atoms layers in a crystal
λ: is the wave length of the x-ray beam.
n: is an integer
XRD: X-Ray Diffraction.

* Crystal Structure of Ionic material:
Ionic material must have crystal structures that ensure electrical neutrality, yet present ions from the different sizes to be Packed efficiently.

① Ionic Radii: the crystal structures of ionically bounded compound, is described by placing the anion of the normal lattice point cell and the cation located at one or more of the intransitial site.

② Electrical neutrality: the over all material have to be electrically neutral.

Allotropy: the ability of the element to exist more the one crystal structure - depending on Temp. & pressure.

Polymorphism: Compound have more the one crystal structure.

Chapter 4

"Crystals are like people it is the defect in them which tend to make them interesting" Colin Humphrey.

* Defect in solids (zero D) Point defect.
- Vacancies
- Intransitial,
- Impurities.

1- D: edge screw edge + screw

2- D: Surface defect

3- D: Volume defect