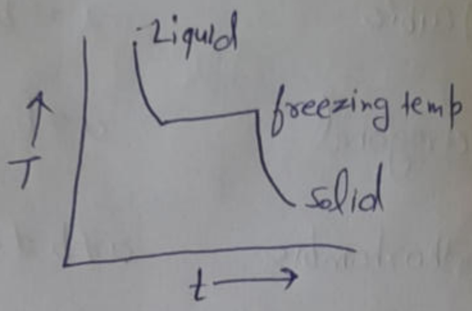
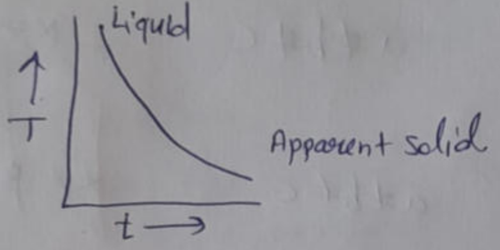
"Solid state"

① Cooling curves:

① for crystalline :-
ⓐ have sharp MP
ⓑ high density
ⓒ Eg: Metals



② for Non-crystalline



② space lattice :- An infinite array of points in 3-d in which each point is identically located wrt each other.

③ Basis :- Atoms, molecules, ions and radicals that is located at each lattice point called basis.

④ lattice (imaginary) + basis = Crystal structure (real)

⑤ Unit cell :- The min. area of cell by repeatation of which whole crystal solid may be generated,

if $\vec{a}, \vec{b}, \vec{c}$ are fundamental vectors then vol. of unit cell →

$$\boxed{V = \vec{a} \cdot \vec{b} \times \vec{c}}$$

⑥ Atoms in 3D :-

ⓐ Primitive = 1

ⓑ BCC = 2

ⓒ FCC = 4

ⓓ base centred = 2

⑦ Total Bravis lattice = 14

⑧ Total types of crystal = 7

(9)

(a) Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$	P, I, F
(b) Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	P, I
(c) orthorhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	P, I, C, F
(d) Monoclinic	$a \neq b \neq c$	$\alpha = \gamma = 90^\circ$, $\beta \neq 90^\circ$	P, C
(e) Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma$	P
(f) Hexagonal	$a = b \neq c$	$\alpha = \beta = 90^\circ$, $\gamma = 120^\circ$	P
(g) Trigonal/ Rhombohedral	$a = b = c$	$\alpha = \beta = \gamma \neq 90^\circ$	P
			14

P = Primitive type
I = BCC type
F = FCC type

(10) Atomic radius relations:

(a) simple cubic: $\boxed{r = a/2}$

(b) BCC: $\boxed{r = \frac{a\sqrt{3}}{4}}$

(c) FCC: $\boxed{r = \frac{a\sqrt{2}}{4}}$

(11) Packing fraction - $\dfrac{\text{vol of atoms per unit cell}}{\text{vol. of unit cell.}}$

(a) SC = 0.52
(b) BCC = 0.68 (c) FCC = 0.74

(12) <u>NaCl structure</u>: (a) Na^+ surrounded by 6 Cl^- & vice versa.

(b) ionic bonding

(c) orthorhombic crystal

(f) $\boxed{\rho = 2.2\ g/cm^3}$

(d) $\mu = 1.5442$

(e) MP = 8000°C , BP = 14650°C

(13) <u>Diamond</u>: (a) 2 interpenetrating FCC arrangement of C.

(b) Unit cell has 18 atoms.

		Effective
↳ 8 at corners	8	1
one on each faces	6	3
4 inside it	4	4
	18 atoms	$\boxed{8}$

(c) tetrahedral coordination of C atoms

(d) $2r = \dfrac{a\sqrt{3}}{4}$ $\boxed{r = \dfrac{a\sqrt{3}}{8}}$

(e) Packing fr = 0.34

(f) $\rho = 3500\ kg/m^3$

(g) <u>Motif/basis</u> :- 0 0 0

$\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$

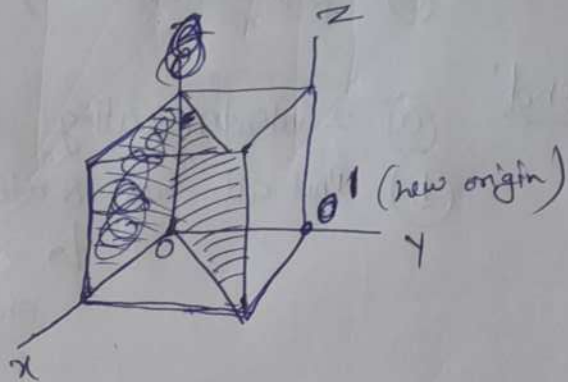
① **Miller indices:-** Miller indices are the 3 smallest possible integers which have the same ratios as the reciprocal of the intercepts of the planes concerned on the 3 axis (h k l)

Rule: (i) find intercept (ii) Take reciprocal (iii) (h k l)

Eg) (a) $(1\ \bar{1}\ 0)$

pre-reci

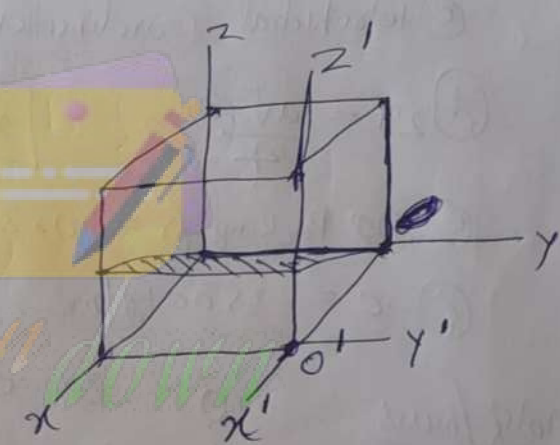
$(1\ \ -1\ \ \infty)$



(b) $(\bar{1}\ 0\ 2)$

pre-reci

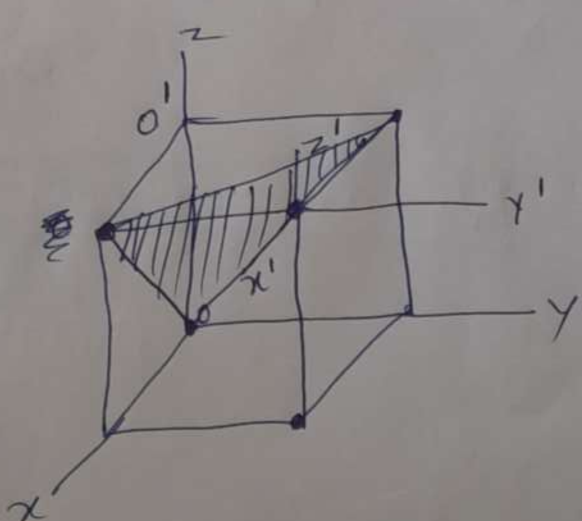
$(-1\ \ \infty\ \ \frac{1}{2})$



(c) $(1\ 1\ \bar{1})$

pre-reci

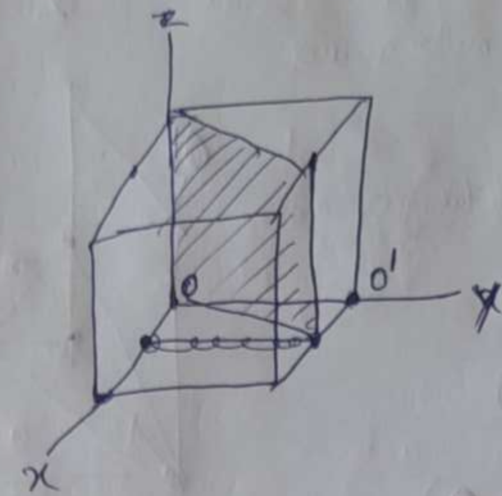
$(1\ 1\ \bar{1})$



(d) $(2\ \bar{1}\ 0)$

pre reci

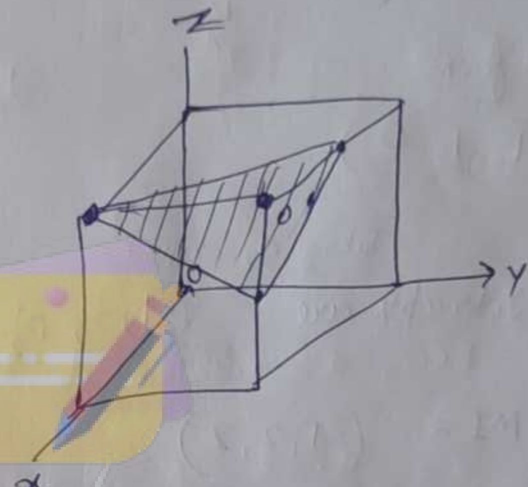
$\left(\frac{1}{2}\ \bar{1}\ \infty\right)$



(e) $(\bar{2}\ \bar{1}\ \bar{2})$

pre reci

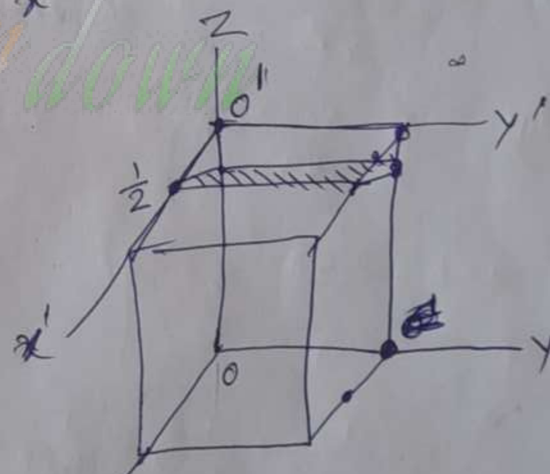
$\left(\frac{\bar{1}}{2}\ \bar{1}\ \frac{\bar{1}}{2}\right)$



(f) $(2\ 0\ \bar{4})$

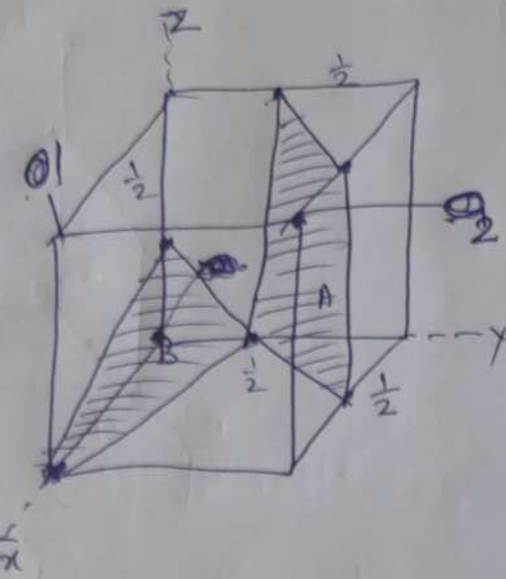
pre reci

$\left(\frac{1}{2}\ \infty\ \frac{\bar{1}}{4}\right)$



Eg 1.5 :-

find miller indices



for A :- (Taking O_1 origin)

Intercepts are

$\left(-\frac{1}{2}, \frac{1}{2}, \infty\right)$

MI = $(-2\ 2\ 0)$

In simple form

$(\bar{1}\ 1\ 0)$

for B : (Taking O_2 origin)

Intercepts are :- $\left(-1, -\frac{1}{2}, -\frac{1}{2}\right)$

MI = $(1, 2, 2)$

② Crystallography :-

Ⓐ Rel^n b/w^n interplanar spacing and cube edge in cubic crystal :-

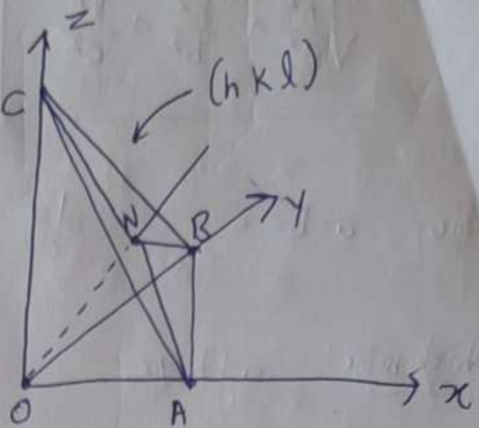
Let ABC be plane having intercept OA, OB, OC resp. then,

$OA = \frac{a}{h}$

$OB = \frac{b}{k}$

$OC = \frac{c}{l}$

where a, b, c are lattice constant along intercepts resp.

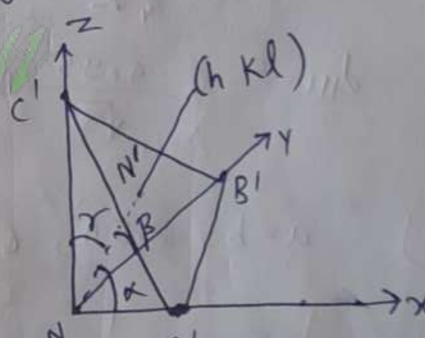


for cubic system $a = b = c = a$ (say)

$OA = \frac{a}{h}$, $OB = \frac{a}{k}$, $OC = \frac{a}{l}$

Let next nal plane ~~passing through origin~~ parallel to plane ABC
Considering N = Origin
NN' is $\perp$ to plane $A'B'C'$

$$\boxed{NN' = d_{hkl}}$$



Now
$$\cos\alpha = \frac{NN'}{NA'} = \frac{d}{a/h} = \frac{dh}{a}$$

sim $\cos\beta = \frac{dk}{a}$, $\cos\gamma = \frac{dl}{a}$

Now $\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$

$$\frac{d^2}{a^2}(h^2 + k^2 + l^2) = 1$$

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

(B) for a General Crystal !

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

(1) for Cubic ! $a=b=c$ $d_{hkl} = \frac{a}{\sqrt{h^2+k^2+l^2}}$

(2) for orthorhombic ! $a \neq b \neq c$ $d_{hkl} = \frac{1}{\sqrt{\frac{h^2}{a^2}+\frac{k^2}{b^2}+\frac{l^2}{c^2}}}$

Eg 1.6) :- FCC, $a = 4.95\,\mathring{A}$, $d_{200} = ?$, $d_{111} = ?$

Sol^n) $d_{200} = \frac{4.95}{2}\,\mathring{A} = 2.475\,\mathring{A}$

$d_{111} = \frac{4.95}{\sqrt{3}}\,\mathring{A} = 2.857\,\mathring{A}$

Eg 1.7) $a = b = 2.5\,\mathring{A}$, $c = 1.8\,\mathring{A}$ $d_{111} = ?$

Sol^n) $d_{111} = \frac{1}{\sqrt{\frac{1}{(2.5)^2} + \frac{1}{(2.5)^2} + \frac{1}{(1.8)^2}}} = 1.26\,\mathring{A}$

X-Ray Diffraction :-

① There are 2 types of x-ray tubes :-

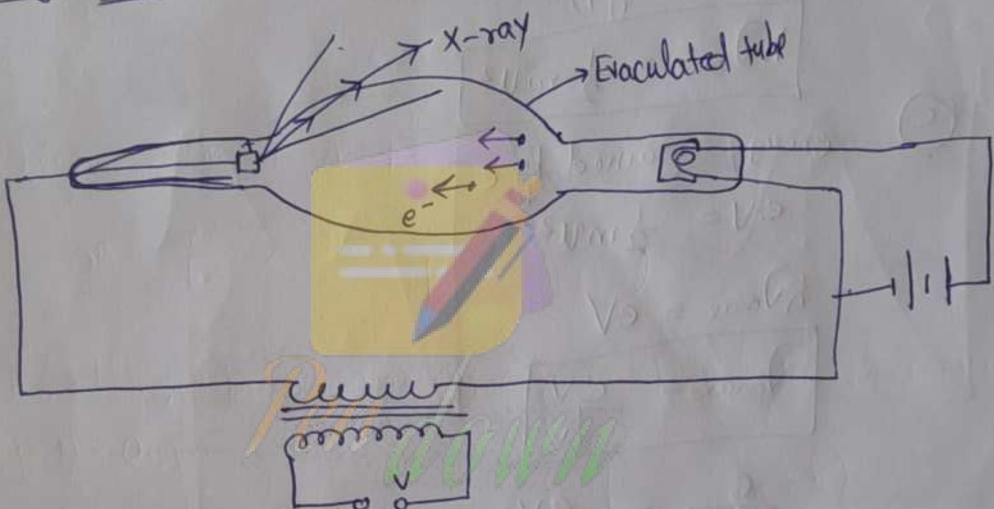
ⓐ The gas tube :- (i) low pressure discharge tube

(ii) Rarely used

Drawbacks : (i) The intensity & frequency produced cannot be easily controlled

(ii) $P \uparrow \Rightarrow$ Energy of $e^- \uparrow \Rightarrow$ higher is the frequency of emitted x-ray

ⓑ Coolidge Tube :-



(i) source of e^- is heated filament

(ii) In this tube intensity depend on no. of e^- striking the target per sec. This can easily change by changing voltage

(iii) The frequency (Energy) depend upon the energy of bombarding e^-.

☆ On basis of penetrating power x rays are 2 types -

Soft x-ray	Hard x-ray
ⓐ low energy	ⓐ high energy
ⓑ $\lambda > 4\mathring{A}$	ⓑ $\lambda < 1\mathring{A}$
ⓒ produced at low potential	ⓒ produced at high potential

(2) ~~Contiguous x-ray~~!

(2) Continuous ~~X~~-ray!
(deceleration process)

Loss of energy = $\frac{1}{2}mu^2 - \frac{1}{2}mu'^2$

energy of x-ray photons,

(a) $$\boxed{h\nu = \frac{1}{2}m(u^2 - u'^2)}$$

(b) max^n energy,

$$\boxed{h\nu_{max} = \frac{1}{2}mu^2}$$

(c) energy gained by e^-

$$eV = \frac{1}{2}mu^2$$

$$h\nu_{max} = eV$$

$$\boxed{\nu_{max} = \frac{eV}{h}}$$

$$\frac{c}{\lambda_{min}} = \frac{eV}{h}$$

$$\boxed{\lambda_{min} = \frac{hc}{eV}}$$

on solving

$$\boxed{\lambda_{min} = \frac{12400}{V} \text{Å}}$$

③ characteristic x-ray!

(Vacancy created and e^- from higher shell to lower shell emit energy)

④ Properties of x-ray!

① x-ray are EM radiation with very short λ

② They can affect a photographic film

③ The produce flourescence

④ $v_{x\text{-ray}} = c$ (in vaccum)

⑤ They can ionise gas

⑥ undeflected in electric & magnetic field

⑦ produce photo electric effect.

⑧ can show interference, diffraction and polarisation.

⑤ Max^m speed of $e^- = \frac{1}{2} m u^2$

$$\boxed{u_{max} = \sqrt{\frac{\text{max speed} \times 2}{m}}}$$

(striking anti cathode)

Bragg's law :- $\boxed{2d\sin\theta = n\lambda}$

[θ = glancing angle, bragg's angle]

only occur for $\boxed{\lambda \le 2d}$

Compton effect :

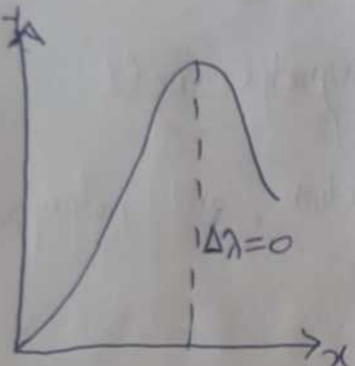
$$\boxed{\Delta\lambda = \lambda - \lambda' = \underbrace{\frac{h}{m_0 c}}_{\text{constant}}(1-\cos\phi)}$$

$$\Delta\lambda = \lambda_c(1-\cos\phi)$$

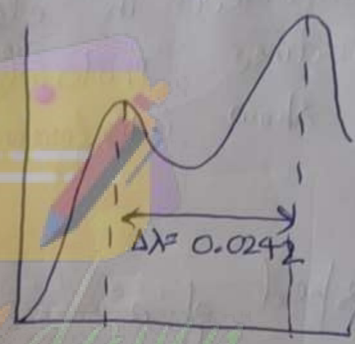
(ϕ = scattering angle)

$$\boxed{\Delta\lambda = 0.0242(1-\cos\phi)}$$

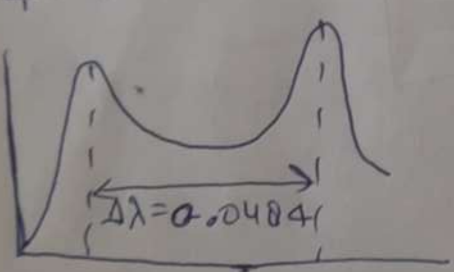
① $\phi = 0$



② $\phi = \frac{\pi}{2}$



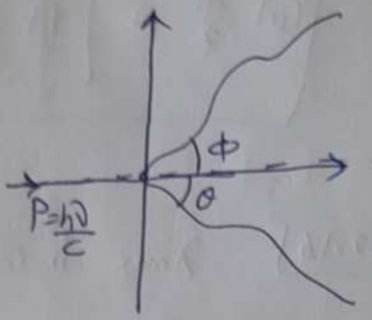
③ $\phi = \pi$



Eq 20(4) ϕ = Scattering $\angle$ of photon
θ = " " of e^-

To Prove: $\cot\left(\frac{\phi}{2}\right) = \left(1 + \frac{h\nu}{m_0c^2}\right)\tan\theta$

Proof: In Compton effect, by Conservation of momentum



~~$P\cos\theta = h\nu - h\nu'\cos\phi$~~ along x-axis -

$$\frac{h\nu}{c} = h\nu'\cos\phi + P\cos\theta$$

$$Pc\cos\theta = h\nu - h\nu'\cos\phi \quad \text{--- (i)}$$

along y-axis -

$$Pc\sin\theta = h\nu'\sin\phi \quad \text{--- (ii)}$$

(ii/i)

$$\tan\theta = \frac{h\nu'\sin\phi}{h\nu - h\nu'\cos\phi} = \frac{\nu'\sin\phi}{\nu - \nu'\cos\phi} \quad \text{--- (iii)}$$

we know that, $\frac{1}{\nu'} = \frac{1}{\nu} + \frac{h}{m_0c^2}(1-\cos\phi)$ (in Compton effect)

$$\nu' = \frac{\nu}{1+\left(\frac{h\nu'}{m_0c^2}\right)2\sin^2\frac{\phi}{2}}$$

putting in equ^n (iii)

$$\tan\theta = \frac{\dfrac{\nu\sin\phi}{1+\left(\frac{h\nu'}{m_0c^2}\right)2\sin^2\left(\frac{\phi}{2}\right)}}{\nu - \dfrac{\nu\cos\phi}{1+\left(\frac{h\nu'}{m_0c^2}\right)2\sin^2\left(\frac{\phi}{2}\right)}} = \frac{2\sin\frac{\phi}{2}\cos\frac{\phi}{2}}{2\sin\frac{\phi}{2}\left(\frac{h\nu}{m_0c^2}+1\right]}$$

$$\tan\theta = \frac{2\cos\left(\frac{\phi}{2}\right)}{\sin\left(\frac{\phi}{2}\right)\left[1+\frac{h\nu}{m_0c^2}\right]}$$

$$\boxed{\cot\frac{\phi}{2} = \left[1+\frac{h\nu}{m_0c^2}\right]\tan\theta}$$

h.p

eg 2.16) λ_{max} in Compton effect is at $\cos\phi = -1$

so

$$\Delta\lambda_{max} = 2\times 0.0242 = 0.0484\,\mathring{A}$$

so compton effect can only for radiation below $\boxed{\lambda < 0.0484\,\mathring{A}}$

$$\boxed{\star\ KE_{max} \text{ of recoil } e^- = \frac{\frac{2h^2\nu^2}{m_0c^2}}{1+\frac{2h\nu}{m_0c^2}}}$$