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Candidate 's Information PH TS-2401050

1. NAME:- Komal Punia
2. UPSC ROLL NO:- ……………………………
3. MOBILE NO:- [redacted]
4. SUBJECT:- Atomic and Molecular
5. DATE:- 11/07/2024

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Q.NO	MARKS
1.	23 1/2
2.	33
3.	33
4.	30 1/2
5.	26
6.	
7.	
8.	

Very well written!

TOTAL MARKS	146/250

EXAMINER SIGNATURE

INVIGILATOR SIGNATURE

18 Pusa Road Karol Bagh New Delhi-110005 Ph:01140079000, 9350934622 e-mail diasindia123@gmail.com

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(1 a) Normal Zeeman effect refers to splitting of fine-structure lines in presence of weak magnetic field.

$$E = -\vec{\mu}\cdot\vec{B} = -\left(g_e\left(\frac{-e}{2m}\right)\cdot\vec{L}\cdot\vec{B}\right)$$

$$= g_e\frac{\mu_B}{\hbar}m_e\hbar B_z = g_e m_e \mu_B B$$

Since, energy of normal zeeman triplet -

$$\boxed{E = \pm\mu_B B} \Rightarrow \boxed{\Delta E = \mu_B B}$$

↳ Energy difference

Given,

$\lambda = 6000\,A^\circ$ & $\Delta\lambda = 0.1\,A^\circ$

$$|\Delta E| = \frac{|hc\Delta\lambda|}{\lambda^2}$$

$$\boxed{\mu_B B = \frac{hc\Delta\lambda}{\lambda^2}} \Rightarrow \boxed{B = \frac{hc\Delta\lambda}{\lambda^2\mu_B}}$$

$\boxed{B = 0.598\,T}$ required to confirm normal zeeman triplets

6/10

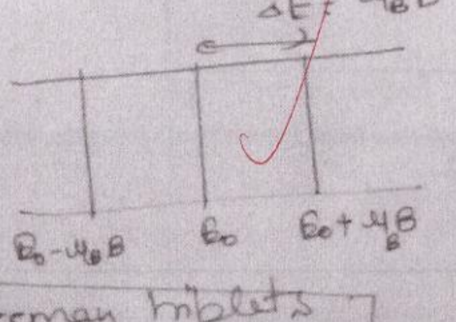


fig. - Zeeman triplets

1 (b) Splitting of energy states in presence of weak magnetic field is called zeeman effect.

Given state: $\boxed{^2P_{3/2}}$

Magnetic moment -

$$\vec{\mu} = g_j \frac{\mu_B}{\hbar} \vec{J} \Rightarrow |\vec{\mu}| = g_j \mu_B \sqrt{J(J+1)}$$

$$g_j = 1 + \frac{j(j+1) + s(s+1) - l(l+1)}{2j(j+1)}$$

$$= 1 + \frac{3/2 \times 5/2 + 1/2 \times 3/2 - 1 \times 2}{2 \times 3/2 \times 5/2} = \underline{\underline{4/3}}$$

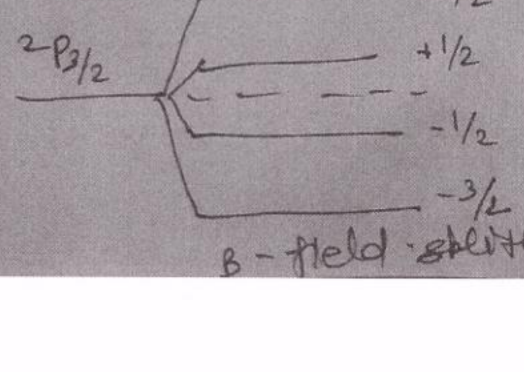
$$\Rightarrow |\vec{\mu}| = \frac{4}{3}\sqrt{\frac{3}{2} \times \frac{5}{2}}\, \mu_B = \sqrt{\frac{20}{3}}\, \mu_B$$

$$\boxed{|\vec{\mu}| = \frac{2\sqrt{15}}{3} \mu_B}$$

$6\frac{1}{2}/10$

Since $\underline{\underline{j = 3/2}}$ & $(2j+1) = 2 \times \frac{3}{2} + 1$
$= \underline{\underline{4}}$

So will split into $\underline{4 \text{ substates}}$.



B - field splitting.

प्रश्न संख्या
(Question No.)

U.P.S.C.

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1(c) LS coupling refers to magnetic interaction between orbital & spin angular momentum vectors.

d^2 state has equivalent electrons.

So using Breit's scheme –

$l_1 = 2$ & $l_2 = 2$ $\Rightarrow L = 4, 3, 2, 1, 0$

$s_1 = 1/2$ & $s_2 = 1/2$ $\Rightarrow$ $S = 0, 1$

m_{l_1} \ m_{l_2}	2	1	0	-1	-2
2	4	3	2	1	0
1	3	2	1	0	-1
0	2	1	0	-1	-2
-1	1	0	-1	-2	-3
-2	0	-1	-2	-3	-4

$\frac{6\frac{1}{2}}{10}$

Diagonal terms (same m_l values so only singlet) $\Rightarrow$ $\boxed{{}^1S_0,\ {}^1D_2,\ {}^1G_4}$

~~${}^1S_{1/2}$ ${}^1D_{3/2, 5/2}$ ${}^1G_{7/2, 9/2}$~~

Other triplet terms –

$\boxed{{}^3P_{0,1,2},\ {}^3F_{2,3,4}}$

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1(d)

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प्रश्न संख्या
(Question No.)

U.P.S.C.

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1(e) IR spectra and Raman spectra, in case of molecules with centre of symmetry, show complementary spectra according to mutual Exclusion Principle.

$\boxed{CO_2}$ show two IR lines which are absent in Raman spectra ⇒ CO_2 has centre of symmetry ⇒ CO_2 is linear.

$\boxed{H_2O}$ show 3 IR lines which overlap with Raman lines ⇒ H_2O doesn't has centre of symmetry ⇒ H_2O is not linear

⇓

H_2O is bent.

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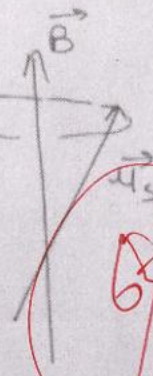
Q.5(a) Molecules with unpaired electron under external magnetic field, exhibits precession of spin angular momentum due to torque experienced by $\vec{B}$.

when they are excited by suitable microwave excitation, leads to resonant transition called as EPR or ESR.

Condition of ESR



$E = -\vec{\mu}.\vec{B}$

$$\boxed{E = g_s \frac{\mu_B}{\hbar} m_s B}$$

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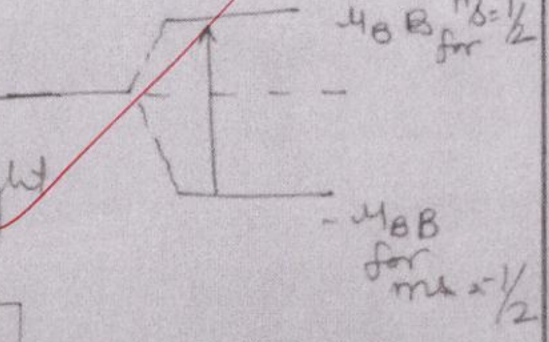
for e^- ⇒ $s = 1/2$ ⇒ $m_s = \pm 1/2$ & $g_s = 2$

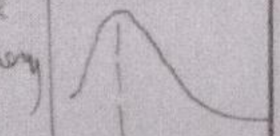
$$\Rightarrow \boxed{E = \pm \mu_B B}$$



when exciting light frequency is

$$\boxed{\nu = \frac{2\mu_B B}{h}}$$

resonance occurs



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5(b)

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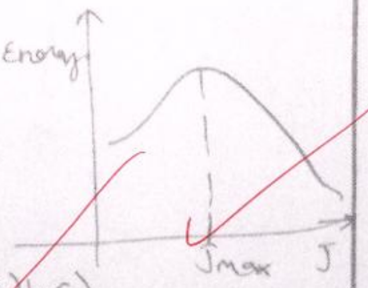
5(c) Rotational molecular transitions are given by

$$F(J) = BJ(J+1)\,cm^{-1}$$



Using maxwell - Boltzman distribution -

~~Energy~~ $N \propto \exp\left(\frac{-BJ(J+1)hc}{kT}\right)$

also considering degeracy of states

$$N \propto (2J+1)\exp\left(\frac{-BJ(J+1)hc}{kT}\right)$$

$\left.\frac{dN}{dJ}\right)_{J=J_{max}} = 0$ & $\frac{d^2N}{dJ^2} < 0$

$\boxed{J_{max} = \sqrt{\frac{kT}{2Bhc}} - \frac{1}{2}}$ where $B = \frac{h}{8\pi^2 I c}$

6½/10

$I = \mu r^2$

$\boxed{B = 10\,cm^{-1}}$

$J_{max} = 4.56 - 0.5$ as $\sqrt{\frac{kT}{2Bhc}} = 4.56$

$= 4.06 \approx 4$

$\Rightarrow \boxed{J_{max} = 4}$ most populated rotational level.

(Don't write anything in this part)

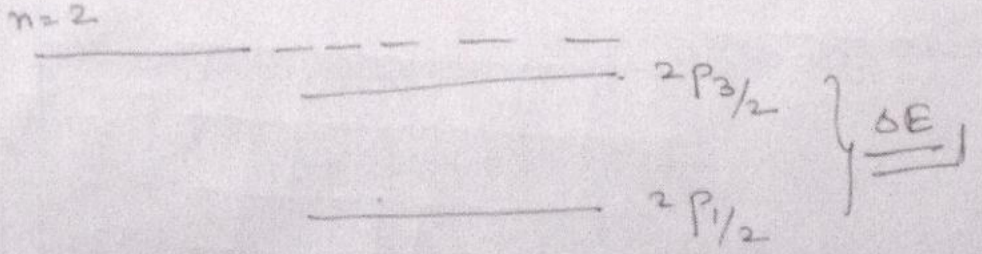
Q5(d) Hydrogen atom — $s = \frac{1}{2}$

Given $n = 2$, $l = 1$ & $s = \frac{1}{2}$

LS coupling $|\vec{j}| = |\vec{l} + \vec{s}|$ to $|\vec{l} - \vec{s}|$

$\Rightarrow j = \frac{3}{2}, \frac{1}{2}$

$\Rightarrow {}^2P_{3/2}$ and ${}^2P_{1/2}$ terms.



LS coupling by using $\vec{l}\cdot\vec{s}$ term in Hamiltonia is

$$\Delta\bar{\nu} = \frac{\Delta E}{c} = \frac{584\, Z^4}{n^3\, l(l+1)}\ \text{m}^{-1}$$

$6\frac{1}{2}$ / 10

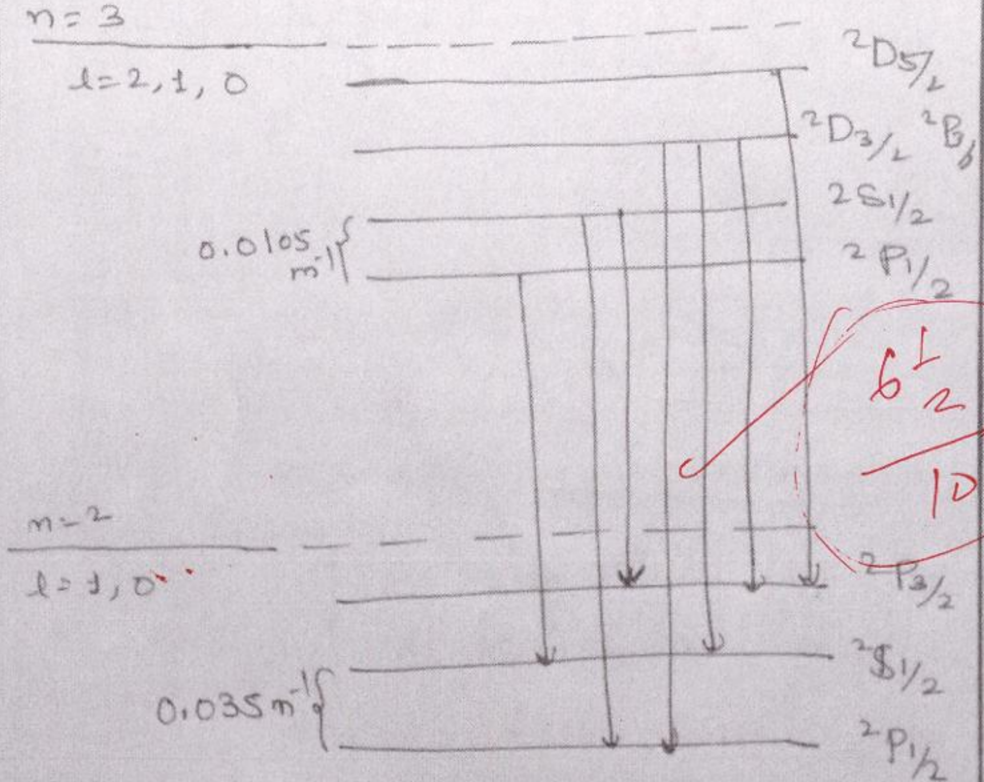
$Z = 1,\ n = 2,\ l = 1$

$$\Rightarrow \Delta\bar{\nu} = \frac{584}{8 \times 1 \times 2} = 36.5\ \text{m}^{-1}$$

$$\Rightarrow \boxed{\Delta E = 4.5 \times 10^{-5}\ \text{eV}}$$

5(e) Lamb shift refers to upliftment in degeneracy of $^2S_{1/2}$ and $^2P_{1/2}$ levels in Hydrogen fine structure due to vaccume polarisation.

H_α lines $(n=3 \rightarrow n=2)$



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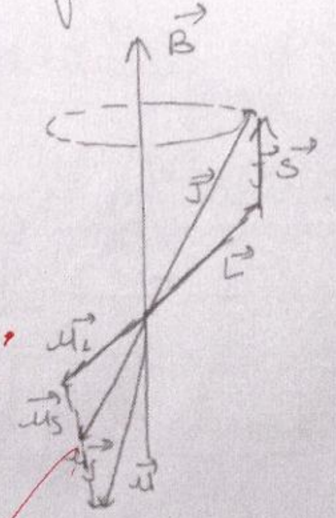
Selection rules $\boxed{\begin{array}{l}\Delta l = \pm 1\\ \Delta S = 0\end{array}}$

7 lines of H-α series.

on unrestricted
$\Delta j = 0, \pm 1$ by $j=0 \not\leftrightarrow j=0$

Q.2 a) Lande's g-factor determines the splitting of spectral lines in presence of magnetic field.



$$\vec{\mu} = \frac{-e}{2m}\left[g_e\vec{L} + g_s\vec{S}\right]$$

$$\vec{\mu} = -\frac{\mu_B}{\hbar}\left[\vec{L} + 2\vec{S}\right]$$

as $g_e = 1$ & $g_s = 2$

$$\boxed{\text{Energy} \quad E = -\vec{\mu_j}\cdot\vec{B}}$$

$$E = \frac{\mu_B}{\hbar}\left[\vec{L} \cancel{+2\vec{S}}\right]\cdot\vec{B}$$

Also, as μ_j spins around magnetic field, $\mu^{\perp al}$ (perpendicular) component sums to zero in cycle & only $\mu_j^{\parallel}$ remains.

So $$\vec{\mu_j} = \frac{(\vec{\mu}\cdot\vec{J})\,\vec{J}}{|\vec{J}|^2}$$

$$\Rightarrow \vec{\mu_j} = -\frac{\mu_B}{\hbar}\left[\vec{L} + 2\vec{S}\right]\cdot\frac{\vec{J}\cdot\vec{J}}{|J|^2}$$

$$\Rightarrow E = \frac{\mu_B}{\hbar}\left[\frac{(\vec{J}+\vec{S})\cdot\vec{J}}{|\vec{J}|^2}\right]J_z\cdot B \quad \text{as } \underline{\underline{\vec{J} = \vec{L} + \vec{S}}}$$

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$$E = \mu_B \left[1 + \frac{\vec{J}\cdot\vec{S}}{|\vec{J}^2|} \right] . m_j B$$

$$\vec{J}\cdot\vec{S} = \frac{J(J+1) + S(S+1) - l(l+1)}{2}$$

putting in E value, we get

$E = \mu_B B g_j m_j$ where

$$\boxed{g_j = 1 + \frac{j(j+1) + S(S+1) - l(l+1)}{2j(j+1)}}$$

Lande's g-factor.

Lande's g-factor can be used to explain Zeeman effect of Na doublet lines (D_1 & D_2).

D_1 $({}^2P_{1/2} \rightarrow {}^2S_{1/2})$

D_2 $({}^2P_{3/2} \rightarrow {}^2S_{1/2})$

Terms	g_j value	m_j	Energy
${}^2S_{1/2}$	2	$\pm 1/2$	$E_0 \pm \mu_B B$
${}^2P_{1/2}$	$2/3$	$\pm 1/2$	$E_0 \pm \frac{\mu_B B}{3}$
${}^2P_{3/2}$	$4/3$	$\pm 3/2, \pm 1/2$	$E_0 \pm \frac{2}{3}\mu_B B$ & $E_0 \pm 2\mu_B B$

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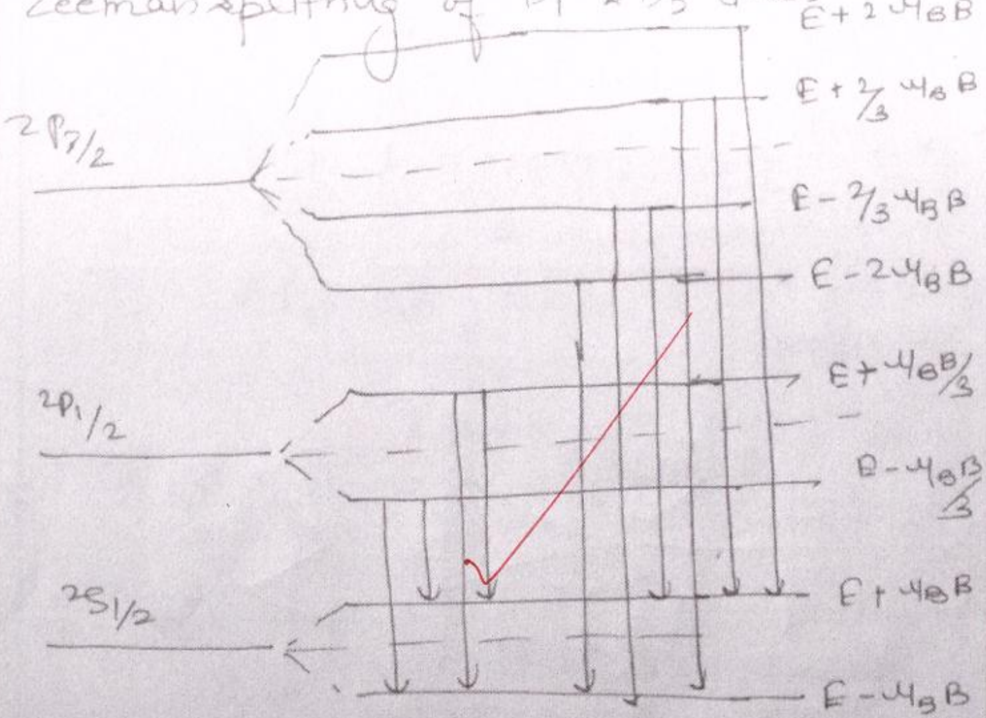
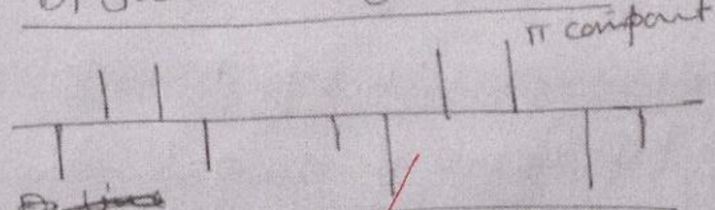
Zeeman splitting of D₁ & D₂ lines —



4 D₁ lines   6 D₂ lines



selection rules — $\boxed{\begin{array}{l}\Delta j = 0, \pm 1 \quad j=0 \not\leftrightarrow j=0 \\ \Delta l = \pm 1 \\ \Delta s = 0\end{array}}$

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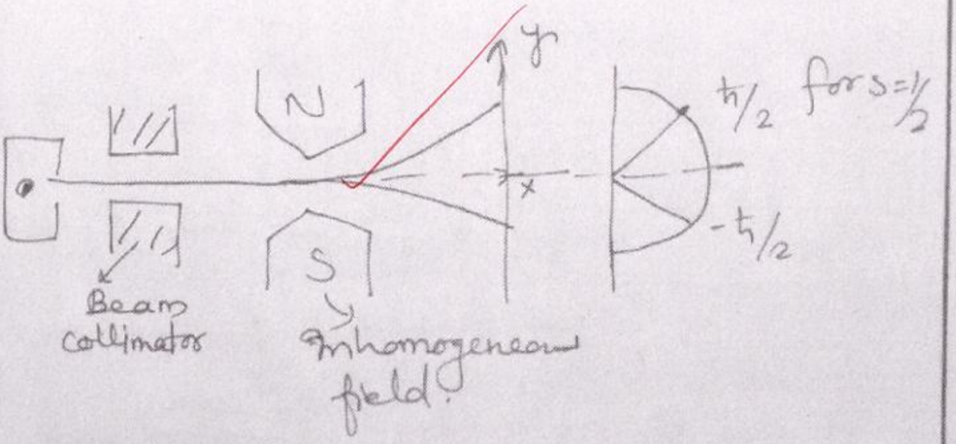
$\boxed{\Delta\nu = \frac{eB}{4\pi m}}$ Zeeman shift

$$\Rightarrow \Delta\lambda = \frac{eB}{4\pi mc}\lambda^2$$

$$\Rightarrow \boxed{\frac{e}{m} = \frac{4\pi c\,\Delta\lambda}{B\lambda^2}} = \underline{\underline{1.748\times10^{11}}}$$

Q.2 (b) Stern-Gerlach experiment conclusively proved existence of spin and also quantisation of magnetic moment.



Stern-Gerlach experimental set up —

└① Beam of neutral silver atoms

└② Inhomogeneous magnetic field.

Force due to magnetic field $= (-\vec{\mu}\cdot\vec{\nabla})\vec{B}$

$$\boxed{F_z = \mu_z \frac{\partial \vec{B}}{\partial z}}$$

$$\boxed{y = \frac{1}{2}at^2} \qquad a = \frac{F_z}{M}$$

$t = \frac{d}{v}$ and $v = \sqrt{\frac{4kT}{m}}$

$$\Rightarrow \boxed{y = \mu_z \frac{\partial B_z}{\partial z} \cdot \frac{d^2}{8kT}}$$

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Given $\frac{\partial B}{\partial z} = 5 \frac{\text{Volt } m^{-2}}{m} = 5\times10^{3} \frac{Vm^{-2}}{m}$

$l = 0.07 \text{ m}$

$T = 1250K$

$$y = \frac{9.27\times10^{-24} \times 5 \times 49\times10^{-4} \times 10^{3}}{8\times 1.38\times10^{-23} \times 1250}$$

$$\boxed{y = 0.1645 \text{ cm}}$$

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separation = $2y$ = $\boxed{0.329 \text{ cm}^{-1}}$

Existence of only two components is a proof of spin angular momentum.

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Q2 c)

i) Heteronuclear diatomic molecules which have a permanent dipole moment exhibits rotational energy levels.

Assuming rigid rotor, $(V(r) = 0)$

$\boxed{-\frac{\hbar^2}{2m}\nabla^2\psi = E\psi}$ solutions give

$$\boxed{E = \frac{J(J+1)\hbar^2}{2I}}$$

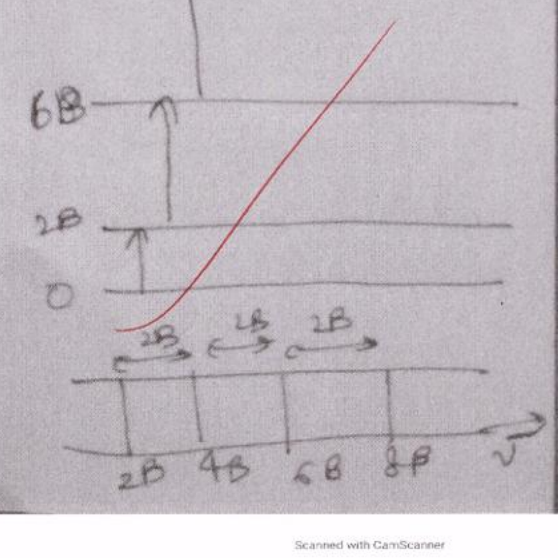
$$F(J) = \frac{E}{hc} = \underline{BJ(J+1)\ cm^{-1}}$$

where $B = \frac{h}{8\pi^2 I c}$

Selection rules $\boxed{\Delta J = \pm 1}$

$F(J+1) - F(J) =$
$\underline{2B(J+1)}\ cm^{-1}$

So spectrum constitute equally spaced lines with $\underline{2B}$ difference.



ii) For pure rotational spectra, necessary condition is presence of permanant dipole moment.

So Homonuclear molecules like H_2 & O_2 doesn't give pure rotational spectra.

HF & NO are Heteronuclear ⇒ permanent dipole moment ⇒ Yes pure rotational spectra.

iii) $F(J=1) - F(J=0)$ where $F(J) = BJ(J+1)\,m^{-1}$

$= \underline{2B}$ where $B = \dfrac{h}{8\pi^2 I c}$

Given $2Bc = 1.153 \times 10^{11}$

$\Rightarrow \boxed{B = 1.92 \times 10^{2}\, m^{-1}}$

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$$\Rightarrow I = \frac{6.626 \times 10^{-34}}{8 \times (3.14)^2 \times 1.92 \times 10^{2} \times 3 \times 10^{8}}$$

$$\boxed{I = 1.43 \times 10^{-46}\, kg\, m^2}$$

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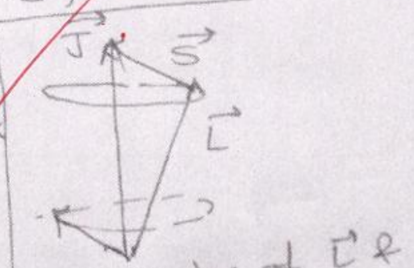
Q.3 a) Vector model of atom models the orbital and spin angular momentum interaction as vector sum (eq.)

$\vec{J} = \vec{L} + \vec{S} \Rightarrow$

$|\vec{J}| = |\vec{L}+\vec{S}|$ to $|\vec{L}-\vec{S}|$



precession of $\vec{L}$ & $\vec{S}$ around $\vec{J}$.

Also, for multielectronic atoms,

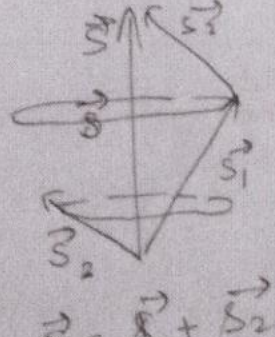
$\vec{L} = \vec{l_1}+\vec{l_2}+ \dots \vec{l_n}$

$|\vec{L}| = |\vec{l_1}+\vec{l_2}+\dots+\vec{l_n}|_{min}$ to $|\vec{l_1}+\vec{l_2}+\dots+\vec{l_n}|_{max}$

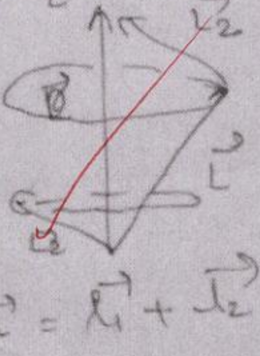
Similarly for $\vec{S} = \vec{s_1}+\vec{s_2}+\dots+\vec{s_n}$ i.e.

$|\vec{S}| = |\vec{s_1}+\vec{s_2}+\dots+\vec{s_n}|_{min}$ to $|\vec{s_1}+s_2+\dots+\vec{s_n}|_{max}$

(e.g.) for 2 electrons



$\vec{S} = \vec{s_1} + \vec{s_2}$



$\vec{L} = \vec{l_1} + \vec{l_2}$

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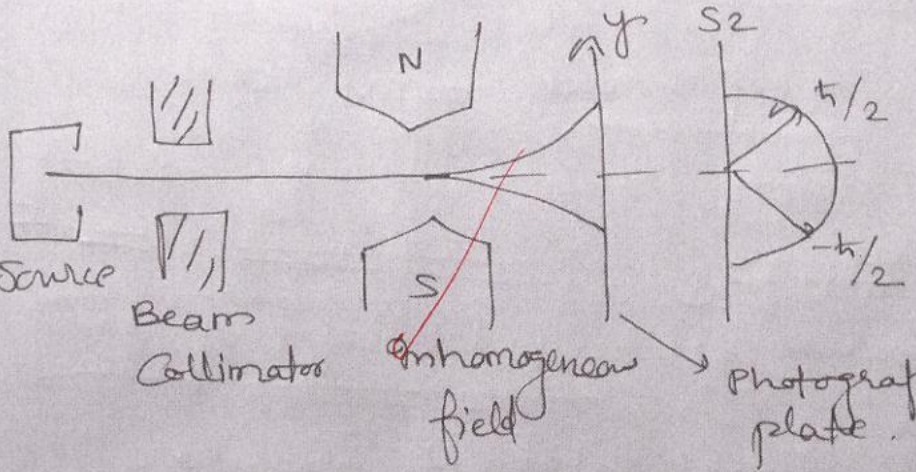
Stern - Gerlach experiment is about passing neutral silver atom beam in non-homogeneous magnetic field.



Requirements —

① Neutral silver atom beam —
↳ charged atoms will exhibit circular motion in $\vec{B}$.

② Inhomogeneous field
↳ Homogeneous field will not exert any force hence non-deflected beam.

$$\text{Force} = (\vec{\mu}\cdot\vec{\nabla})\vec{B} = \mu_z \frac{\partial B_z}{\partial Z}$$

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$\mu_z = g_s m_s \mu_B$ for e^-

$y = \frac{1}{2} a t^2 = \frac{1}{2} \frac{\mu_z \frac{\partial B_z}{\partial z}}{m} \cdot \frac{d^2}{4kT} \times \frac{1}{m}$

$\Rightarrow \boxed{y = g_s m_s \mu_B \frac{\partial B_z}{\partial z} \cdot \frac{d^2}{8kT}}$

from experiment, $g_s m_s = \pm 1$

since $g_s = 2 \Rightarrow m_s = \pm 1/2 \Rightarrow S = 1/2$

Results ① ~~hence~~ established concept of spin.

② Quantisation of angular momentum → proof of vector model of atom.

③ laid foundation of quantum mechanics.

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i) If e^-'s spin is $\frac{3}{2}\hbar$ instead of $\hbar/2$ than 4 traces would be obtained on screen instead of two.

As for $S = \frac{3}{2}\hbar \Rightarrow m_s = 3/2, 1/2, 3/2, -1/2$

ii) In case of neutral atoms passing through homogeneous field, $F_z = 0$ ⇒ No deflection & hence no trace will be obtained.

Hence inhomogeneous field is a necessity of Stern Gerlach expt.

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(Q.3 b) Larmour precession refers to precession of angular momentum due to torque acting on it.

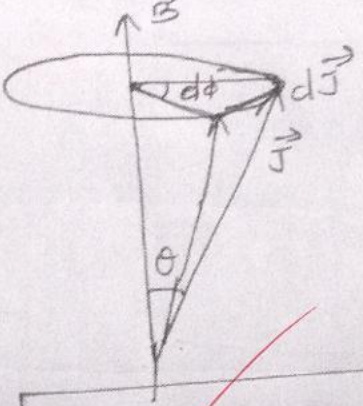

fig: precession of $\vec{J}$

from figure,

$$d\phi = \frac{d\vec{J}}{\vec{J}\sin\theta}$$

$\Rightarrow$

$$\frac{d\phi}{dt} = \frac{d\vec{J}/dt}{\vec{J}\sin\theta}$$

$$\Omega = \frac{|\vec{\tau}|}{|\vec{J}|\sin\theta} = \frac{|\vec{\mu}|B\sin\theta}{|\vec{J}|\sin\theta}$$

$$\boxed{\Omega = \frac{|\vec{\mu}|B}{|\vec{J}|}}$$ Larmor frequency.

$|\vec{\mu}| = g_p \frac{e}{2m}|\vec{J}|$ for proton

$g_p = 5.585$

$\Rightarrow$

$$\boxed{\Omega = \frac{g_p e B}{2m}}$$

or $$\boxed{\nu = \frac{eB}{4\pi m}g_p}$$

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$$\nu = \frac{1.60 \times 10^{-19} \times 1 \times 5.585}{4 \times 3.14 \times 1.67 \times 10^{-27}}$$

$$= 4.26 \times 10^{7}\,\text{Hz} = \underline{42.6\,\text{MHz}}$$

$$\boxed{\nu = 42.6\ \text{MHz}}$$

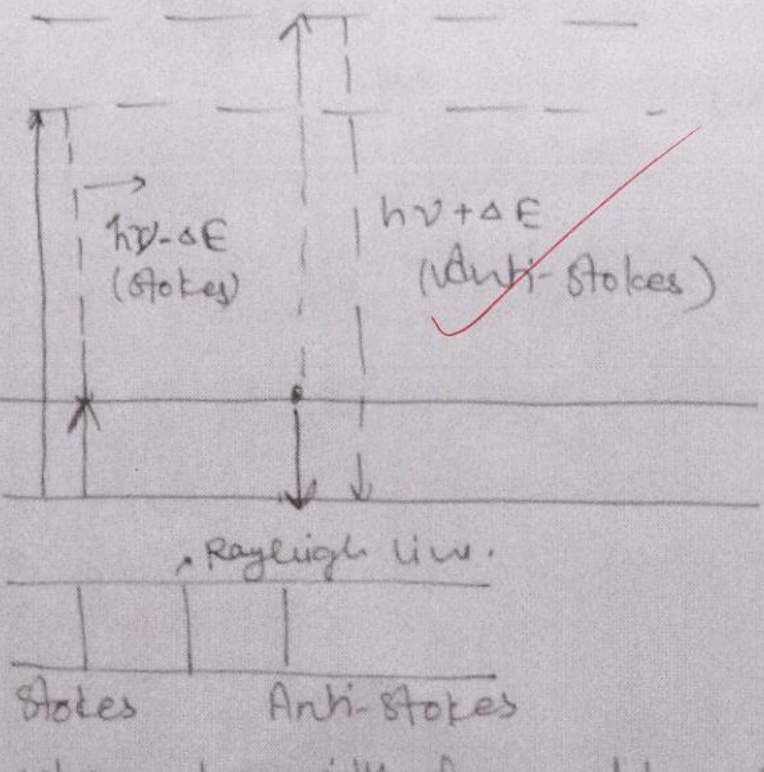
$\frac{10}{15}$

This depends only on magnetic field & not on orbit angle.

3(c) Raman spectra constitutes both low frequency (Stokes) lines and high frequency (Anti-Stokes) lines due to internal transitions (vibrational or rotational) while scattering.

Mechanism of production of Raman lines —

Molecules undergo rotational or vibrational transitions —



→① when transition from uppar to lower is Anti-Stokes line

(2) When transition from lower to upper → Stokes line.

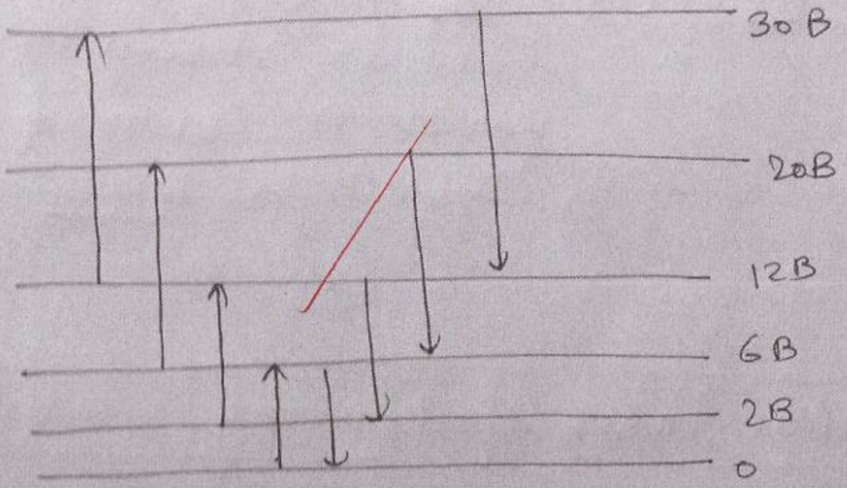
Considering rotational transitions -

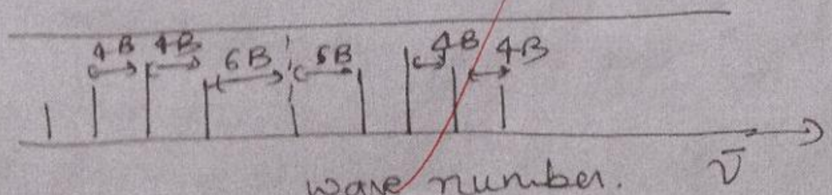
$\bar{\nu} = \bar{\nu}_0 + BJ(J+1)$ cm^{-1}

Selection rules $\Delta J = 0, \pm 2$

$$\boxed{\bar{\nu} = \bar{\nu}_0 \pm B(4J+6)}$$

$\Delta J = 0$ (Rayleigh line)
$\Delta J = +2$ (Anti Stokes)
$\Delta J = -2$ (Stokes)





1st line at separation of 6B & rest at 4B.

Complementarity with IR |

① According to mutual exclusion Principal, molecules with centre of symmetry (e.g.) CO_2 & CS_2 exhibits IR lines which are missing in Raman Spectra.

② This can be used to classify molecules as linear or bent.

(e.g.) CO_2 & CS_2 – 2 IR lines which are absent in Raman ⇒ Centre of Symmetry ⇒ linear structure.

Raman Laser spectroscopy revolutionised

↳ ① High precision & high resolution

↳ ② Detection of colored salts

↳ ③ Non-destructive detection of molecules

↳ ④ Small amount of sample needed.

Given $\lambda_0 = 4358\ A^\circ$

$\Rightarrow \bar{\nu}_0 = \frac{1}{\lambda_0} = 2.2946 \times 10^6$ (Rayleigh Line)

$\lambda_1 = 4567\ A^\circ$, $\bar{\nu}_1 = 2.1896 \times 10^6$ (Stokes Line)

$\Delta\bar{\nu} = \bar{\nu}_0 - \bar{\nu}_s =$

$\boxed{\Delta\bar{\nu} = 1049[illegible]8\ m^{-1}}$

$\Rightarrow$

$\boxed{\bar{\nu}_{AS} = 2399578\ m^{-1}}$ Anti-Stokes Line.

$\Rightarrow \boxed{\lambda_{AS} = 4167\ A^\circ}$

$\frac{10}{15}$

It will be less intense as it occurs due to transition from upper to lower level which are less probable than lower to upper as per M-B distribution.

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Q4. (a) Electronic spectra of diatomic molecules consists of series, bands and progressions due to V-R gross spectra and rotational fine spectra.

$$\boxed{\Delta E = T_e' - T_e'' + G_{v'} - G_{v''} + F_{J'} - F_{J''} \text{ cm}^{-1}}$$

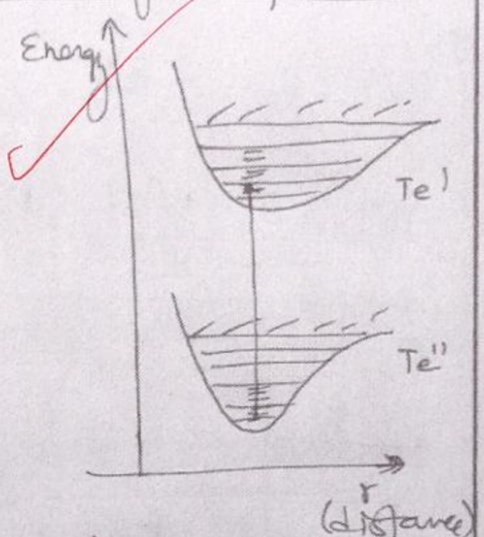

fig: Electronic spectra.

Gross specra - VR

↳ Ignoring rotational transitions.

$$\Delta\bar{\nu} = \bar{\nu}_e + G_{v'} - G_{v''} \quad \& \quad \boxed{\Delta v = \text{unrestricted}}$$

$$G(v) = \left(v+\tfrac{1}{2}\right)\bar{\omega}_e - \left(v+\tfrac{1}{2}\right)^2 \bar{\omega}_e x_e \text{ cm}^{-1}$$

$v''=0 \rightarrow v'=1$ transion (fundamental band)

$v''=0 \rightarrow v'=2$ 1st overtone

$v''=1 \rightarrow v'=2$ Hot bands.

$$\boxed{\Delta\bar{\nu} = \bar{\nu}_e + (v'-v'')\bar{\omega}_e - \left[(v'^2 - v''^2) + (v'-v'')\right]\bar{\omega}_e x_e \text{ cm}^{-1}}$$

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Rotational fine structures

$\bar{\nu} = \bar{\nu}_0 + B_{v'} J'(J'+1) - B_{v''} J''(J'+1)$ cm^{-1}

where $\bar{\nu}_0 = \bar{\omega}_e(1-2x_e)$ cm^{-1} [0 → 1 transition]

Selection rules - $\boxed{\Delta J = 0, \pm 1}$

① $B_v' < B_v''$ (If $r' > r''$) & $\boxed{B = \frac{h}{8\pi^2 I c}}$

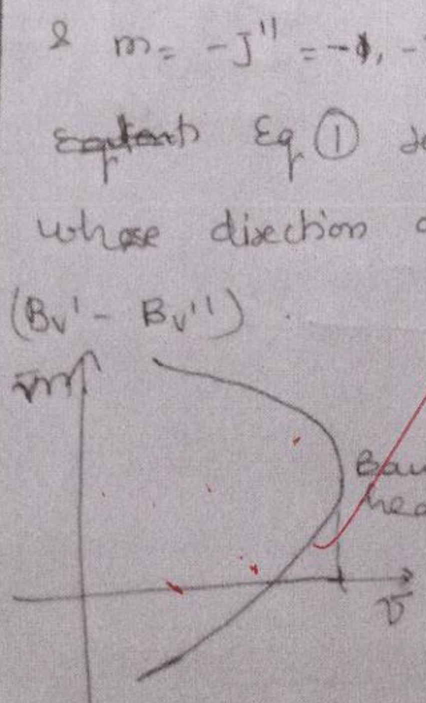
& $B_v' > B_v''$ (If $r' < r''$)

$$\boxed{\bar{\nu} = \bar{\nu}_0 + (B_v' + B_v'')m + (B_v' - B_v'')m^2 \text{ cm}^{-1}} \quad —①$$

$m = J'' + 1$ (R-branch)
$= 1, 2, 3, 4$
R(0), R(1), R(2) - - .

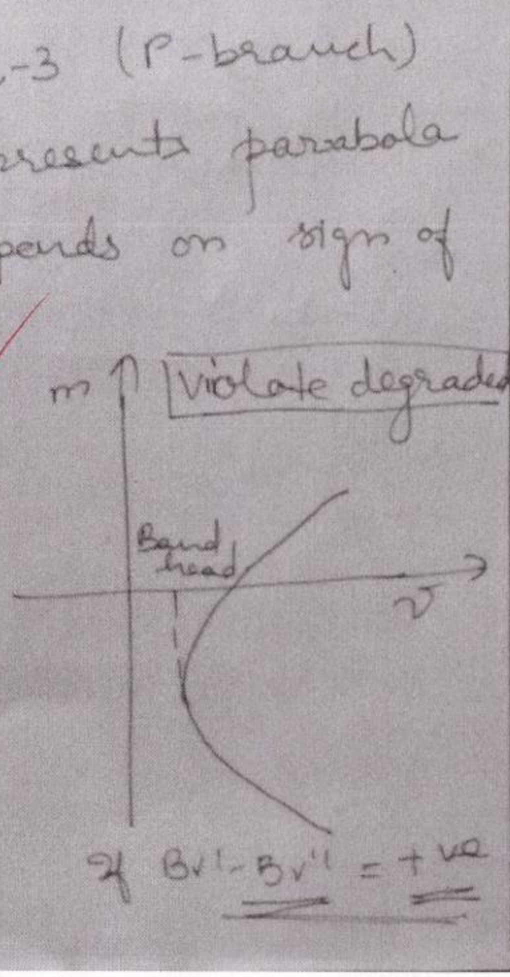
& $m = -J'' = -1, -2, -3$ (P-branch)

~~Equation~~ Eq ① represents parabola whose direction depends on sign of $(B_v' - B_v'')$.



Red degraded

If $B_v' - B_v'' = -ve$



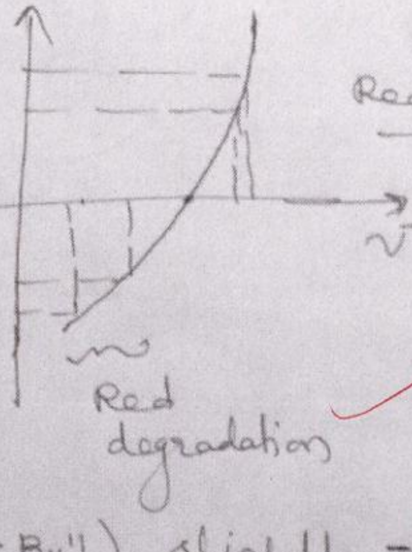
Violate degraded

If $B_v' - B_v'' = +ve$

Electronic spectra has -

↳ ① strong tendency of head formation as B_v' & B_v'' are from different electronic orbitals & vary significantly.

In V-R spectra - B_v' is slightly ~~greater~~ less than B_v'' as both are from same electronic state



Red degraded parabola with weak head formation

Here

$(B_v' - B_v'')$ slightly −ve

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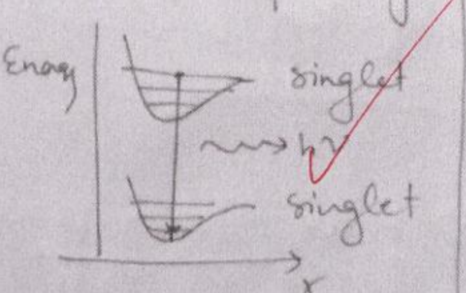
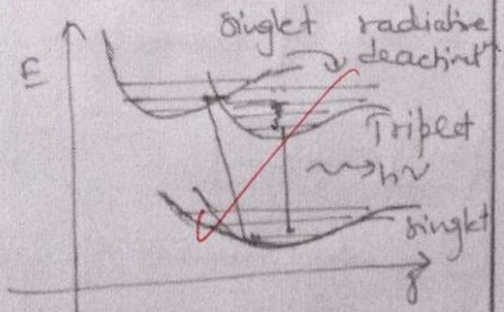
Q4 (b)

Luminoscence refers to transition from excited state to ground states resulting in release of photons.

Fluoescence	Phosphoescence
1) Transition to lower states of same multiplicity.	2) Transition between states of different multiplicities
	
2) Instantaneous transitions	2) Delayed emission due to spin forbidden nature.
3) No internal conversion occurs	3) Internal conversion occurs due to collisions.
4) Used in Zinc sulphide, Stronsium etc.	5) eg. Diamond, Ruby
	6) Can be used to store light for few microseconds.

Fluorescence	Raman
mechanism –	
① Transition between Electronic energy levels.	① Scattering of light by molecules.
② Due to quantisation of energy levels – exciting wavelengths should be equal to energy of transition.	② since scattering, so any exciting frequency can show Raman spectra.
Difference	
① Only lines of lower wavenumber are observed.	① Both Stokes (lower wavenumber) & Anti-Stokes (large $\bar{\nu}$) are observed.
② Emitted lines depend on excitation frequency	② Emitted lines only characteristic of material.

$\frac{9\frac{1}{2}}{15}$

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Q.4 (c) from V-R spectra, we can determine force constant, nature of molecules, isotopic masses etc.

Given k = 573 m

Energy = 450 eV (Dissociation)

$$G(v) = \left(v+\frac{1}{2}\right)\bar{\nu}_e - \left(v+\frac{1}{2}\right)^2 \bar{\nu}_e x_e \text{ cm}^{-1}$$

$$\boxed{\bar{\nu} = \frac{1}{2\pi c}\sqrt{\frac{k}{\mu}}}$$

Neglecting x_e by assuming Simple Harmonic potential.

$$\mu = \frac{m_H m_H}{m_H + m_H} = \frac{m_H}{2}$$

$$= \frac{1.67\times10^{-27}}{2} = 8.35\times10^{-28} \text{ kg.}$$

$$\bar{\nu} = \frac{1}{2\times3.14\times3\times10^{8}}\sqrt{\frac{573}{8.35\times10^{-28}}}$$

$$\boxed{\bar{\nu} = 4.396\times10^{5} \text{ m}^{-1}}$$

$$G(v) = \left(v+\frac{1}{2}\right)\bar{\nu}$$

where $\boxed{G(v) = \frac{E(v)}{hc}}$

~~450×~~

$$\text{So } G(v) = \frac{540\times1.6\times10^{-19}}{hc}$$

putting in equations —

$$\left(v+\frac{1}{2}\right) = \frac{540\,eV}{1240\,eV \times 10^{-9} \times 4.396 \times 10^{5}}$$

$\Rightarrow v+\frac{1}{2} = 82.25$

$\Rightarrow \boxed{V = 81.75}$ 822

So vibrational quantum number corresponding to dissociation energy 450 eV is V = 81.

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