

चौधरी PHOTOSTAT

"I don't love studying. I hate studying. I like learning. Learning is beautiful."



"An investment in knowledge pays the best interest."

Hi, My Name is

Physics

Dias IAS

Vajpaye Sir

ATOMIC AND MOLECULAR PHYSICS

DATA INTERPRETATION

As a result of the interpretation of data, have become an important part of all competitive examinations. The following are some of the important points to be noted in this regard.

1. The data should be presented in a clear and concise manner. The data should be presented in a clear and concise manner. The data should be presented in a clear and concise manner.

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Atomic & Molecular Physics

Reference books:-

- 1.) Resnick & Eisberg :- for atomic physics portion
- 2.) Banwell :- for Molecular Physics
- 3.) Raj Kumar :- for both atomic & Molecular Physics
- 4.) Modern Physics :- by Arthur Beiser
- 5.) Some of the questions given in P. E. ~~and~~ Irodov
- 6.) Modern Physics :- Schaum Series
- 7.) For problem solving :- refer U.G.C net book of Physics (UPkar Publications) subjective

CIVIL SERVICES EXAMINATION (MAINS)

PHYSICS TEST SERIES 2009

TEST 2 : ATOMIC & MOLECULAR PHYSICS

Time allowed: 2 hours

Max. Marks: 200

Question No.1 is compulsory. Out of Question numbering (2), (3) & (4) attempt any two

- Q1.** (i) Why weak field is prerequisite for Zeeman Effect?
(ii) NMR & EPR operates in which part of EM spectrum? What is the role of static field in NMR?
(iii) Give the mechanism of creation of stokes and anti stokes lines? What is the effect of temperature on their intensities?
(iv) First line in rotational spectra of co molecule occurs at 3.84235 cm^{-1} . Find out the bond length of the molecule.
(v) Find out the magnetic field responsible for D_1 & D_2 lines of sodium of wave lengths 5896 \AA & 5890 \AA respectively
(vi) Write down the spectral terms in P^2 configuration
(vii) Write down any three differences between Raman spectra and Fluorescent spectra.
(viii) Explain in brief Stern – Gerlach experiment. Will it succeed in non homogenous field and performed by ions?
(8×10=80 marks)
- Q2.** (a) Derive an expression for magnetic moment responsible for anomalous Zeeman Effect. Draw Zeeman pattern of sodium D_2 lines and calculate separation (in cm^{-1}) between any two components and state their state of polarization
(30 marks)
(b) Taking Lamb shift into account, draw the fine structure of H_α lines of hydrogen.
(20 marks)
(c) Explain the origin and significance of 21 cm line of hydrogen atom.
(10 marks)
- Q3.** (a) Explain in detail that electronic spectra has strong tendency towards head formation and bonds degraded at both ends are formed.
(30 marks)
(b) Use of Lasers in Raman spectra has revolutionized its applications. Why?
(10 marks)
(c) Why energy levels of a rotating molecule are discrete? For Hcl molecule, $B = 10.34 \text{ cm}^{-1}$. How many rotational levels this molecule has in 0.2 eV vibrational mode?
(20 marks)
- Q4.** (a) The Zeeman components of a 5461 \AA spectral lines are 0.417 \AA apart when the magnetic field is 1.5T. From there data, calculate the $\frac{e}{m}$ of an electron.
(20 marks)
(b) A substance shows a Raman line at 4567 \AA when exciting line of 4358 \AA is used. Deduce the positions of stokes and Anti stokes lines for the same substance when two exciting line of 4047 \AA is used.
(20 marks)
(c) The mean of the inter-nuclear distances for HCl^{35} in the $V = 0 \rightarrow V = 1$ levels is 1.293 \AA calculate the difference in cm^{-1} between R (0) and P (1) lines of fundamental band for HCl^{35} . (20 marks)

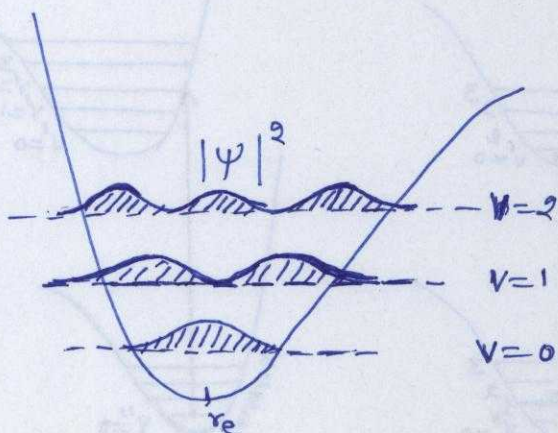
Frank Condon Principle:-

~~It is~~ Electronic transition in a molecule takes place so rapidly compared to the vibrational motion of the nuclei that the instantaneous internuclear distance can be considered remaining unchanged during the electronic transition.

Thus an electronic transition between the states A and B is represented by a vertical line from one level to the other. This is known as Frank-Condon Principle.

The Frank-Condon principle can be combined with the probability density $|\psi|^2$ of linear Harmonic oscillator to understand the intensity distribution among the bands of a band system.

If a molecule is in the lowest vibrational level of a given electronic state, the probability distribution function $|\psi|^2$ is maximum at mid point while in the excited vibrational states this probability distribution function $|\psi|^2$ is maximum at the end points.



As we see that $|\psi|^2$ is maximum at the mid point of the $v=0$ level, and near the turning points of the higher vibrational levels.

Thus the most probable vibrational transitions are those in which one of the two ~~pe~~ turning points of a vibrational level of one electronic state lie at the same internuclear distance as one of the two turning points of a level of the other electronic state, except in case of $v=0$ level for which mid point rather than the turning point is substituted.

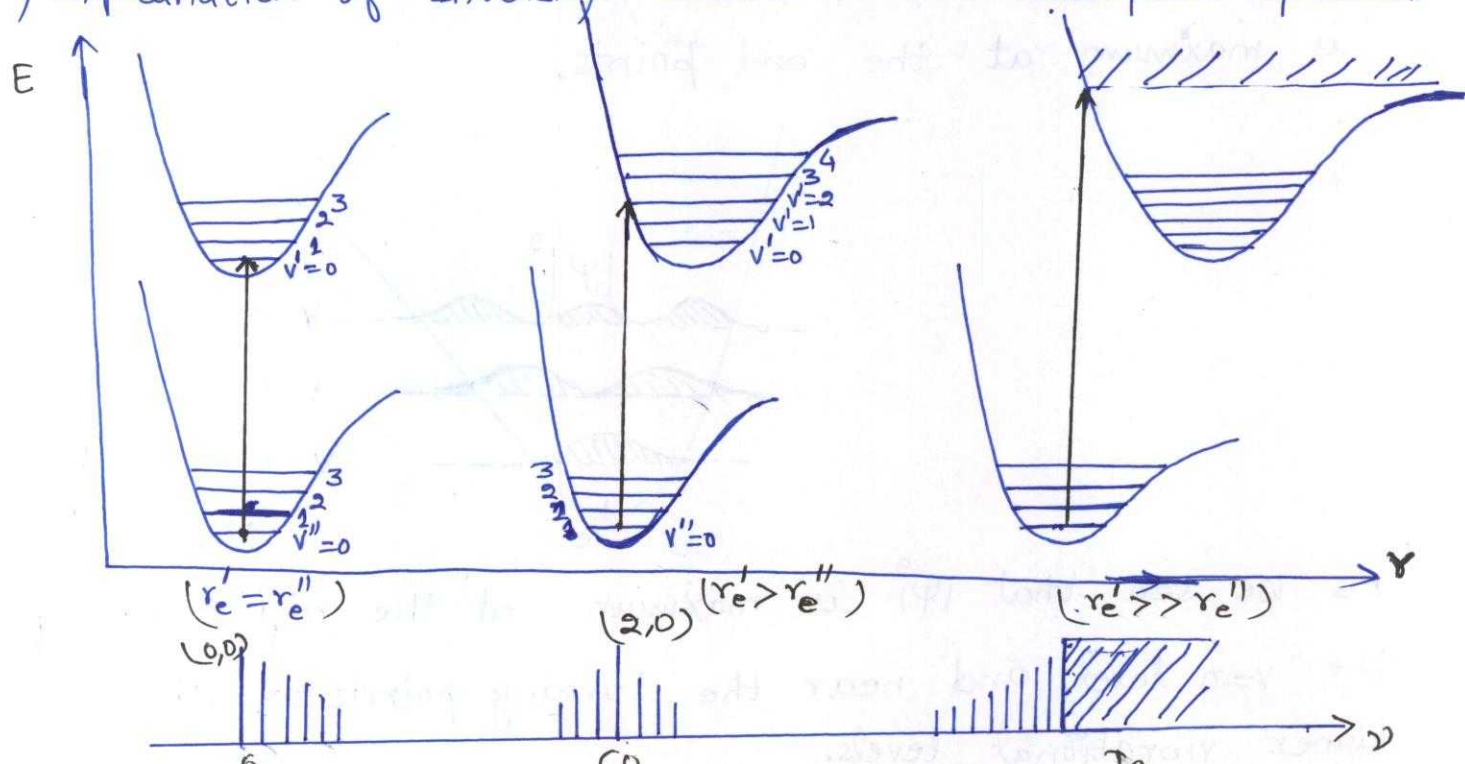
Quantum-mechanically, the transition is governed by what is known as Frank-Condon factor, which is

$$f_{v',v''} = \left[\int \Psi_{v'}^* \Psi_{v''} d\tau \right]^2$$

The most intense transitions will be those for which the overlap between $\Psi_{v''}$ (determined from the lower electronic state) and $\Psi_{v'}$ (determined from the upper electronic state) is a maximum.

Use of Frank-Condon principle:-

i) Explanation of Intensity distribution in Absorption spectrum.



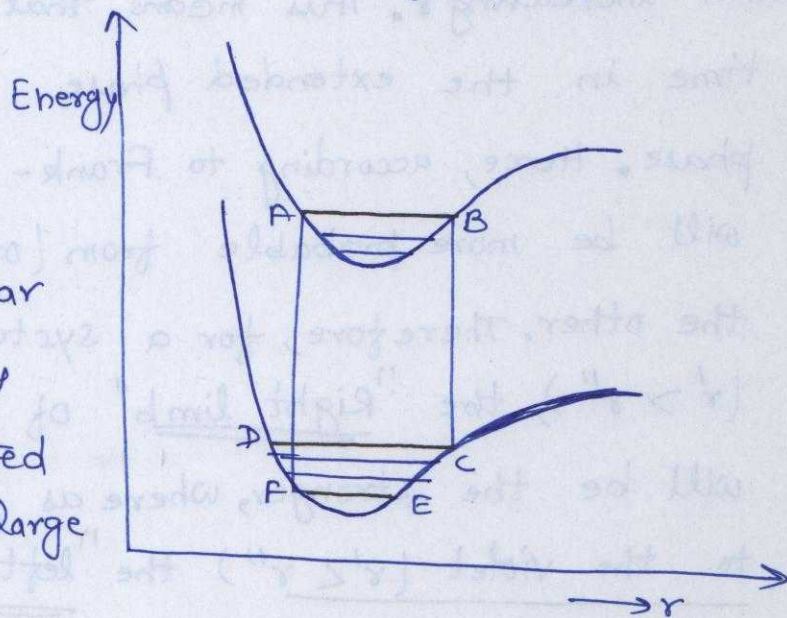
1) Intensity distribution in Emission spectrum:-

According to the Frank-Condon principle, the distribution of intensity in a band progression with $v'=0$ in emission corresponds exactly to that of a progression with $v''=0$ in absorption. For a $v'=0$, greater is the value of $(r_e' - r_e'')$ i.e. the difference, the larger is the v'' value for maximum intensity.

Since in the emission spectrum, in the upper electronic state a large no. of v' are populated so a no. of v'' progressions will be obtained.

The intensity distribution of progression corresponding to $(v' \neq 0)$ is different from that of $(v' = 0)$.

We see that in an emission spectrum, there will be two intensity maximum for a particular value of v' ($v' \neq 0$). They would be more separated depending upon how large is v' .



Thus a plot of intensities of the bands of a system in a $(v' - v'')$ array, ~~and~~ and join up the most intense bands, we obtain a parabolic curve. It is called the "Condon Parabola".

NUCLEAR PHYSICS

-: Nuclear Physics Notes :-

Books Referred

- ① Resnik & Eisberg
- ② Arthur Beiser
- ③ S. B. Patel - Nuclear Physics
- ④ S. N. Ghoshal - Nuclear Physics
- ⑤ D. C. Tayal - Nuclear Physics
- ⑥ Pandya & Yadav - Nuclear Physics
- ⑦ U.G.C Net guide on Physics

Notes of

- ① Prashant Kumar - I.A.S 2004 batch
- ② Supreet Singh Gulati - I.A.S 2008 batch
- ③ Prashant Mishra - I.R.S 2007 batch
- ④ Rajeev Jain - I.P.S 2007 batch
- ⑤ Vipul Singhal - I.R.S 2008 batch
- ⑥ Puneet Nayyar - I.F.O.S 2010 batch
- ⑦ D.P. Vajpeyi - D.I.A.S Institute, Delhi
- ⑧ Mohit Agarwal - I.R.S 2006 batch

ANNEXURE - VII

FORMAT - E

FORMAT OF PAYMENT REGISTER FOR V.W.S.C.

Name of the Scheme _____

SL. NO.	Date	Particulars (Detail of Project)	Cheque No.	Amount Released
Total				

DÎAS

Delhi Institute for
Administrative Services

CIVIL SERVICES EXAMINATION (MAINS)

PHYSICS TEST SERIES 2009

TEST 3 : NUCLEAR & PARTICLE PHYSICS

Time allowed: 2 hours

Max. Marks: 200

Question No.1 is compulsory. Out of Question numbering (2), (3) & (4) attempt any two

Q1. (i) Plot a typical energy spectrum of beta particles coming out of a β -decay process. Point out the salient features of this spectrum. How will you explain these features?

(ii) Write the quark content of neutron and proton. Using the properties of these quarks (electric charge, spin, isospin & baryon no), show that this is the only quark content which gives all their properties.

(iii) The intrinsic spin J , parity π and isospin I of f^0 , ω^0 & η^0 mesons are $(2^+, 0)$, $(1^-, 0)$ and $(0^-, 0)$ respectively. Assuming that iso, spin and parity are conserved, which of these particles can undergo decay into two pions? Give the reasons.

(iv) Check the feasibility and interaction involved of following nuclear reaction
 $\pi^- + p \rightarrow \lambda^0 + K^0$

(v) What light does deuteron throw on nature of nuclear forces?

(vi) Stating their range, particles involved and exchanged, life time and relative strength write down in brief about various fundamental interactions

(vii) Why does neutron has negative dipole moment? Explain.

(viii) Predict ground state spins & parity of following ${}^{15}_7N$, ${}^{17}_8O$ and ${}^{39}_{19}K$

(10×8=80 Marks)

Q2. (a) Explain why fusion of light nuclei only leads to production of energy. Similarly, explain why fission of heavy nuclei leads to production of energy. The binding energy for ${}^{239}U$ is about 7 MeV per particle and that of its fission fragments is about 8 MeV per particle. How much energy will be released by the burning of 1gm of ${}^{239}U$?

(b) Name the interactions responsible for each of the following decays

(i) $n \rightarrow p + \bar{e} + \bar{\nu}_e$

(ii) $\pi^0 \rightarrow \gamma + \gamma$

(iii) $\Delta^0 \rightarrow \pi^0 + p$

(iv) $\pi^+ \rightarrow \mu^+ + \nu_\mu$

(c) Write down the first four terms of the semi-empirical mass formula and explain their origin in one sentence each. Assume the surface & coulomb constants to be 16 MeV and 0.5 MeV respectively. Using this information, find the atomic no of the heaviest element that you can think of which would be stable against fission.

(20×3=60 Marks)

Assumption of shell model:-

It is an attempt to explain the extra stability of magic nuclei and predict ground state spin, parity, magnetic moment for large no. of nuclei. It is simplest nuclear model obtained by applying quantum mechanics.

Assumptions of shell model are:-

- i) ~~the~~ Each nucleon moves ~~is~~ independently inside the nucleus ~~due to~~ under the effect of net central potential $V(r)$ or central attractive force produced by the average interaction between remaining $(A-1)$ nucleons in the nucleus. It is possible to describe the central field as short range potential well whose exact nature is not known.
- ii) In this central potential field, each nucleon is imagined to move in a shell, depending on its energy and angular momentum, in a manner analogous to atomic electrons.
- iii) Motion of nucleon is independent of other nuclei. It assumes interaction between nucleons to be weak despite its very high density (weak interaction paradox). Since nucleons are fermions, no two of them can occupy same quantum state. Even though strong interaction is present, it is not able to manifest itself because all quantum states into which a nucleon might get scattered after collision are already occupied by other nucleons.
- iv) It is assumed that potential $V(r)$ is fairly constant within the nucleus and changes rapidly near the edges and the Schrödinger equation for the particle in the above potential is solved.

skip

skip It was found that the energy of a nucleon energy level of the net nuclear potential $V(r)$ depends on quantum numbers n, l and m_s , obeying the exclusion principle with each level occupying maximum of $2(2l+1)$ neutrons or protons. Taking into account of this model, ^{it was found that} ~~no~~ no form of $V(r)$ could explain the magic numbers.

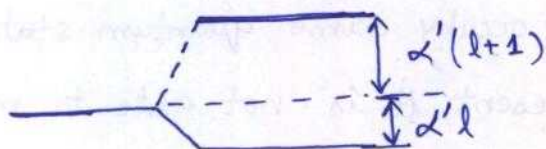
v.) So in 1949, Mayer and Jensen proposed that each nucleon in a nucleus feels in addition to net nuclear potential, a strong inverted spin-orbit coupling between nucleons, which is proportional to $\vec{S} \cdot \vec{L}$. "Strong" means that consequent splitting of energy levels into sublevels is many times larger than analogous splitting of atomic energy levels. Inverted means that the energy of the nucleon is decreased when $\vec{S} \cdot \vec{L}$ is positive, and increased when it is negative.

$$E_{ls} = -\alpha (\vec{L} \cdot \vec{S}) \quad \text{i.e. inverted l-s coupling}$$

$$\text{for any nucleon, } j = l + \frac{1}{2} \text{ or } l - \frac{1}{2}$$

$$\text{So, } E_{ls} = -\alpha' l \quad \text{for } j = l + \frac{1}{2}$$

$$\& E_{ls} = -\alpha' (l+1) \quad \text{for } j = l - \frac{1}{2}$$



The nuclear spin orbit interaction is not magnetic in nature & is rather an attribute of the nuclear force. The spin-orbit coupling can be either be LS coupling or JJ-coupling. LS coupling holds for very light nuclei, where as JJ coupling holds for heavier nuclei. So it is JJ coupling which holds for great majority of nuclei

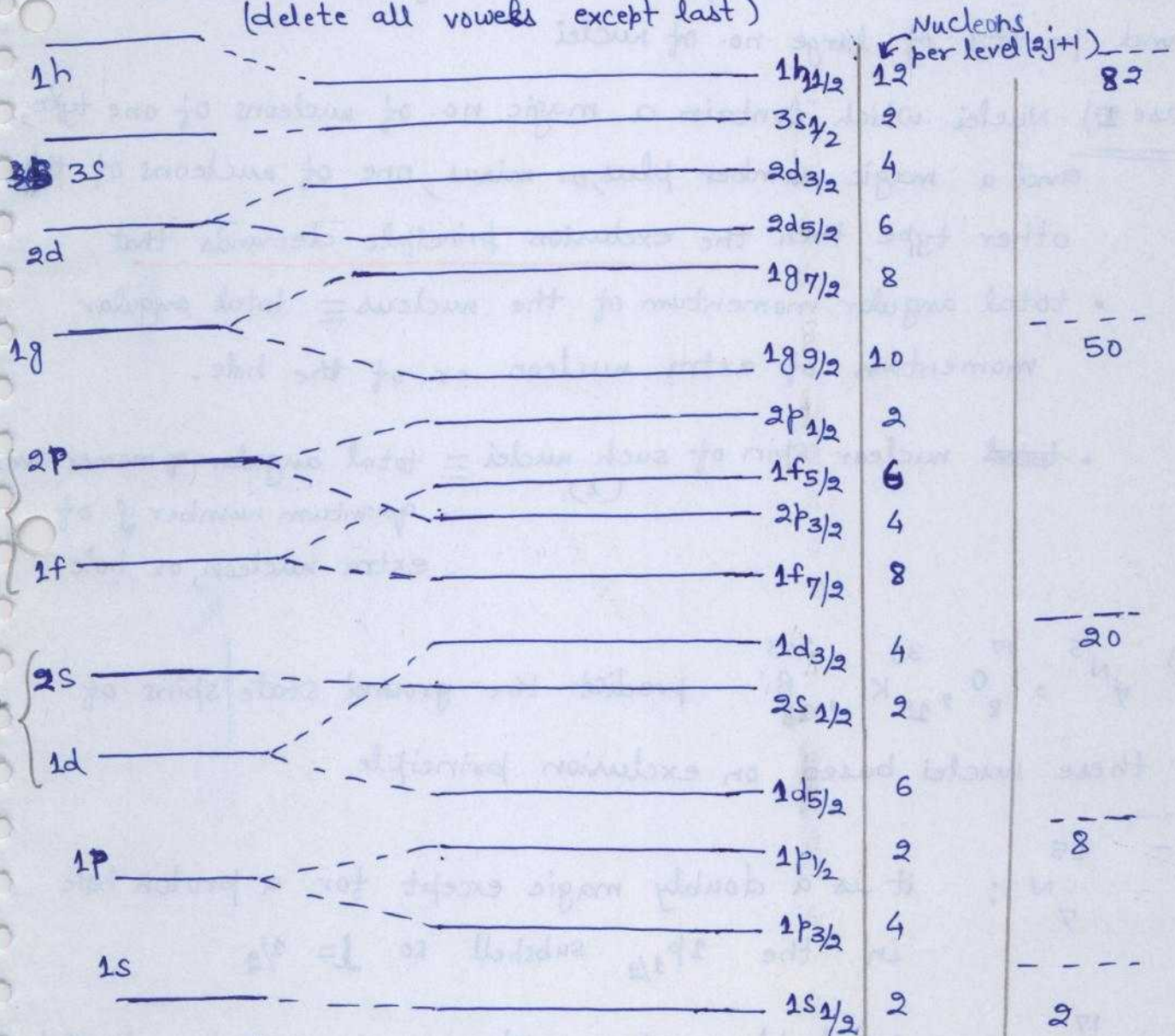
vi) As a result of the spin-orbit interaction, the energies of the split levels depends on quantum number j as well as on " n " and l . According to the exclusion principle, each of these level has a capacity of $(2j+1)$, which is equal to no. of possible values of m_j .

When an appropriate strength is assumed for the spin-orbit interaction, ^[and schrodinger eqn is solved assuming $V(r)$] the energy level falls into the following sequence. ^[$V(r)$ to be constant within the nucleus & changes rapidly near the edges]

1s 1p 1d 2s 1f 2p 1g 2d 3s 1h 2f 3p 1i 2g 3d 4s.

"spuds if pug dish of pig"

(delete all vowels except last)



without $\vec{s} \cdot \vec{L}$ with $\vec{s} \cdot \vec{L}$
(spin-orbit coupling)

Theoretical Explanation of Mossbauer effect:-

The explanation of Mossbauer effect is based on the quantum theory of the specific heat of solids, first proposed by Einstein and later modified by Debye.

Einstein's theory assumes that a solid consisting of N atoms is a set of $3N$ harmonic oscillators all of the same frequency ω , which is determined by $\hbar\omega = kT_E$. T_E is the Einstein temperature which is a characteristic constant of the solid.

If the solid consists of atoms with excited nuclei then the emission of a γ -quantum by such a nucleus will lead to the recoil of the latter, the mean recoil energy of such nucleus is given by $\langle E_r \rangle = \frac{E_\gamma^2}{2Mc^2}$

M = mass of recoiling nucleus

E_γ = Energy of γ -photon.

If $\langle E_r \rangle$ is less than $\hbar\omega$ then some of γ -transitions will be recoilless (no excitation of the oscillator) since the minimum energy transfer into the oscillators is $\hbar\omega$ so that in some cases the photon emission will not lead to any energy transfer to the emitting nucleus which will thus fail to excite the oscillators,

The condition $\langle E_r \rangle$ is less than $\hbar\omega$ can be expressed as

$$\langle E_r \rangle = (1-f)\hbar\omega$$

so that $f = 1 - \frac{\langle E_r \rangle}{\hbar\omega}$ is known as the "Mossbauer Coefficient".

It gives the fraction of recoilless transitions

Since the total energy of an oscillator is twice the mean kinetic energy (E_k) and since at $T=0$ K, the zero point energy is $E_{osc} = \hbar\omega/2$ we can write

$$\hbar\omega = 2E_{osc} = 2 \times 2 \langle E_k \rangle = \frac{\langle p^2 \rangle}{2M}$$

where p is the momentum of nucleus

$$\text{Since, } \langle E_r \rangle = \frac{p_r^2}{2M} = \frac{p_r^2}{2M} = \frac{\hbar^2}{2M\lambda^2} \quad \left\{ \because p_r = \frac{\hbar}{\lambda} \right.$$

So, we have

$$\frac{\langle E_r \rangle}{\hbar\omega} = \frac{\hbar^2}{2M\lambda^2} \frac{2M}{\langle p^2 \rangle}$$

$$\lambda = \frac{\lambda}{2\pi}$$

is the wavelength of the radiation.

$$\frac{\langle E_r \rangle}{\hbar\omega} = \frac{\hbar^2}{\lambda^2 \langle p^2 \rangle} = \frac{\langle x^2 \rangle}{\lambda^2} \quad \text{--- 2.)}$$

where $\langle x^2 \rangle$ give the mean squared position of the oscillator.

$$\text{Since, } (\Delta x)^2 = \langle x^2 \rangle - \langle x \rangle^2 = \langle x^2 \rangle$$

$$\text{and } (\Delta p)^2 = \langle p^2 \rangle - \langle p \rangle^2 = \langle p^2 \rangle$$

$$\text{also, } \Delta x \cdot \Delta p = \hbar/2$$

$$\text{so, } \langle x^2 \rangle = \frac{\hbar^2}{\langle p^2 \rangle}$$

Now using equⁿ 2.) in equⁿ 1.) we have Mossbauer Coeff as

$$f = 1 - \frac{\langle E_r \rangle}{\hbar\omega} = \frac{\langle x^2 \rangle}{\lambda^2}$$

$$\text{so, } \boxed{f = \frac{\langle x^2 \rangle}{\lambda^2}} \quad \text{--- 3.)}$$

A more rigorous treatment gives for the general case ($T \neq 0$)

$$f = \exp\left(-\frac{\langle x^2 \rangle}{\lambda^2}\right) \quad \text{--- 4)}$$

From the eqnⁿ (3) it can be seen that the recoilless transition becomes more probable if

a.) Temperature is low (for which Δx^2 and hence $\langle x^2 \rangle$ are quite small)

b.) the emitter is a solid (for which $\langle x^2 \rangle$ is small)

c.) Transition energy is low, which makes λ large.

d.) Elastic constants of the material are large which makes ω large so corresponding T_E is large.

These conclusions are in agreement with observations.

→ The theory is now modified with T_D replacing T_E . For a monoatomic crystal, the following expression for f is obtained

$$f = \exp\left[-\frac{6\langle E_r \rangle}{kT_D} \left\{ \frac{1}{4} + \left(\frac{T}{T_D}\right)^2 \int_0^{T_D} \frac{y dy}{e^y - 1} \right\}\right]$$

In the limit $T \rightarrow 0$, this reduces to

$$f = \exp\left\{-\frac{3}{2} \frac{\langle E_r \rangle}{kT_D}\right\} \rightarrow 1 - \frac{3}{2} \frac{\langle E_r \rangle}{\hbar\omega_m}$$

QUANTUM - PHYSICS - I

Quantum Mechanics:-

Reference books

- Quantum Mechanics by H.C. Verma (latest edition)
- Quantum Mechanics by Zetili
- Quantum Mechanics by Griffiths (has very good problems in the end)
- Quantum Mechanics by Ghatak & Logamathan.
- Resnick & Eisberg
- Quantum Mechanics:- Schaum Series
- Quantum Mechanics:- Satya Prakash

First 4 books are must Read for
Quantum Mechanics

New Problems of HCV

Chapter 1: Young Double slit Expt.

- (1) What is linear p of photon having $\vec{E} = E_0 \hat{i} \cos [k_0(y+z) - \omega t]$ (What is its magnitude?)

Ans: The eqⁿ for electric field of an em wave can be written as

$$\vec{E} = \vec{E}_0 \cos(\vec{k} \cdot \vec{r} - \omega t)$$

$$\text{or, } \vec{E} = E_0 \hat{i} \cos [(k_0 \hat{j} + k_0 \hat{k}) \cdot (x \hat{i} + y \hat{j} + z \hat{k}) - \omega t]$$

$$= E_0 \hat{i} \cos(\vec{k} \cdot \vec{r} - \omega t) \quad \text{where } \vec{k} = k_0 \hat{j} + k_0 \hat{k}$$

$$\vec{r} = x \hat{i} + y \hat{j} + z \hat{k}$$

The linear momentum of photon is

$$\vec{p} = \hbar \vec{k} = \hbar (k_0 \hat{j} + k_0 \hat{k})$$

$$|\vec{p}| = \hbar |k_0 \hat{j} + k_0 \hat{k}| = \sqrt{2} \hbar k_0$$

- (2) What is mag of p of photon in a beam of He-Ne laser ($\lambda = 634 \text{ nm}$).
Write Ans. in eV/c .

Solⁿ $p = h/\lambda = \frac{hc}{\lambda c} = \frac{1240 \text{ eV-nm}}{(634 \text{ nm}) c} = 1.96 \text{ eV}/c$

- (3) A beam of light ($\lambda = 420 \text{ nm}$) has same intensity as other beam ($\lambda = 630 \text{ nm}$).
1st beam, falling 1 m^2 on wall, deposit 12×10^{16} photons/s. How many 2nd beam deposit?

Solⁿ $I = \text{total energy}/\text{Area}/\text{time}$ or $I \propto c \cdot \lambda$.

Thus, both beam deposit same energy on 1 cm^2 in 1 sec.

If $n_1 = n_0$ of photon deposited by 1st beam.

$$E = n_1 \left(\frac{hc}{\lambda_1} \right) \quad \text{or } E = n_2 \left(\frac{hc}{\lambda_2} \right)$$

$$\text{or, } n_1 = n_2 \quad \text{or, } n_2 = 18 \times 10^{16}$$

QUANTUM - II

Wave Packets :-

According to classical physics, the position and velocity of a particle can be calculated simultaneously to arbitrary precision. But in quantum mechanics, the accuracy to which we can measure the momentum and position simultaneously, is dictated by Heisenberg's uncertainty principle, i.e. $\Delta x \Delta p_x \geq \frac{\hbar}{2}$.

Further De-Broglie's hypothesis states that every moving particle has a wave function associated with it. This wave function however spreads throughout the space and can not be localised.

If we are able to construct a wave function ψ , for a free particle such that the probability of finding the particle is considerable only in the ^{neighbourhood of} classical ~~region~~ trajectory then it can be used to describe the dynamics of the particle. This ψ is almost localised and such a localized wave function is called a "wave packet".

To construct such a wave function, we superimpose a group of waves of slightly different wavelengths, with phases and amplitudes so chosen that they interfere constructively over a small region of space and destructively elsewhere. Wave packets, thus helps in understanding the connection between classical and quantum mechanics.

Construction of wave packet

Let us consider a free particle (i.e. $V=0$) moving along x-direction, we solve the Schrödinger eqn for such a free particle.

The schrodinger eqnⁿ is

$$i\hbar \frac{\partial \psi}{\partial t} = -\frac{\hbar^2}{2m} \frac{\partial^2 \psi(x,t)}{\partial x^2} \quad \text{--- i)}$$

using the method of separation of variables,

$$\psi(x,t) = \psi(x) \tau(t)$$

substitution in eqnⁿ i), it gives

$$i\hbar \frac{1}{\tau(t)} \frac{d\tau}{dt} = -\frac{\hbar^2}{2m} \frac{1}{\psi} \frac{d^2\psi}{dx^2} = E \quad \text{--- ii)}$$

$$\text{or,} \quad \frac{d\tau}{dt} = -\frac{iE}{\hbar} \tau(t)$$

the solution of which gives $-iEt/\hbar$

$$\tau(t) = (\text{constant}) e^{-iEt/\hbar}$$

From eqnⁿ ii), we also have

$$\frac{d^2\psi}{dx^2} + \frac{p^2}{\hbar^2} \psi(x) = 0$$

$$\text{where, } p = \sqrt{2mE}$$

the solution to which will be

$$\psi_p(x) = \frac{1}{\sqrt{2\pi\hbar}} e^{ipx/\hbar}; \quad -\infty < p < \infty$$

The complete solution is therefore

$$\psi(x,t) = \frac{1}{\sqrt{2\pi\hbar}} \exp\left[\frac{i}{\hbar} (px - Et)\right]$$

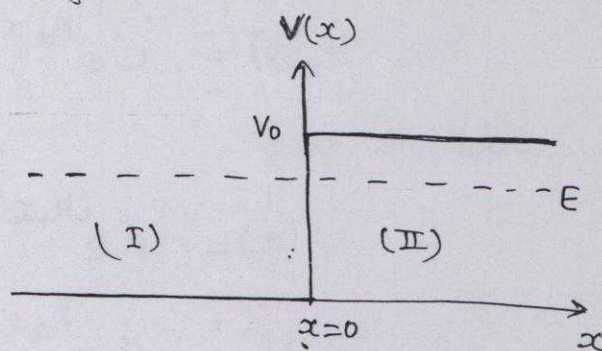
Since $\psi_p(x)$ satisfies the completeness condition, ~~also~~ also p can take any value from $-\infty$ to $+\infty$, the most general solution would be a linear combination of separate solutions, which over the continuous variable p , become an integration to give $\psi(x,t)$

QUANTUM - III

Reflection and Transmission through a potential step:

Consider a particle moving from left to right with energy E which encounters a one dimensional step of V_0 i.e.

$$V(x) = \begin{cases} 0 & \text{for } x < 0 \\ V_0 & \text{for } x > 0 \end{cases}$$



Case I: ($E < V_0$)

Classically, the particle arriving at the potential step from left will be stopped at $x=0$ and there will be total reflection of the particle. Since the total energy E is constant, classical mechanics says that no particle can enter the region $x > 0$ because of the reason that $k \cdot E$ would be negative for $x > 0$. So the motion of the particle is reversed by the potential barrier.

Quantum mechanically, the picture will be different

The Schrodinger eqn^h for region I ($x < 0$)

$$\frac{d^2 \psi_1}{dx^2} + \frac{2mE}{\hbar^2} \psi_1 = 0$$

$$\text{or, } \frac{d^2 \psi_1}{dx^2} + k_1^2 \psi_1 = 0 \quad \text{--- 1)}$$

$$\text{or, } \psi_1(x) = A e^{ik_1 x} + B e^{-ik_1 x} \quad \text{--- 2)}$$

$$\text{where, } k_1 = \sqrt{2mE}/\hbar$$

The Schrodinger eqn^h for region II ($x > 0$)

$$\frac{d^2 \psi_2}{dx^2} + \frac{2m}{\hbar^2} (E - V_0) \psi_2 = 0$$

$$\text{or, } \frac{d^2 \psi_2}{dx^2} + k_2^2 \psi_2 = 0$$

$$\text{where, } k_2 = \sqrt{2m(V_0 - E)}/\hbar$$

$$\frac{d^2 \psi_2}{dx^2} - k_2^2 \psi_2 = 0 \quad \text{--- 3.)}$$

$$\text{So, } \psi_2(x) = C e^{k_2 x} + D e^{-k_2 x} \quad \text{--- 4.)}$$

Solutions are

$$\psi_1(x) = A e^{ik_1 x} + B e^{-ik_1 x} \quad (x < 0)$$

$$\psi_2(x) = C e^{k_2 x} + D e^{-k_2 x} \quad (x > 0)$$

Since the wave function must be finite everywhere, and since the term $e^{k_2 x}$ diverges when $x \rightarrow \infty$. So the constant C must be zero.

$$\therefore \psi_2(x) = D e^{-k_2 x} \quad \text{--- 5.)}$$

At the boundary $x=0$, the wave function in the two region and their derivatives must be continuous

$$\text{so, at } x=0, \quad \psi_1 = \psi_2 \quad \text{and} \quad \frac{d\psi_1}{dx} = \frac{d\psi_2}{dx}.$$

$$\text{So, i) at } x=0, \quad \psi_1 = \psi_2$$

$$\text{or, } A + B = D \quad \text{--- 6.)}$$

$$\text{ii) at } x=0, \quad \frac{d\psi_1}{dx} = \frac{d\psi_2}{dx}.$$

$$ik_1(A - B) = -k_2 D \quad \text{--- 7.)}$$

solving 6) and 7), we obtain

$$B = \frac{k_1 - ik_2}{k_1 + ik_2} A, \quad D = \frac{2k_1}{k_1 + ik_2} A \quad \text{--- 8.)}$$

$$\text{or, } \boxed{A = \frac{D}{2} \left(\frac{1 + ik_2}{k_1} \right)} \quad \times \quad \boxed{B = \frac{D}{2} \left(\frac{1 - ik_2}{k_1} \right)} \quad \text{--- 9.)}$$

$$\text{or, } \psi(x) = \begin{cases} \frac{D}{2} \left(\frac{1 + ik_2}{k_1} \right) e^{ik_1 x} + \frac{D}{2} \left(\frac{1 - ik_2}{k_1} \right) e^{-ik_1 x} & (x < 0) \\ D e^{-k_2 x} & (x > 0) \end{cases}$$

SOLID STATE PHYSICS.

CIVIL SERVICES EXAMINATION (MAINS)
PHYSICS TEST SERIES 2009
TEST 4 : SOLID STATE PHYSICS & ELECTRONICS

Time allowed: 2 hours

Max. Marks: 200

Question No.1 is compulsory. Out of Question numbering (2), (3) & (4) attempt any two

- Q1.** (i) Show that bcc is reciprocal to fcc lattice.
(ii) What are Type I & Type II Superconductors?
(iii) What would be the electron velocity at the zone edge of a solid crystal of atomic spacing 5 \AA . Can this velocity be realized in practice?
(iv) Simplify Boolean expression $y = B\bar{C}\bar{D} + \bar{A}B\bar{C}D + AB\bar{C}D + \bar{A}BCD + ABCD$
(v) Show that FCC-crystals are more closely packed than BCC-crystals.
(vi) How can the NAND-gates be combined to perform the OR-operation?
(vii) A certain colpits oscillator uses a tank circuit with $L = 20 \text{ mH}$; $C_1 = 200 \text{ pf}$ and $C_2 = 300 \text{ pf}$. What is the frequency of oscillation?
(viii) Distinguish between 'soft' and 'hard' super-conductors. Explain how penetration depth varies with magnetic field strength and temperature.

(10×8 =80 marks)

- Q2.**(a) Write down the expressions for specific heat obtained by Debye's and Einstein's theories. What is essential difference between them? Show that Debye's theory reduces to famous T^3 law in lower temperature region?
(b) Design a digital circuit which may check that sum of two binary numbers is more than third number.

(20 marks)

- (c) Determine V_0 for network using a silicon diode $V_T = 0.7V$

(20 marks)

- Q3.** (a) What is a full adder circuit? Make a truth table, write Boolean expression and realize it by using gates.

(20 marks)

- (b) What is Barkhausen criteria for oscillators? Explain the working of a phase shift oscillator.

(20 marks)

- (c) Derive an expression for forward current gain and leakage current of CE mode of a transistor in terms of current gain and leakage current of CB mode. Of $\alpha = 0.98$ $I_{CBO} = 5 \text{ mA}$ calculate β & I_{CEO} .

(20 marks)

- Q4.** (a) What is $A \cdot C$ Josephson effect? Derive an expression for frequency of current produced. How this phenomena can be used in devising SQUIDS?

(30 marks)

- (b) Define Brillouin zone for a lattice by considering simple cubic crystal. Construct first Brillouin zone for a bcc lattice.

(15 marks)

- (c) Starting from $2\vec{K} \cdot \vec{G} + G^2 = 0$, obtain the diffraction condition $2d \sin \theta = n\lambda$

(15 marks)

DIAS

Delhi Institute for
Administrative Services

CIVIL SERVICES EXAMINATION (MAINS)

PHYSICS TEST SERIES 2008

Test 4: Solid state physics & Electronics

Time allowed: 2 Hrs

Max Marks: 200

Attempt all questions.

Q1(a) What is reciprocal lattice? Discuss some of its important properties and show that fcc lattice is the reciprocal of bcc lattice and vice versa. Do you know a lattice which is self reciprocal? (20 Marks)

(b) The Bragg angle for reflection from the (111) planes in aluminium (fcc) is 19.2° for an x-Ray wave length of 1.54 \AA , compute (i) the cube edge of the unit cell

(ii) the Interplaner distance of these planes. (20 Marks)

(c) How are Brillouin zones constructed? Describe and sketch the first Brillouin zones of bcc and fcc lattices Mention their importance in crystal analysis (20 Marks)

(d) What are Type I & Type II Superconductors?

In a one dimensional crystal the electron energy is given by $E = Ak^2 + Bk^3$ where k is a wave vector and A and B are positive constants. Obtain the electron velocity at Brillouin zone?

(e) Energy of a Solid at temperature T is given by

$$E = 9RT \left(\frac{T}{\theta_D} \right)^3 \int_0^{\theta_D/T} \frac{x^3 dx}{e^x - 1}$$

Where $x = \frac{h\nu}{kT}$, θ_D = Debye's temp. Estimate its specific heat when $T \ll \theta_D$ and explain

why it differs so much from Einstein's theory of specific heat of solids.

Q2(a) Simplify the following Boolean expressions:

(i) $\overline{ABC} + A\overline{BC} + ABC$

(ii) $A[B + C(\overline{AB} + \overline{AC})]$

(b) How will you construct a full adder with the help of half adders? Describe its function with truth table?

(c) which gates are known as universal building blocks and why? Construct three basic logic functions with their help only.

(d) Show that (i) $\overline{ABC} + \overline{ABC} + ABC + ABC = C$. Realise this logic using NAND gates.

(e) Design a digital circuit to check the Boolean relation $A + B > C$, where A, B & C are binary digits.

Test 4: Solid state Physics & Electronics

Time allowed: 2 HRS]

[Max. Marks: 200

Attempt all questions.

Q1 (a) What is reciprocal lattice? Discuss some of its important properties and show that fcc lattice is the reciprocal of bcc lattice and vice versa. Do you know a lattice which is self reciprocal? (20 marks)

(b) The Bragg angle for reflection from the (111) planes in aluminium (fcc) is 19.2° for an X-Ray wavelength of 1.54 \AA . Compute (i) the cube edge of the unit cell (ii) the interplaner distance of these planes. (20 marks)

c) How are Brillouin Zones constructed? Describe and sketch the first Brillouin Zones of bcc and fcc lattices. Mention their importance in crystal analysis. (20 marks)

1) What are Type I & Type II Superconductors? (5 marks)

In a one dimensional crystal the electron energy is given by $E = Ak^2 + Bk^3$ where k is a wave vector and A and B are positive constants. Obtain the electron velocity at Brillouin zone? (15 marks)

2) Energy of a solid at temperature T is given by

$$E = 9RT \left(\frac{T}{\Theta_D} \right)^3 \int_0^{\Theta_D/T} \frac{x^3 dx}{e^x - 1}$$

where $x = \frac{h\nu}{KT}$, $\Theta_D = \text{Debye's temp.}$

Estimate its specific heat when $T \ll \Theta_D$ and explain why it differs so much from Einstein's theory of specific heat of solids. (20 marks)

Magnetism (old IAS Questions)

- 1.) Distinguish between dia-, para and ferromagnetism. Give an account of Weiss theory of ferromagnetism. [50 Marks, 1986]
- 2.) Considering the electrons in the atom, what is the difference between a diamagnetic and a paramagnetic substance? State how magnetic susceptibility varies with temperature for dia, para, ferro- and anti-ferro-magnetic materials. (No theoretical discussion required) [20 marks, 1989]
- 3.) What is ferrimagnetism. How is it different from anti ferromagnetism? [20 marks, 1993]
- 4.) Derive an expression for magnetic susceptibility below Neel's temperature for a ferrimagnetic substance. [20 marks, 1994]
- 5.) How does a ferromagnetic material get magnetized? Why is the demagnetization process irreversible? What is the physical significance of the magnetic hysteresis loop for a ferromagnetic material? Under what conditions the ferromagnetic materials become paramagnetic? [20 marks, 1995]
- 6.) Assuming that for a paramagnetic material, the magnetic susceptibility is inversely proportional to temperature in Kelvin, obtain Curie-Weiss Law for the ~~paramagn~~ paramagnetic phase of a ferromagnetic material. [20 marks, 1997]
- 7.) Distinguish qualitatively between dia-, para-, ferro-, anti-ferro- and ferrimagnetism. How is the weak and temperature independence ~~of~~ paramagnetism of metal explained? [20 marks, 1998]
- 8.) What are the salient characteristic of ferromagnetic? Explain how the Curie law of paramagnetism is modified to the Curie-Weiss Law. [20 marks, 2000]

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Third handwritten paragraph of text.

Fourth handwritten paragraph of text.

Fifth handwritten paragraph of text.

Sixth handwritten paragraph of text.

Seventh handwritten paragraph of text.

Eighth handwritten paragraph of text.

* Magnetism in Solids

- When a solid is placed in a magnetic field, it gets magnetised.

The mag moment per unit volume dev^d inside a solid is called magnetization and is denoted by \vec{M} .

- Magnetic susceptibility, χ is a measure of the quality of the mag material. Defined as \vec{M} produced p.u. applied mag field i.e.

$$\boxed{\chi = \vec{M}/\vec{H}} \quad (\text{M \& H in A/m})$$

H is strength of applied mag field - mag field intensity.

Vectors \vec{M} and \vec{H} can have different dir's, so χ is a tensor.

In isotropic media, \vec{M} and \vec{H} point in same dir and χ is a scalar quantity.

If M refers to a gram molecule of substance, then χ is χ_m .

- Magnetic induction or mag flux density \vec{B} produced inside the medium as a consequence of the applied mag field \vec{H} is given by

$$\boxed{\vec{B} = \mu_0 (\vec{H} + \vec{M})} \quad (\text{B in Wb/m}^2 \text{ or T})$$

$$\Rightarrow \vec{B} = \mu_0 (1 + \chi) \vec{H}$$

$$\Rightarrow \vec{B} = \mu \vec{H} = \mu_0 \mu_r \vec{H}$$

μ : absolute permeability; also a tensor like χ .

μ_r : relative permeability (μ/μ_0)

$$\boxed{\mu_r = 1 + \chi}$$

In absence of any material medium, $\vec{B} = \mu_0 \vec{H}$