[This question paper contains 4 printed pages.]

Your Roll No.....

Sr. No. of Question Paper : 5557 **J**

Unique Paper Code : 2222013602

Name of the Paper : DSC Atomic, Molecular and Nuclear Physics

Name of the Course : **B.Sc. (Hons.) Physics_ NEP: UGCF-2022**

Semester : VI

Duration : 3 Hours Maximum Marks : 90

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt **FIVE** questions in all
3. **Question No. 1 is compulsory**
4. Attempt **four** questions from the rest of the paper
5. Use of non-programmable scientific calculator is allowed.

1. Attempt any **six** questions from the following: **(6 x 3 = 18)**

a) Briefly explain the modes of relaxation of an excited atomic state.

b) The effective potential (in arbitrary units) when solving a one-electron atom problem is

$$V_{\{eff\}}(r) = -\frac{2}{r} + \frac{l(l+1)}{r^2}$$

Plot $V_{\{eff\}}$ Vs r for hydrogen atom for $l = 0$ and $l = 1$.

c) What is the consequence of breaking of the Born-Oppenheimer approximation on the ro-vibrational spectrum of a diatomic molecule?

P.T.O.

d) Show that the Darwin term results in a shift of 0.7305 cm^{-1} for $S_{1/2}$ state in H atom. Given 1 eV = 8065.54 cm^{-1}; $\alpha^2 \approx (1/137)^2 = 1/18769$; Rydberg constant = 1.097×10^5 cm^{-1}.

e) Differentiate between σ and π bonds.

f) State the Geiger-Nuttal law and represent it graphically.

g) What conclusions can be drawn from Weisskopf estimates about transition probabilities in terms of multipole order and the type of radiation?

2. a) Calculate the change in energy due to spin orbit interaction responsible for the fine structure of hydrogenic atoms.

b) The D_1 line of Sodium is due to the transition $^2P_{1/2} \rightarrow {}^2S_{1/2}$. Draw and discuss the shifts in the spectral line caused by a strong magnetic field. What is the name of this effect?

c) For the hydrogen atom at the $n = 2$ energy level, demonstrate that the spin-orbit interaction causes no energy shift for $S_{1/2}$ state. **(9+6+3)**

3. a) State the differences between the spectra of rigid rotator and non-rigid rotator. Support with a diagram.

b) What are the dipole selection rules for one-electron atoms?

c) A free neutron decays into a proton by the emission of β^- particles of maximum kinetic energy 0.782 MeV. Find the mass of proton and hydrogen atom. Given the rest mass of electron = 0.0005486 u, rest mass of neutron = 1.008665 u. **(6+6+6)**

4. a) Derive the following expression for the wave number for energy level(s) (cm^{-1}) in case of Raman spectra $\bar{\vartheta} = (\overline{\vartheta_0} \pm B(4J + 6))$ cm^{-1} where $\bar{\vartheta}$ and $\overline{\vartheta_0}$ are the wave numbers of energy levels of Raman Spectra and the exciting lines respectively, B is the rotational constant and J is the rotational quantum number. What do the positive and negative signs in the above equation, refer to?

b) The first rotational absorption of $^{12}C^{16}O$ occurs at 3.84235 cm^{-1} while that of $^{13}C^{16}O$ is at 3.67337 cm^{-1}. Find the atomic weight of ^{13}C. Given mass of ^{16}O =16.00 u and mass of ^{12}C = 12.00 u.

c) State the Franck-Condon principle. Draw electronic transitions illustrating the principle. **(9+6+3)**

5.a) A radioactive substance A with decay constant λ_A transforms into another radioactive substance B with decay constant λ_B which further decays into a stable end- product C $(A \rightarrow B \rightarrow C)$. Assume at $t = 0$ only substance A with N_{A0} atoms is present. The number of atoms of substances A and B present at any instant t are $N_A(t)$ and $N_B(t)$ respectively. Discuss the equilibrium conditions for (i) longer lived parent nucleus compared to the daughter nucleus (ii) longer lived daughter nucleus than the parent nucleus. In each case represent graphically the variation of activity with time.

b) Using the nuclear Shell model, explain how does the spin orbit interaction explain the existence of magic number 28. Why are the low-lying excited states assigned $(1/2)^+$ and $(1/2)^-$? **(6+12)**

6.a) Explain the fine structure splitting of spectral lines in H-atom due to the transition from the first excited state to the ground state. Identify the allowed transitions according to the selection rules. Why does each line from the first excited state to the ground state, split into a doublet in the fine structure of the hydrogen atom?

b) Show that the laws of conservation of energy and angular momentum are not violated if a neutrino or an anti-neutrino is emitted in beta decay.

c) Explain the origin of P and R branches in the vibration rotation spectra of diatomic molecules. **(6+6+6)**

Useful information:

$$\langle 1/r \rangle = \frac{Z}{n^2 a_0} \; ; \langle \frac{1}{r^2} \rangle = \frac{Z^2}{\left(l+\frac{1}{2}\right) n^3 a_0{}^2} \; ; \langle \frac{1}{r^3} \rangle = \frac{Z^3}{l(l+\frac{1}{2})(l+1) n^3 a_0{}^3}$$

a_0 is the Bohr radius

Z is the nuclear charge, l is the orbital quantum number

n is the principal quantum number

(2000)