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SARDAR PATEL UNIVERSITY
M. Sc. Physics I[st] Semester Examination
Wednesday, Date: 26-10-2016 Time: 10.00 am to 01.00 pm
CBCS Course No.: PS01CPHY03
Subject: Atomic, Molecular and Laser Physics

Note: Symbols have their usual meaning. **Total Marks: 70**

Q.1 Write answers of all eight questions in a table form by showing your choice against the question number. **(8)**

(1) For alkali metals as atomic number (Z) increases _____.
 (a) atomic radius increases but ionization potential decreases.
 (b) atomic radius decreases but ionization potential increases
 (c) atomic radius and ionization potential both decrease
 (d) atomic radius and ionization potential both increase

(2) For three level laser system, _____ gives necessary mathematical condition for population inversion between level 1 and 2.
 (a) $T_{32} = T_{21}$ (b) $T_{32} > T_{21}$ (c) $T_{32} < T_{21}$ (d) $T_{32} > T_{31}$

(3) In the case of H-atom "centrifugal force" varies as _____.
 (a) $\frac{1}{r}$ (b) $\frac{1}{r^2}$ (c) $\frac{1}{r^3}$ (d) r^2

(4) Life time for cavity photon in a given lasing system depends on _____.
 (a) internal absorption (b) leakage through window (mirror-2)
 (c) scattering (d) all of the above

(5) _____ gas used to increase the efficiency of the CO_2 gas laser.
 (a) He (b) N_2 (c) O_2 (d) NH_3

(6) The energy difference between various vibrational levels corresponds to the _____ region
 (a) infrared (b) visible (c) ultraviolet (d) far infrared

(7) Angle between HOH in H_2O molecule is more than 90^0, because of _____.
 (a) repulsion between electrons (b) stretching effect of rotation
 (c) hybridization effect of 2s and 2p orbitals (d) dipolar nature of H_2O

(8) Unit of *rotational constant* (B) is _____.
 (a) $J.mol^{-1}K^{-1}$ (b) J.sec (c) sec^{-1} (d) J

Q.2 Answer any seven questions. **(14)**

(1) Draw and explain the graph for effective potential for H-atom.
(2) What are Positronium and Muonium systems?
(3) Prove that (i) $S^2\chi_-(1,2) = 0$ and (ii) $S^2\chi_+(1,2) = 2\,\chi_+(1,2)$.
(4) Write two advantages of Thomas-Fermi model for many-electron atom.

(5) For the case of homonuclear diatomic molecule, explain the symbol $X^1\sum_g^+$.
(6) Why the normal optical sources emit only spontaneous light?
(7) Give two differences between laser and maser.
(8) What are Rayleigh and Raman scattering?
(9) Give difference between stimulated and hyper Raman effects?

Q.3 **(a)** Name different contributions to total Hamiltonian when relativistic effects and spin-orbit interaction are included. Give expression for corrected energy ($E_{n,j}$). Draw and discuss in detail *fine structure* energy level diagram for H-atom. **(6)**

(b) Give detailed account of Lamb shift experiment. **(6)**

OR

(b) Give difference between Hyperfine structure and isotope shifts in energy levels of Hydrogenic system. Construct spin-independent Hamiltonian for two-electron atomic system, and discuss *para* and *ortho* states. Discuss the role of Pauli's exclusion principle. **(6)**

Q.4 **(a)** Based on Taylor series expansion of electronic energy as a function of nuclear separation, derive vibrational and rotational energy eigenvalues for diatomic molecule. What is the advantage of using Morse potential compared to Taylor series expansion of electronic energy while determining $E_{s,v,j}$? – explain. **(6)**

(b) Write assumptions involved in Thomas–Fermi model for many-electron atoms, and derive $\frac{d^2\chi(x)}{dx^2(x)} - \frac{1}{\sqrt{x}}[\chi(x)]^{\frac{3}{2}}=0$. **(6)**

OR

(b) Give detailed note on LCAO method considering an example of H_2^+ ion. **(6)**

Q.5 **(a)** For three level laser system, obtain rate equation. **(6)**

(b) Considering applied electric field as perturbation to atomic Hamiltonian, derive the following equation for transition probability, **(6)**

$$|C_2(t)|^2 = \frac{\mathcal{D}_{21}^2 \mathcal{E}_0^2}{4\hbar^2}\left\{\frac{\sin\left\{\frac{(\omega_{21}-\omega)}{2}\right\}t}{\left\{\frac{(\omega_{21}-\omega)}{2}\right\}}\right\}^2.$$

OR

(b) For two-level laser system, derive ratio of Einstein coefficients using classical theory. Average pump frequency of a given three-level Ruby laser is 6.25×10^{14} Hz. Density of Cr^{+3} ions and threshold pump rate (W_{pt}) are 1.6×10^{19}cc and 330 s^{-1}, respectively. Calculate (i) threshold pump power and (ii) threshold pump energy. **(6)**

Q.6 **(a)** Discuss the construction and working of CO_2 laser. **(6)**

(b) Write note on *free electron laser*. Give its advantages. **(6)**

OR

(b) Discuss hyper Raman effect using classical mechanics and quantum mechanical treatments. **(6)**

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