M.Sc. Examination, 2019

Semester - IV

Physics

Paper: MPC-41

(Atomic and Molecular Physics)

Time: Three Hours **Full Marks: 40**

Questions are of equal value as indicated in the margin.

Answer ***any four*** questions

1. Discuss the physical significance of Dipole approximation. Use dipole approximation to establish the matrix elements $\boldsymbol{p}_{ba} = im w_{ba} \boldsymbol{r}_{ba}$. Under dipole approximation, calculate the transition rate for absorption. 2+3+5

2. Establish that the vector potential for a constant magnetic field $\left(\vec{B}\right)$ is $\vec{A} = \frac{1}{2}\left(\vec{B} \times \vec{r}\right)$. Write down the Hamiltonian and hence the nonrelativistic Schrödinger equation for a hydrogenic atom in a constant magnetic field. Justify that the quadratic term involving $\vec{A}$ could be neglected compared to the linear counterpart from the said Hamiltonian. 2+2+6

3. What a Lamb Shift is? Why these shifts are unavailable in the relativistic theory of hydrogen atom due to Dirac? How the experiment of Lamb-Retherford is used to obtain the Lamb shift? 2+2+6

4. Obtain the linear Stark effect and hence the splitting of the hydrogen atom in its first excited state. Obtain the eigenstates of the Stark-splitted levels. Give a rough estimate about the magnitude of the applied electrostatic field for Stark effect. 6+2+2

5. Draw comparative differences between homogeneous and inhomogeneous broadening. Obtain the normalized Doppler broadened lineshape function. Obtain the expression of the FWHM of the said lineshape function. 2+5+3

6. a) Write down the Hamiltonian of a hydrogen molecule ion. Explain the meaning of LCAO.
   b) In connection with the hydrogen molecular ion, explain the bonding and antibonding orbitals and their physical significances. 1+1+8

7. a) The diatomic molecule HCl has a B value of 10.593 cm^{-1} and a centrifugal distortion constant D of $5.3\times10^{-4}\,cm^{-1}$. Estimate the vibrational frequency and force constant of the molecule. The observed vibrational frequency is 2991 cm^{-1}, explain the discrepancy.
   b) The spacing between molecular vibration levels is $100 cm^{-1}$. At 300 K, show that the population in the first vibrational level $v = 1$ is approximately 1% of the $v = 0$ level.
   c) By taking care the appropriate degeneracies, write down the ratio of the number of molecules in the rotational level J to that of the lowest level (i.e. $J = 0$) at temperature T. Obtain the level J_{max} with maximum population. 6+2+2

   You may use the following parameters: $h = 6.626\times10^{-34} J\,s$, $k = 1.381\times10^{-23} J\,K^{-1}$, $c = 2.998\times10^{8}\, ms^{-1}$

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