15/11/2018

Paper / Subject Code: 24241 / Physics: Atomic & Molecular Physics

Time: 3 Hrs

Total Marks : 100

N.B. : (1) All questions are compulsory.

(2) Figures to the right indicate full marks.

(3) Draw neat diagrams wherever necessary.

(4) Symbols have usual meaning unless otherwise stated.

(5) Use of non-programmable calculator is allowed.

1. Attempt any two:---

(a) Set up steady state Schrodinger's equation for H-atom in spherical polar co-ordinates. Solve it by the method of separation of variables. Explain how magnetic quantum numbers m_l arises in solving ϕ equation. **10**

(b) State Pauli's exclusion principle. Show that particles obeying Pauli's exclusion principle are described by antisymmetric wave functions. **10**

(c) Explain with neat diagrams, Stern-Gerlach experiment to demonstrate space quantization of electron spin. **10**

2 Attempt any two:---

(a) If an electron undergoes a transition from a higher energy level E_m to a lower energy level E_n, prove quantum mechanically that it emits a radiation of frequency, **10**

$$v = \frac{(Em - En)}{h}$$

(b) Derive an expression for Lande's 'g' factor and obtain its value for 5D state. **10**

(c) Explain with neat diagrams, L-S and J-J coupling schemes for two electron atoms. **10**

3. Attempt any two:---

(a) Derive an expression for the vibrational frequency of a diatomic molecule in terms of its reduced mass and force constant. Show that the vibrational energy levels are equally spaced assuming that the molecule performs a linear harmonic motion. **10**

(b) Write expression for rotational energy of a rigid diatomic molecule. Explain in detail, how energy levels get modified if effect of bond elongation is taken into consideration. Draw appropriate energy level diagram. **10**

(c) Draw the block diagram of a double beam infrared spectrophotometer and explain each block in detail. **10**

4. Attempt any **two**:---

(a) Discuss quantum theory of Raman effect in detail. **10**

(b) Explain pure rotational Raman spectra of a linear diatomic molecule. Show graphical representation of energy levels and spectral lines. **10**

(c) What is the basic principle of Nuclear Magnetic Resonance (NMR)? Explain NMR spectrometer with a neat diagram. **10**

5. Attempt any **four**:---

(i) Write note on radial probability density of electron in H-atom. **05**

(ii) Show that **05**

$\Theta_{20} = \frac{\sqrt{10}}{4}\,[3\cos^2\theta - 1]$ is a solution of Θ equation:

$$\frac{1}{\sin\theta}\ \frac{d}{d\theta}\left(\sin\theta\,\frac{d\Theta_{lml}}{d\theta}\right) + \left[\ell(\ell+1) - \frac{m_l^2}{\sin^2\theta}\right]\Theta_{lml}$$

(iii) Calculate the angle between $\vec{J}$ and $\vec{L}$ in $^2P_{3/2}$ state. **05**

(iv) A sample of certain element is placed in a magnetic field of intensity 0.3 T. How far apart Zeeman components of wavelength 4500 A will be? **05**
Given : $e/m = 1.7588 \times 10^{11}$ c/kg $\quad c = 3 \times 10^8$ m/s

(v) The lowest rotational energy of CO molecule is 4.76×10^{-4}eV corresponding to a transition from J = 0 to J = 1. Calculate the bondlength of CO molecule whose reduced mass is 1.138×10^{-26}Kg. **05**
Given : $h = 1.054 \times 10^{-34}$Js $\quad 1\ \text{eV} = 1.6 \times 10^{-19}$J

(vi) Determine the force constant of HCl molecule if its vibrational frequency is 9×10^{13}Hz. Given : M(H) = 1.67×10^{-27}Kg , M(Cl) = 5.81×10^{-26}Kg **05**

(vii) If bondlength of H_2 is 0.07417nm, what would be the position of the first rotational Raman line in the spectrum? **05**
Given : M(H) = 1.673×10^{-27} Kg, $\quad h = 6.63 \times 10^{-34}$Js, $\quad c = 3 \times 10^8$m/s

(viii) Calculate the magnetic field strength required to get a transition frequency of 60 MHz for fluorine. **05**
Given : $g_n = 5.255$, $h = 6.63 \times 10^{-34}$Js, $\mu_N = 5.051 \times 10^{-27}$ J/T

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