**2023**

( CBCS )

( 5th Semester )

**PHYSICS**

EIGHTH (A) PAPER

**( Atomic and Molecular Spectroscopy )**

*Full Marks* : 75

*Time* : 3 hours

*The figures in the margin indicate full marks for the questions*

**( SECTION : A—OBJECTIVE )**

( *Marks* : 10 )

Tick (✓) the correct answer in the brackets provided : 1×10=10

**1.** In hydrogen spectrum, the wave number limit corresponding to Balmer series is

*(a)* $R/4$ ( )

*(b)* $R/9$ ( )

*(c)* $R/16$ ( )

*(d)* $R/25$ ( )

where $R$ is Rydberg constant.

**2.** The selection rule for Azimuthal quantum number ($k$) in Sommerfeld atomic model is

*(a)* $\Delta k = 0$ ( )

*(b)* $\Delta k = 0, \pm 1$ ( )

*(c)* $\Delta k = \pm 1$ ( )

*(d)* $\Delta k = \infty$ ( )

3. The distance of the $^2d_{5/2}$ level from hypothetical term value for the centre of gravity of the doublet as a result of spin-orbit interaction is given by

(a) $\Gamma\left(j=\frac{5}{2}\right)=-\frac{3}{2}a$ ( )

(b) $\Gamma\left(j=\frac{5}{2}\right)=a$ ( )

(c) $\Gamma\left(j=\frac{5}{2}\right)=\frac{1}{2}a$ ( )

(d) $\Gamma\left(j=\frac{5}{2}\right)=-a$ ( )

(Symbols have their usual meanings)

4. The ground state of single electron system is always singlet and its spectral term symbol is written as

(a) $^1S_{1/2}$ ( )

(b) $^2S_{1/2}$ ( )

(c) $^1S_0$ ( )

(d) $^2S_0$ ( )

5. The number of normal Zeeman splitting components of $^1P-^1D$ transition is

(a) 9 ( )

(b) 4 ( )

(c) 3 ( )

(d) 8 ( )

6. Due to electron spin consideration in X-ray spectra, the $M$ state

(a) does not split ( )

(b) splits into 2 levels ( )

(c) splits into 3 levels ( )

(d) splits into 5 levels ( )

7. In a non-rigid rotator, the molecules are in simple harmonic motion. The force constant $k$ is given by

(a) $k = \pi^2 \omega^2 c^2 m$ ( )

(b) $k = 2\pi \omega^2 c^2 m$ ( )

(c) $k = 4\pi^2 \omega^2 c^2 m$ ( )

(d) $k = 4\pi^2 \omega^2 c^2 m^2$ ( )

where, $\omega$ = vibrational frequency in $met^{-1}$, $m$ = reduced mass of the molecule.

8. The molecular energy level can be divided into electronic $E_e$, vibrational $E_v$ and rotational $E_r$ energy levels, the order of magnitude of these energy levels is

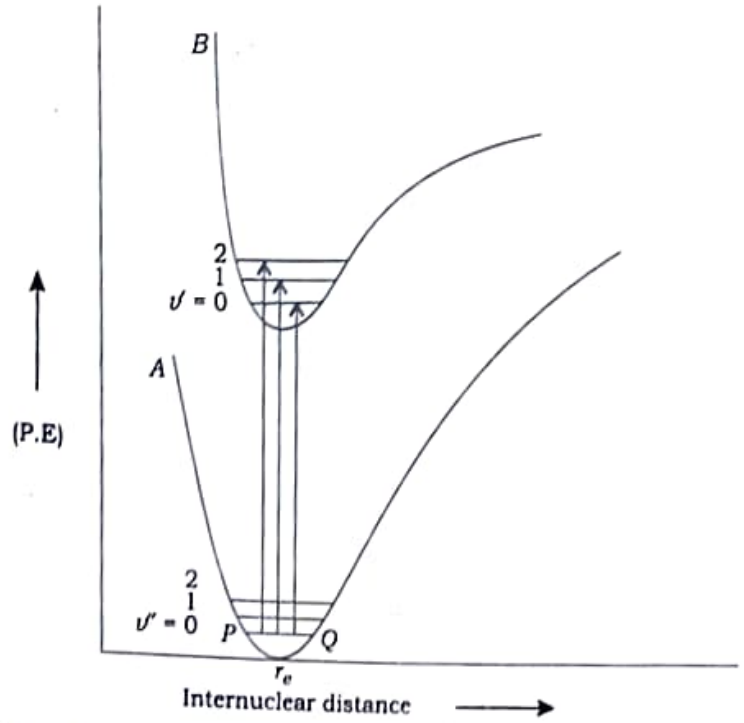
(a) $E_e > E_v < E_r$ ( )

(b) $E_e > E_v > E_r$ ( )

(c) $E_e < E_v > E_r$ ( )

(d) $E_e = E_v = E_r$ ( )

9. During absorption or emission of radiation, the inter nuclear distance in a molecule does not change appreciably; the electronic transition should then be represented by




(a) vertical line ( )

(b) horizontal line ( )

(c) the curve $A$ ( )

(d) the curve $B$ ( )

10. In an electronic vibrational transition, $B'$ and $J'$ refer to the upper electronic state, $B''$ and $J''$ to the lower state of rotational constant quantum number respectively, $\upsilon_0$ is wave number, the frequency of radiation is

(a) $\upsilon_0 + B'J'(J'+2) - B''J''(J''+2)\ \text{cm}^{-1}$ ( )

(b) $\upsilon_0 - B'J'(J'+1) + B''J''(J''+1)\ \text{cm}^{-1}$ ( )

(c) $\upsilon_0 + B'J'(J'-2) - B''J''(J''-2)\ \text{cm}^{-1}$ ( )

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## ( SECTION : B—SHORT ANSWERS )

( *Marks* : 15 )

Answer the following : 3×5=15

### UNIT—I

**1.** In Rutherford's experiment, the number of α particles scattered by an element of atomic number $Z$ through an angle 60° is 112 per minute. Find the number of α particles scattered through an angle of 90° per minute scattered by an element of twice the atomic number.

**OR**

**2.** With the introduction of elliptical orbit by Sommerfeld, show that the orbit with principal quantum number $n = 3$ splits into three sub-orbits.

### UNIT—II

**3.** Find the maximum number of electrons with all the shells filled up to principal quantum number $n = 3$.

**OR**

**4.** For a particular atomic state $^2P_{3/2}$, what are the different possible orientations of inner angular momentum in space (angle between inner angular momentum and vertical axis)?

### UNIT—III

**5.** How does sodium $D$ line split when atom is subjected to low magnetic field? Draw energy level diagram showing π and σ components.

**OR**

**6.** Explain the method of pumping in LASER.

UNIT—IV

7. What is the selection rule for rotational transition in a non-rigid diatomic molecule?

**OR**

8. Define the coupling of rotation and vibration in spectroscopy.

UNIT—V

9. What are homonuclear diatomic molecules? Give an example of homonuclear diatomic molecules and write their electronic configurations.

**OR**

10. Explain the temperature effects on spectral lines in the vibrational Raman spectra.

## ( SECTION : C—DESCRIPTIVE )

( *Marks* : 50 )

Answer the following : 10×5=50

UNIT—I

1. Discuss Rutherford's atomic model and its failure. Derive the formula for Rutherford's scattering cross-section. 4+6=10

**OR**

2. Derive the energy expression for electrons after the introduction of Sommerfeld relativistic mass correction. Up to what extend does it help in explaining the fine structure of $H_\alpha$ line? 7+3=10

UNIT—II

3. *(a)* State and prove Larmor's theorem. 2+4=6

   *(b)* What is the effect of space quantization introduced by vector atom model? Does it result in the formation of new energy level? 2+2=4

**OR**

4. *(a)* Discuss Stern-Gerlach experiment. How does it explain the vector atom model? 4+4=8

   *(b)* Find the Γ-factor for the *p*-orbital. Show it in a diagram with spectral notation. 1+1=2

## UNIT—III

5. *(a)* What are the normal and anomalous Zeeman effect? Explain anomalous Zeeman effect with vector atom model. 2+5=7

   *(b)* Illustrate with diagrams the splitting of $^2D$ level of sodium in weak and strong magnetic field. 3

**OR**

6. *(a)* Explain X-ray fluorescent and an Auger effect. 4

   *(b)* Derive the rate equation for three-level LASER system. 6

## UNIT—IV

7. *(a)* Discuss the molecule as anharmonic oscillator and hence explain the formation of fundamental band, overtone band and the hot band. 3+4=7

   *(b)* Calculate the moment of inertia and inter-molecular distance of HCl molecule. Given atomic weight of Hydrogen = 1·00794 amu and chlorine = 35·453 amu, $h = 6{\cdot}62 \times 10^{-27}$ erg.sec and $c = 3 \times 10^{10}$ cm sec$^{-1}$. 3

**OR**

8. *(a)* Define the coupling of rotation and vibration in spectroscopy. 3

   *(b)* Obtain the energy levels, frequency of spectral line, selection rule and the spectrum in rigid rotator. 7

## UNIT—V

9. *(a)* Explain Fortrat diagram. Show that there is 10% difference between the two levels of rotational constants $B'$ and $B''$ for the band head, which occurs at $p \simeq 10$. 2+4=6

   *(b)* What do you mean by the vibrational spectroscopy? Mention some important applications of vibrational spectroscopy. 2+2=4

**OR**

10. *(a)* What are sequence and progressions in an electronic band system? 3

    *(b)* What is Raman effect? Define the quantum mechanical explanation of Raman effect. 2+5=7

★★★

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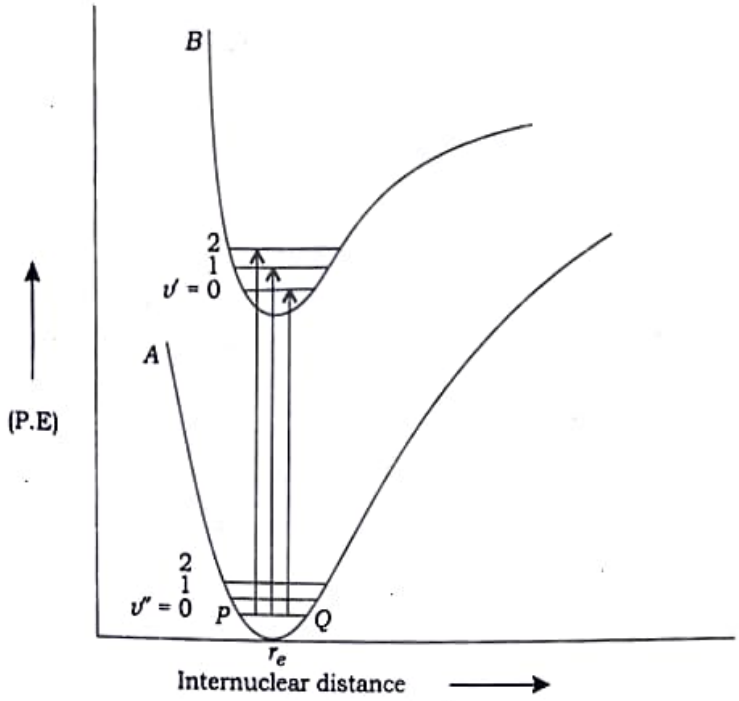


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