M.SC. PHYSICS
SECOND SEMESTER
ATOMIC, MOLECULAR AND LASER PHYSICS
MSP – 204

(Use Separate Answer Scripts for Objective & Descriptive)

Duration : 3 hrs. **Full Marks : 70**

(PART-A : Objective)

Time : 20 min. **Marks : 20**

Choose the correct answer from the following: ***1×20=20***

1. The ratio of the frequencies of first spectral line of Lyman series and the first spectral line of Balmer series is
   a. $\frac{27}{5}$ **b.** $\frac{27}{8}$
   c. $\frac{8}{27}$ **d.** $\frac{4}{27}$

2. Bohr's model gives the value for the ionization of Li^{2+} ion as
   a. 122.4 eV **b.** 13.6 eV
   c. 27.2 eV **d.** 40.8 eV

3. For an atom in the state of $^2d_{5/2}$, the Land 'g' factor is
   a. 1.20 **b.** 2.0
   c. 1.75 d. 1.33

4. The transition which is NOT allowed
   a. $^2d_{3/2} \rightarrow {}^2s_{1/2}$ **b.** $^2f_{5/2} \rightarrow {}^2d_{5/2}$
   c. $^2d_{3/2} \rightarrow {}^2p_{1/2}$ **d.** $^2p_{5/2} \rightarrow {}^2s_{1/2}$

5. Assuming that L-S coupling is valid, the number of permitted transition from $^2p_{1/2}$ to $^2s_{1/2}$ state due to weak magnetic field is
   a. 2 b.6 c. 4 d. 10

6. In case of spectra of alkali atom common series limit is found in the
   a. sharp and fundamental series **b.** sharp and diffuse series
   c. diffuse and principal series **d.** principal and fundamental series

7. The energy level which lie deepest in the electronic s p state is
   a. $^1p_1$ **b.** $^3p_0$
   c. $^3p_1$ **d.** $^3p_2$

8. In NMR spectroscopy the product of the nuclear g factor (g_N) the nuclear magnetron (β_N) and the magnetic field strength (B_0) give
   a. energy of transition from α to β state **b.** chemical shift
   c. spin-spin coupling constant **d.** Magneto-gyric ratio

9. For the diatomic molecule AB, the rotational transition from J=0 to J=1 state is 3.9 cm^{-1}. The energy for rotational transition from J=3 to J=4 state would be
   a. 3.9 cm^{-1} **b.** 7.8 cm^{-1}
   c. 11.7 cm^{-1} **d.** 15.6 cm^{-1}

10. The vibrational Raman spectrum of a homonuclear diatomic molecule, the selection rule under harmonic approximation is
    a. $\Delta v=0$ only
    b. $\Delta v=\pm 1$ only
    c. $\Delta v=\pm 2$ only
    d. $\Delta v=0, \pm 1$ only

11. The population of J^{th} rotational level N_J is given by $N_J= N_0(2J+1)e^{-J(J+1)B/KT}$. J value for maximum intensity of rotational spectral line is
    a. $\frac{KT}{B}$
    b. $\frac{KT}{4B}$
    c. $\sqrt{\frac{KT}{2hcB}}-\frac{1}{2}$
    d. $\sqrt{\frac{2KT}{hcB}}-\frac{1}{2}$

12. IR spectrum of CO2 molecule exhibit which of the following number of absorption
    a. two
    b. three
    c. four
    d. six

13. The selection rule for R and P branches of rotational spectral lines is respectively
    a. $\Delta J=-1$ and $+1$
    b. $\Delta J=0$ and -1
    c. $\Delta J=1$ and -1
    d. $\Delta J=-1$ and 0

14. The Stoke's rotational Raman lines in oxygen molecule (O_2) are separated by a distance equal to
    a. 4B
    b. 2B
    c. 12B
    d. 8B

15. Which of the following is an example of optical pumping?
    a. Ruby laser
    b. Semiconductor laser
    c. Helium-Neon laser
    d. Dye laser

16. The life time of atoms in the excited state is normally
    a. 10^{-6} s
    b. 10^{-5} s
    c. 10^{-4} s
    d. 10^{-8} s

17. "Full angle beam divergence" is associated with
    a. Directionality
    b. Intensity
    c. Monochromaticity
    d. Coherence

18. If the power output of Ruby laser is $\sim 10^9$ W and energy of one photon is 10^{-19} Joules, then the photon output per second is
    a. $\sim 10^6$
    b. $\sim 10^{16}$
    c. $\sim 10^{20}$
    d. $\sim 10^{28}$

19. Brewster windows are used in He-Ne laser system to reduce the
    a. polarization loss
    b. reflection loss
    c. bending loss
    d. refraction loss

20. Holography records the
    a. Intensity only
    b. Phase only
    c. Both intensity and phase
    d. None of these

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Contd...

(PART-B : Descriptive)

Time : 2 hrs. 40 min. **Marks : 50**

[Answer question no.1 & any four (4) from the rest]

1. a. Explain what you mean by ortho-helium and para-helium. Write down the lowest states of these two. Explain the meaning of meta stable states. 5+5=10
   b. What you mean by breadth of spectral line? Explain the contribution of Doppler effect towards the breadth of the spectral line

2. a. What are the different types of coupling schemes of orbital and spin angular momenta of two electron system? Explain with various diagrams and give examples of each. 5+5=10
   b. State the rule which determines the separation of fine structure lines in L-S coupling and apply these rule for a ^3D term to find the separation of energy levels.

3. a. What you mean by normal and anomalous Zeeman effects? Write the expression of energy of an atom in a weak magnetic field and show the splitting of the sodium D_1 line in weak magnetic field. 7+3 =10
   b. Calculate the Doppler broadening at 1200°C for Argon ion transition at 488 nm. Why ^{193}Hg is an ideal source for sharp spectral line?

4. a. What are the different types of intensity distributions of vibrational bands in electronic transition? Give example of each. State Born-Oppenheimer approximation applied to molecules. 5+5 =10
   b. State and explain Franck-Condon principle to explain various intensity distributions of vibrational bands in electronic transition.

5. Give the Quantum theory of Raman effect. Why classical theory fails to explain Raman effect? Discuss the rotational Raman spectra of oxygen molecule (O_2). What are the drawbacks of harmonic oscillator model of diatomic molecule? Starting from the vibrational energy of an anharmonic oscillator calculate the expressions for the frequency of fundamental, first overtone and second overtone vibration of a diatomic molecule. 5+5=10

6. Discuss Einstein's Quantum Theory of radiation and establish the ratio between A and B coefficients. 10

7. Discuss the construction and operation of the following laser systems: 5+5=10
   a. Ruby Laser
   b. CO_2 Laser

8. What do you mean by holography? State the basic principle of holography and explain briefly the steps of its construction. Give an application of Holography. 1+8+1 =10

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