**Govt. PG College, Ambala Cantt**

**Session: 2023-24**

**Name of Assistant Professor: Mrs. Neelam**

**Department: Physics**

**Class: B.Sc. III/ 6th Semester/ Sec: Computer Science**

**Subject Code & Name: PH-602/ ATOMIC AND MOLECULAR SPECTROSCOPY**

**SYLLABUS**

**Max Marks: 50 External: 40**

**Minimum Pass Marks: 14 Internal: 10**

**Time: 3 hours**

**Note:**

1. The syllabus is divided into 4 units. 9 questions will be set.

2. Question no 1 will be compulsory, it contains 6 parts (form all the four units) and answer should be brief but not in yes / no.

3. Four more questions will have to be attempted, selecting one question from each unit. Questions 2-9 may contain two or more parts. All questions carry equal marks.

4. 20% numerical problems will be set.

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

**Unit – I: Historical background of Atomic Spectroscopy**

Historical background of atomic spectroscopy Introduction of early observations, emission and absorption spectra, atomic spectra, wave number, spectrum of Hydrogen atom in Balmer series, Bohr atomic model(Bohr’s postulates) , spectra of Hydrogen atom , explanation of spectral series in Hydrogen atom, un-quantized states and continuous spectra, spectral series in absorption spectra, effect of nuclear motion on line spectra (correction of finite nuclear mass), variation in Rydberg constant due to finite mass, short comings of Bohr’s theory, Wilson Sommerfeld quantization rule, de-Broglie interpretation of Bohr quantization law, Bohr’s corresponding principle, Sommerfeld’s extension of Bohr’s model, Sommerfeld relativistic correction, Short comings of Bohr-Sommerfeld theory, Vector atom model; space quantization, electron spin, coupling of orbital and spin angular momentum, spectroscopic terms and their notation, quantum numbers associated with vector atom model, transition probability and selection rules.

**Unit –II: Vector Atom Model (Single Valance Electron)**

Orbital magnetic dipole moment (Bohr magneton), behaviour of magnetic dipole in external magnetic field; Larmor’s precession and theorem. Penetrating and non-penetrating orbits, Penetrating orbits on the classical model; Quantum defect, spin orbit interaction energy of the single valance electron, spin orbit interaction for penetrating and non-penetrating orbits. quantum mechanical relativity correction, Hydrogen fine spectra, Main features of Alkali Spectra and their theoretical interpretation, term series and limits, Rydberg-Ritze combination principle, Absorption spectra of Alkali atoms. observed doublet fine structure in the spectra of alkali metals and its Interpretation, Intensity rules for doublets, comparison of Alkali spectra and Hydrogen spectrum.

**UNIT-III: Vector Atom Model (Two Valance Electrons)**

Essential features of spectra of Alkaline-earth elements, Vector model for two valance electron atoms: application of spectra. Coupling Schemes’ or Russell – Saunders Coupling Scheme and JJ coupling scheme, Interaction energy in L-S coupling (sp, pd configuration), Lande interval rule, Pauli principal and periodic classification of the elements. Interaction energy in JJ Coupling (sp, pd configuration), equivalent and non-equivalent electrons, two valance electron system-spectral terms of non-equivalent and equivalent electrons, comparison of spectral terms in L-S And J-J coupling. Hyperfine structure of spectral lines and its origin; isotope effect, nuclear spin.

**Unit –IV: Atom in External Field**

Zeeman Effect (normal and Anomalous), Experimental set-up for studying Zeeman effect, Explanation of normal Zeeman effect (classical and quantum mechanical), Explanation of anomalous Zeeman effect (Lande g-factor), Zeeman pattern of D1 and D2 lines of Na atom, Paschen-Back effect of a single valence electron system. Weak field Stark effect of Hydrogen atom.

**Molecular Physics**

General Considerations, Electronic States of Diatomic Molecules, Rotational Spectra (Far IR and Microwave Region), Vibrational Spectra (IR Region), Rotator Model of Diatomic Molecule, Raman Effect, Electronic Spectra.

**REFERENCE BOOKS:**

1. Beiser A, Concept of Modern Physics (1987), Mc Graw Hill Co Ltd, New Delhi
2. Rajab J B, Atomic Physics (2007), S Chand & Co, New Delhi
3. Fewkes J H and Yarwood J Atomic Physics Vol II (1991) Oxford University Press
4. Bransden B H and Joachain C J, Physics of Atoms and Molecules 2nd Ed (2009), Pearson Education, New Delhi.
5. Banwell, Molecular Spectroscopy
6. Ghoshal S N, Atomic and Nuclear Physics Vol I (1996) S Chand & Co, New Delhi
7. Gopalkrishnan K, Atomic and Nuclear Physics (1982), Mc Millan India New Delhi
8. Raj Kumar, Atomic and Molecular Spectra: Laser, Kedarnath Ram Nath pub.
9. S.L.Gupta, V.Kumar, R.C.Sharma, Elements of Spectroscopy, Pragati Prakashan.

**COURSE OBJECTIVES:**

* Understanding about various Atomic Models and their use.
* Students will acquire a solid understanding of the fundamental principles and rules governing spectroscopy.
* They will learn about various spectroscopic techniques and their applications.
* The course equips students with the necessary knowledge to explore research and development opportunities in this field.
* They will be familiar with types of Coupling and how to apply that knowledge for practical use.
* The course will give them understanding about various types of Atomic spectra of various atoms and to identify atoms on basis of that.
* It will give detailed knowledge to students about various effects like Zeeman, Paschen Back, Stark & Raman effect which will further strengthen their core understanding about the subject.

**COURSE OUTCOMES:**

After the successful completion of the course, students will be able to:

* Understand about various models for explaining the Atomic Structure.
* Understand about various types of Atomic Spectra and their origin.
* Explain the H atom spectra and Wilson Sommerfeld rules.
* Apply Sommerfeld rules to understand the key concept about atomic orbitals and their shapes and sizes.
* Explain the Vector atom model and apply its understanding to find out various Quantum no.s.
* Explain the hyperfine spectra of H atom and calculate the Interaction energy based on Spin Orbit Interaction.
* Understand various coupling schemes i.e. LS & jj coupling and to solve questions based on them.
* Explain the Alkali atom spectra and Alkaline Earth metal spectra.
* Apply the knowledge to show transitions for any Alkali atom spectra.
* Understand the equivalent and non-equivalent electrons and calculate spectral terms regarding these.
* Differentiate between Zeeman effect, Paschen Back Effect and Stark effect and apply these concepts to find out various Transitions and calculate them.
* Apply and analyse the knowledge acquired to calculate the numerical problems based on these topics.
* Explain Rotational Spectra and Raman spectra and apply them also.

**LESSON PLAN**

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| **Sr. No.** | **Schedule of Weeks** | **Topics to be covered** |
|  | **08.01.24 to 13.1.24** | Historical background of atomic spectroscopy Introduction of early observations, emission and absorption spectra, atomic spectra, wave number, spectrum of Hydrogen atom in Balmer series, Bohr atomic model (Bohr’s postulates), spectra of Hydrogen atom, explanation of spectral series in Hydrogen atom |
|  | **15.1.24 to 20.1.24** | Un-quantized states and continuous spectra, spectral series in absorption spectra, effect of nuclear motion on line spectra (correction of finite nuclear mass), variation in Rydberg constant due to finite mass, short comings of Bohr’s theory, Wilson Sommerfeld quantization rule, de-Broglie interpretation of Bohr quantization law |
|  | **22.1.24 to 27.1.24** | Bohr’s corresponding principle, Sommerfeld’s extension of Bohr’s model, Sommerfeld relativistic correction, short comings of Bohr-Sommerfeld theory |
|  | **29.1.24 to 3.2.24** | Vector atom model; space quantization, electron spin, coupling of orbital and spin angular momentum, spectroscopic terms and their notation, quantum numbers associated with vector atom model, transition probability and selection rules.  **ASSIGNMENT 1** |
|  | **5.2.24 to 10.2.24** | Orbital magnetic dipole moment (Bohr magneton), behaviour of magnetic dipole in external magnetic field; Larmor’s precession and theorem. Penetrating and non-penetrating orbits, Penetrating orbits on the classical model |
|  | **12.2.24t to 17.2.24** | Quantum defect, spin orbit interaction energy of the single valance electron, spin orbit interaction for penetrating and non-penetrating orbits. quantum mechanical relativity correction, Hydrogen fine spectra |
|  | **19.2.24 to 24.2.24** | Main features of Alkali Spectra and their theoretical interpretation, term series and limits, Rydberg-Ritze combination principle, Absorption spectra of Alkali atoms. |
|  | **26.2.24 to 2.3.24** | Observed doublet fine structure in the spectra of alkali metals and its Interpretation, Intensity rules for doublets, comparison of Alkali spectra and Hydrogen spectrum.  **ASSIGNMENT 2, TEST** |
|  | **4.3.24 to 9.3.24** | Essential features of spectra of Alkaline-earth elements, Vector model for two valance electron atoms: application of spectra. Coupling Schemes’ or Russell – Saunders Coupling Scheme and JJ coupling scheme |
|  | **11.3.24 to 13.3.24** | Interaction energy in L-S coupling (sp, pd configuration), Lande interval rule, Pauli principal and periodic classification of the elements. Interaction energy in JJ Coupling (sp, pd configuration), equivalent and non-equivalent electrons. |
|  | **18.3.24 to 22.3.24** | Two valance electron system-spectral terms of non-equivalent and equivalent electrons, comparison of spectral terms in L-S And J-J coupling. Hyperfine structure of spectral lines and its origin; isotope effect, nuclear spin. |
|  | **23.3.24 to 31.3.24** | **HOLI BREAK** |
|  | **1.4.24 to 6.4.24** | Zeeman Effect (normal and Anomalous), Experimental set-up for studying Zeeman effect, Explanation of normal Zeeman effect (classical and quantum mechanical), Explanation of anomalous Zeeman effect (Lande g-factor), Zeeman pattern of D1 and D2 lines of Na atom |
|  | **8.4.24 to 13.4.24** | Paschen-Back effect of a single valence electron system. Weak field Stark effect of Hydrogen atom. General Considerations, Electronic States of Diatomic Molecules |
|  | **15.4.24 to 20.4.24** | Rotational Spectra (Far IR and Microwave Region), Vibrational Spectra (IR Region), Rotator Model of Diatomic Molecule, Raman Effect, Electronic Spectra. |
|  | **22.4.24 to 27.4.24** | **REVISION FOLLOWED BY TEST** |
|  | **29.4.24 to 4.5.24** | **REVISION AND DOUBTS SOLUTION** |

**(NEELAM)**

**ASSISTANT PROFESSOR**

**PHYSICS DEPARTMENT**

**GOVT. PG COLLEGE AMBALA CANTT, AMBALA**