

DISCIPLINE SPECIFIC CORE COURSE – DSC - 17: ATOMIC, MOLECULAR AND NUCLEAR PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Atomic, Molecular and Nuclear Physics DSC – 17	4	3	1	0	Class XII pass with Physics and Mathematics as main subjects	Light and Matter, Modern Physics and Quantum Mechanics-I of this course or their equivalent

LEARNING OBJECTIVES

This course introduces the basic concepts of atomic, molecular and nuclear physics to an undergraduate student. Advanced mathematics is avoided and the results of quantum mechanics are attempts to explain, or even to predict, the experimental observations of spectroscopy. The student learns to visualize a nucleus, an atom or molecule as a physical entity rather than a series of mathematical equations.

LEARNING OUTCOMES

On successful completion of the module students should be able to elucidate the following main features.

- Stern-Gerlach experiment, electron spin, spin magnetic moments, space quantization and Zeeman effect, spectral notations for atomic and molecular states and corresponding term symbols, understanding of atomic spectra and molecular spectra
- Basic principle of Raman spectroscopy and Franck Condon principle.
- The radioactive processes, stability of the nuclei and the nuclear models
- The full scientific potential lies on how we are able to interpret the fundamental astrophysical and nuclear data. The acquired knowledge can be applied in the areas of astrophysics, nuclear, medical, geology and other interdisciplinary fields of Physics, Chemistry and Biology. It will enhance the special skills required for these fields

SYLLABUS OF DSC - 17

THEORY COMPONENT

Unit – I - Atomic Physics

(15 Hours)

One-electron atoms: Degeneracy of energy levels and selection rules, modes of relaxation of an excited atomic state.

Fine structure of Hydrogenic atoms: Shifting of energy levels, Splitting of spectral lines, relativistic correction to kinetic energy, spin-orbit term, Darwin term, fine structure spectral lines, Lamb shift (qualitative idea).

Atoms in external magnetic fields: Larmor's theorem, Stern-Gerlach experiment, normal Zeeman Effect, Paschen Back effect, anomalous Zeeman effect, Lande g-factor.

Unit - II – Molecular Physics

(15 Hours)

Molecular structure: The Born-Oppenheimer approximation, Concept of bonding and anti-bonding molecular orbitals, Concept of Potential energy curve for a diatomic molecule, Morse potential, Classification of molecular states of diatomic molecule, The Franck-Condon principle

Molecular spectra of diatomic molecule: Rotational Spectra (rigid and non-rigid rotor), Vibrational Spectra (harmonic and anharmonic), Vibration-Rotation Spectrum of a diatomic molecule, Isotope effect, Intensity of spectral lines

Raman Effect: Classical theory (with derivation) of Raman effect, pure rotational Raman Lines, Stoke's and Anti-Stoke's Lines, comparison with Rayleigh scattering.

Unit – III – Nuclear Physics

(15 Hours)

Nucleus stability: *Alpha decay*: Energetics of alpha-particle decay, barrier penetration model, Geiger-Nuttall rule, α - decay spectroscopy, decay Chains. *Beta Decay*: Q-values for beta decay, β -spectrum, positron emission, electron capture, neutrino hypothesis, Qualitative idea about Fermi theory, Fermi and Gamow-Teller decays, the role of angular momentum and parity, electron capture, and selection rules. *Gamma decay*: Gamma-ray production, and multipolarities, Weisskopf estimates, the role of angular momentum and parity, internal conversion.

Nuclear models: Evidence of shell structure in nuclei, Magic numbers, nuclear mean field, single particle shell model, spin-orbit splitting, shell model configurations for nuclear ground states, and low-lying excited levels

References:

Essential Readings:

- 1) Physics of Atoms and Molecules, B. H. Bransden and C. J. Joachain, 2nd edition, Pearson
- 2) Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, 1994, Tata McGraw – Hill
- 3) Atomic physics, J. B. Rajam and foreword by Louis De Broglie, 2010, S. Chand & Co.
- 4) Atoms, Molecules and Photons, W. Demtroder, 2nd edition, 2010, Springer
- 5) Introduction to Spectroscopy, D. L. Pavia, G. M. Lampman, G. A. Kriz and J. R. Vyvyan, 5th edition, 2014, Brookes/Cole
- 6) Concept of Nuclear Physics, B. L. Cohen, 2003, Tata McGraw – Hill
- 7) Nuclear Physics, S. N. Ghoshal, 1st edition, 2019, S. Chand Publication
- 8) Introducing Nuclear Physics, K. S. Krane, 2008, Wiley India

Additional Readings:

- 1) Basic Atomic and Molecular Spectroscopy, J. M. Hollas, Royal Society of Chemistry
- 2) Molecular Spectra and Molecular Structure, G. Herzberg
- 3) Basic Ideas and Concepts in Nuclear Physics: An Introductory Approach (Series in Fundamental and Applied Nuclear Physics), K. Heyde (Institute of Physics Publishing 3rd edition
- 4) Nuclear Physics: principles and applications, John Lilley, 2006, Wiley
- 5) Schaum's Outline of Modern Physics, 1999, McGraw-Hill Education
- 6) Introduction to elementary particles, D. J. Griffiths, 2008, Wiley
- 7) Atomic and molecular Physics, R. Kumar, 2013, Campus Book Int.
- 8) The Fundamentals of Atomic and Molecular Physics (Undergraduate Lecture Notes in Physics), 2013, Springer