**FIRST SEMESTER 2019-2020**
**Course Handout (Part II)**

01.08.2019

In addition to part I (General Handout for all courses appended to the time table) this portion gives further specific details regarding this course.

***Course No.*** **: CHEM F412**

***Course Title*** **: Photochemistry and Laser Spectroscopy**

***Instructor-in-Charge*** **: Subit Kumar Saha**

**Scope and Objective of the course:** Students will be exposed to the subject of Spectroscopy, Photophysical Chemistry, and high resolution laser spectroscopy. This will cover topics like absorption of the electromagnetic radiation, photophysical processes like fluorescence, phosphorescence, non-radiative transitions, and delayed luminescence, excimer and exciplex formation, energy transfer, and quenching of fluorescence, fluorescence decay, application of photophysics for the characterization of biological as well as bio-mimicking systems, introduction to different lasers and laser spectroscopy, fluorescence spectroscopy with lasers.

**Text Book (TB):**

TB1. Principles of Fluorescence Spectroscopy by J R Lakowicz; Springer; 3rd edition.

TB2. W. T. Silvast, Laser Fundamentals, Cambridge University Press; 2nd edition.

**Reference Books (RB):** RB1. Photophysics of Aromatic Molecules by J B Birks; Wiley-Interscience. RB2. Modern Molecular Photochemistry by N. J. Turro, University Science Books, U.S.; New edition.

**Course Plan:**

| Lecture No. | Learning objectives | Topics to be covered | No. of Lectures per topic | Chapter in the Text Book |
|---|---|---|---|---|
| 1-2 | Representation of Spectra | Regions of the Spectrum, Elements of Practical Spectroscopy, Signal-to-noise, Resolving Power, Width of Transitions | 2 | Lecture notes |
| 3-4 | Excited states of aromatic molecules: Electronic and molecular structures, selection rules | Electronic and molecular structures, PFEO model, selection rules | 2 | RB1 1.1-1.5 |
| 5-6 | Various photophysical processes | Jablonski diagram, unimolecular processes, biphotonic processes, bimolecular processes | 2 | RB1 2.1-2.5, TB1 1.2 |

| Lecture No. | Learning objectives | Topics to be covered | No. of Lectures per topic | Chapter in the Text Book |
|---|---|---|---|---|
| 7-12 | Absorption of radiation | Absorption, hot bands, extinction coefficient, Born-Oppenheimer approximation | 1 | RB1 3.1-3.4 |
| | | Einstein coefficients, transition moments, oscillator strength, | 2 | RB1 3.5-3.7 |
| | | Franck-Condon principle, absorption spectra | 1 | RB1 3.8, 3.9 |
| | | Symmetry of states, transition moment integral, allowed and forbidden transition | 2 | Lecture notes |
| 13-19 | Fluorescence emission, Fluorescence spectrum and influence of environment, excited state lifetime | Fluorescence spectrum, mirror symmetry relation, radiative lifetime, delayed fluorescence | 2 | RB1 4.1-4.3, TB1 2.1, 2.2,2.3,2.6, 3.1 |
| | | Fluorescence parameters, competing bimolecular processes | 1 | RB1 4.4-4.5, |
| | | Determination of fluorescence quantum yield, Determination of fluorescence lifetime, time-correlated single photon counting (TCSPC) | 2 | RB1 4.7 TB1 4.1-4.6 |
| | | Influence of environment on fluorescence and absorption spectra | 2 | RB1 4.12, TB1 6.1-6.3 |
| 20-22 | Non-radiative processes | Singlet-singlet internal conversion, intersystem crossing, triplet-triplet internal conversion, internal quenching of fluorescence | 1 | RB1 5.1-5.4 |
| | | $T_1 – S_o$ intersystem crossing, Franck-Condon factors, theory of radiationless transitions, isotope rule | 1 | RB1 5.5-5.8 |
| | | Energy gaps, $S_1 – S_o$ internal conversion, $S_2$-$S_1$ internal conversion, dual luminescence | 1 | RB1 5.10-5.13 |
| 23-24 | Application of fluorescence in protein and DNA | Protein and DNA fluorescence | 2 | TB1 3.2, 3.4, 16.1-16.4, 21.1 |

| Lecture No. | Learning objectives | Topics to be covered | No. of Lectures per topic | Chapter in the Text Book |
|---|---|---|---|---|
| 25-28 | Triplet state radiative and non-radiative transitions | Triplet and phosphorescence parameter, determination of triplet quantum yield | 1 | RB1 6.1-6.2 |
| | | Phosphorescence quantum yield and lifetime, spectra, heavy atom effect | 1 | RB1 6.5-6.7 |
| | | Singlet-triplet absorption, triplet-triplet absorption | 1 | RB1 6.8-6.9 |
| | | Spin-orbit interaction, singlet-triplet intersystem crossing, triplet-triplet internal conversion and fluorescence | 1 | RB1 6.12-6.14 |
| 29-31 | Molecular interactions and quenching of fluorescence | Dynamic quenching, Stern-Volmer equation, static quenching, exam-ples | 1 | TB1 8.1-8.3, 8,5 |
| | | Combined dynamic and static quenching, deviation from Stern-Volmer equation: quenching sphere of action, fractional accessibility to quenchers | 1 | TB1 8.4, 8.6, 8.8 |
| | | Applications of quenching to proteins and membranes | 1 | TB1 8.9, 8.10 |
| 32-33 | Fluorescence anisotropy: Extent of polarization of emission | Definition and theory of fluorescence anisotropy | 1 | TB1 10.1, 10.2 |
| | | Measurement of fluorescence anisotropy and its application | 1 | TB1 10.4, 10.8 |
| 34 | Energy transfer: Fluorescence resonance energy transfer (FRET) | Theory of resonance energy transfer and its biochemical application | 1 | TB1 13.1, 13.2, 13.4 |
| 35-36 | Study of solvation dynamics using picoseconds pulsed laser | Theory of Time-resolved Emission Spectra (TRES), measurement of TRES and its application | 2 | TB1 7.1, 7.3, 7.4 |

| Lecture No. | Learning objectives | Topics to be covered | No. of Lectures per topic | Chapter in the Text Book |
|---|---|---|---|---|
| 37-40 | Introduction to laser, laser construction and functions, types of lasers | Einstein coefficients and physical principles of laser action, Stimulated emission, population inversion and light amplification. | 1 | TB2 7.1-7.3 |
| | | Basic elements of a laser, construction and function of the laser, Laser types: dye lasers, continuous lasers, pulsed lasers, ultrafast lasers, semiconductor lasers. | 3 | TB2 5.2-5.4, Lecture notes |
| 41-42 | LASER applications | Laser applications in molecular physics and chemical physics and diagnostic purposes | 2 | Lecture notes |

Evaluation Scheme:

| Component | Duration | Weightage (%) | Date & Time | Nature of Component |
|---|---|---|---|---|
| Mid Semester Test | 90 Minutes | 30 | 5/10, 11.00 -- 12.30 PM | Closed book |
| Assignment/Quiz | - | 20 | Continuous | Closed book |
| Term-paper | - | 10 | | - |
| Comprehensive Examination | 3 hours | 40 | 13/12 AN | Both closed and open book (Minimum 20%) |

**Chamber Consultation Hour:** To be announced in the class
**Notices:** Notices concerning this course will be displayed on CMS.
**Make-up Policy:** Refer to Part-I of the handout for details.

**Learning Outcomes:**
By the end of the course, the students should be able to
1. Consolidate the basic ideas of absorption of radiation, selection rules, and the relevant aspects of photophysics and spectroscopy.
2. Identify the various excited state photochemical/photophysical processes: Fluorescence, Phosphorescence, vibrational relaxation, internal conversion, inter-system crossing etc.
3. Apply the knowledge of oscillator strength, transition moment integral and derive selection rules, and also find the origin of allowed-ness/ forbidden-ness of electronic transitions.
4. Model the energy transfer process in terms of Forster theory.
5. Apply the knowledge of fluorescence quenching and fluorescence lifetime to study biomolecules and other materials.
6. Identify suitable methods like solvation dynamics, fluorescence anisotropy, FRET to study various bio-mimicking and real bio-systems.
7. Relate the photo-processes with the current research practices in various fields.
8. Apply the concepts of photochemical processes/reactions to daily life applications:

Photosynthesis, LEDs, LASERs etc.
9. Demonstrate how the fundamental understanding of photophysics is used up in constructing LASERs and the applications of laser spectroscopy.

**9. Academic Honesty and Integrity Policy**: Academic honesty and integrity are to be maintained by all the students throughout the semester and no type of academic dishonesty is acceptable.

**Instructor-in-charge,**
**CHEM F412**