Approval: 8th Senate Meeting

Course Title: Advanced NMR Spectroscopy- A problem based approach.

Course Number: CY646

Credits: 3-0-0-3

Prerequisites: BSc (with Chemistry as one of the subject)

Intended for: PG

Distribution: Elective Course

Semester: Even / Odd

Course Preamble: NMR spectroscopy is a very useful and important technique for characterization of organic compounds, during the last couple of decades tremendous improvements have been made on the application of two dimensional spectroscopy for the purpose of structural elucidation of organic compounds. It is therefore essential to introduce these new techniques to students through interesting problems. Though theoretically knowledge is sufficient for the interpretation of NMR spectra, one can develop mastery in interpretation only by practice, therefore early exposure of students to this aspect of learning is very important, this course is carefully designed to teach them learn through problem solving.

Course Outline: The course topics are organized in such a way that initial few topics were devoted to understanding basic concepts, principles and terminologies associated with NMR spectroscopy. The middle part of this course addresses various strategies in interpreting complex spectra and the later topics are dedicated to interpretation of various 1D and 2D NMR spectra of simple and complex organic molecules. During the class students will be presented with NMR spectral interpretation problems, they will be asked to interpret the spectra in a systematic way, the level of difficulty of the problem will increase as the classes progresses.

Course Modules:

1. Nuclear Magnetic Resonance Spectroscopy [2 Lectures]

The NMR Phenomenon, The spinning nucleus, the effect of an external magnetic field, Precessional motion, Precessional frequency, Energy transitions.

2. Theory of Nuclear Magnetic Resonance [3 Lectures]

Chemical Shift and its Measurement, internal standards, the NMR spectrometer, units used in NMR spectroscopy, Factors Influencing Chemical Shift, Electronegativity—shielding and deshielding, anisotropic effects, Correlation Data for Proton NMR Spectra, Use of correlation tables, Influence of restricted rotation. Choice of solvent for proton NMR spectra, Solvent

shifts—concentration and temperature effects—hydrogen bonding, Integrals in Proton NMR Spectra.

3. Symmetry and Topicity [1 Lectures]

Homotopicity, Enantiotopicity, Diastereotopicity, Chemical Equivalence, Magnetic Equivalence.

4. Through-Bond Effects: Spin-Spin (J) Coupling & Origin of J-Coupling [2 Lectures]

Skewing of the Intensity of Multiplets, Prediction of First-Order Multiplets, The Karplus Relationship for Spins Separated by Three Bonds, The Karplus Relationship for Spins Separated by Two Bonds, Long Range J-Coupling, Decoupling Methods, One-Dimensional Experiments Utilizing J-Couplings, Two-Dimensional Experiments Utilizing J-Couplings, Homonudear

5. Two-Dimensional Experiments utilizing J-Couplings [4 Lectures]

COSY, HMQC, HSQC, HMBC, TOCSY, INADEQUATE, Heteronuclear Two-Dimensional Experiments Utilizing J-Couplings,

6. Through-Space Effects: The Nuclear Overhauser Effect (NOE) [4 Lectures]

The Dipolar Relaxation Pathway, The Energetics of an Isolated Heteronuclear Two-Spin System, Decoupling One of the Spins in a Heteronudear Two-Spin System, Rapid Relaxation via the Double Quantum Pathway, A One-Dimensional Experiment Utilizing the NOE, Two-Dimensional Experiments Utilizing the NOE, NOESY and ROESY.

7. Strategies for Assigning Resonance to Atoms within a Molecule [4 Lectures]

Prediction of Chemical Shifts, Prediction of Integrals and Intensities, Prediction of ^{1}H Multiplets, good Bookkeeping Practices, Assigning ^{1}H Resonances on the Basis of Chemical Shifts, Assigning Resonances on the Basis of Multiplicities, Assigning ^{1}H Resonances on the Basis of the gCOSY Spectrum, The Best Way to Read a gCOSY Spectrum, Assigning ^{13}C Resonances on the Basis of Chemical Shifts, Pairing ^{1}H and ^{13}C Shifts by Using the HSQC/HMQC Spectrum, Assignment of Nonprotonated ^{13}C's on the Basis of the HMBC Spectrum, Variable Temperature NMR techniques. ^{19}F and ^{31}P NMR.

8. Strategies for Elucidating Unknown Molecular Structures [1 Lectures]

Initial Inspection of the One-Dimensional Spectra Good Accounting Practices, Identification of Entry Points, Completion of Assignments.

9. Simple Problems [8 Lectures]

2-Acetylbutyrolacton, a,-Terpinene, (1R)-endo-(+)-Fenchyl Alcohol in $CDC1_3$, (—)-Bornyl Acetate, N-Acetylhomocysteine Thiolactone, Guaiazulene, 2-Hydroxy-3-Pinanone, (R)-(+)-Perilly1 Alcohol, 7-Methoxy-4-Methylcoumarin, Sucrose and some more interesting molecules from literature if time permits.

10. Complex Problems [10 Lectures]

Longifolene, (+) Limonene, l-Cinchodine, (3aR)-(+) Sclareolide, (-)-Epicatechin, (-)-Eburnamonine, *trans*-Myrtanol, *cis*-Myrtaol, Naringenin, (-) Ambroxide and some more complex molecules from literature if time permits.

Textbooks:

1. NMR Spectroscopy 2nd Edition, Harald Gunther, Wiley Publishers, 1995.
2. Modern NMR Spectroscopy: A workbook of Chemical Problems 2nd Edition, Jeremy K.M. Sanders, Edwin C. Constable, Brian K. Hunter and Clive M. Pearce Oxford University Press, 1993.
3. Organic Structure Determination, using 2-D NMR Spectroscopy, a problem based approach, Jeffrey H. Simpson, Academic Press, 2012.

References:

1. Structure Determination of Organic Compounds, Tables of Spectral Data, Erno Pretsch, Philippe Buhlmann, Martin Badertscher, Springer, 2009.
2. Spectrometric Identification of Organic Compounds, Robert M. Silverstein, Francis X. Webster, David Kiemle, John Wiley & Sons; 7th Edition edition, 2005.
3. Organic Spectroscopy 3rd Edition, William Kemp, Palgrave Publishers Ltd.