Birla Institute of Technology & Science, Pilani
Hyderabad Campus

First Semester 2024-2025
Course Handout (Part-II)

Date: 01.08.2024

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

Course No.	CHEM F313
Course Title	Instrumental Methods of Analysis
Instructor-in-charge	**Prof.** Amit Nag
Team of Instructors (Prof./Dr.)	**Profs.** Krishnan Rangan, Himanshu Aggarwal, Ramakrishnan Ganesan, Satyanarayan Guin, Amit Nag

Course Description:
This course describes the principles and practice of modern instrumental methods of chemical analysis. Emphasis will be given on spectroscopic techniques such as UV-Visible and Infrared spectroscopy, XRD, XPS, XRF, NMR (^{1}H, ^{13}C and other elements, NOE, correlation spectroscopies), ESR, Mass spectroscopy, atomic absorption and atomic emission spectroscopies, fluorescence spectroscopy-microscopy and chromatographic techniques such as GC/HPLC. Other topics will include Circular dichroism and thermal analysis studies.

Scope and Objective of the Course:
Chemists extensively use modern sophisticated electronic and optical instruments in various areas such as chemical analysis, structure elucidation, identification of reaction pathways, reaction rates etc. This course aims to introduce the basic theory and experimental details of such instrumentations. Some of the popular absorption spectroscopic techniques like UV-Visible, IR, NMR, etc. will be discussed in detail; other techniques such as XPS, XRD, mass spectrometry, thermal analysis, chromatographic techniques – GC, HPLC, etc. will also be covered.

Text Books:
T1. Gary D. Christian, “Analytical Chemistry”, 6th ed., John Wiley & Sons (Asia) Pvt. Ltd. Singapore (2003).
T2. Kemp W, “Organic Spectroscopy”, 3rd ed., Palgrave, New York (1991).

Reference Books:
R1. Lampman G.M., Pavia D.L., Kriz G.S., and Vyvyan J.R., “Spectroscopy”, 4th Edition, Cengage Learning (2010).
R2. Silverstein R. M., and Webster F. X., “Spectrometric Identification of Organic Compounds”,6th Edition, John Wiley & Sons, New York (1998).
R3. Willard H. H., Merritt L. L., Dean J. A., and Settle F. A. Jr., “Instrumental Methods of Analysis”, 7th Edition. Wadsworth, New York (1989).
R4. Kalsi P. S., “Spectroscopy of Organic Compounds”, 6th Edition, New Age International Publishers, New Delhi (2005).

Course Plan : A. Lecture Sessions

Lec. No.	Topics to be covered	Learning Objectives	Learning outcomes	Reference: Chap./Sec. #(Book)
1-3	Atomic absorption, emission spectroscopy	Specific atomic energy levels for different elements; instrumentation; quantitative estimations; interferences etc.	1)Will be able to interpret atomic absorption spectroscopy 2) Explain the basic principles of AAS. 3)Can Illustrate the working principle and outline of AAS 4) Recall Maxwell's distribution law 5) Discuss the above similarities with Flame emission spectrophotometry	Ch 17 (T1)
4-5	Chromatographic Techniques: GC, HPLC, Electrophoresis	Theories of separation techniques; stationary and mobile phases etc.	1)Infer the theoretical aspects of techniques used for separation 2) Make use of mobile and stationery phases and estimate certain physical parameters dealing with the above mentioned techniques	Ch. 19 20.1, 21.1(T1)
6-7	Thermo analytical methods	Differential Thermal Analysis; Thermo Gravimetric Analysis; Differential Scanning Calorimetry etc.	1)Define and demonstrate the thermoanalytical methods: DTA, TGA and DSC 2)Conclude the changes in the sample, exothermic or endothermic can be detected relative to the inert reference 3) Develop knowledge pertaining to the appropriate use of the instrument for thermal analysis.	Ch. 20 (R3)
8	Energy and Electromagnetic spectrum	Regions of Electromagnetic Spectrum; units.	1) Explain the interaction between light and matter 2) Contrast various regions of the electromagnetic spectrum 3) Estimate the energy of transition and relate to the units	Ch.1 (T2)
9	Ultraviolet (UV) and visible spectroscopy: Light Absorption, theory, instrumentation	Chromophore concept; electronic energy levels.	1)Relate the basic principle of UV-Vis spectroscopy and explain relevant terms 2) Outline the working principle, analyzing the spectra and extend the construction of device 3) Evaluate absorption parameters	4.1-4.3 (T2)
10-11	UV-Visible spectroscopy: Solvent effects, applications	Solvent effects; Absorption wavelength calculations based on empirical rules	1)Recall the basic concepts of electronic transitions and organize the study of solvent effect on UV-Spectra 2)Calculate the wavelength of absorption in conjuagted systems using Woodward rule	4.4-4.10 (T2)
12-14	Fluorescence and phosphorescence	Principles of fluorescence and phosphorescence and applications	1)Define fluorescence and phosphorescence 2)Elaborate Jablonskii diagram 3)Interpret fluorescence property of the molecules 4)Decide quenching phenomenon 5)Fluorescence lifetime and its applications 6) Fluorescence microscopy	4S.2 (T2) & 16.15 (T1)
15-16	Characterization of materials by XPS and XRF	Theory and applications in characterizing various materials	Understanding the basis X-ray based absorption and emission techniques	Lecture notes
17	Characterization of materials by XRD	Basic theory of XRD and its application in characterizing different inorganic material	Analyzing ability of diffractograms from the XRD study	Lecture notes

18	Circular Dichroism (CD)	Circular polarization of light: CD and its applications	1)Understand the preferential absorption of circularly polarized light by an optically active chiral molecule 2)Interpret the CD spectra correctly 3)Investigate the secondary structure of proteins	Lecture notes
19	Infrared spectroscopy: Instrumentation, Applications	IR instrumentation details; FT-IR; sample preparations recording details	1) What are the key components/parts in an IR spectrometer? 2) What is FT-IR? 3) How to do sample recording? Solid/Liquid/Gas 4) Basis of using a particular compound for sample preparation.	2.4-2.7 (T2) & 2.1-2.9 (R1)
20	Infrared spectroscopy: Molecular vibrations; related factors	IR absorption due to molecular vibrations; influence of factors such as hydrogen bonding.	1) Understanding the basis of IR spectroscopy and how Hooke's law is used in IR spectroscopy. 2) Identify bonds which are IR active. 3) Relate IR absorption to factors such as hydrogen bonding, dipole moment, hybridization etc.	2.1-2.3 (T2)
21	Infrared spectroscopy: Correlation charts; Supplementary materials	Obtaining structural information from IR spectrum; Reflectance mode IR spectra	1) Analysis of an IR spectrum, to obtain information about presence of functional groups and also examine the possibility of getting some structural insights. 2) IR in reflectance mode ; key aspects.	2.8-2S.3 (T2) & 2.10-2.21 (R1)
22-23	Nuclear Magnetic Resonance (NMR) spectroscopy. ^{1}H NMR Theory, chemical shift, related factors	Understanding Magnetic Resonance phenomena and the concept of chemical shift	1) Identifying magnetically active nuclei. 2) Understanding the importance of nuclear spin. Basis of NMR spectroscopy. 3) Showing the importance of chemical shift.	3.1-3.4 (T2)
24-26	NMR- Correlation Data, Solvents, Integrals, spin-spin coupling, related factors	Extracting chemical shift related structural information from simple NMR spectrum; spin-spin coupling and its effect on the spectrum	1) Solving the structure of molecule by using NMR data. 2) Type of solvents to be used in NMR. 3) What is spin-spin coupling and its role?	3.5-3.9 (T2)
27-30	NMR- Non-first order spectra, simplification of spectra, tables, ^{13}C NMR applications	What is meant by non-first order NMR spectrum; different methods of extracting information from such spectra; ^{13}C NMR how to interpret.	1) Meaning of non-first order spectra and extracting structural information from such spectra. 2) What is ^{13}C NMR and how to interpret ^{13}C NMR spectrum?	3.10-3.16 (T2)
31-33	NMR- double irradiation, multi pulses, MRI, polarization techniques, other isotopes ^{19}F, ^{31}P, ^{15}N, ^{17}O etc.	Understanding a few of the advanced methods in NMR; Interpreting NMR spectra of nuclei other than ^{1}H and ^{13}C	1) What are the various advanced methods in NMR and how to obtain molecular structure related information from them ? 2) How to interpret NMR data for other magnetically active nuclei like ^{19}F, ^{31}P, ^{15}N, ^{17}O etc. ? 3) What is the basis of MRI ?	3S.1-3S.6 (T2)
34	Mass spectrometry: Basics, Instrumentation, Isotopic abundance, and Molecular ion.	Principles of mass spectrometry; the effect of isotopic abundance in the mass spectrum	1) Basic principle of mass spectroscopy. 2) Understanding the effect of isotopic abundance in the mass spectrum.	5.1-5.4 (T2) & 8.3-8.5 (R1)

35-37	Mass spectrometry: Metastable ions, fragmentation processes	Understanding the molecular fragmentations at the time of ionization and during flight; stabilities of fragments.	1) Understanding the molecular fragmentations and stabilities of the fragments generated at the time of ionization and during flight.	5.5-5.6 (T2)
38-39	Mass spectrometry: fragmentations associated with functional groups	Extracting the structural information from mass spectra	1) How to interpret mass spectrum?	5.7 (T2) & 8.6 (R1)
40	Mass spectrometry: Supplementary topics	Different kind of mass spectrometers, hyphenated techniques such as GC-MS, isotopic substitution etc.	1) What are the different kind of mass spectrometers and the techniques they use ?	5S.1-5S.5 (T2) & 8.2 (R1)
41-42	Electron Spin Resonance Spectroscopy	Principles and applications of electron spin resonance spectroscopy	1) What is ESR, and how it is useful? 2) Interpretation of the ESR data.	3S.7 (T1)

Course Plan : B. Practical Sessions

Regular sessions: (10 to 12 classes)

In these sessions, the students (in groups) will perform an experiment using various instrumental techniques such as UV-Visible spectroscopy, spectrofluorimetry, IR spectroscopy, AAS, TGA & DSC, NMR, CD, HPLC-Mass spectrometry, XPS and XRD. All students are required to write a report about the performed experiment and submit it during the next session. The instructors will make procedure sheets available for each of these laboratory experiments.

Evaluation Scheme: **Total 200 marks**

A. Theory (150 Marks/75% Weightage)

Components	Duration	Weightage	Date & Time	Nature of Component
Mid-Sem	1.5 h	25 %	03/10 - 9.30 - 11.00AM	Closed Book
Class tests*	---	10 %	Continuous	Closed Book
Comprehensive Examination	3 h	40 %	02/12 FN	Closed Book

* There will be four announced class tests of 5 marks each. All four are mandatory.

B. Practical (50 Marks/25% Weightage – Open Book component)

There will be **ten regular experiments**: Each experiment shall carry 5 marks, out of which 3 would be for record submission and 2 marks for performance.

Chamber consultation hour: will be announced later

Makeup Policy: See Part I for details. However, it may be noted that it is difficult to arrange the make-up of practical sessions.

Notices: All the notices pertaining to this course will be displayed on the **CMS and via email, if needed**.

Academic Honesty and Integrity Policy: Academic honesty and integrity are to be maintained by all the students throughout the semester, and any type of academic dishonesty is unacceptable.

Course Policies: Absences: Students are responsible for all the materials presented in the course as well as for acquiring missed information.

Amit Nag
Instructor-in-charge, CHEM F313