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State Public University since 1985
Recognized by UGC u/s 12-B
(Accredited by NAAC with A Grade)

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GU/Acad –PG/BoS -NEP/2022/339/11 Date: 19.08.2022

CIRCULAR

The University has notified Ordinance OA-35 governing the **Master of Science in Chemistry Programme** offered at the **School of Chemical Sciences**, Goa University Campus and the Affiliated Colleges for implementation from the Academic year 2022-2023 onwards.

The approved Semester I and II Syllabus of the **Master of Science in Chemistry** Programme (Organic, Inorganic, Analytical and Physical as Annexure I, Pharmaceutical Chemistry as Annexure II, Skill Based Course as Annexure III and Bridge Course as Annexure IV) is attached.

The Dean/ Vice-Deans of the School of Chemical Sciences/ Principals of Affiliated Colleges offering the Master of Science in Chemistry Programme are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

Digitally signed by
DONALD AGNELO
ERASMO RODRIGUES
Date: 2022.08.19 12:40:52
'+05'30

(Donald A. E. Rodrigues)
Joint Registrar – Academic

To,

1. The Dean, School of Chemical Sciences, Goa University.
2. The Vice-Deans, School of Chemical Sciences, Goa University.
3. The Principals of Affiliated Colleges offering the Master in Sciences in Chemistry Programme.

Copy to:

1. The Chairperson, Board of Studies in Chemistry PG.
2. The Programme Director, M. Sc. Chemistry, Goa University.
3. The Controller of Examinations, Goa University.
4. The Assistant Registrar, PG Examinations, Goa University.
5. Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

ANNEXURE-I

M.Sc. Chemistry (Organic, Inorganic, Analytical and Physical Chemistry) Part-I (SEM I & II) Syllabus (80 Credit course)

SEM I			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1.	**CHOC-411**	Fundamentals of Organic Chemistry **(DSCC)**	4
2.	**CHIC-411**	Fundamentals of Inorganic Chemistry **(DSCC)**	4
3.	**CHPC-411**	General Physical Chemistry **(DSCC)**	4
4.	**CHAC-411**	Techniques in Analytical Chemistry-I **(DSCC)**	4
5.	**CHOE-411**	Practical Course in Organic Chemistry-I **(DSOC)**	2
6.	**CHOE-412**	Practical Course in Organic Chemistry-II **(DSOC)**	2
7.	**CHIE-411**	Practical Course in Inorganic Chemistry-I **(DSOC)**	2
8.	**CHIE-412**	Practical Course in Inorganic Chemistry-II **(DSOC)**	2
9.	**CHPE-411**	Practical Course in Physical Chemistry-I **(DSOC)**	2
10.	**CHPE-412**	Practical Course in Physical Chemistry-II **(DSOC)**	2
11.	**CHAE-411**	Practical Course in Analytical Chemistry-I **(DSOC)**	2
12.	**CHAE-412**	Practical Course in Analytical Chemistry-II **(DSOC)**	2
SEM II (Inorganic Chemistry)			
1.	**CHIC-412**	Chemistry of Coordination & Organometallic Compounds **(DSCC)**	4
2.	**CHIC-413**	Chemistry of Materials **(DSCC)**	4
3.	**CHIC-414**	Concepts in Molecular Symmetry and Spectroscopy **(DSCC)**	4

4.	**CHIC-415**	Concepts in Inorganic Chemistry **(DSCC)**	4
SEM II (Analytical Chemistry)			
1.	**CHAC-412**	Chemical Methods of Analysis **(DSCC)**	4
2.	**CHAC-413**	Techniques in Analytical Chemistry-II **(DSCC)**	4
3.	**CHAC-414**	Separation Techniques **(DSCC)**	4
4.	**CHAC-415**	Instrumental Methods of Analysis **(DSCC)**	4
SEM II (Organic Chemistry)			
1.	**CHOC-412**	Organic Spectroscopy **(DSCC)**	4
2.	**CHOC-413**	Pericyclic and Organic Photochemical Reactions **(DSCC)**	4
3.	**CHOC-414**	Synthetic Methodologies in Organic Chemistry **(DSCC)**	4
4.	**CHOC-415**	Stereochemistry and Organic Transformations **(DSCC)**	4
SEM II (Physical Chemistry)			
1.	**CHPC-412**	Quantum Chemistry and Statistical Thermodynamics **(DSCC)**	4
2.	**CHPC-413**	Group Theory and Molecular Spectroscopy **(DSCC)**	4
3.	**CHPC-414**	Chemical Kinetics and Thermodynamics **(DSCC)**	4
4.	**CHPC-415**	Electrochemistry and Surface Studies **(DSCC)**	4

Programme: **M.Sc. Part-I (Chemistry)**

Course Code: **CHAC-411**

Title of the course: **Techniques in Analytical Chemistry - I**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objective:	1. Learning various methods of data handling in analysis. 2. Understanding the significance of sampling and calibration techniques. 3. Understanding principles and applications of various types of techniques in 4. Training the students to deduce structures based on IR, NMR, MS combined data.
Course Outcome:	1. Students will be able to analyse the role of statistical tools for determination of error and organised data management for systematic interpretation. 2. Student will be able to apply the sampling and calibration methods for obtaining reliable results. 3. Students will be able to understand basic principles and scope of different methods of Analysis 4. Students will be able to solve problems based on IR, NMR, MS combined spectral data.

Content	*Hrs*
1. Analytical Objectives and Data Handling Importance of analytical chemistry in research and industry; statistics and data handling in analytical chemistry, standard operating procedures, good laboratory practices: quality assurance, method validation and quality control.	5
2. Sampling and Calibration Techniques Sampling and sample preparation, general steps in chemical analysis, calibration of glass wares. Finding the best straight line-least square regression, correlation coefficient; Calibration curves, standard addition technique and internal standards. Chemical concentrations.	5
3. Classical methods of Analysis Gravimetry and Titrimetric methods, Principle, methodology, Advantages & Disadvantages over instrumental methods. Conditions for identifying a given reaction as method of Analysis, Classification of reactions in titrimetric analysis (Acid-Base, redox, complexometric and precipitation), Standard solutions and their preparation. Selection of Visual Indicators in titrimetric Analysis	6
4. Introduction to Electroanalytical techniques Introduction to electrochemical cell, electrode potential, Classification of electroanalytical techniques, working principles, and their applications	4
5. Introduction to Thermoanalytical techniques Principle, Instrumentation and applications of Thermo Gravimetric Analysis, Differential Thermal Analysis, and Differential Scanning Calorimetry.	5

Numericals based on TGA.	
6. Introduction to Chromatographic Techniques a. Principles of chromatography, classification of chromatographic techniques based on mechanism of retention, configuration, mobile and stationary phase. Efficiency of separation- plate theory (theoretical plate concept) and rate theory (van Deemter equation). b. Principles and applications of Paper chromatography, thin layer chromatography, HPTLC, Size exclusion and Ion exchange chromatography. Counter-current chromatography for isolation of natural products. c. Gas and Liquid Chromatography: Introduction; Instrumental Modules; The Separation System; Choice of Conditions of Analysis; Sample Inlet Systems; Detectors; Practical Considerations in Qualitative and Quantitative Analysis; Coupled Systems-introduction to GCMS, LCMS; Applicability-interpretation and numericals.	15
7. Introduction to Spectroscopic Techniques a. Interaction of Electromagnetic Radiation with Matter: Electromagnetic spectra, regions of spectrum, numericals. b. Ultraviolet and visible Spectroscopy: Electronic spectra and Molecular structure: types of electronic transition, Chromophore and auxochrome, absorption by isolated chromophore, conjugated chromophores, aromatic compounds, inorganic chelates. Calculating λmax for Conjugated Dienes, Trienes, polyenes, α,β-unsaturated carbonyl compounds, Numericals. Choices and effect of solvents on UV-Vis. Quantitative Calculations: Beer-Lambert Law; Mixtures of absorbing species-laws of additivity of absorbance; calibration curve for calculation of unknown; Spectrometric errors in measurement; Deviation from Beer-Lambert Law - chemical deviation, instrumental deviation; Numericals for quantitative analysis using UV-VIS spectroscopy. c. Infrared Spectroscopy: Infrared absorption and molecular structures, molecular vibrations, types of vibrations, IR spectra, overtones and bands-basis of NIR absorption. Spectra interpretation, Frequencies of functional group, Spectral Databases, Identification of unknown compounds. d. Spectrometric Instrumentation of UV-Vis and IR: Sources, monochromators, sample cells, detectors, instrumental wavelength and absorption calibration. e. Proton and Carbon NMR Spectroscopy: Theory of NMR, Instrumentation, Chemical shift, factors influencing chemical shift, solvents used in NMR, spin-spin splitting, coupling constant calculation, factors influencing coupling constant. f. Mass Spectrometry: Principle, Instrumentation and various fragmentation patterns. g. Conjoint spectrometry problems: Structural elucidation of organic molecules using IR, UV, NMR and MS. h. Raman Spectroscopy: Theory, Basic instrumentation and Structural analysis using Raman Spectra. (Note: Assignment based on all above spectrometric methods should be given	20

to student. More weightage of lectures shall be given for solving IR and NMR data problems for structure elucidation)	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. G. D. Christian, *Analytical Chemistry*, 6th Ed.; Wiley, 2004. 2. J. H. Kennedy, *Analytical Chemistry: Principles*, 2nd Ed.; Saunders College Publishing, 1990. 3. G. W. Ewing, *Instrumental Methods of Chemical Analysis*, 5th Ed.; McGraw- Hill Int., 1985. 4. W. Kemp, *Organic Spectroscopy*, 3rd Ed.; Palgrave, 1991. 5. D. A. Skoog, D. M. West, F. J. Hollar, S. R. Crouch, *Fundamentals of Analytical Chemistry*, 9th Ed.; Cengage learning, 2014. 6. F. J. Holler, D. A. Skoog, S. R. Crouch, *Principles of Instrumental Analysis*, 6th Ed.; Thomson Books, 2007. 7. H. Willard, L. L. Merritt, J. A. Dean, F. A. Settle, *Instrumental methods of Analysis*, 7th Ed.; HCBS Publishing, 2004. 8. C. N. Banwell, E. M. McCash, *Fundamentals of Molecular Spectroscopy*, 4th Ed.; Tata McGraw- Hill, 2006. 9. R. M. Silverstein, F. X. Webster, *Spectrometric identification of Organic Compounds*, 6th Ed.; Wiley, 1998. 10. H. Gunzler, A. Williams, *Handbook of Analytical Techniques*, 1st Ed.; Wiley, 2001. 11. P. S. Kalsi, *Spectroscopy of Organic Compounds*, 2nd Ed.; New Age International, 2000. 12. E. Pretsch, P. Buhlmann, C. Affolter, *Structural Determination of Organic Compounds*, 2nd Ed.; Springer, 2005. 13. L. D. Field, S. Sternhell, J. R. Kalman; *Organic Structures from Spectra*, 4th Ed.; Wiley, 2007. 14. R. A. Day, A. L. Underwood, *Quantitative Analysis*, 6th Ed.; Prentice Hall, 2001. 15. B. K Sharma, *Instrumental methods of chemical analysis*, Goel Publishing House, Meerut, 2004. 16. K. Nakamoto, *Infrared and Raman Spectra of Inorganic and Coordination Compounds*, 6th Ed.; Wiley, 2009. 17. P. J. Larkin, *Infrared and Raman Spectroscopy: principles and spectral interpretation*, 2th Ed.; Elsevier, 2018. 18. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, *Vogel's Text Book of Quantitative Chemical Analysis,* 6th Ed.; Pearson, 2009.

Programme: **M. Sc -I (Analytical Chemistry)**

Course Code: **CHAC-412**

Title of the Course**: Chemical methods of analysis**

Number of Credits**: 4** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied analytical chemistry courses at M.Sc. Chemistry in semester I
Course Objectives:	1. Introduction to the various chemical method of analysis, details of underlying principle of chemical methods, advantages and limitations 2. Application of chemical methods for qualitative and quantitative analysis
Course Outcomes:	1. Students will be able to explain the basic principle and chemistry behind different conventional method of analysis. 2. Student will know the limitation of method of analysis and will be in a position to choose an appropriate chemical method for particular analysis

Content	Hrs
1. Acid-Base Titrations a. Standard acids and Base solutions, b. Theory of acid-base indicators for Acid-Base titrations i. Colour change and range of indicator ii. Selection of proper indicator iii. Indicator errors c. Neutralization curves for strong acid-strong base; weak acid-strong base and weak base-strong acid weak acid-weak base titrations d. Polyfunctional acids and bases; titration curves for poly functional acids and bases; titration curves for amphiprotic species e. Determining the equivalence point; feasibility of acid - base titrations; magnitude of the equilibrium constant; effect of concentration f. Typical applications of acid-base titrations	10
2. Complexometric titrations a. The complex formation reactions; Stability of complexes; stepwise formation constants b. Organic complexing agents; amino carboxylic acid titration c. EDTA; acidic properties of EDTA; EDTA complexes with metal ions; equilibrium calculations involving EDTA in solution; condition of formation constants d. EDTA titration curves; effect of other complexing agents on EDTA; factors affecting the titration curves; completeness of reaction e. Indicators for EDTA titrations; Theory of common indicators f. Titration methods using EDTA- direct titration; back titration and displacement titration; indirect determinations; titration of mixtures; selectivity, masking and damasking agents g. Applications of EDTA titrations- hardness of water; magnesium and Al in antacids; magnesium, manganese and zinc in a mixture.	8
3. Precipitation titrations a. Introduction to precipitation titrations; feasibility of precipitation titrations b. Titration curves	6

i. Effect of titrant and analyte concentration on titration curves ii. Effect of reaction completeness on titration curves iii. Titration curves for mixture of anions c. Indicators for precipitation titrations d. The Volhard, the Mohr's and the Fajan's methods e. Titration of sulfate with barium	
4. Basic concepts in Electrochemical Titrations a. Faradic and non-Faradic currents b. Reversible and irreversible cells c. EMF series; standard electrode potential; Nernst equation; calculation ofcell potential; effect of current; ohmic potential; polarization; decomposition potential; over voltage; concentration polarization; mechanism of mass transport. d. Introduction to potentiometric methods	4
5. Redox and potentiometric titrations a. Redox Titrations: Equilibrium constants for redox reactions- electrode potentials in equilibrium systems; calculation of equilibrium constants b. Redox titration curves- formal redox potentials; derivation of titration curves c. Factors affecting the shape of titration curves concentration; completeness of reaction; titration of mixtures- feasibility of redox titrations d. Detection of end point and redox indicators i. Structural aspect of redox indicators ii. Specific and nonspecific indicators iii. Choice of indicator iv. Potentiometric end point detection e. Sample preparation: pre-reduction and pre-oxidation f. Potentiometric titrations	8
6. Gravimetric analysis a. Introduction to gravimetric method of analysis b. Properties of precipitates and precipitating reagents i. Completeness of precipitates ii. Super saturation and precipitate formation iii. Particle size and filterability of precipitates c. Colloidal precipitates and crystalline precipitates d. Purity of the precipitate; coprecipitation, post precipitation; conditions for precipitation. e. Fractional precipitation; precipitation from homogenous solution; f. Organic reagent as precipitants-dimethyl glyoxime, oxine, cupferron, salicylaldoxime g. Washing of precipitates; drying and ignition of precipitates; calculation of results from gravimetric data; h. Applications of gravimetric method	6
7. Clinical methods of analysis a. Composition of Blood; Collection and Preservation of Samples; b. Immunoassay: Radioimmunoassay; its principle and applications; instrumentation	10

for radio bioassay c. Clinical application of the radioimmunoassay of insulin, estrogen and progesterone; receptor techniques of breast cancer d. Enzyme- linked immunosorbent assay; principles; practical aspects; applications e. Blood gas analyzer f. Trace elements in the body	
8. Environmental Sampling and Analysis a. Acquiring meaningful Sample b. Air Sample Collection and Analysis c. Water Sample Collection and Analysis d. Soil and Sediment Sampling e. Sample Preparation for Trace Organics f. Methods and Performance-Based Analyses	8
Pedagogy:	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
References/ Readings	1. G. D. Christian, *Analytical Chemistry*, 6th Ed., John Wiley, New York, 2004. 2. D. A. Skoog, D. M. West & F. J. Holler, *Fundamentals of Analytical Chemistry*, 9th Ed., Sounders College publishing, 2014. 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, *Vogel's Textbook of Quantitative Inorganic Analysis*, 6th Ed., Pearson Education Asia, 2000. 4. D. Harvey, *Modern analytical chemistry*, 1st Ed., The McGraw-Hill, 2000. 5. G. H. Jeffery, J. Bassett, J. Mendham, R C. Denney, *Vogel's Text Book of Quantitative Chemical Analysis*, 5th Ed., John Wiley, New York, 1989.

Programme: **M.Sc. Part-I (Analytical Chemistry)**

Course Code: **CHAC-413**

Title of the course: **Techniques in Analytical Chemistry - II**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied analytical chemistry courses at M.Sc. Chemistry in semester I
Course Objective:	1. Provide understanding of the principle of optical analytical techniques like Nephelometry, Turbidimetry, and Polarimetry. 2. Introduce the principles and applications of Absorption and Emission spectroscopic techniques. 3. Develop concepts in various Electroanalytical techniques such as pH metry, conductometry and Karl Fischer titration. 4. Acquaint the students to the basic principles of Radioanalytical techniques and solvent extraction techniques.
Course Outcome:	1. Students will be able to explain the principle of Nephelometry, Turbidimetry, and Polarimetry. 2. Students will be able to describe and differentiate between the absorption and emission techniques such as AAS, AES. 3. Students will be able to illustrate the principle of Electroanalytical techniques such as voltametry, conductometry and Karl Fischer titration. 4. Students will be able to explain and apply the principles of Radioanalytical techniques and solvent extraction methods.

Content	*Hrs*
1. Optical analytical techniques a. Nephelometry and Turbidimetry: Introduction to principle, instrumentation and application of nephelometry, turbidimetry. Factors affecting measurement; comparison between nephelometry, turbidimetry, colorimetry and fluorimetry; applications of nephelometry and turbidimetry. b. Polarimetry: Introduction, principle and Instrumentation of Polarimetry; application of optical rotation method in rate constant determination; acid-catalyzed mutarotation of glucose; inversion of cane sugar. Introduction to terms such as optical rotatory dispersion (ORD), cotton effect curves, circular dichroism, octant rule for ketones.	15
2. Introduction to Absorption and Emission Techniques Introduction, principles and applications of Atomic absorption Spectroscopy (AAS) Atomic Emission spectroscopy (AES), and Flame Emission spectroscopy (FES). Excitation techniques, electrodes and their shapes, Quantitative and qualitative application, brief introduction to ICP-MS, ICP-OES	5

3. Electroanalytical techniques a. Brief introduction to electroanalytical techniques. Voltametry and polarography, cyclic voltametry, coulometry, controlled potential coulomety and coulometric titrations, Stripping voltammetry, ion-selective electrodes and sensors; Evaluation and Calculation; Application to Inorganic and Organic Trace analysis b. Introduction to Ion selective electrodes; construction, application and selectivity coefficient of Ion selective electrode; pH measurement; buffer solution; glass electrode; instrument for pH measurement. c. Basic aspects of conductometric titration; types of conductometric titration; advantages and disadvantages of conductometric titration; Introduction; theory; instrumentation; advantages, disadvantages and applications of High frequency titrations.	15
4. Karl Fischer Titration Introduction, theory, instrumentation, advantages and disadvantages Karl Fischer reagent, determination of water content in industrial samples.	5
5. Radioanalytical techniques Theory and principles of radio analytical technique, detection of nuclear radiation, radiation detectors, pulse height analysis, counting error, analytical application of radioisotopes, neutron activation analysis and isotope dilution analysis.	8
6. Introduction to Extraction Techniques a. Liquid-liquid extraction/solvent extraction: partition coefficient, distribution ratio and percent extraction, choice of solvents, Solvent extraction of metal ions-ion association complexes and metal chelates, multiple batch extraction, Craig's counter-current distribution. b. Introduction to green analytical extraction methods: Supercritical Fluid Extraction, Pressurized Liquid Extraction, Ultrasound assisted Extraction, Microwave assisted Extraction, Enzyme assisted Extraction, Solid phase microextraction, Solid Phase Extraction.	12
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. G.D. Christian, *Analytical Chemistry*, 6th Ed.; Wiley, 2004. 2. D. A. Skoog, D. M. West, F. J. Hollar, S. R. Crouch; *Fundamentals of Analytical Chemistry*, 9th Ed.; Cengage Learning, 2014. 3. F. J. Holler, D. A. Skoog, S. R. Crouch, *Principles of Instrumental Analysis*, 6th Ed.; Thomson Books, 2007. 4. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, *Vogel's Text Book of Quantitative Chemical Analysis,* 6th Ed.; Pearson, 2009. 5. H. H. Willard, L. L. Merritt, J. A. Dean, F.A. Settle, *Instrumental Methods of Analysis*, 7th Ed.; CBS Publishing, 1988. 6. J. H. Kennedy, *Analytical Chemistry: Principles*, 2nd Ed.; Saunders College Publishing, 1990.

	7. G. W. Ewing, *Instrumental Methods of Chemical Analysis*, 5th Ed.; McGraw-Hill, 1985. 8. R. A. Day, A. L. Underwood, *Quantitative Analysis*, 6th Ed.; Prentice Hall, 2001. 9. B. K. Sharma, *Instrumental methods of chemical analysis*, Goel Publishing House, Meerut, 2004. 10. R. D. Braun, *Introduction to Instrumental analysis*, Pharma Med Press, 2012. 11. G. R. Chatwal, S. K. Anand, *Instrumental Methods of Chemical Analysis*, 5th Ed.; Himalaya publishing House, 2019. 12. H. Gunzler, A. Williams, *Handbook of Analytical Techniques*, 1st Ed.; Wiley, 2001 13. M. A. Rostagno, J. M. Prado, *Natural Product Extraction: Principles and Applications*, RSC, 2013. 14. E. Scholz, *Karl Fischer Titration: Determination of Water*, Springer, 2011.

Programme: **M.Sc. Part-I (Analytical Chemistry)**

Course Code: **CHAC-414**

Title of the course: **Separation Techniques**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied analytical chemistry courses at M.Sc. Chemistry in semester I
Course Objective:	1. Introduction of various separation techniques. 2. Evaluate the use of chromatographic techniques for chemical analysis.
Course Outcome:	1. Students will be able to select the separation techniques for purification of analytes from interferents. 2. Students will be able to analyse data and interpret chromatogram. 3. Students will be able to perform qualitative and quantitative estimation using HPLC data.

Content	*Hrs*
1. Basic Separation Technique: a. General aspects of separation techniques-role of separation technique in analysis; separating the analyte from interferents, general theory of separation efficiency: separation factor. b. Classifying separation techniques: Separations based on size; separations based on mass or density, separations based on complexation reactions (Masking); separations based on a change of state; separations based on a partitioning between phases. (Note: Following techniques shall be discussed as representative example) i. Basic principles of distillation; theory of vacuum, steam, azeotropic and fractional distillation. ii. Fractionation by solvent extraction: based on chemical nature and based on polarity of analyte. iii. Membrane techniques: dialysis, reverse osmosis, ultrafiltration. iv. Centrifugation techniques: Sedimentation velocity, Sedimentation equilibrium, analytical and preparative centrifugation, differential centrifugation, density gradient centrifugation; applications in separation.	10
2. Chromatographic Methods: Introduction to chromatography: Principle of chromatographic technique, terms and parameters used in chromatography, classification of chromatographic methods, partition versus adsorption chromatography, qualitative and quantitative analysis by chromatography; a. Planar Chromatography (Paper and thin layer): i. Paper Chromatography: Principle, types (ascending, descending, circular, two dimensional paper chromatography), choice of solvent, adsorbents, multiple development, qualitative and quantitative measurement applications. ii. Thin Layer Chromatography (TLC): Principle; efficiency of thin layer plates, methodology (technique), criteria for selection of stationary and	30

mobile phases (numerical to calculate elution strength of mixed solvents used as mobile phase), choice of adsorbents, preparation of plates, spotting (spot capacity), development of chromatogram, identification and detection using physical and chemical methods, reproducibility of Rf values and improving resolution, Two-dimensional TLC, comparison of TLC with paper chromatography and column chromatography, thin layer ionophoresis and electrophoresis, qualitative, quantitative evaluation and applications. iii. High-performance TLC (HPTLC): Introduction, theory, classification (classical, high performance, ultra, preparative HPTLC), difference between TLC and HPTLC with respects to the parameters, scanning densitometer, quantitative analysis and applications. b. Column Chromatography: Introduction, types (conventional, flash, LPLC, Dry column vacuum chromatography), principle, packing, loading, eluting and collecting eluent in the column chromatography and experimental requirements, theory of development, migration rates of solutes, band broadening, resolution and column efficiency, variables that affect column efficiency, van Deemter equation, qualitative and quantitative analysis, numericals and applications. c. Gas Chromatography (GC): Instrumentation, selection of operating condition, carrier gases, stationary phases, choices of GC column, temperature selection, sampling techniques, methods to prepare derivatives of samples (silylation, acylation, alkylation), factors affecting separation, working principle of GC detectors such as TCD, ECD, FID, quantification methods such as normalizing peak area, internal std., external std, standard addition, advances in GC, hyphenated techniques; GC-FTIR, GC-MS. Analysis of data obtained using GC chromatogram, GC-MS. d. Liquid-Liquid Partition Chromatography: HPLC Introduction, selection of stationary and mobile phase, types of bonded phase chromatography-NPC and RPC and stationary phases used, reversed phase partition chromatography, steps in HPLC method development in partition chromatography, elution techniques (isocratic and gradient), ion pairing agents, buffer agents, organic modifiers, optimization of capacity factor, gradient selectivity factor and column plate numbers, numericals on method development using Snyder's polarity index, advances in LC, Preparative vs analytical HPLC, Chiral chromatography- Pirkle stationary phases, examples of enantiomer separation such as ibuprofen, calculation of enantiomeric excess. Choosing detectors- working principle of RI, UV-Vis, conductivity and ELSD, hyphenated techniques; LC-MS. Analysis of chemical data obtained using HPLC chromatogram, LC-MS. application of HPLC method development in food analysis/drugs, etc.	
3. Other Chromatographic Methods: a. Size Exclusion Chromatography: Principle, types, stationary phases in gel chromatography, physical and chemical characteristics of gel, mechanism of gel permeation chromatography (GPC), instrumentation of GPC,	10

applications of GPC- determination of molecular weight of polymer with numericals. b. Supercritical-Fluid Chromatography: Introduction, important properties of supercritical-fluids, instrumentation and variables, SFC column vs other column, applications and data analysis. c. Affinity Chromatography: Principle, affinity matrix, ligands, mobile phase, separation mechanism, application in the separation of proteins, etc d. Ion Exchange Chromatography: Introduction, mechanism of separation, types of stationary phases, factor affecting separation; Ion exclusion chromatography; separation mechanism- Donnan theory, application in the separation of alkaloids, carboxylic acids etc.	
4. Electrophoresis: a. Theory of electrophoresis, Types- Free solution and supporting medium electrophoresis, paper electrophoresis, capillary electrophoresis and gel electrophoresis. b. Capillary electrophoresis- Instrumentation, sample introduction in CE, types of CE methodology, electrophoretic mobility and electroosmatic mobility, total mobility, efficiency and resolution in CE column, numericals. c. Gel electrophoresis - types of gel, Polyacrylamide gel electrophoresis PAGE, Agarose GE, SDS-PAGE, 2D Gel electrophoresis, factors affecting separation; d. Capillary Electrochromatography. e. Separation of neutral molecule by MEKC; Separation and determination of Vitamin B-complex by using CZE and MEKC. Staining and detecting electrophoresis band.	10
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. G. D. Christian, *Analytical Chemistry*, 6th Ed.; John Wiley, 2004. 2. D. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, *Fundamentals of Analytical Chemistry*, 9th Ed.; Cengage Learning, 2014. 3. David. Harvey, *Modern Analytical Chemistry*, 1st Ed.; The McGraw-Hill, 2000. 4. L. R. Snyder, J. J. Kirkland, J. W. Dolan, *Introduction to modern liquid chromatography*, 3rd Ed.; John Wiley & Sons, 2009. 5. H. H. Willard, L. L. Merritt, J. A. Dean, F. A. Settle, *Instrumental methods of Analysis*, 7th Ed.; CBS Publishing, 1986. 6. G. H. Jeffery, J. Bassett, J. Mendham, R. C. Denney, *Vogel's Text Book of Quantitative Chemical Analysis*, 5th Ed.; John Wiley, 1989. 7. H. Gunzler, A. Williams, *Handbook of analytical techniques*, 1st Ed.; Wiley, 2002. 8. F. W. Fifield, D. Kealey, *Principles and Practice of Analytical Chemistry*, 5th Ed.; Blackwell Science Ltd., 2000.

	9. A. Braithwaite, F. J. Smith, *Chromatographic methods*, 5th Ed.; Kluwer academic publishers, 1999. 10. J. Inczedy, *Analytical Applications of Ion Exchangers*, 1st Ed.; Oxford Pergamon Press, 1966.

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Programme: **M.Sc. Part-I (Analytical Chemistry)**

Course Code: **CHAC-415**

Title of the course: **Instrumental Methods of Analysis**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied analytical chemistry courses at M.Sc. Chemistry in semester I
Course Objective:	1. Introduction of various instrumental methods for analysis. 2. Understanding the utility of various instrumental methods as a qualitative and quantitative analytical tool.
Course Outcome:	1. Students will be able to explain theory and instrumentation of various instrumental methods of analysis. 2. Students will be able to judge suitability of different instrumental methods for qualitative and quantitative analysis.

Content	*Hrs*
1. Diffraction Techniques: X-ray and Neutron Diffraction a. Introduction to X-rays; interaction of X-rays with matter; X-ray diffraction by crystals, Bragg's law. b. Powder X-ray diffraction: instrumentation and applications. Interpretation of powder X-ray diffraction pattern. calculation of lattice parameters. c. Powder diffraction file and other crystallography databases. d. Powder Neutron diffraction: theory, instrumentation and applications.	15
2. X-ray Spectroscopic Techniques: a. X-ray spectroscopy, theory of X-ray absorption and emission. b. X-ray fluorescence (XRF) spectroscopy: introduction, instrumentation, wavelength dispersive and energy dispersive XRF, applications. c. Energy dispersive X-ray (EDX) spectroscopy and Electron probe microanalysis (EPMA): introduction, instrumentation and their applications. d. Introduction to X-ray absorption near edge structure (XANES), Extended X-ray absorption fine structure (EXAFS) and their applications.	15
3. Electron Spectroscopic Techniques: a. Introduction to Electron spectroscopy techniques. b. X-ray and UV Photoelectron spectroscopy (XPS, UPS): theory, instrumentation and their applications. c. Introduction to Auger electron spectroscopy (AES) and electron energy loss spectroscopy (EELS) and their applications.	5
4. Microscopic Techniques: a. Optical microscopy: components of microscope, different types of optical microscopy techniques; significance and applications. b. Electron microscopy: Scanning electron microscopy (SEM), Transmission	10

electron microscopy (TEM) and Scanning transmission electron microscopy (STEM) –Principle, instrumentation and applications. c. Atomic force microscopy (AFM): theory, instrumentation, operational modes and applications. d. Sample preparation for microscopy: Sample selection, sectioning, mounting, grinding, different polishing methods; microstructure – etching, heat tinting, different etching methods, e. SEM/TEM sample preparation: TEM grids, ion milling, electropolishing etc.		
5. Molecular Fluorescence, Phosphorescence and Chemiluminescence Spectrometry: a. Fluorescence and phosphorescence: theory; factors influencing fluorescence and phosphorescence; instrumentation; spectrofluorometer and phosphorimeter; applications of photoluminescence methods b. Chemiluminescence: Introduction; instrumentation; measurement of chemiluminescence, gas phase chemiluminescence analysis, chemiluminescence titrations. Application in Organic and Inorganic Analysis. c. Electrochemiluminescence and Bioluminescence: theory and their applications.		10
6. Automation of Analytical Methods: a. An overview of automated system, distinction between automatic and automated devices; advantages and disadvantages by automation. b. Process Control with automated instruments, discrete and continuous analyzers, automatic instruments. Flow and Sequential Injection Analysis, Laboratory Information Management System.		5
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
Text Books/ References / Readings	1. A. R. West, *Solid State Chemistry and Its Applications*, 2nd Ed.; Wiley, 2014. 2. V. K. Pecharsky and P. Y. Zavalij, *Fundamentals of Powder Diffraction and Structural Characterization of Materials*, 1st Ed.; Springer, 2003. 3. D. A. Skoog, F. J. Holler and S. R. Crouch, *Principles of Instrumental Analysis*, 7th Ed.; Cengage, 2017. 4. T. G. Rochow and E. G. Rochow, *An Introduction to Microscopy by Means of Light, Electrons, X-Rays, or Ultrasound*, 2nd Ed.; Springer, 2012. 5. Y. Leng, *Materials Characterization: Introduction to Microscopic and Spectroscopic Methods*, 2nd Ed.; Wiley-VCH, 2013. 6. A. M. Garcia-Campana, *Chemiluminescence in Analytical Chemistry*, 1st Ed.; CRC Press. 2001. 7. R. F. Egerton, *Physical Principles of Electron Microscopy: An*	

	Introduction to TEM, SEM, and AEM, 2nd Ed.; Springer, 2016. 8. E. H. Kisi and C. J. Howard, *Applications of Neutron Powder Diffraction*, 1st Ed., Oxford Science Publications, 2008. 9. G. D. Christian, *Analytical Chemistry*, 6th Ed. Wiley, 2004.

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Programme: **M. Sc. Part-I (Chemistry)**

Course Code: **CHAE-411**

Title of the Course: **Practical Course in Analytical Chemistry - I**

Number of Credits: **02** Total Contact Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objectives:	1. Introduction of various experimental techniques for analysis. 2. Learning data analysis, handling and interpretation of spectra.
Course Outcomes:	1. Students will be able to explain how to determine an unknown concentration of solution. 2. Students will use statistical methods to analyse data in laboratory. 3. Students will be able to use different techniques for qualitative and quantitative estimation.

Content	*Hrs*
This course consists of 7 units of experiments in various areas of Analytical chemistry. Minimum 13 experiments which include at least 02 experiments from unit 1-6 and 01 experiment from unit 7 shall be conducted.	
Unit 1: Statistics i. Calibration of selected Volumetric apparatus ii. Calibration of selected Laboratory instruments iii. Preparation of standard solutions and standardisation.	9
Unit 2: Colorimetry/ UV-Visible Spectrophotometry i. Estimation of Iron from Pharmaceutical sample (capsule) by thiocyanate method ii. Estimation of phosphoric acid in cola drinks by molybdenum blue method. iii. Estimation of KNO_3 by UV spectroscopy and $K_2Cr_2O_7$ by Visible spectroscopy iv. Simultaneous determination and Verification of law of additivity of absorbances ($K_2Cr_2O_7$ and $KMnO_4$).	9
Unit 3: Flame Spectrophotometry and AES/AAS/ICP Spectroscopy i. Estimation of Na and K in food supplements or cosmetic products. ii. Estimation of Pb in water sample by AES/AAS/ICP. iii. Estimation of Fe and Al in Iron ore sample by AES/AAS/ICP.	9
Unit 4: Ion Exchange Chromatography and High Pressure Liquid Chromatography i. Separation and Estimation of chloride and bromide. ii. Separation of Anthracene and Naphthalene using reverse phase chromatography iii. Separation of Benzaldehyde and Benzyl alcohol using normal phase chromatography	10
Unit 5: Volumetric Titrations i. Estimation of Ca in pharmaceutical tablet. ii. Estimation of Al and Mg in antacid tablet. iii. Estimation of CaO in cement.	10
Unit 6: Solvent Extraction and spectrophotometry i. Extraction of Cu as copper dithiocarbamate (DTC) using solvent extraction and estimation by spectrophotometry.	10

ii. Determination of Ni as Dimethylglyoxime complex by spectrophotometry. iii. Determination of Silver as ion association complex with 1,10-Phenanthroline and Bromopyrogallol red.	
Unit 7: Interpretation Exercises i. Thermal studies: TG/DTA and Isothermal weight loss studies of various hydrated solids like $CuSO_4 \cdot 5H_2O$, $Ca_2C_2O_4 \cdot H_2O$, $Fe_2C_2O_4 \cdot 2H_2O$. ii. X-ray powder diffractometry: Calculation of lattice parameters from X-ray powder pattern of cubic system such as $NiMn_2O_4$, $CoFe_2O_4$ etc. iii. IR spectra of Urea, benzoic acid, Copper sulphate pentahydrate etc.	4
Pedagogy:	Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. J. H. Kennedy, *Analytical Chemistry Principles*, Saunders College Publishing, 2nd Ed., 1990. 2. G. D. Christian, *Analytical chemistry*, 5thEd., John Willey and Sons, 1994 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, *Vogel's Textbook of Quantitative Chemical Analysis*, 6thEd., Pearson Education Asia 2009. 4. A. J. Elias, *Collection of interesting chemistry experiments*, University press, 2002. 5. R.A. Day & A.L. Underwood, *Quantitative Analysis*, 6thEd., Prentice Hall, 2001. 6. J. Kenkel, *Analytical Chemistry for Technicians*, 3rdEd., Lewis publishers, 2002.

Programme: **M. Sc. Part-I (Chemistry)**

Course Code: **CHAE-412**

Title of the Course: **Practical Course in Analytical Chemistry - II**

Number of Credits: **02** Total Contact Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objectives:	1. Introduction of various experimental techniques for analysis. 2. Learning data analysis, handling and interpretation of spectra.
Course Outcomes:	1. Students will be able to standardize a material to determine an unknown concentration. 2. Students will use statistical methods to analyse data in laboratory. 3. Students will be able to use different techniques for qualitative and quantitative estimation.

Content	*Hours*
This course consists of 7 units of experiments in various areas of Analytical chemistry. Minimum 13 experiments which include at least 02 experiments from unit 1-6 and 01 experiment from unit 7 shall be conducted.	
Unit 1: Statistics i. Calibration of selected Volumetric apparatus ii. Calibration of selected Laboratory instruments iii. Preparation of standard solutions and standardisation.	9
Unit 2: Titrimetric Analysis i. Standardisation and estimation of Chloride using precipitation titration (Mohr's method) ii. Analysis of commercial caustic soda by neutralisation titrimetric method iii. Determination of sulphates by complexometric titrations using EDTA.	8
Unit 3: Flame Spectrophotometry and AES/AAS/ICP Spectroscopy i. Estimation of Na and K in food supplements or cosmetic products using flame photometer. ii. Estimation of chromium in water sample by AES/AAS/ICP. iii. Estimation of nickel, molybdenum in Hastelloy C-22 using AES/AAS/ICP..	10
Unit 4: Natural product isolation and Ion Exchange Chromatography i. Isolation of cinnamaldehyde from cinnamon ii. Isolation of Caffeine from tea powder iii. Separation and estimation of Cadmium and Zinc	9
Unit 5: UV-Visible Spectrophotometry and High-Pressure Liquid Chromatography i. Estimation of KNO_3 and $K_2Cr_2O_7$ using UV- Visible spectroscopy ii. Separation of Benzaldehyde and benzoic acid using reverse phase HPLC. iii. Quantification of naphthalene in a sample using reverse phase HPLC.	10

Unit 6: Solvent Extraction and spectrophotometry i. Spectrophotometric determination of aspirin/phenacetin/ caffeine in APC tablet using solvent extraction ii. Colorimetric determination of iron with salicylic acid. iii. Determination of copper in brass sample by colorimetry.	10
Unit 7: Data Interpretation Exercises I. NMR/Mass spectra II. HPLC and GC chromatograph III. XRD powder pattern of cubic systems IV. Thermogram of coordination compounds	4
Pedagogy:	Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. J. H. Kennedy, *Analytical Chemistry Principles*, Saunders College Publishing, 2nd Ed., 1990. 2. G. D. Christian, *Analytical chemistry*, 5th Ed., John Willey and Sons, 1994 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, *Vogel's Textbook of Quantitative Chemical Analysis,* 6th Ed., Pearson Education Asia 2009. 4. J. Elias, *Collection of interesting chemistry experiments*, University press, 2002. 5. R.A. Day & A.L. Underwood, *Quantitative Analysis*, 6th Ed., Prentice Hall, 2001. 6. J. Kenkel, *Analytical Chemistry for Technicians*, 3rd Ed., Lewis publishers, 2002.

Programme: **M.Sc. Part-I (Chemistry)**

Course Code: **CHIC-411**

Title of the course: **Fundamentals of Inorganic Chemistry**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University
Course Objective:	1. To introduce atomic structure, molecular structure, bonding, and symmetry. 2. To provide fundamental knowledge of solid state chemistry, coordination chemistry, organometallic chemistry, and bioinorganic chemistry. 3. To provide fundamental aspects of transition & inner transition elements & their compounds. 4. To introduce air and water pollution, and its treatments, to follow directive of the Supreme Court in 1993 to introduce environmental education at all levels.
Course Outcome:	1. Students will be able to predict geometry and shape of different molecules, and the point group symbols. 2. Students will be able to explain the fundamentals of atomic and molecular structure, solid state chemistry, coordination chemistry, organometallic chemistry, and bioinorganic chemistry. 3. Students should be able to describe and explain the properties and usefulness of transition & inner transition metals. 4. Students will able to explain different air and water pollutants and will be in a position to apply knowledge to treat these pollutants.

Content	*Hrs*
1. Atomic structure, molecular structure and bonding a. Atomic Structure: Structures of hydrogenic atoms: some principles of quantum mechanics, atomic orbitals. Many electron atoms: penetration & shielding, building up principle, classification of elements. Spectroscopic terms. Atomic properties: atomic radii, ionic radii, ionization energy, electron affinity, electronegativity, polarizability. b. Molecular Structure & bonding: Lewis structures: octet rule, resonance. VSEPR model: basic shapes, modification of the basic shapes. Valence bond theory: hydrogen molecule, homonuclear diatomic molecules, polyatomic molecules, promotion, hypervalence, hybridization. Molecular orbital theory: approximation, boding & antibonding orbitals. Homonuclear diatomic molecules & Heteronuclear diatomic molecules	10
2. Molecular Symmetry a. Symmetry elements and symmetry operations. b. Equivalent symmetry elements and equivalent atoms, symmetry point groups with examples, point groups of higher symmetry. c. Systematic procedure for symmetry classification of molecules and illustrative examples, dipole moment, optical activity and point groups	4

3. Solid state chemistry a. Structures of solids: crystal structures, lattices and unit cells, fractional atomic coordinates and projections, close packing of spheres, holes in closed-packed structures. b. Structures of metals & alloys: polytypism, nonclosed-packed structures, polymorphism of metals, atomic radii of metals, alloys, substitutional and interstitial solid solutions, intermetallic compounds. c. Ionic solids: characteristic structures of ionic solids, binary phases, ternary phases, rationalization of structures, ionic radii, radius ratio, structure maps, energetics of ionic bonding, lattice energy and the Born–Haber cycle, The calculation of lattice enthalpies. (numerical expected)	10
4. Chemistry of transition & inner transition elements a. Transition elements**:** IUPAC definition of transition elements, occurrence, physical and chemical properties, noble character, metal halides, oxides & oxido complexes, examples of metal-metal bonded clusters, difference between 1^{st} row and other two rows. b. Inner transition elements: Lanthanides, occurrence, properties, oxidation states, electronic structure, colour and spectra, magnetic properties, lanthanide contraction, compounds of lanthanides. Actinoid chemistry: general trends and properties, electronic spectra, thorium and uranium.	10
5. Coordination and Organometallic Chemistry a. Coordination chemistry: Introduction, representative ligands, nomenclature. Constitution and geometry: low coordination numbers, intermediate coordination numbers, higher coordination numbers, polymetallic compounds. Isomerism & chirality in square planar and octahedral complexes, ligand chirality. Thermodynamics of complex formation: formation constants, chelate and macrocyclic effects, steric effects and electron delocalization. Electronic properties of metal complexes: CFT applied to octahedral and tetrahedral complexes, magnetic moments, CFSE. Electronic spectroscopy: basic concepts, interpretation of spectra of d^1 & d^9 ions (Orgel diagram for octahedral and tetrahedral complexes). b. Organometallic Chemistry: Introduction to organometallic chemistry, nomenclature, stability and inert gas rules (neutral atom and donor pair electron count methods). Ligands: CO & phosphines, homoleptic carbonyls its synthesis and properties, oxidation-reduction of carbonyls, metal carbonyl basicity, reactions of CO ligand, spectroscopic properties of metal carbonyls. Oxidative addition and reductive elimination.	12
6. Basic Bioinorganic Chemistry a. Macronutrients/micronutrients. Role of elements in biology. Metal ion transport role. b. Definition of metallobiomolecules, metalloporphyrins, structure of porphine and heme group, examples of metalloenzymes of Cu and Zn.	4
7. Environmental Chemistry	10

a. Air Pollution: Classification of air pollutants and photochemical reactions in the atmosphere. Common air pollutants (e.g. CO, NOx, SO_2, hydrocarbons and particulates) (a) sources (b) physiological and environmental effect (c) monitoring, (d) various remedial & technological measures to curb pollution. Air quality standards. b. Water pollution: Importance of buffer & buffer index in waste water treatments. Chemical, physical & biological characteristics of water pollution, specific & non-specific characterization of water. DO, BOD, COD, and chlorine demand, typical water treatment & waste water treatment (Municipal). Impact of plastic pollution and its effect.		
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
Text Books/References / Readings	1. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, *Shriver & Atkins Inorganic Chemistry*, 5th Ed.; Oxford Publications, 2009. 2. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, *Inorganic Chemistry: Principles of Structure & Reactivity*, 4th Ed.; Pearson, 2011. 3. F. A. Cotton, G. Wilkinson, P. L. Gauss, *Basic Inorganic Chemistry*, 3rd Ed.; Wiley, 2008 (reprint). 4. J. D. Lee, *Concise Inorganic Chemistry*, 5th Ed.; Wiley, 2008. 5. F. A. Cotton, *Chemical applications of group theory*, 3rd Ed.; Wiley Eastern, 2012 (reprint). 6. L. Pauling, *The Nature of The Chemical Bond*, 3rd Ed.; Cornell University Press, 1960. 7. M. C. Day, J. Selbin, *Theoretical Inorganic Chemistry*, 2ed Ed.; Van Nostrand-Reinhold, 1969. 8. H. V. Keer, *Principles of Solid state Chemistry*, 1st Ed.; New Age Intl. Ltd, 1993, (reprint 2008). 9. A. R. West, *Solid State Chemistry and Its Applications*, 1st Ed.; John Wiley & Sons, Singapore, 1984 (reprint 2007). 10. D. K. Chakrabarty, *Solid State Chemistry*, 2ed Ed.; New Age Intl. Publishers, 2010. 11. F. A. Cotton, G. Wilkinson, *Advanced Inorganic Chemistry*, 3rd Ed.; Wiley Eastern, 2001. 12. A. V. Salker, *Environmental Chemistry: Pollution and Remedial Perspective*, 1st Ed.; Narosa Publication, 2017. 13. A.K. De, *Environmental Chemistry*, 3rd Ed.; New Age Intl. Publishers, 2005. 14. A. C. Stern, R. W. Boubel, D. Bruce turner, D. L. Fox, *Fundamentals of Air Pollution*, 1st Ed.; Academic Press, 1984. 15. R. A. Horne, *Chemistry of Our Environment*, 1st Ed.; John Wiley, 1978. 16. R. S. Drago, *Physical Methods in Inorganic Chemistry*, Affiliated	

	East West Press Pvt. Ltd., 2017 17. G. C. Miessler, D. A. Tarr, *Inorganic Chemistry*, 3rd Ed.; Pearson, 2004

Programme: **M.Sc. Part-I (Inorganic Chemistry)**

Course Code: **CHIC-412**

Title of the course: **Chemistry of Coordination & Organometallic Compounds**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied Inorganic chemistry courses at M.Sc. Chemistry in semester I
Course Objective:	1. To make understand fundamentals of coordination and organometallic chemistry. 2. To gain the knowledge on structural aspects of compounds. 3. To make understand bonding using various models. 4. To correlate spectroscopic and magnetic properties with bonding models. 5. To develop a skill of interpretation of magnetic and spectroscopic properties. 6. To understand fundamental concepts of inorganic chemistry reaction mechanisms. 7. To provide knowledge on applications of organometallic compoundsin homogenous catalysis.
Course Outcome:	1. Students will be able to understand the electronic structure of coordination and organometallic compounds. 2. Students will be well equipped with knowledge of CFT and MOT 3. Students will be in position to understand the magnetic and electronic properties. 4. Students will be able to acquire skill on interpretation of electronic and IR spectra of inorganic compounds 5. Students will be able understand concepts of inorganic reactions & mechanisms. 6. Students will be aware of applications of organometallic compounds in industrial processes.

Content	*Hrs*
1. Electronic structure of coordination compounds Basic introduction to bonding theories: a.Valence Bond theory & its utility, limitations of VBT. b. Crystal field theory and its uses in: i) Octahedral compounds; ii) tetrahedral compounds; iii) square-planar compounds and other geometries; iv) tetragonally distorted compounds (Jahn-TellerEffect); v) octahedral vs tetrahedral; vi) Evidences showing covalency to the M-L bonds. c. Molecular orbital theory (MOT): σ & π-bonding in octahedral, tetrahedral, square planar compounds.	12
2. Spectra and magnetic studies of coordination compounds a.(i) Electronic spectra of atoms, (ii) Electronic spectra of complexes; Orgel diagrams, correlation diagrams, T-S diagrams examples and problem solving, (iii) Charge-transfer bands; (iv) Selection rules and intensities,(v)	12

Luminescence. b. Vibrational spectra of coordination compounds. c. Magnetic studies: cooperative magnetism, basic concepts of magnetic properties: diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, temperature dependent magnetism, Curie law, Curie Weiss Law; spin cross over phenomenon.	
3. Inorganic reaction mechanisms a. The thermodynamics of complex formation: Formation constants; Trends in successive formation constants; The chelate and macrocyclic effects; Steric effects and electron delocalization. b. Ligand substitution reactions and mechanisms: Rates of ligand substitution; The classification of mechanisms; Ligand substitution in square-planar complexes: The nucleophilicity of the entering group; The shape of the transition state. Ligand substitution in octahedral complexes: Rate laws and their interpretation; The activation of octahedral complexes; Base hydrolysis; Stereochemistry; Isomerization reactions. C. Redox reactions: The classification of redox reactions; The inner-sphere mechanism; The outer-sphere mechanism. d. Photochemical reactions: Prompt and delayed reactions; d–d and charge-transfer reactions; Transitions in metal–metal bonded systems.	12
4. Organometallic chemistry of d-block elements a. Stable electron configurations; Electron count preference; Electron counting and oxidation states. b. Ligands: Carbon monoxide, Phosphines, Hydrides and dihydrogen complexes, η^1-Alkyl, -alkenyl, -alkynyl, and -aryl ligands, η^2-Alkene and -alkyne ligands, Nonconjugated diene and polyene ligands, Butadiene, cyclobutadiene, and cyclooctatetraene, Benzene and other arenes, The allyl ligand, Cyclopentadiene and cycloheptatriene, Carbenes, Alkanes, agostic hydrogens, and noble gases, Dinitrogen and nitrogen monoxide. c. Compounds: *d*-Block carbonyls, Metallocenes, Metal–metal bonding and metal clusters. d. Reactions: Ligand substitution, Oxidative addition and reductive elimination, σ-Bond metathesis, 1,1-Migratory insertion reactions, 1,2-Insertions and β-hydride elimination, α-, β-, and δ-Hydride eliminations and cyclometallations. e. Catalysis: general concepts, catalytic cycle for isomerization of prop-2-en-l-ol to prop-1-en-l-ol, Alkene metathesis, hydrogenation of alkenes, hydroformylation, Wacker oxidation of alkenes, Asymmetric oxidations, Palladium catalyzed C-C bond forming reactions, methanol carbonylation (Monsanto acetic acid process).	24
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.

Text Books/References / Readings	1. P. W. Atkins, T. L. Overton, J. P. Rourke, M. T. Weller & F. A. Armstrong 2010, *Shriver & Atkins' Inorganic Chemistry*, 5th Ed., Oxford University Press, 2010. 2. J. E. Huheey, E. A. Keiter& R. L. Keiter, *Inorganic Chemistry:Principles of structure and reactivity*, 4th Ed.;Pearson, 2014. 3. J. D. Lee, *Concise Inorganic Chemistry*, 5thEd, Chapman and Hall, 1996. 4. F. A. Cotton, G. Wilkinson & P. L. Gaus, *Basic Inorganic Chemistry*, 3rd Ed.; John Wiley, 1995. 5. F. A. Cotton & G. Wilkinson, *Advanced Inorganic Chemistry*, 3rd Ed. (4th & 5th Eds. preferred);Wiley Eastern, New-Delhi, 1984. 6. D. Banerjee, *Coordination Chemistry,* 1st Ed.;Tata McGraw–Hill, New Delhi, 1994. 7. N. N. Greenwood & A. Earnshaw, *Chemistry of the Elements*, Pergamon Press, Exeter, 1984. 8. G. Rodgers, *Introduction to coordination, solid state, and descriptiveInorganic chemistry*, 1st Ed.; McGraw–Hill,1994. 9. R. S. Drago, *Physical Methods in Inorganic Chemistry*, Affiliated East West Press Pvt. Ltd., 2017 10. G. C. Miessler, D. A. Tarr, *Inorganic Chemistry*, 3rd Ed.; Pearson, 2004

Programme: **M.Sc. Part-I (Inorganic Chemistry)**

Course Code: **CHIC-413**

Title of the course: **Chemistry of Materials**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied Inorganic chemistry courses at M.Sc. Chemistry in semester I
Course Objective:	1.To provide information about different types of materials. 2.To provide knowledge about different types of synthesis. 3.To be familiar with different solid state properties of materials.
Course Outcome:	5.Students will be able to explain different methods of material synthesis. 6.Students can explaineffect of size variations on solid state properties of materials. 7.Students can explain different types of defects and phase transformations in materials. 8.Students will be in position to describe magnetic, electrical, dielectric, optical, and semiconductor properties of materials.

Content	*Hrs*
1. Introduction to Materials Chemistry Basic knowledge about properties, structure and applications of materials.	1
2. Structure and bonding in solid materials Crystal lattice; unit cell; Miller indices and planes; X-Ray diffraction method; Molecular, Metallic, Covalent and Ionic solids, Hydrogen bonding; Structural classification of binary and tertiary compounds; Spinel and Perovskite structures	6
3. Crystal defects & Non-stoichiometry in Solids a. Types of defects: Point defects, Dislocations: Line defects and Plane defects. b.Oxygen deficient oxides; Metal deficient oxides and classification of non-stoichiometry.	6
4. Materials preparation techniques a. Broad Classification of methods: Ceramic method, and Different wet chemical methods. b.Types of Materials: Powdered bulk materials, Single crystal and Thin films, Amorphous materials, and Nanomaterials. c. Preparation methods for different materials with their advantages and disadvantages: i. Powder materials: Co-precipitation method, Precursor method, Combustion method: Solid state and solution method, Precursor-combustion method, Sol-gel method, Spray roasting method, Freeze drying method. ii. Single crystals: (a) Growth from melt (b) from solution (c) using Flux method (d) Epitaxial growth of single crystal thin films: Using Chemical and Physical methods (e) Chemical vapour transport (f) Hydrothermal method (g) Dry high pressure method, electrochemical	16

reduction method. iii. Amorphous Materials: Synthesis & applications. iv. Nanomaterials: Synthesis, properties: structural, optical and magnetic and applications.	
5. Reactivity of Solid Materials Tarnish reactions, decomposition reaction, solid-solid reactions, addition reactions, double decomposition reaction, electron transfer reaction, solid-gas reactions, sintering, factors influencing reactivity of solids.	4
6. Phase Transformations in Solids Thermodynamic consideration, Burgers classification, structural change in phase transformation, Martensite transformation, temperature and pressure induced transformations, order-disorder transitions, electronic transition, transformation with a change in composition, enantiotropy and monotropy, Ehrenfest's classification.	6
7. Electrical Properties Electrical conductivity, free electron theory, Fermi energy, insulators, semiconductors and conductors, band theory of semiconductor, Brilliouin zones, Hall effect, Peltier effect, Seebeck effect, photo conductivity and ionic conductivity, Superconductivity, BCS theory, Meissner effect, high temperature superconductor.	7
8. Semiconductor Devices Diodes and transistors, Junction field effect transistor and metal oxide semiconductor field effect transistor, light meter, photodiode, phototransistor, solar cells, light emitting diodes. Laser materials.	5
9. Optical and dielectric properties Luminescence and phosphorescence, piezoelectric, ferroelectric materials and applications, thermal conductivity, phonon interaction, thermal expansion coefficient.	4
10. Magnetic properties Introduction to magnetism, behavior of substance in a magnetic field, magnetic moments, diamagnetism, paramagnetism, experimental determinations of susceptibility, ferromagnetism, anti-ferromagnetism and ferrimagnetism, magnetization of ferromagnetic substance.	5
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/References / Readings	18. A.R. West, *Solid State Chemistry and Its Applications*, 1st Ed., John Wiley & Sons, Singapore, 1984 (reprint 2007). 19. L.V. Azaroff, *Introduction to Solids*, 1st Ed., Tata McGraw Hill, 2009, (33rd Reprint). 20. N. B. Hannay, *Treatise on Solid State Chemistry Vol.4 Reactivity of Solids*, 1st Ed.; Plenum Press, 1976. 21. D. K. Chakraborty, *Solid State Chemistry*, 2nd Ed.; New Age International Publisher, 2010. 22. H. V. Keer, *Principles of the Solid State*, 1st Ed., New Age

International (P) Ltd., (Wiley Eastern Ltd,), 1993, (Reprint 2008).
23. C. N. R. Rao & K. J. Rao, *Phase Transitions in Solid*, 1st Ed.; McGraw Hill, 1977.
24. W. D. Callister, *Materials Science and Engineering:An Introduction*, 7th Ed.; John Wiley, 2007.
25. B. D. Fahlman, *Materials Chemistry*, 2nd Ed.; Springer, 2011.
26. H. R. Allcock, *Introduction to materials chemistry*, 1st Ed.; John Wiley & Sons, 2011.
27. C. N. R Rao & Gopalkrishnan, *New directions in solid state chemistry*, 2nd Ed.; Cambridge University Press, 1997.
28. R. S. Drago, *Physical Methods in Inorganic Chemistry*, Affiliated East West Press Pvt. Ltd., 2017.
29. G. C. Miessler, D. A. Tarr, *Inorganic Chemistry*, 3rd Ed.; Pearson, 2004.

Programme: **M.Sc. Part-I (Inorganic Chemistry)**

Course Code: **CHIC-414**

Title of the course: **Concepts in Molecular Symmetry and Spectroscopy**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied Inorganic chemistry courses at M.Sc. Chemistry in semester I
Course Objective:	1. To train the students to understand the concepts of molecularsymmetry and their applications in chemistry 2. To train the students to understand different spectroscopictechniques viz. magnetic resonance, vibrational & Mössbauer spectroscopy with emphasis on spectral interpretation.
Course Outcome:	1. Students will be able to explain symmetry aspects of simplemolecules and their applications in chemistry. 2. Students will be able to explain IR, Raman, ESR, NMR, Mössbauer spectra of simple molecules to determinemolecular geometry.

Content	*Hrs*
1. Molecular symmetry a. Symmetry elements and symmetry operations, symmetry planes and symmetry reflections, inversion center, proper axes and proper rotations, improper axis and improper rotations. b. Products of symmetry operations, equivalent symmetry elements and equivalent atoms, relations among symmetry elements and operations, symmetry elements and optical isomerism, symmetry point groups, symmetries with multiple high order axes, classes of symmetry operations, procedure for symmetry classification of molecules. c. Group and it's defining properties, order of the group, examples of group, group multiplication table, cyclic group, acyclic group, abelian group, non-abelian group. Sub groups, classes, properties of conjugate elements. d. Some properties of matrices and vectors, the great orthogonality theorem, reducible and irreducible representations, irreducible representations and their characters, character tables. Bases for irreducible representations, direct product. Symmetry Adapted Linear Combinations and its applications. Cage and cluster compounds, metal sandwich compounds. e. Crystal symmetry, space groups.	30
2. Spectroscopy a. Magnetic Resonance Spectroscopy; interaction between electron spin and magnetic field, interaction between nuclear spin and magnetic field, Resonance condition, instrumental requirements, b. Presentation of ESR (electron spin resonance) and NMR (nuclear magnetic resonance) spectra, line widths of ESR and NMR spectra, hyperfine coupling in isotropic systems (e.g. H atom, methyl radical etc.), anisotropic system, number of expected ESR signals for one electron paramagnetic species, zero field splitting and Kramer's degeneracy, Spin energy levels of octahedral Mn(II) complexes, nuclear quadrupole interaction, spin	30

Hamiltonian, ESR spectra of some transition metal compounds, Electron delocalization, NMR spectral interpretation of a few nuclei like ^{19}F, ^{29}Si, ^{31}P. c. Mössbauer spectroscopy; Mössbauer effect, Mössbauer principle, Recoilless emission and absorption spectral line widths, Doppler shift, experimental arrangement of Mössbauer spectroscopy, chemical shift (isomer shift), quadrupole splitting, magnetic hyperfine interaction, discussion of selected Mössbauer nuclei like ^{57}Fe, ^{129}I. d. Vibrational spectroscopy: Infrared spectroscopy and Raman spectroscopy, principle, their use in determination of molecular structure.	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. F. A. Cotton, *Chemical Applications of Group theory*, 3rd Ed.; John Wiley,1990 2. J. E. Huheey, E. A. Keiter, R.L. Keiter, *Inorganic Chemistry: Principles of structure and reactivity*, 4thEd.; Pearson, 1993. 3. G. R. Desiraju, J. J. Vittal, A. Ramanan, *Crystal Engineering*, IISC Press, world Scientific, 2011. 4. R. L. Dutta, A. Syamal, *Elements of Magnetochemistry*, 2nd Ed.; Affiliated East-West Press, New Delhi, 1993. 5. C. N. Banwell, E. M. McCash, *Fundamentals of Molecular Spectroscopy*, 4th Ed.; Tata McGraw Hill, New Delhi, 1994. 6. G. Aruldhas, *Molecular structure and spectroscopy*, Prentice Hall of India, 2001 7. P. Atkins, J. De Paula, J. Keeler, *Atkins' Physical Chemistry*, International Ed.; Oxford University Press, 2018. 8. M. Weller, T. Overton, J. Rourke, F. Armstrong, *Inorganic Chemistry*, International Ed.;Oxford University Press, 2018. 9. E. A. V. Ebsworth, D. W. H. Rankin, S. Cradock, *Structural Methods in Inorganic Chemistry*, ELBS, 1988. 10. K. Nakamoto, *Infrared and Raman Spectra of Inorganic and Coordination Compounds, Part A: Theory and Applications in Inorganic Chemistry*, 6thEd.; Wiley, 2009. 11. K. Nakamoto, *Infrared and Raman Spectra of Inorganic and Coordination Compounds, Part B: Applications in Coordination, Organometallic and Bioinorganic Chemistry*, 6thEd.; Wiley, 2009. 12. R. S. Drago, *Physical Methods in Inorganic Chemistry*, Affiliated East West Press Pvt. Ltd., 2017 13. G. C. Miessler, D. A. Tarr, *Inorganic Chemistry*, 3rd Ed.; Pearson, 2004

Programme: **M.Sc. Part-I (Inorganic Chemistry)**

Course Code: **CHIC-415**

Title of the course: **Concepts in Inorganic Chemistry**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied Inorganic chemistry courses at M.Sc. Chemistry in semester I
Course Objective:	1. To gain knowledge in selected topics in inorganic chemistry and study the applications of inorganic compounds in selected areas. 2. To learn in details about the s-block elements and their compounds. 3. To understand the concepts in acid-base reactions in the Inorganic chemistry. 4. To gain knowledge about atomic stability and nuclear reactions. 5. To study the importance of metal ions in the field of medicinal chemistry.
Course Outcome:	1. Students will be able to explain the chemistry of s-block elements. 2. Students will be able to explain fundamentals of inorganic medicinal chemistry. 3. Students will be able to solve numerical problems related to some concepts in acid-base and nuclear chemistry. 4. Students will be able to analyse reactions and processes in field of nuclear chemistry.

Content	*Hrs*
1. s-Block elements and their compounds a.Hydrogen and hydrides; Electronic structure, position in periodic table, abundance, preparation, properties, isotopes, ortho and para hydrogen. Classification of hydrides, preparation & properties of hydrides; hydrogen ion, hydrogen bonding and its influence on properties. b. Group 1 elements; Introduction, abundance, extraction, physical and chemical properties, solubility and hydration, solutions of metal in liquid ammonia, complexes, crowns and cryptands, electrides, alkalides, difference between lithium and the other group 1 elements, diagonal relationship between Li and Mg. c. Group 2 elements; Introduction, abundance, extraction, physical and chemical properties, solutions of metal in liquid ammonia, complexes, anomalous behaviour of beryllium, difference between beryllium and the other group 2 elements, diagonal relationship between Be and Al, preparation and properties of Grignard reagent.	17
2. Inorganic medicinal chemistry a. Anticancer agents; Platinum and Ruthenium complexes as anticancer drugs, Cancerchemotherapy, phototherapy, radiotherapy using borane compounds. b. Chelation therapy. c. Gadolinium and technetium complexes as MRI contrast agents, X-ray contrast agents.	16

d. Anti-arthritis drugs. e. Anti-bacterial agents (Ag, Hg, Zn and boron compounds). f. Antiseptic and anti-biotic. g. Deodorants and anti-perspirants.	
3. Chemistry of radioactive elements a. Atomic nucleus; Classification of nuclides and nuclear stability. b. Review of Nuclear models. c. Radioactivity, Decay processes and decay energy, half-life of radioactive elements. d. Nuclear reactions; Nuclear fission and fusion processes. e. Nuclear Reactors; Nuclear reactor components and functions, Q values for nuclear reactions. f. Detection and measurement of activity; Radiation detection principles. g. Physical and Chemical separation techniques of radioactive elements. h. Radio-analytical techniques, Activation analysis. i. Nuclear waste management. j. Applications of radioactivity.	15
4. Acids and Bases a. Brønsted acidity; Proton transfer equilibria in water, Solvent levelling, The solvent system definition of acids and bases, Characteristics of Brønsted acids, Periodic trends in aqua acid strength, Simple oxoacids, Anhydrous oxides, Polyoxo compound formation, Nonaqueous solvents. b. Lewis acidity; Examples of Lewis acids and bases, Group characteristics of Lewis acids. c. Reactions and properties of Lewis acids and bases; The fundamental types of reaction, Hard and soft acids and bases, Thermodynamic acidity parameters, Solvents as acids and bases. d. Applications of acid–base chemistry, Superacids and superbases, Heterogeneous acid–base reactions.	12
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/References / Readings	1. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, *Shriver & Atkins Inorganic Chemistry*, 5th Ed.;Oxford Publications, 2009. 2. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, *Inorganic Chemistry: Principles of Structure & Reactivity*, 4th Ed.;Pearson, 2011. 3. F. A. Cotton, G. Wilkinson, P. L. Gauss, *Basic Inorganic Chemistry*, 3rd Ed.;Wiley, 2008. 4. J. D. Lee, *Concise Inorganic Chemistry*, 5thEd.;Wiley, 2008. 5. F. A. Cotton, G. Wilkinson, *Advanced Inorganic Chemistry*, 3rd Ed.; Wiley, 1984. 6. N. N. Greenwood, A. Earnshaw, *Chemistry of the Elements*,

	Pergamon Press, 1st Ed.; 1984. 7. A. G. Sykes, *Advances in Inorganic Chemistry*, UK Ed.;Academic Press Ltd., 1991. 8. H. J. Arnikar, *Essentials of Nuclear Chemistry*, 4th Revised Ed.; New Age Intl.Publishers, 2011. 9. G. Friedlander, J. W. Kennedy, E. S. Macias, J. M. Miller, *Nuclear & Radiochemistry*, 3rd Ed.; John Willey & Sons, 1981. 10. K.A. Strohfeldt, *Essentials of Inorganic Chemistry*, Ist Ed.; John Willey & Sons, 2015. 11. G.R. Choppin, J-O. Linjenzin, *Radiochemistry and Nuclear Chemistry*, 2nd Ed.; Butterworth-Heinemann Ltd, 1995. 12. R. S. Drago, *Physical Methods in Inorganic Chemistry*, Affiliated East West Press Pvt. Ltd., 2017 13. G. C. Miessler, D. A. Tarr, *Inorganic Chemistry*, 3rd Ed.; Pearson, 2004

Programme: **M.Sc. Part-I (Chemistry)**

Course Code: **CHIE-411**

Title of the course: **Practical course in Inorganic Chemistry-I**

Number of Credits: **02** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objective:	1. Students shall acquire skills in synthetic inorganic chemistry. 2. Students will learn to prepare coordination compounds. 3. Students will learn to prepare useful potash alum from scrap aluminum. 4. Students will learn how to grow single crystals. 5. Students will acquire skills in determination of chromium, oxalate, and aluminum by redox titrations. 6. Students will be trained to fix the formula of compounds and find lattice water molecules by complexometric, redox & iodometric titrations. 7. Students shall acquire skills in determination of metal content at very low concentrations (ppm) using colorimetry / spectrophotometry.
Course Outcome:	1. Students will be in a position to synthesis coordination compounds with different metals and ligands. 2. Students will be able to grow single crystal. 3. Students will be able to prepare potash alum compound from waste scrap Al source. 4. Students will be able to determine metal content in the synthesised inorganic compounds. 5. Students will be able to fix the formula of compounds. 6. Students will be able to use and explain the diverse methods available for estimation of the metals including colorimeters and spectrometers.

Content	*Hrs*
Minimum 13 experiments from the list shall be conducted.	
1. Preparations / Synthesis of Inorganic Compounds: (Any Five) i. Preparation of hexaamminenickel(II) chloride. ii. Preparation of Trisethylenediaminecobalt(III) chloride. iii. Preparation of potassium trioxalatoaluminate trihydrate. iv. Preparation of potassium hexathiocyanato-*κN*-chromate tetrahydrate. v. Preparation of potassium trioxalatochromate trihydrate. vi. Preparation of potash alum from scrap aluminum.	25
2. Estimations / Determinations: (Any Eight) i. Estimation of nickel in $[Ni(NH_3)_6]Cl_2$by complexometry or Gravimetry. ii. Estimation of cobalt in $[Co(en)_3]Cl_3$ by complexometry. iii. Estimation of oxalate in $K_3[Al(C_2O_4)_3]\cdot xH_2O$ or $K_3[Cr(C_2O_4)_3]\cdot xH_2O$ iv. Estimation of nitrite by redox titration. v. Estimation of calcium from calcite ore. vi. Iodometric determination of Copper in gun metal alloy/Devarda's alloy.	35

vii. Determination of chromium in chrome alum and $K_3[Cr(C_2O_4)_3]\cdot xH_2O$ and to determine degree of hydration. viii. Colorimetric/Spectrophotometric determination of nickel or chromium. ix. Estimation of manganese by colorimetric / spectrophotometry method.		
Pedagogy	Students will be given pre-lab and post-lab assignments on theoretical aspects of laboratory experiments prior to the conduct of each experiment. Exams will be in the form of ISA, SEA which will involve performing given experiments and conduct of viva, systematic reporting of experiments, results and observations in laboratory report. Sessions should be interactive in nature to enable peer group learning.	
Text Books/ References / Readings	1. G. Brauer, *Handbook of Preparative Inorganic Chemistry*, Vol. 1 &2, 1963. 2. G. Pass & H. Sutcliffe, *Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods*, 2nd Ed.; Chapman & Hall, 1974. 3. S. De Meo, *J. Chem. Ed*., Vol 80, Pg.No.796-798, 2003. 4. W. L. Jolly, *The Synthesis & Characterization of Inorganic Compounds*, Prentice-Hall, INC, 1970. 5. A. J. Elias, *General Chemistry Experiments*, Revised Ed.; University Press, 2008. 6. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, *Vogel's Text Book of Quantitative Chemical Analysis*,6th Ed.; Pearson, 2002. 7. G. Svehla, *Vogel's Text Book of Qualitative Inorganic Analysis*, 7th Ed, Pearson, 2011. 8. G. Marr, B. W. Rockett, *Practical Inorganic Chemistry*, Van Nostrnad Reinhold London, 1972.	

Programme: **M.Sc. Part-I (Chemistry)**

Course Code: **CHIE-412**

Title of the course: **Practical course in Inorganic Chemistry-II**

Number of Credits: **02** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objective:	8. Students shall acquire skills in synthetic inorganic chemistry. 9. Students will learn to prepare coordination compounds. 10. Students will learn how to grow single crystals. 11. Students will acquire skills in determination of metal present by gravimetric and titrimetric method. 12. Students shall acquire skills in determining the metal content at very low concentrations (ppm) using colorimetry / spectrophotometry.
Course Outcome:	7. Students will be in a position to synthesize coordination compounds with different metals and ligands. 8. Students will be able to grow single crystal. 9. Students will be able to determine metal content in the given sample. 10. Students will be in position to apply diverse methods available for estimation of the metals and can use colorimeters and spectrometers. 11. Students will able to detect cations and anions in the given salt.

Content	*Hrs*
Minimum 13 experiments from the list shall be conducted.	
1. Preparations / Estimation of Inorganic Compounds: (Any Nine) i. Preparation of hexaamminecobalt(III) nitrate. ii. Estimation of cobalt in hexaamminecobalt(III) nitrate by volumetric titration. iii. Preparation of Potassium Trioxalatoferrate(III) Trihydrate iv. Estimation of iron and oxalate by redox titration v. Synthesis of metal nanoparticles (Cu, Ag, Au, Ni) and determining the absorption maxima by UV-visible spectrophotometer. vi. Estimation of amount of calcium in given sample by gravimetric method. vii. Estimation of amount of nickel in given sample by gravimetric method. viii. Estimation amount of zinc present in given sample by gravimetric method. ix. Estimation of iron by colorimetric / spectrophotometry method. x. Estimation of barium by complexometric titration method. xi. Estimation of manganese in presence of iron by complexometric titration method.	40
2. Semi-micro qualitative analysis of cation and anion in a given inorganic mixture: (Any four mixture) Mixture containing total six cations and/or anions. **Cations :** Pb^{2+}, Cu^{2+}, Cd^{2+}, Sn^{2+}, Fe^{2+}, Fe^{3+}, Al^{3+}, Cr^{3+}, Zn^{2+}, Mn^{2+}, Ni^{2+}, Co^{2+}, Ba^{2+}, Sr^{2+}, Ca^{2+}, Mg^{2+}, $(NH_4)^{+}$, K^{+} **Anions:** Cl^{-}, Br^{-}, I^{-}, NO_2^{-}, NO_3^{-}, SO_3^{2-}, CO_3^{2-}, SO_4^{2-}, PO_4^{3-}, S^{2-}	20
Pedagogy	Students will be given pre-lab and post-lab assignments on theoretical

	aspects of laboratory experiments prior to the conduct of each experiment. Exams will be in the form of ISA, SEA which will involve performing given experiments and conduct of viva, systematic reporting of experiments, results and observations in laboratory report. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	9. G. Brauer, *Handbook of Preparative Inorganic Chemistry*, Vol. 1 & 2, 1963. 10. G. Pass & H. Sutcliffe, *Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods,* 2nd Ed.; Chapman & Hall, 1974. 11. S. De Meo, *J. Chem. Ed*., Vol 80, Pg.No.796-798, 2003. 12. W. L. Jolly, *The Synthesis & Characterization of Inorganic Compounds*, Prentice-Hall, INC, 1970. 13. A. J. Elias, *General Chemistry Experiments*, Revised Ed.; University Press, 2008. 14. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, *Vogel's Text Book of Quantitative Chemical Analysis*,6th Ed.; Pearson, 2002. 15. G. Svehla, *Vogel's Text Book of Qualitative Inorganic Analysis*, 7th Ed, Pearson, 2011. 8. G. Marr & B. W. Rockett, *Practical Inorganic Chemistry*, Van Nostrand Reinhold Company, London, 1972.

Programme: **M.Sc. Part-I (Chemistry)**

Course Code: **CHOC-411**

Title of the course: **Fundamentals of Organic Chemistry**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objective:	1. To study the various concepts based on molecular orbital theory. 2. To understand the concepts of topicity, prostereoisomerism and chemo-, regio- and stereoselectivity in organic reactions. 3. To understand the mechanistic aspects of various type of reactions in organic synthesis.
Course Outcome:	1. Students will be in a position to evaluate the effect of delocalization of electrons & presence or absence of aromaticity in organic compounds. 2. Students will be able to apply various concepts in stereochemistry to understand stereochemical outcome in a reaction. 3. Students shall be in a position to understand/propose plausible mechanism of organic reactions.

Content	*Hrs*
1.Molecular orbitals and delocalized chemical bonding a. Qualitative description of molecular orbitals of simple acyclic and monocyclic systems, frontier molecular orbitals. b.Conjugation, cross conjugation, resonance, hyperconjugation and tautomerism (types and examples). c. Aromaticity: Origin of Huckel's rule, examples of aromatic, non-aromatic and antiaromatic compounds; concept of Mobius aromaticity.	08
2.Structure & Reactivity a. Acidity, basicity and pKa of organic compounds; Acid and base strengths; HSAB concept & Factors affecting it, effect of structure & medium on acid and base strength. b. Concept of superacids and superbases. c. Electrophilicity&nucleophilicity, examples of ambident nucleophiles & electrophiles. (Including revision of aromatic electrophilic and nucleophilic substitution)	08
3.Stereochemistry a. Brief revision of configurational nomenclature: R & S; D & L; E & Z; cis & trans and *syn*&*anti* nomenclature. Chirality in molecules with two and more chiral centres. b. Conformational analysis of open chain compounds (Butane, 2, 3-butane diol, 2,3-dibromobutane etc.). *Erythro*and *threo*nomenclature. c. Topicity and Prostereoisomerism: Topicity of ligands and faces-homotopic, enantiotopic and Cram's rule /diastereotopic ligands and faces. d. Introduction to chemoselective, regioselective and stereoselective reactions. e. Stereochemistry of *cis*- and *trans*-decalins, conformation and reactivity of	14

cyclohexane and substituted cyclohexanes, cyclohexene / cyclohexanone. conformational isomerism and analysis in acyclic and simple cyclic systems – substituted ethanes, cyclopentane, cyclohexane cycloheptane, cyclooctane and decalins, f. optical isomerism - optical activity - molecular dissymmetry and chirality - elements of symmetry. optical isomerism in biphenyls, allenes and spirans - optical isomerism of nitrogenous compounds racemisation and resolution.	
4.Reaction Mechanism a. Brief revision of carbocations, carbanions, free radicals, carbenes, Arynes and nitrenes with reference to generation, structure, stability and reactivity; b. Types of mechanisms, types of reactions, thermodynamic and kinetic control. c. The Hammond postulate and principle of microscopic reversibility, d. Methods of determining reaction mechanisms like- i. Identification of products, ii. Determination of the presence of intermediates (isolation, detection, trappingandaddition of suspected intermediate, iii. Isotopic labelling, iv. Stereochemical evidence, v. Kinetic evidence and vi. Isotope effect (at least two reactions to exemplify each method be studied)	08
5.Aliphatic Nucleophilic substitution a. Brief revision of nucleophilic substitutions with respect to Mechanism, various factors affecting such reactions; b. The Neighbouring Group Participation (NGP)/ Anchimeric assistance: General approach to various NGP processes; NGP by unshared/lone pair of electrons; NGP by π-electrons; NGP by aromatic rings (formation of phenonium ion intermediate); NGP by sigma bonds with special reference to bornyl and nor-bornyl system (formation of nonclassical carbocation)	08
6.Elimination reactions a. The E2, E1 and E1cB mechanisms. Orientation of the double bond, Saytzeff and Hofmann rule. b. Effects of changes in the substrate, base, leaving group and medium on i. Overall reactivity, ii. E1 vs. E2 vs. E1cB iii. Elimination vs substitution, Mechanism and orientation in pyrolytic *syn* elimination (various examples involving cyclic and acyclic substrates to be studied).	08
7. Selective reagents for Organic transformation a. Oxidation of organic compounds, PCC, PDC and MnO_2, ozonolysis, peracids. b. Reduction of organic compounds: $NaBH_4$, LAH, DIBAL reduction and reduction with borane and dialkylboranes. Clemmensen reduction, Birch reduction and Wolff-Kishner reduction	06

Pedagogy	Mainly lectures and tutorials. Seminars/term papers/assignments/presentations/ self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. W. Caruthers, I. Coldham, *Modern Methods of Organic Synthesis*, Cambridge University Press, 4th Ed., 2016. 2. M. B. Smith, *Organic Synthesis*, McGraw–HILL, New York, International Edition, 1994. 3. J. Clayden, N. Greeves, S. Warren, P. Wothers, *Organic Chemistry*, Oxford University Press, 2nd Ed., 2012. 4. R. Bruckner, *Advanced Organic Chemistry – Reaction Mechanisms*, San Diego, CA: Harcourt /Academic Press, San Diego, 2002. 5. J. Fuhrhop, G. Penxlin, *Organic Synthesis – Concepts, Methods, Starting Materials*, VCH Publishers Inc., New York, 1994. 6. H. O. House, *Modern Synthetic Reactions*, W. A. Benjamin, 2nd Ed.,1965 7. M. Nogradi, Stereoselective Synthesis, VCH Publishers, Inc., Revised and Enlarged Edition, 1994. 8. F. A. Carey, R. J. Sundberg, *Advanced Organic Chemistry*, Springer India Private Limited, 5th Ed, 2007. 9. T. Laue, A. Plagens, *Named Organic Reactions*, John Wiley and Sons, Inc., 2005.

Programme: **M.Sc. Part-I (Organic Chemistry)**

Course Code: **CHOC-412**

Title of the course: **Organic Spectroscopy**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied Organic chemistry courses at M.Sc. Chemistry in semester I
Course Objective:	1. To study various theoretical concepts related to organic spectroscopic techniques. 2. To understand the introductory aspects of commonly used 2D NMR techniques. 3. To learn interpretational aspects of spectral data pertaining to UV, IR, PMR, CMR and MS.
Course Outcome:	1. Students will be in a position to understand how spectral techniques can be used in structure elucidation. 2. Students will be able to deduce structures of simple to moderately complex molecules by combining the spectral data obtained using two or more spectral techniques. 3. Students will be in a position to apply various concepts in organic spectroscopy (PMR, CMR, MS and 2D NMR) and analyse/ predict PMR, CMR, MS and 2D NMR spectral data based on given structures of simple molecules.

Content	*Hrs*
1. UV-Visible Spectroscopy a. Introduction. Electronic transition and energy levels, the absorption laws. b. Measurement of the spectrum, chromophores, Effect of solvent, Conjugation on UV-spectra. c. Study of Tautomerism, Steric effect and geometrical isomerism in UV spectra. d. Woodward-Fieser rule for conjugated dienes and carbonyl compounds.	04
2. **Infrared Spectroscopy** a. IR spectroscopy in structural elucidation of organic compounds (various functional classes to be considered). b. Methods in IR-Spectroscopy, effect of hydrogen bonding and solvent effect on vibrational frequencies, overtones, combination and Fermi resonance bands. c. Factors influencing vibrational frequencies. d. Characteristic frequencies of organic molecules. e. Interpretation of spectra.	08
3. **NMR Spectroscopy** a. Principles of NMR. b. Instrumentation. c. Chemical shift- (revision of the basic concepts) d. Interpretation of PMR spectra. i.Coupling constants and AB, A_2B_2/A_2X_2, AMX and ABX spin systems. ii. Double resonance and decoupling	14

iii. Nuclear Overhauser Effect and its applications. iv. NMR Shift reagents v. Determination of Absolute and Relative configuration	
3. ^{13}C –NMR spectroscopy a. Introductionto ^{13}C –NMR spectroscopy. b. ^{13}C- chemical shifts effects (α-, ß-, γ-, δ-substituent effects, π-conjugation, heavy atom effect and ring size effects) c. Proton coupled and proton decoupled 13Cspectra. d. Off- resonance decoupling, APT & DEPT techniques.	8
4. ^{19}F- NMR and ^{31}P- NMR spectroscopy Principles and applications; heteronuclear coupling of carbon to ^{19}F and ^{31}P.	6
5. Two-dimensional NMR spectroscopy Introduction to 2D NMR techniques and interpretation ofspectra of simple organic compounds using following 2d-NMR techniques-COSY, NOESY, HSQC, HMQC, HMBC, TOCSY and INADEQUATE	8
6. Mass spectrometry a. Ionization Methods, Mass Analysis, Even and odd electron ions and fragmentation modes. b. Molecular Formulae Index (D.B.E), Molecular ion peak, base peak, metastable ions, Nitrogen rule, effect of isotopes. c.Prediction of molecular formulae based on relative abundance. Rules for fragmentation, McLafferty rearrangement, retro-Diels-Alder fragmentation, fragmentation associated with functional groups; rearrangement and mass spectra of some chemical classes. **Note: Problems involving combined use of different type of spectra, in line with course objective/ learning outcome are to be emphasized.**	12
Pedagogy	Mainly lectures and tutorials. Seminars/term papers/assignments/presentations/self-study or a combination of some of these can be used. ICT mode should be preferred. Sessions should be interactive to enable peer group learning.
Text Books/ References / Readings	1. P.S. Kalsi, *Spectroscopy of Organic compounds*, New Age International Pub. Ltd. & Wiley Eastern Ltd., 2nd Ed., 1995. 2. R.M. Silverstein, F. X. Webster, D.Kiemle, D. Bryce, S.Samant, V. S. Nadkarni,*Spectrometric Identification of Organic compounds*, An Indian Adaptation John Wiley & Sons Inc., 8th Ed., 2022. 3. D. L. Pavia, G. M. Lampman, G. S. Kriz, J. R. Vyvyan, *Introduction to Spectroscopy*, Brooks Cole, 5th Ed., 2015. 4. R.M. Silverstein, F. X. Webster, *Spectrometric Identification of Organic compounds*, John Wiley & Sons Inc., 7th Ed. (reprint), 2011. 5. V.M. Parikh, *Absorption Spectroscopy of Organic Molecules*, Addison Wesley Longman Publishing Co., 1974. 6. D.H Williams & I. Fleming, *Spectroscopic Methods in Organic Chemistry*, Tata Mcgraw Hill Education, 6th Ed., 2011. 7. W. Kemp, *Organic Spectroscopy*, Palgrave Macmillan, 3rd Ed., 1991. 8. W. Kemp, *NMR in Chemistry: A Multinuclear Introduction*, Macmillan,

	1986. 9. J. R. Dyer, *Applications of Absorption Spectroscopy of Organic compounds*, Prentice Hall of India, 1987. 10. L. D. Field, H. L. Li., A. M. Magill, *Organic Structures from 2D NMR Spectra*, Wiley, 2015.

Programme: **M.Sc. Part-I (Chemistry)**

Course Code: **CHOC-413**

Title of the course: **Pericyclic and Organic Photochemical Reactions**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied organic chemistry courses at M.Sc. Chemistry in semester I
Course Objective:	1. To introduce various concepts in pericyclic chemistry based on molecular orbital theory and apply for solving pericyclic reactions 2. To introduce analysis of pericyclic reactions using theoretical concepts. 3. To learn mechanistic aspects of pericyclic & photochemical reactions in organic synthesis.
Course Outcome:	1. Students will be in a position to predict course of a given pericyclic reaction using the theoretical concepts. 2. Students will be able to applyknowledge of stereochemical output in a reaction. 3. Students will be able to understand and propose plausible mechanism of pericyclic/photochemical reactions.

Content	*Hrs*
1. Pericyclic Reactions a. Theory of pericyclic reactions i. Frontier Molecular Orbital (FMO) theory ii. Transition state aromaticity (Mobius-Huckel theory) concept iii. Orbital correlation diagram method. b. Analysis of pericyclic reactions (including stereochemistry) using the above concepts i. Cycloaddition reactions ii. Electrocyclic reactions iii.Sigmatropic rearrangements under thermal and photochemical conditions (Note: Various important features to be discussed taking examples important reactions of each type) c. Some synthetically useful reactions (examples via theory of pericyclic reaction). d. Diels–Alder and retro Diels-Alder reaction: Regiochemistry, stereochemistry and intramolecular reactions. e. 1, 3-dipolar additions f. [3, 3]-Shifts; Claisen and Cope, aza-Cope-, oxy-Cope rearrangements and fluxional molecules, variants of Claisen Rearrangement such as Johnson-Claisen, Eschenmoser-Claisen, Carroll- Claisen and Ireland-Claisen. g. [2,3]-Sigmatropic rearrangements such as Sommelet-Hauser rearrangement, Sulfonium ylide rearrangement, Meisenheimer rearrangement, Wittig rearrangement, Mislow-Evans rearrangement h. Ene reaction, hetero-ene, retro-ene reactions i. [1,5]-Thermal and [1,7]-photochemical sigmatropic hydrogen shifts	34

2. Organic Photochemistry a. Interaction of electromagnetic radiation with matter, laws of photochemistry; fateof excited molecule; principles of energy transfer, types of photochemical reactions. Theoretical concepts in organic photochemistry w. r. t. cycloadditions, Electrocyclicreactions and sigmatropic reactions b. Photochemical reactions of alkenes, dienes, carbonyl compounds and arenes including the following- geometrical isomerisation: *Cis-trans* isomerization andphotostationary equilibrium; Paterno-Buchi reaction; Norrish Type cleavages; Di-pimethane rearrangement; bicycle rearrangement c. Photochemistry of aromatic compounds: valance isomerization; photostationary state of benzene and azabenzenes. [4+4]-photodimerization ofderivatives of naphthalenes. cycloaddition reaction of benzene, naphthalene, pyrrole and indoles with alkenes and alkynes d.Reactions involving singlet and triplet oxygen: Photooxygenation reactions, examples of [2+2] and [4+2]-cycloaddition reaction with isocyclic, heterocyclic, dienes and polynuclear aromatic compounds e. Applications of Organic Photochemistry: Photochemical Reactions as Key Steps in Natural Product Synthesis (any four examples); example of photopolymerization; photochemical functionalization at unactivated carbon: Barton reaction, the hypohalite reaction and the Hofmann-Loffler-Freytag reaction	26
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/References / Readings	1. N. Turro, V. Ramamurthy, J.C. Scaiano, *Modern Molecular Photochemistry of Organic molecules* , University Science Books, 2010. 2. B. Dinda, *Essentials of Pericyclic and Photochemical Reactions*, Springer, 1st Ed. 2017. 3. S.Kumar, V. Kumar, S.P. Singh, *Pericyclic Reactions: A Mechanistic and Problem-Solving Approach*, Elsevier, 2016. 4. R. E. Lehr., A. P. Marchand, *Orbital Symmetry: A Problem Solving Approach*, Academic Press, 1972. 5. R. B. Woodward, R. Hoffmann, *Conservation of Orbital Symmetry*, Verlag chemie, Academic Press, NY, 1972. 6. I. Fleming, *Frontier Orbitals and Organic Chemical Reactions*, John Wiley & Sons, 1st Ed., 1991 7. T. L. Gilchrist, R. C. Storr, *Pericyclic Reactions*, Cambridge Univ. Press, 1972. 8. F. A. Carrey, R. J. Sundberg , *Advanced Organic Chemistry* Part A and B, Pelnum Pub., 3rd Ed. 1990. 9. T. Lowery, K. Richardson, *Mechanisms and Theory in Organic Chemistry*, Harper and Row Pub., NY, 3rd Ed., 1987. 10. C. H. DePay, *Molecular Reactions and Photochemistry*, Prentice Hall (I)

	Ltd, NewDelhi. 11. J. Kopecky, *Organic Photochemistry- A Visual Approach*, VCH Pub., 1992.

Programme: **M.Sc. Part-I (Chemistry)**

Course Code: **CHOC-414**

Title of the course: **Synthetic Methodologies in Organic Chemistry**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied organic chemistry courses at M.Sc. Chemistry in semester I
Course Objective:	1. To study various concepts related to carbon-carbon bond formation. 2. To understand designing of organic synthesis to make molecules of interest. 3. To plan total synthesis based on protection-deprotection strategy.
Course Outcome:	1. Students will be in a position to explain how a carbon-carbon bond can be constructed along with the selectivity in bond formations. 2. Students will be able to apply knowledge of various reactions in constructions of simple to complex organic molecules. 3. Students will be in a position to design protecting group strategies for synthesis of organic molecules.

Content	*Hrs*
1. Chemistry of enols and enolates a. Keto-enol tautomerism; Introduction, acidity, basicity concepts &pKa scale, neutral nitrogen and oxygen bases. Formation of enols by proton transfer, mechanism of enolization by acids & bases, types of enols & enolates, kinetically & thermodynamically stable enols, consequences of enolization, stable enolate equivalents, preparation and reactions of enol ethers. b. Formation of Enolates; Introduction, preparation & properties, non-nucleophilic bases, E / Z geometry in enolate formation, kinetic vs. thermodynamic control, other methods for the generation of enolates, issue of enolate ambidoselectivity. c.Alkylation of enolates; diverse reactivity of carbonyl groups, alkylation involving nitriles and nitroalkanes, choice of electrophile for alkylation, lithium enolates of carbonyl compounds and alkylation, specific enol equivalents to alkylate aldehydes and ketones, alkylation of β-dicarbonyl compounds, problem of regioselectivity during ketone alkylation and the remedy provided by enones. d. Reaction of enolates with aldehydes and ketones; Introduction, aldol reaction including cross & intramolecular version, enolisable substrates which are not electrophilic in nature, controlling aldol reactions with specific enol equivalents, specific enol equivalents for carboxylic acids, aldehydes and ketones. e.Acylation at carbon; Introduction, the Claisen ester condensation (intramolecular and inter / crossed), acylation of enolates by esters, preparation of keto-esters by the Claisen reaction, directed C-acylation of enols and enolates & acylation of enamines. f. Conjugate addition of enolates; Introduction, thermodynamic control vs. conjugate addition, utility of various electrophilic alkenes in conjugate	22

addition, formation of six-membered rings via conjugate addition and nitroalkanes as versatile synthons. g. Examples pertaining to the application of following condensation reactions in organic synthesis; Mukaiyama reaction, Perkin reaction, Dieckmann condensation, Michael addition, Robinson annulation, Sakurai reaction, Knoevenagel Reaction, Darzen, Stobbe, Benzoin, Pechmann condensation.	
2. Synthetic utility of important name reactions / methodology a. Mannich Reaction, Nef Reaction, Mitsunobu and Appel Reaction, Baylis Hillman reaction, Mc. Murry coupling, vicarious nucleophilic substitution, Steglich and Yamaguchi esterification. b. Ring closing and cross metathesis; Grubb's various generation, Grubbs-Hoveyda, Schrock catalysts.	8
3. The Ylides in Organic Synthesis a. Phosphorus Ylides; Nomenclature and Preparation. Wittig olefination: mechanism, stereoselectivity, cis- and trans selective reactions, Wittig reagents derived from α-halo carbonyl compounds. b. Modified Wittig, Horner – Wadsworth – Emmons, Stille-Gennari modification with achiral and chiral substrates, Peterson reaction, Julia Olefination. c. Sulfur Ylides; Sulfonium &sulfoxonium ylides in synthesis, diphenylcyclopropyl sulfonium ylides & their reactions with carbonyl compounds / Michael acceptors	8
4. Protecting Groups in Organic Synthesis a. Introduction and effective use of protecting groups, umpolung of reactivity. b. Common protective groups namely acetals & ketals, dithio acetal/ketals, trialkylsilyl, TBDMS, THP, MOM, MEM, SEM & benzyl ether, methyl ether, benzyl amine, Cbz, *t*-Boc, Fmoc, *t*-butyl ester and methods for deprotection. Some examples of multistep synthesis using protection-deprotection procedures.	6
5. Asymmetric Synthesis a. Chiral pool (chiron approach). b. Chiral auxiliary approach; Oxazolidinone & norephedrine-derived chiral auxiliary controlled Diels-Alder reaction and alkylation of chiral enolates and aldol reaction, Alkylation using SAMP and RAMP. c. Chiral Reagents - Use of (-)-sparteine. d. Asymmetric catalysis; CBS catalyst, Ruthenium catalyzed chiral reductions of ketones, Catalytic asymmetric hydrogenation of alkenes, Asymmetric epoxidation (Sharpless and Jacobson), Sharpless asymmetric dihydroxylation reaction, Organocatalyzed aldol reaction (Use of proline).	12
6. Halogenation and esterification reactions a. Formation of Carbon Halogen bonds; Substitution in saturated compounds,	4

	alcohols, carbonyl compounds, substitution at allylic and benzylic compounds, bromodecarboxylation (Hunsdiecker reaction), Finkelstein reaction, iodolactonisation. b. Acid and base catalyzed esterification and hydrolysis.	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
Text Books/ References / Readings	1. W. Caruthers, I. Coldham, *Modern Methods of Organic Synthesis*, Cambridge University Press, 4th Ed, 2016. 2. M. B. Smith, *Organic Synthesis*, McGraw–HILL, New York, International Edition, 1994. 3. J. Clayden, N. Greeves, S. Warren, P. Wothers, *Organic Chemistry*, Oxford University Press, 2nd edition, 2012. 4. R. Bruckner, *Advanced Organic Chemistry – Reaction Mechanisms*, San Diego, CA: Harcourt /Academic Press, San Diego, 2002. 5. J. Fuhrhop, G. Penxlin, *Organic Synthesis – Concepts, Methods, Starting Materials*, VCH Publishers Inc., New York, 1994. 6. H. O. House, *Modern Synthetic Reactions*, W. A. Benjamin, 1965, 2nd Ed. (revised with corrections). 7. M. Nogradi, *Stereoselective Synthesis*, VCH Publishers, Inc., Revised and Enlarged Edition, 1994. 8. F. A. Carey, R. J. Sundberg, *Advanced Organic Chemistry*, Springer India Private Limited, 5th Ed, 2007. 9. T. Laue, A. Plagens, *Named Organic Reactions*, John Wiley and Sons, Inc., 2005.	

Programme: **M.Sc. Part-I (Chemistry)**

Course Code: **CHOC-415**

Title of the course: **Stereochemistry and Organic Transformations**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied organic chemistry courses at M.Sc. Chemistry in semester I
Course Objective:	1. To study various principles of stereochemistry 2. To understand the importance of chirality in organic syntheses 3.To learn stereoselective reactions and toplan oxidation, reduction reactions
Course Outcome:	1.Students will be in a position to explainstereochemistry and organic transformations 2.Students will be in a position to apply knowledge of various reactions in functional group manipulations. 3. Students will be in a position to apply stereoselective reactions for thesynthesis of chiral organic molecules

Content	*Hrs*
1. Stereochemistry a. Stereoselectivity in cyclic compounds: Introduction,stereochemical control in six membered rings, reactions on small rings, regiochemical control in cyclohexene epoxides, Stereoselectivity in bicyclic compounds b. Conformations, stability and reactivity of fused ring compounds: Fused bicyclic systems with small and medium rings: cis- and trans- decalones and decalols, Octahydronaphthalins (octalins), Bicyclo [4.3.0] nonane (cis- and trans-hydrindanes) c. Fused polycyclic systems: Perhydrophenanthrenes, Perhydroanthracenes, Perhydrocyclopentenophenanthrene system (steroids, triterpenoids and hormones). Conformations and reactivity towards esterification, hydrolysis, chromium trioxide oxidation, ionic additions of halogen (X_2) to double bonds, formation and opening of epoxide ring, epoxidation by peroxy acids. d. Spirocyclic compounds e. Reactions with cyclic intermediates or cyclic transition state f. Stereoisomerism due to axial chirality, planar chirality and helicity. g. Stereochemistry and configurational (*R/S*) nomenclature in appropriately substituted allenes, alkylidenecycloalkenes, spiranes, adamantoids, biaryls, trans-cycloalkenes, cyclophanes and ansa compounds. h. Atropisomerism in biphenyls and bridged biphenyls	20
2. Conformation of bridged ring compounds a. Bicyclo [2.2.1] heptane (norbornane): Geometry and topic relationship of hydrogens, solvolysis of bicycle [2.2.1]heptyl systems, formation, stability and reactivity of norbornylcation, relative stability and the rate of formation of endo and exo isomers in both bornane and norbornane systems.	10

b. Bicyclo [2.2.2] octane system: Geometry and topic relationship of hydrogens, solvolysis of bicycle [2.2.2]octyl system. c. Other bridged ring systems: starting from bicycle [1.1.1]pentane to bicycle [3.3.3] undecane d. Bicyclo system with heteroatom: the relative stabilities of tropine, pseudotropine and benzoyl derivatives of norpseudotropine.	
3. Dynamic Stereochemistry: Stereoselective Reactions a. Stereoselectivity: classification, terminology and principle. Selectivity in chemistry– substrate and product selectivity. b. Stereoselective reaction of cyclic compounds: Introduction, reactions of four, five and six-membered rings. Conformational control in the formation of six-membered ring. c. Diastereoselectivity: Introduction, making single diastereoisomers using stereospecific reactions of alkenes. d. 1,2-Addition to carbonyl compounds: Predicting various addition outcomes using different predictive models such as, Cram Chelate, Cornforth, Felkin-Anh. Specific reactions: allylation/crotylation by Brown, Roush, BINOL catalyzed. e. Stereoselective reaction of acyclic alkenes: The Houk model	14
4. Oxidation and reduction reactions a. Oxidation reactions: Oxidation of organic compounds using Oppenauer oxidation, Swern oxidation. Other methods of oxidation such as selenium dioxide, $Pb(OAc)_4$, HIO_4, OsO_4, RuO_4, DMSO (Swern) sodium bromate / CAN &NaOCl, DDQ, Prevost's reagent and Woodward Conditions; Catalytic oxidation over Pt, Photosensitised oxidation of alkenes, oxidation with molecular oxygen, aromatization, silver based reagents. b. Reduction reactions: Reduction of organic compounds using hydride-transfer reagents and related reactions: MPV reduction, Trialkylborohydrides, LAH, mixed LAH-$AlCl_3$ reagents, enzymatic reduction involving liver alcohol dehydrogenase/NADH & Bakers' yeast, catalytic hydrogenation, dissolving metal reductions including acyloin condensation, other methods of reduction: Raney Ni desulphurisation, di-imide.	16
Pedagogy	Lectures & tutorials. Seminars / assignments / presentations / self-study or a combination of some of these could also be used to some extent. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. M. B. Smith, J. March, *Advanced Organic Chemistry- 50 Reaction, Mechanism and Structure*, Wiley, 2006, 6th Ed. 2. D. Nasipuri, *Stereochemistry of Organic compounds, Principles and applications*, New Age International Pvt. Ltd., 1994, 2nd Ed. 3. E.L. Eliel, *Stereochemistry of Carbon Compound*, Tata McGraw Hill, 1975. 4. W. Caruthers, I. Colddham, *Modern Methods of Organic Synthesis*, Cambridge University Press, 2016, 4th Ed.

	5. J. Clayden, N. Greeves, S. Warren, Oxford, 2016. 6. I. L. Finar, *Stereochemistry and the Chemistry of Natural Products*, ELBS, Vol. 2, Longman Edn, 1975. 5th Ed. 7. E.S. Gould, *Mechanism and Structure in Organic Chemistry*, Holt, Reinhart and Winston, 1965. 8. F. A. Carey, R. J. Sundberg, *Advanced Organic Chemistry: Part A and B*, Springer India Private Limited, 2007, 5th Ed. 9. R. O. Norman J, M. Coxon, *Principles of Organic Syntheses*, CRC Press Inc, 1993, 3rd Ed. 10. V.M. Potapov, A. Beknazarov, *Stereochemistry*, Central Books Ltd., 1980. 11. D. G. Morris, *Stereochemistry*, Wiley-RSC, 2002, 1st Ed. 12. Clayden, Greeves, Warren, Wothers, *Organic Chemistry*, Oxford University Press, 2002, 2nd Ed. 13. M. Nogradi, *Stereoselective Synthesis*, VCH Publishers, Inc., 1994, Revised and Enlarged Ed.

Programme: **M. Sc. Part-I (Chemistry)**

Course Code: **CHOE-411**

Title of the Course: **Practical Course in Organic Chemistry-I**

Number of Credits: **02** Total Hours:**60** Effective from AY: **2022-23**

Prerequisites for the course	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objective:	To translate certain theoretical concepts learnt earlier into experimental knowledge by providing hands on experience of basic laboratory techniques required for organic syntheses.
Course Outcome	1. Students will be in a position to understand stoichiometric requirements during organic syntheses. 2. Students will be in a position to understand Safe and good laboratory practices, handling laboratory glassware, equipment and chemical reagents. 3. Students will be in a position to apply the practical knowledge to perform experiments involving common laboratory techniques like reflux, distillation, steam distillation, vacuum distillation, aqueous extraction, thin layer chromatography (TLC) etc.

Content	*Hrs*
Minimum 13 experiments from the list shall be conducted.	
1. Introduction to laboratory equipments, apparatus and safety a. Use of common laboratory equipments like fume hoods, vacuum pumps, weighing balance etc. to be explained to the students. b. Introduction to various types of quick fit joints and apparatus to the students. c. Discussion of Safety Techniques: i) Disposal of chemicals ii) Usage of protective equipment's iii) First aid iv) Fire extinguishers, types of fire v) Hazards of chemicals and risk assessment	04
2. Laboratory Techniques a. Simple distillation (any one): i. Toluene-dichloromethane mixture using water condenser. ii. Nitrobenzene and aniline using air condenser. b. Steam distillation (anyone): i. Separation of *o*- and *p*- nitrophenols. ii. Naphthalene from its suspension in water, iii. Clove oil from cloves. c. Crystallisation: Concept of induction of crystallization (any one) i. Crystallisation of phthalic acid from hot water using fluted filter paper and stemless funnel. ii. Acetanilide from boiling water iii. Naphthalene from ethanol. iv. Decolorisation and crystallization of brown sugar (sucrose) with animal charcoal	24

using gravity filtration. d. Sublimation: Simple or vacuum sublimation of camphor, naphthalene, anthracene or succinic acid (any one). e. Vacuum distillation (any one): o-dichlorobenzene, diphenyl ether. Also use of nomograph should be explained. f. Thin layer Chromatography (any one): i. Separation of *o* and *p*-nitroanilines. ii. Separation of analgesic drugs iii. Separation of *o* and *p*-nitrophenols,		
3. Organic synthesis (Any Seven experiments) a. Aliphatic electrophilic substitution: Preparation of iodoform from ethanol & acetone. b. Aromatic electrophilic substitution (anyone): i. Preparation of *p*-bromoacetanilide. ii. Bromination of acetophenone to phenacyl bromide iii. Nitration of napththalene to 1-nitronaphthalene iv. Nitration of benzaldehyde to 3-nitrobenzaldehdye. c. Oxidation (any one) i. Benzoic acid from toluene. ii. Cyclohexanone from cyclohexanol. iii) Isoborneol to camphor using Jones reagent. d. Reduction (any one) i. Reduction of *o*-nitroaniline to *o*-phenylenediamine using Sn/HCl ii. Reduction of *p*-nitro benzaldehyde to *p*-nitrobenzyl alcohol using $NaBH_4$. e. Bromination of an alcohol using CBr_4/ triphenylphosphine. f. Grignard reaction: Triphenylmethanol from benzoic acid ester or benzophenone. g. Aldol condensation: Dibenzal acetone from benzaldehyde h. Acetoacetic ester condensation: Preparation of ethyl *n*-butylacetoacetate or ethyl acetoacetate. i. Cannizzaro reaction using 4-chlorobenzaldehyde as substrate. j. Friedel Craft's reaction (any one): i. using toluene and succinic anhydride ii. Resorcinol to resacetophenone, benzene and maleic anhydride to *β*-benzoylacrylic acid k. Solvent free preparation of coumarin by the Knoevenagel condensation under MW irradiation. l. Preparation of oxidizing agent (any one): Pyridinium chlorochromate-silica, pyridinium chlorochromate-alumina, MnO_2. m. Preparation of cuprous chloride.		24
4. **Isolation from natural sources (Any two)** i. Caffeine from tea powder. ii. Piperine from pepper. iii. Cinnamaldehyde from cinnamon iv. Lemongrass oil from lemongrass		8
Pedagogy:	Students should be given suitable pre- and post-lab assignments and explanation revising the theoretical aspects of laboratory	

	experiments prior to the conduct of each experiment. Each of the experiments should be done individually by the students.	
References/Readings	1. A.I. Vogel, A., R. Tatchell , B. S. Furniss, A.J. Hannaford, *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Prentice Hall; 2011. 2. D. Pasto, C. Johnson and M. Miller, *Experiments and Techniques in Organic Chemistry*, 1st Ed., Prentice Hall, 1991. 3. L.F. Fieser, K.L. Williamson,*Organic Experiments*, 7th edition D. C. Heath, 1992. 4. K.L. Williamson, K.M. Masters, *Macroscale and Microscale Organic Experiments*, 6th Edition, Cengage Learning, 2010 5. R.K. Bansal, *Laboratory Manual in Organic Chemistry*, New Age International, 5th Edition, 2016. 6. S. Delvin, *Green Chemistry*, Sarup& Sons, 2005. 7. O.R. Rodig, C.E. Bell Jr. and A.K. Clark, *Organic Chemistry Laboratory Standard and Microscale Experiments*, Saunders College Publishing, 3rd edition, 2009. 8. J. Mohan, *Organic Analytical Chemistry*, Narosa Publishing House, 2014.	

Programme: **M. Sc. Part-I (Chemistry)**

Course Code: **CHOE-412**

Title of the Course: **Practical Course in Organic Chemistry-II**

Number of Credits: **02** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objective:	To translate certain theoretical concepts learnt earlier into experimental knowledge by providing hands on experience of basic laboratory techniques required for organic syntheses.
Course Outcome	1. Students will be in a position to adopt Safe and good laboratory practices, handling laboratory glassware, equipment and chemical reagents. 2. Students will be in a position to understand and calculate stoichiometric requirements during organic syntheses. 3. Students will be in a position to perform common laboratory techniques including reflux, distillation, vacuum distillation, aqueous extraction, thin layer chromatography (TLC).

Content	*Hrs*
Minimum 13 experiments from the list shall be conducted.	
1. Introduction to laboratory equipments, apparatus and safety a. Common Hazards in Chemical Laboratory, Risk assessment b. Accidents and Emergency procedures	04
2. Laboratory Techniques (Any Two) a. Simple distillation i. Simple distillation of thionyl chloride under anhydrous condition ii. Simple distillation under Nitrogen atmosphere b. Fractional distillation i. Chloroform-dichloromethane mixture using water condenser. ii. Toluene and cyclohexane by fractionating column. c. Vacuum distillation under inert atmosphere Dry Distillation of DMF, *o*-dichlorobenzene, $POCl_3$ d. Thin layer Chromatography i. Purification and isolation of mixture of acids by using Preparative TLC. ii. Purification and isolation of mixture of phenols by using Preparative TLC. iii. Purification and isolation of pharmaceutical drugs using Preparative TLC.	08
3. Organic Synthesis (Any Four) a. *p*-Iodonitrobenzene by Sandmeyer reaction b. Pinacol- Pinacolone rearrangement c. Hydrogenation of Maleic acid (Hydrogen balloon) d. Preparation of nitrostyrene from aldehyde e. Preparation of α,β-dibromocinnamic acid f. Reduction of nitro compounds g. Synthesis of Urea from ammonium cyanate	16
3. Solvent Free Organic synthesis (Any Two) a. Reduction using ball milling technique	08

b. Oxidation of 2° alcohol using $KMnO_4$/Alumina by grinding technique. c. Synthesis of (±)-Binol from β-naphthol d. Hunsdiecker reaction of cinnamic acid derivatives e. Beckmann rearrangement of oxime derivatives	
4. Two-step Organic Synthesis (Any Two) a. Benzamide-Benzoic acid-Ethyl Benzoate b. Phthalic anhydride – Phthalimide – Anthranilic acid. c. Methyl benzoate- *m*-nitrobenzoate- *m*-nitrobenzoic acid d. Chlorobenzene – 2, 4 – dinitrochlorobenzene – 2,4-dinitrophenol e. Acetanilide – *p*–Bromo acetanilide – *p*–Bromoaniline f. Acetophenone – Oxime – Acetanilide	16
5. **Separation, Isolation and Identification of Organic compounds (Any One)** a. Separation, purification and identification of compounds of binary mixture (Solid-Solid, Solid-liquid and Liquid-liquid) using the TLC and column chromatography, chemical tests. IR spectra to be used for functional group identification.	08
Pedagogy	Students should be given suitable pre- and post-lab assignments and explanation revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.
References /Readings	1. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Prentice Hall; 2011. 2. K. Tanaka, *Solvent-free Organic Synthesis*, Wiley-VCH, 2nd Ed., 2009 3. L. F. Fieser, K. L. Williamson "*Organic Experiments*" 7th edition D. C. Heath, 1992. 4. K. L. Williamson, K. M. Masters, *Macroscale and Microscale Organic Experiments*, 6th Edition, Cengage Learning, 2010 5. R. K. Bansal, *Laboratory Manual in Organic Chemistry*, New Age International, 5th Edition, 2016. 6. S. Delvin, *Green Chemistry*, Sarup& Sons, 2005. 7. O. R. Rodig, C. E. Bell Jr., A. K. Clark, *Organic Chemistry Laboratory Standard and Microscale Experiments*, Saunders College Publishing, 3rdedition, 2009. 8. J. Mohan, *Organic Analytical Chemistry*, Narosa Publishing House, 2014.

Programme: **M.Sc. Part-I (Chemistry)**

Course Code: **CHPC-411**

Title of the course: **General Physical Chemistry**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objective:	1. Introduction of various concepts on thermodynamics. 2. Introduction of electro chemistry and kinetics. 3. Learning quantum chemistry.
Course Outcome:	1. Students should be in a position to understand and explain various concepts in physical chemistry. 2. Students should be in a position to apply these concepts during the lab course in physical chemistry.

Content	*Hrs*
1. Mathematical Preparations a. Introduction to various functions and function plotting (exponential, logarithmic, trigonometric etc.), functions of many variables. Complex numbers and complex functions. b. Linear equations, vectors, matrices and determinants. c. Basic rules of differentiation and integration, Partial differentiation, location and characterization of critical points of a function, Regression methods, curve fitting. d. Introduction to series, convergence and divergence, power series, Fourier series e. Probability (permutations and combinations).	12
2. Quantum Chemistry a. Operators, Functions, Eigen value equations, Postulates. b. Schrodinger equation, application to simple system viz. free particle, particle in one dimensional, two dimensional and three-dimensional box (quantization, separation of variables, degenerate wave functions). c. Hydrogen like atoms, Schrodinger equation and its solutions, atomic orbital wave functions and interpretation. d. Hückel MO theory, Secular equations, Secular determinant, delocalization energy, charge density, π-bond order, free valence, applications to C_2H_4, C_3H_5 (radical), C_4H_6, C_4H_4, C_6H_6, C_6H_8.	20
3. Thermodynamics a. Thermodynamic properties: Gas laws, Real gasses, Boyle temperature, Critical temperature, State and path properties. Intensive and extensive properties. Exact and inexact differentials. Internal energy, enthalpy, entropy, free energy and their relations and significances. Maxwell relations. Thermodynamic equations of state b. Joule-Thomson effect. Joule-Thomson coefficient for van der Waals' gas. Joule-Thomson effect and production of low temperature, adiabatic demagnetization, Joule-Thompson coefficient, inversion temperature.	12

c. The third law of thermodynamics. Need for the third law. Apparent exceptions to third law. Application of third law. Use of thermodynamic functions in predicting direction of chemical change. Entropy and third law of thermodynamics. d. Phase equilibria: Phase rule, Discussion of two component systems forming solid solutions with and without maximum or minimum in freezing point curve. Systems with partially miscible solid phases. e. Three component systems: Graphical representation. Three component liquid systems with one pair of partially miscible liquids. Influence of temperature. Systems with two pairs and three pairs of partially miscible liquids. The role of added salts.	
4. Electrochemistry a. EMF series, The cell potential: The Nernst equation, Cells at equilibrium. Determination of thermodynamic functions. b. Decomposition potential and overvoltage, electronegativity, basic principles, completeness of deposition, Separation with controlled potentials, constant current electrolysis, composition of electrolyte, potential buffers, physical characteristics of metal deposits. c. Electroplating and electroless plating, electrosynthesis. d. Concepts of acid-base aqueous and non-aqueous solvents, hard and soft acid-base concept and applications.	8
5. Chemical Kinetics a. General introduction to various types of order of reaction including fractional order, Molecularity of the reaction. b. Introduction to reversible and irreversible reactions and reactions leading to equilibrium. Van't Hoffs equation and analysis of Gibbs free energy of equilibrium reactions. c. Collision Theory and Maxwell Boltzmann distribution of energies of colliding molecules (derivation not required). The concept of collisional cross section and reactive cross section and its significance. d. Comparative study of transition state and collision state theory (derivation not required). e. Reaction Mechanisms: elementary reactions, Consecutive elementary reactions, steady state approximation, the rate determining step and pre-equilibria f. Free radical reactions, Complex reactions such as acetaldehyde decomposition and reaction between H_2 and Br_2, Homogeneous reactions and acid-base catalysis. g. Elementary enzyme reactions. Lineweaver-Burk plot and its analysis	8
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References	1. P. W. Atkins and J. D. Paula, *Physical Chemistry*, 8th Ed., Oxford University Press, (2007) New Delhi. 2. G. M. Barrow, *Physical Chemistry*, 5th Ed., Tata McGraw Hill, (2016)

/ Readings	New Delhi. 3. J. E. House, *Principles of Chemical Kinetics*, 2nd Ed., Academic Press, (2007) Elsevier Burlington, USA 4. I. N. Levine, *Quantum Chemistry*, 7th Ed., Prentice-Hall, (1999) New Delhi.

Programme: **M.Sc. Part-I (Chemistry)**

Course Code: **CHPC-412**

Title of the course: **Quantum Chemistry and Statistical Thermodynamics**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied physical chemistry courses at M.Sc. Chemistry in semester I
Course Objective:	1. Introduction of various concepts of quantum chemistry. 2. To introduce various concepts of statistical thermodynamics.
Course Outcome:	1. Students should be in a position to understand and explain various concepts of quantum chemistry viz. the wave function and applications. 2. Students should be able to explain various concepts in statistical thermodynamics viz. the partition function and applications.

Content	*Hrs*
1. Quantum Chemistry a. The origin of quantum mechanics: Planck's quantum theory, wave particle duality, uncertainty principle concept of wave function, the Born interpretation of wave function. Normalization and orthogonalizations, quantization, Eigen values and Eigen functions. b. Postulates of quantum mechanics; Schrödinger equation for free particle, particle in a box, degeneracy. Quantum mechanical operators and their properties, commutation relations, Hamiltonian and Laplacian operators, Harmonic oscillators, Angular momentum, Ladder Operators. c. Approximate methods, Schrödinger equation, its importance and limitations, Born-Oppenheimer approximation, Anti-symmetric wave functions and Slater determinants (many electron system e.g. He atom), Exclusion and Aufbau principle, Variation method, Linear Variation Principle, Perturbation theory (first order non-degenerate) and their applications to simple systems. d. MO theory, Hückel MO theory, Bond-order, Charge density matrix, Unification of HMO and VB theory, their applications in spectroscopy and chemical reactivity, electron density forces and their role in chemical bonding. Hybridization and valence MOs of H_2O, NH_3 and CH_4. Application of Hückel Theory to ethylene, butadiene and benzene molecules.	34
2. Statistical Thermodynamics a. The language of statistical thermodynamics: Probability, ensemble, microstate, degeneracy, permutations and combinations. Configuration and weights, the dominant configuration. The Boltzmann distribution. The molecular partition function: its interpretation and its relation to uniform energy levels. b. Translational, Rotational, Vibrational and Electronic Partition functions for diatomic molecules. Relation between thermodynamic functions and partition functions and their statistical interpretations. Equilibrium	26

	constants from partition function. c. Law of Equipartition energy. Theories of specific heat of solids. Comparison between Einstein and Debye theories. d. Concept of symmetric and antisymmetric wave functions. Ortho and para hydrogens. Quantum Statistics: Fermi-Dirac (FD)and Bose-Einstein (BE) statistics. Comparison between MB, FD and BE Statistics.	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
Text Books/ References / Readings	1. P. W. Atkins and J. D. Paula, *Physical Chemistry*, 8th Ed., Oxford University Press, (2007) New Delhi. 2. G. M. Barrow, *Physical Chemistry*, 5th Ed., Tata McGraw Hill, (2016) New Delhi. 3. M.C. Gupta, *Statistical Thermodynamics*, Wiley Eastern, (1990) New Delhi. 4. I. N. Levine, *Quantum Chemistry*, 7th Ed., Prentice-Hall, (1999) New Delhi. 5. H. Metiu, Physical Chemistry, Statistical Mechanics, Taylor & Francis, (2006) New York	

Programme: **M.Sc. Part-I (Chemistry)**

Course Code: **CHPC-413**

Title of the course: **Group Theory and Molecular Spectroscopy**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied physical chemistry courses at M.Sc. Chemistry in semester I
Course Objective:	1. To introduce concepts in Group Theory and it applications to chemistry. 2. To introduce some advance topics in spectroscopy.
Course Outcome:	1. Students should be in a position to explain various concepts in Group Theory. 2. Should be able to apply character table to solve various problems. 3. Students should be in a position to apply the knowledge of spectroscopy for their dissertation and research work.

Content	*Hrs*
1. Group Theory for Chemistry a. Symmetry elements and symmetry operations, Concept of group and group multiplication tables, order of the group, classes and subgroups in a group, Different types of groups (cyclic, abelian and non-abelian groups). b. Point groups, Matrix representations of a group, Reducible and Irreducible representations groups, Great Orthogonality Theorem, Properties of Irreducible representations, Mulliken symbols for Irreducible representations, Character tables. c. Standard reduction formula, Direct products of representations and it applications Quantum Chemistry and spectroscopy: Vanishing of integrals, Selection rules. Applications of group theory for hybridization of atomic orbitals. Projection operator and Symmetry adapted linear combinations (SALCs), MO treatment (within Huckel Molecular Orbital Theory) of large molecules with symmetry. Applications of group theory to Infra-red and Raman spectroscopy. d. Space Groups**:** Symmetry elements, Schoenflies, and Hermann Mauguin notation, Representation of point groups and space groups, point symmetry, space symmetry, glide plane, helical screw axis	30
2. Microwave, IR and Raman Spectroscopy a. Theoretical treatment of Rotational and Vibrational spectroscopy. b. Principle of Fourier Transform (FT) spectroscopy, FTIR spectroscopy: Theory, instrumentation and applications. c. Quantum theory of Raman effect, Raman shift, Instrumentation, Resonance Raman spectroscopy, Complimentary nature of IR and Raman spectroscopy in structure determination, Applications.	12
3. NMR Spectroscopy a. Basic principles of NMR b. Theory of pulse NMR and Fourier analysis, FT-NMR. c. Solid state NMR, magic angle spinning (MAS), dipolar decoupling and cross	10

polarization, applications of solid-state NMR. d. Double resonance, NOE, Spin tickling, Solvent and shift reagents, Structure determination by NMR.	
4. ESR Spectroscopy a. Theory and experimental techniques, Identification of odd-electron species (methyl and ethyl free radicals) and radicals containing hetero atoms. b. Spin trapping and isotopic substitution, Spin densities and McConell relationship, Double resonance techniques.	8
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. P. W. Atkins and J. D. Paula, *Physical Chemistry*, 8th Ed., Oxford University Press, (2007) New Delhi. 2. F.A. Cotton, *Chemical Applications of Group Theory*, 3rd Ed., John Wiley & Sons-Asia, (1999) New Delhi 3. K. V. Raman, *Group Theory and its applications to chemistry*, Tata McGraw-Hill, (1999) New Delhi 4. C. N. Banwell and E.M. McCash, *Fundamentals of Molecular Spectroscopy*, Tata McGraw-Hill, (1994) New Delhi. 5. W. Kemp, *NMR in Chemistry a multinuclear introduction*, Macmillan (1986). 6. R.S. Drago, *Physical Methods in Chemistry*, W.B. Saunders Company (1977).

Programme: **M.Sc. Part-I (Chemistry)**

Course Code: **CHPC-414**

Title of the course: **Chemical Kinetics and Thermodynamics**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied physical chemistry courses at M.Sc. Chemistry in semester I
Course Objective:	1. To introduce concepts of reaction kinetics and thermodynamics 2. To provide fundamental knowledge of theories that govern chemical reactions 3. To introduce newer classes of reaction types and their kinetics 4. To introduce latest developments in the advance instrumental techniques and methods for monitoring reaction kinetics and dynamics.
Course Outcome:	1. Students should be in a position to understand and explain various concepts in chemical kinetics and thermodynamics. 2. Students should be in a position to apply these concepts during the lab course in experimental physical chemistry.

Content	*Hrs*
1. Theories of reaction rates a. Generalized kinetic theory and extended collision theory. Concept of collisional number, collisional frequency factor, collisional and reactive cross section, steric factor, microscopic rate constant. Assumptions and limitations of collision theory. b. Conventional transition state theory, equilibrium hypothesis and derivation of reaction rates. Thermodynamic formulation of transition state theory. Arrhenius temperature dependent and independent activation energy and its significance. Assumptions and limitations of transition state theory. Lindemann-Hinshelwood theory of thermal unimolecular reactions.	10
2. Elementary reactions in solutions Collisional kinetics in solution, effect of solvent polarity, solvent cohesion energy, and ion-dipole and dipole-dipole reactions on reaction rates.	3
3. Kinetics of Homogeneous reactions Homogeneous kinetics, enzymatic reactions and Michaelis-Menten, Lineweaver-Burk and Eadie Analysis, Autocatalytic reactions.	5
4. Composite reactions Types of composite mechanisms, kinetics of parallel and consecutive reactions. Introduction to shock tube method and its use in combustion analysis.	3
5. Fast Reactions Photochemical fast reactions, Pulsed laser photolysis, and its use in monitoring fast reactions.	3
6. Reversible, Irreversible and Oscillatory reactions. a. Kinetics of reversible reactions and graphical analysis b. Oscillatory reactions, Voltera-Lotka hypothesis of oscillatory reactions. The	4

significance of bi-stability in the Briggs-Rauscher Reaction and Belousov-Zhabotinskii reaction.	
7. Reaction Dynamics Introduction to potential energy surfaces, description of H_2O and HF potential energy surface diagrams.	2
8. Equilibrium Thermodynamics a. Important terminologies in Thermodynamics; Thermodynamics state functions; work & heat; work expansion; Mathematical interlude Exact and inexact differentials. Cyclic rule; partial derivatives. b. Heat change at constant pressure, volume; relationship between Qp &Qv; Heat capacities Cp, Cv; Concept of Entropy, entropy change for an ideal gas at different conditions; Entropy of mixing of ideal gas and the Gibbs paradox; Physical significance of entropy. c. Work function and free energy function; Variation of free energy with temperature and pressure; Maxwell relations; Thermodynamic equations of state; Gibbs-Helmholtz equation. d. Thermodynamics of open systems, partial molar properties; chemical potential, variation of chemical potential with temperature and pressure; Gibbs-Duhem equation; Duhem-Margules equation; applications of chemical potential; thermodynamic derivation of phase rule.	17
9. Non-Equilibrium thermodynamics a. Concept of internal entropy and spontaneity of a process in relation to free energy. Chemical affinity and extent of a reaction. Phenomenological Laws and Onsager's Reciprocal Relations; Conservation of Mass and energy in closed and open system. b. Postulates of non-equilibrium thermodynamics. Entropy production in heat flow. Entropy production of chemical reactions and Entropy production/entropy flow in open system. c. Principle of microscopic reversibility and the Onsager reciprocal relations; Validity of Onsager's equation and its verification; Application of Irreversible Thermodynamics to Biological Systems; Application to thermo-electric and electrokinetic phenomena.	13

Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. K. J. Laidler, *Chemical Kinetics*, 3rd Ed.*;* Pearson Education, 1987; (printed in India by Anand Sons, 2004). 2. P.W. Atkins and J. De. Paulo, *Atkins' Physical Chemistry,* 8th Ed. Oxford University Press, 2007. 3. J. I. Steinfeld, J. S. Francisco and W. L. Hase, *Chemical Kinetics and Dynamics*, 2nd Ed.*;* Prentice Hall, 1999. 4. D. K. Chakrabarty and B. Viswanathan, *Heterogeneous Catalysis*, New Age International Publishers, 2008. 5. S. K. Scott, *Oscillations, waves and Chaos in chemical kinetics*,

Oxford Science Publications, 1994.
6. T. S. Briggs, and W. C. Rauscher, *An oscillating iodine clock, J.* Chem. Educ., 1973.
7. G. W. Castellan, *Physical Chemistry*, 3rd Ed.; University of Maryland, Addison-Wesley Publishing Company, 1983.
8. E. N. Yeremin, *Fundamentals of Chemical Thermodynamics* Firebird Publications, 1978.
9. D. A. McQuarrie & John D. Simon, *Physical Chemistry*: A molecular approach, Viva Books Pvt. Ltd., New Delhi.
10. S. R. De Groot, *Non-equilibrium thermodynamics*, Dover Publications, 2011.
11. A. Kleidon, R.D. Lorenz (Eds.), *Non-equilibrium thermodynamics and the production of entropy: life, earth, and beyond*, Springer Berlin Heidelberg New York, 2005.
12. J. Rajaram, J. C. Kuriacose, S. N. & Co., *Thermodynamics for students of Chemistry, Classical, Statistical and Irreversible*, Jalandhar, 1996.
13. P. W. Atkins & J. De. Paulo, Atkins' *Physical Chemistry*, 8th Ed.; Oxford Univ. Press, 2007.

Programme: **M.Sc. Part-I (Chemistry)**

Course Code: **CHPC-415**

Title of the course: **Electrochemistry and Surface Studies**

Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied physical chemistry courses at M.Sc. Chemistry in semester I
Course Objective:	1. To introduce some core concepts of electrochemical processes including ionic interaction theories, electrified interfaces, electrochemical kinetics and thermodynamics 2. To develop problem solving skills in electrochemistry 3. To introduce fundamental concepts and applications of electrochemistry in day-today life eg. batteries, solar cells, capacitors
Course Outcome:	1. Students will be in a position to explain various fundamental and core concepts of electrochemistry. 2. Students should be in a position to apply the knowledge of electrochemistry for their dissertation and research work 3. Students should be in a position to apply these concepts during the lab course in physical chemistry

Content	*Hrs*
1. Ionic Interactions and Conductance in Electrolytes a. Ion-solvent interactions. Born Theory, validity and limitations. b. Solvation number and coordination number. c. Ion-ion interactions and Debye-Huckel theory of ion cloud. d. Applications of Debye- Huckel equation. Concept of ionic strength and activity coefficient. e. Debye-Huckel limiting law and its modifications. f. Debye-Huckel-Onsager equation, validity and limitations. g. Einstein-Smoluchowski equation. h. Influence of ionic atmospheres on ionic migration: Relaxation and Electrophoretic effects. i. Conductance in strong and weak electrolytes.	10
2. Electrified Interfaces a. Formation of an electrode/electrolyte interface and its structure. b. Polarizable and non-polarizable interfaces. c. Potential difference across electrical double layer: outer potential, surface potential, inner potential and relationship between them, chemical and electrochemical potentials. d. Thermodynamics of electrified interface: Surface tension, surface excess, Electro-capillary curves. Determination of surface excess. Condition for thermodynamic equilibrium at electrified interface. e. Generalized Gibbs equation, Lippmann equation and electrical	10

capacitance at the doublelayer. f. Models of the electrified interface. g. Ion adsorption at the electrode: hydrated electrodes, contact adsorption, Gibbs adsorption equation.	
3. Pure Liquid Electrolytes: Ionic Liquids a. Thermal loosening of ionic lattice. b. Ionic liquids in surface electrochemistry: Electrode/electrolyte interfacial processes in ionic liquids. c. Electrochemistry of Ti (IV) in Ionic liquids.	8
4. Electrode Kinetics and Corrosion a. Disturbance of electrode equilibrium, cause of electron transfer, fast and slow systems and their current-potential relationship. b. Butler-Volmer equation and its low and high field approximations. c. Nernst equation as a special case of B-V equation. d. Tafel plots for anodic and cathodic processes. e. Fundamentals of Impedance spectroscopy; determining exchange current densities and rate constants from impedance plots. f. Principles of corrosion, electrochemical methods of avoiding corrosion. g. pH-potential diagrams: Pourbaix diagram for corrosion of iron and stability of water.	12
5. Colloidal Chemistry a. Interaction of double layers and stability of Sols. DLVO theory. b. Colloidal electrolytes, critical micelle concentration, Kraft temperature. c. Electrokinetic phenomena: Electroosmosis, streaming potential and current, electrophoresis. Zeta potential. d. Donnan membrane equilibria. e. Micellesandreversemicelles, Emulsions and Microemulsions.	8
6. Electrochemical Energies: Conversion and Storage a. Thermodynamics of electrochemical energy conversion. b. Batteries: Basic principles; rating and shelf life. Zinc-Manganese dioxide: Leclanche and alkaline batteries. Lithium ion batteries and recharge ability. c. Fuel cells: Principle of a hydrogen-oxygen fuel cell. Classification of fuel cell systems based on types of electrolytes/temperature. Efficiency w.r.t. thermodynamic efficiency, reliability and economic benefits. Direct methanol-polymer electrolyte fuel cell and electro-catalysts - a case study. Reactions occurring in various fuel cells and calculation of their electrode and cell potentials. d. Super-capacitors: Introduction: Origin of Supercapacitance.	7

7. Photoelectrochemistry a. Semiconductor/Electrolyte Interface: Band edge and Band bending. b. Light absorption and carrier generation at the electrode: photoinduced charge transfer, hot carriers. c. Photoelectrodes: p-type photocathode, n-type photoanode. d. Determination of surface states. e. Photoelectrocatalysis: photoelectrochemical water splitting and CO_2 reduction. f. Types of photoelectrochemical devices.		5
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
Text Books/ References / Readings	1. J.O.M.Bockris &A.K.N.Reddy,*Modern Electrochemistry*, Springer India, Pvt.Ltd,2000,Vol.1,2and3. 2. D. Crow,*PrinciplesandApplicationsofElectrochemistry*,Blackie AcademyandProfessional, 1994. 3. C.M.A.Brett&A.M.O.Brett, *Electrochemistry:Principles, methods and applications*, Oxford, NewYork Oxford University Press, 1993. 4. R.D.Vold&M.J.Vold,*ColloidandInterfaceChemistry*,Addison-Wesley, 1983. 5. A. Vincent & B. Sacrosati, *Modern Batteries*, John Wiley, NewYork,1997. 6. J.O.M.Bockris&S.Srinivasan,*Fuelcells: TheirElectrochemistry*,McGraw-HillBookCo., 1969. 7. A. A. J. Torriero, *Electrochemistry in Ionic Liquids*, Vol. 1: Fundamentals, Springer International Publishing, 2015 8. B. A.J., Stratmann M., Licht D, *Encyclopedia of Electrochemistry, Semiconductor Electrodes and Photoelectrochemistry*, Wiley-VCH, 2002.	

Programme: **M.Sc. Part-I (Chemistry)**

Course Code: **CHPE-411**

Title of the course: **Practical course in Physical Chemistry-I**

Number of Credits: **02** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objective:	1. To develop experimental skills on basic lab techniques in physical chemistry 2. To acquire skills for data analysis and interpretation 3. To help the students to develop research skills
Course Outcome:	1. Students will able to explain various fundamental lab techniques. 2. Students should be in a position to apply the knowledge for their dissertation and research work.

Content	*Hrs*
Minimum 13 Experiments to be performed per Semester	30
Non-instrumental Experiments (any 7)	
1. To study the kinetics of hydrolysis of ethyl acetate and to determine a) Energy of activation b) Entropy of activation and c) Free energy change.	
2. To determine the order of reaction between potassium persulphate and potassium iodide by graphical, fractional change and differential methods.	
3. To study the three-component system such as acetic acid, chloroform; and water and obtain tie line.	
4. To determine the molecular weight of polyvinyl alcohol by viscosity measurement.	
5. To study the electro-kinetics of rapid reaction between SO_4^{2-} and I^- in an aqueous solution.	
6. To determine the buffer capacity of acidic buffer solution.	
7. To determine the partial molal volume of ethanol-water mixture at a given temperature.	
8. To measure energy content of various types of plastics using bomb calorimetry	
9. To determine number average molecular weight of a polymer sample with an indirect titration method.	
10. To investigate basic hydrolysis of ethyl acetate at four different temperatures and find out energy of activation	
Instrumental Experiments (any 6)	
11. To determine the degree of hydrolysis of salt of weak base and strong acid using conductometer.	30
12. To determine the dissociation constants of a tribasic acid (Phosphoric	

acid obtain derivative plot to get equivalence point. 13. To determine formal redox potential of Fe^{2+}/Fe^{3+} and Ce^{3+}/Ce^{4+} system obtain derivative plot to get equivalence point. 14. To study spectrophotometric titration of ferrous ammonium sulphate with potassium permanganate (or dichromate vs permanganate) 15. To determine Avogadro's number by improved electroplating. 16. To determine the zeta potential of colloidal system and investigate the effect of different surfactants on stability of the colloids 17. To verify the Kohlrausch's law for weak electrolyte by conductometry 18. To determine the transport numbers of Cu^{2+} and SO_4^{2-} ions in $CuSO_4$ solution by Hittorf's method.	
Pedagogy	Mainly pre-laboratory exercises Seminars / term papers /assignments / presentations / lab hand-out /self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. A. Finlay & J.A. Kitchener, "*Practical Physical Chemistry*", Longman. 2. F. Daniels & J.H. Mathews, "*Experimental Physical Chemistry*", Longman. 3. A.M.James, "*Practical Physical Chemistry*", Longman. 4. D.P. Shoemaker & C.W. Garland, "*Experimental Physical Chemistry*", McGraw-Hill.

Programme: **M.Sc. Part-I (Chemistry)**

Course Code: **CHPE-412**

Title of the course: **Practical course in Physical Chemistry-II**

Number of Credits: **02** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test.
Course Objective:	1. To develop experimental skills on basic lab techniques in physical chemistry 2. To acquire skills for data analysis and interpretation 3. To help the students to develop research skills
Course Outcome:	1. Students will gain knowledge of various fundamental lab techniques. 2. Students should be in a position to apply the knowledge for their dissertation and research work.

Content	*Hrs*
Minimum 13 experiments to be conducted per Semester	35
Non-instrumental Experiments (any 8)	
1. To determine the radius of a molecule by viscosity measurements.	
2. To determine ΔG, ΔH and ΔS of silver benzoate by solubility product method	
3. To investigate the adsorption of oxalic acid by activated charcoal and test the validity of Freundlich and Langmuir's isotherms.	
4. To determine the molecular weight of a given polymer by turbidimetry	
5. To study the rate of reaction between ethyl bromoacetate and sodium thiosulphate kinetically.	
6. To determine the percentage composition of a given mixture of two liquids by stalagmometer method.	
7. To study the kinetics of hydrolysis of methyl acetate and to determine a) Energy of activation b) Entropy of activation and c) Free energy change.	
8. To study the kinetics of the reaction between Potassium per sulphate ($K_2S_2O_8$), and Potassium iodide (KI), and to determine a) Energy of activation b) Entropy of activation and c) Free energy change.	
9. To determine the order of reaction for hydrolysis of ethyl acetate by graphical, fractional change and differential methods.	
10. To determine the molecular weight of polystyrene by viscosity measurement.	
Instrumental Experiments (any 5)	
11. To determine the relative strength of chloroacetic acid and acetic acid by conductometry.	25
12. To determine the degree of hydrolysis of salt of weak base and strong acid using conductometry.	
13. To determine the composition of a mixture of acetic acid, dichloroacetic acid	

and hydrochloric acid by conductometric titration. 14. To determine the dissociation constants of monobasic acid and dibasic acid and obtain derivative plot to get equivalence point. 15. To determine the redox potential of Fe^{2+}/Fe^{3+} system by titrating it with standard $K_2Cr_2O_7$ solution. 16. To study the electrodeposition of metal.	
Pedagogy	Mainly pre-laboratory exercises Seminars / term papers /assignments / presentations / lab hand-out /self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. A. Finlay & J.A. Kitchener, "*Practical Physical Chemistry*", Longman 2. F. Daniels & J.H. Mathews, "*Experimental Physical Chemistry*", Longman. 3. A. M. James, F. E. Prichard "*Practical Physical Chemistry*", Longman 4. D.P. Shoemaker & C.W. Garland, "*Experimental Physical Chemistry*", McGraw-Hill.

ANNEXURE II

M.Sc. Pharmaceutical Chemistry Part-I (SEM I and SEM II) Syllabus

SEM I			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1.	**CHOC-411**	Fundamentals of Organic Chemistry **(DSCC)**	4
2.	**CHHC-411**	Fundamentals of Pharmaceutical Chemistry-I **(DSCC)**	4
3.	**CHPC-411**	General Physical Chemistry **(DSCC)**	4
4.	**CHAC-411**	Techniques in Analytical Chemistry-I **(DSCC)**	4
5.	**CHOE-411**	Practical Course in Organic Chemistry-I **(DSOC)**	2
6.	**CHOE-412**	Practical Course in Organic Chemistry-II **(DSOC)**	2
7.	**CHHE-411**	Practical Course in Pharmaceutical Chemistry-I **(DSOC)**	2
8.	**CHHE-412**	Practical Course in Pharmaceutical Chemistry-II **(DSOC)**	2
9.	**CHPE-411**	Practical Course in Physical Chemistry-I **(DSOC)**	2
10.	**CHPE-412**	Practical Course in Physical Chemistry-II **(DSOC)**	2
11.	**CHAE-411**	Practical Course in Analytical Chemistry-I **(DSOC)**	2
12.	**CHAE-412**	Practical Course in Analytical Chemistry-II **(DSOC)**	2
SEM II (Pharmaceutical Chemistry)			
1.	**CHHC-412**	Fundamentals of Pharmaceutical Chemistry-II **(DSCC)**	4
2.	**CHHC-413**	Drug Product Formulation, Development and Manufacture **(DSCC)**	4
3.	**CHHC-414**	Drug Design, Discovery and Development **(DSCC)**	4
4.	**CHHC-415**	Biopharmaceutics and Pharmacokinetics **(DSCC)**	4

Programme: **M.Sc. Part-I (Pharmaceutical Chemistry)**

Course Code: **CHOC-411**
Title of the course: **Fundamentals of Organic Chemistry**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objective:	1. To study the various concepts based on molecular orbital theory. 2. To understand the concepts of topicity, prostereoisomerism and chemo-, regio- and stereoselectivity in organic reactions. 3. To understand the mechanistic aspects of various type of reactions in organic synthesis.
Course Outcome:	1. Students will be in a position to evaluate the effect of delocalization of electrons & presence or absence of aromaticity in organic compounds. 2. Students will be able to apply various concepts in stereochemistry to understand stereochemical outcome in a reaction. 3. Students shall be in a position to understand/propose plausible mechanism of organic reactions.

Content	*Hrs*
1.Molecular orbitals and delocalized chemical bonding a. Qualitative description of molecular orbitals of simple acyclic and monocyclic systems, frontier molecular orbitals. b.Conjugation, cross conjugation, resonance, hyperconjugation and tautomerism (types and examples). c. Aromaticity: Origin of Huckel's rule, examples of aromatic, non-aromatic and antiaromatic compounds; concept of Mobius aromaticity.	08
2.Structure & Reactivity a. Acidity, basicity and pKa of organic compounds; Acid and base strengths; HSAB concept & Factors affecting it, effect of structure & medium on acid and base strength. b. Concept of superacids and superbases. c. Electrophilicity&nucleophilicity, examples of ambident nucleophiles & electrophiles. (Including revision of aromatic electrophilic and nucleophilic substitution)	08
3.Stereochemistry a. Brief revision of configurational nomenclature: R & S; D & L; E & Z; cis & trans and *syn*&*anti* nomenclature. Chirality in molecules with two and more chiral centres. b. Conformational analysis of open chain compounds (Butane, 2, 3-butane diol, 2,3-dibromobutane etc.). *Erythro*and *threo*nomenclature. c. Topicity and Prostereoisomerism: Topicity of ligands and faces-homotopic, enantiotopic and Cram's rule /diastereotopic ligands and faces. d. Introduction to chemoselective, regioselective and stereoselective reactions.	14

e. Stereochemistry of *cis*- and *trans*-decalins, conformation and reactivity of cyclohexane and substituted cyclohexanes, cyclohexene / cyclohexanone. conformational isomerism and analysis in acyclic and simple cyclic systems – substituted ethanes, cyclopentane, cyclohexane cycloheptane, cyclooctane and decalins, f. optical isomerism - optical activity - molecular dissymmetry and chirality - elements of symmetry. optical isomerism in biphenyls, allenes and spirans - optical isomerism of nitrogenous compounds racemisation and resolution.	
4.Reaction Mechanism a. Brief revision of carbocations, carbanions, free radicals, carbenes, Arynes and nitrenes with reference to generation, structure, stability and reactivity; b. Types of mechanisms, types of reactions, thermodynamic and kinetic control. c. The Hammond postulate and principle of microscopic reversibility, d. Methods of determining reaction mechanisms like- i. Identification of products, ii. Determination of the presence of intermediates (isolation, detection, trappingandaddition of suspected intermediate, iii. Isotopic labelling, iv. Stereochemical evidence, v. Kinetic evidence and vi. Isotope effect (at least two reactions to exemplify each method be studied)	08
5.Aliphatic Nucleophilic substitution a. Brief revision of nucleophilic substitutions with respect to Mechanism, various factors affecting such reactions; b. The Neighbouring Group Participation (NGP)/ Anchimeric assistance: General approach to various NGP processes; NGP by unshared/lone pair of electrons; NGP by π-electrons; NGP by aromatic rings (formation of phenonium ion intermediate); NGP by sigma bonds with special reference to bornyl and nor-bornyl system (formation of nonclassical carbocation)	08
6.Elimination reactions a. The E2, E1 and E1cB mechanisms. Orientation of the double bond, Saytzeff and Hofmann rule. b. Effects of changes in the substrate, base, leaving group and medium on i. Overall reactivity, ii. E1 vs. E2 vs. E1cB iii. Elimination vs substitution, Mechanism and orientation in pyrolytic *syn* elimination (various examples involving cyclic and acyclic substrates to be studied).	08

7. Selective reagents for Organic transformation a. Oxidation of organic compounds, PCC, PDC and MnO_2, ozonolysis, peracids. b. Reduction of organic compounds: $NaBH_4$, LAH, DIBAL reduction and reduction with borane and dialkylboranes. Clemmensen reduction, Birch reduction and Wolff-Kishner reduction		06
Pedagogy	Mainly lectures and tutorials. Seminars/term papers/assignments/presentations/ self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
Text Books/ References / Readings	1. W. Caruthers, I. Coldham, *Modern Methods of Organic Synthesis*, Cambridge University Press, 4th Ed., 2016. 2. M. B. Smith, *Organic Synthesis*, McGraw–HILL, New York, International Edition, 1994. 3. J. Clayden, N. Greeves, S. Warren, P. Wothers, *Organic Chemistry*, Oxford University Press, 2nd Ed., 2012. 4. R. Bruckner, *Advanced Organic Chemistry – Reaction Mechanisms*, San Diego, CA: Harcourt /Academic Press, San Diego, 2002. 5. J. Fuhrhop, G. Penxlin, *Organic Synthesis – Concepts, Methods, Starting Materials*, VCH Publishers Inc., New York, 1994. 6. H. O. House, *Modern Synthetic Reactions*, W. A. Benjamin, 2nd Ed.,1965 7. M. Nogradi, Stereoselective Synthesis, VCH Publishers, Inc., Revised and Enlarged Edition, 1994. 8. F. A. Carey, R. J. Sundberg, *Advanced Organic Chemistry*, Springer India Private Limited, 5th Ed, 2007. 9. T. Laue, A. Plagens, *Named Organic Reactions*, John Wiley and Sons, Inc., 2005.	

Programme: **M.Sc. Part-I (Pharmaceutical Chemistry)**

Course Code: **CHHC-411**
Title of the course: **Fundamentals of Pharmaceutical Chemistry-I**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University. Knowledge of Pharmaceutical Chemistry is added advantage but not mandatory. This is to understand the basics in pharmaceutical chemistry and importance of chemistry in pharmacy.
Course Objective:	1. To get introduced to pharmaceutical chemistry and terms involved. 2. To understand the various classes of drugs with examples with special reference to Structure, IUPAC name, Mechanism of action, Structure Activity Relationships and Synthesis.
Course Outcome:	1. Students will be able to identify the examples in different classes of drugs. 2. Students will be able to write IUPAC names and Structure of drugs. 3. Students will be in a position to understand the mechanism of action of selected classes of drugs. 4. The students will have a clear understanding of concepts on SAR analysis. 5. The students will be able to apply synthetic organic chemistry knowledge in devising a synthesis for a drug.

Content	*Hrs*
1. Pharmaceutical chemistry, physicochemical properties of drugs, drug metabolism and assay of drugs: Role of Chemistry in Pharmacy: Introduction to pharmaceutical chemistry. Need to study pharmaceutical chemistry. Important terminologies: Pharmacodynamics, Pharmacokinetics, Pharmacognosy, Materia medica, Toxicology, Pharmacopoeia, Pharmacophore- Effect of functional groups on physiological activity of drugs: hydroxy, acidic, alkyl, aldehyde, ketone, cyano, halogens, ether and ester groups with examples. Physicochemical properties of Drugs: Effect of Solubility, Partition Coefficient, Ionisation constant, Surface Active agents, Chelation, Hydrogen bonding, stereoisomers on the pharmacological action of drugs (specific example of API to be given). Drug Action, Drug Metabolism-Significance of drug metabolism. Phase I, Phase II pathways with reactions. Factors on which drug metabolism depends. Assay of drugs-Chemical, biological and immunological assay.	12
Classification of Chemotherapeutic Drugs: Development of the following drugs including structure activity relationship (S.A.R.), mechanisms of action (MA), outline of synthesis ($), chemical nomenclature, generic names	

(GN) and side effects (SE) (outline of synthesis only of those marked$) **2. Anti-Infective agents-I:** **Antiseptics and Disinfectants**: Alcohols, substituted phenols, methenamine mandalate, Chloramine-T (MA), 8-hydroxy quinoline derivatives, Acridine derivatives, Mercurials like (Mercurochrome, Thiomersal) and Nitrofurantoin derivative, Triclosan $. **Antitubercular agents**- Aminosalicylic acid, PAS (MA), Pyrazinamide$, Ethambutol (SAR and $), Clofazemine, **Antimalarials**: Life cycle of parasite, drug acting on different stages- Quinine, Chloroquine$, Primaquine, Trimethoprim, Proguanil (MA), Cycloguanil, Drug combinations. **Antiamoebics**: General aspect of infection, Life cycle of parasite, Hydroxyl quinolines, Metronidazole (SAR and $), Lucanthone (MA), **Anthelmentics**: Diethylcarbamazine, Niclosamide, Mebendazole$, Oxamniquine.	12
3. Anti-Infective agents-II: **Antivirals** including drugs acting on HIV Idoxuridines, Amantadine Hydrochloride$, Acylclovir. **Antineoplastics**: 6-Mercaptopurine (MA), Thiotepa$, Chlorombucil, Taxol, **Antifungal**: **Antibiotics** like Nystatin, Tolnaflate$, Clotrimazole$. Sulfonamides and other antifolics: Sulfonamides (MA) and other para-aminobenzoic acid antagonist, Sulfacetamide$, Sulfamethoxazole, Newer antibacterial agents: Quinoline carboxylic acids such as Ciprofloxacin, Temafloxacin. Hypoglycemics: Insulin and various sulfonyl ureas like tolbutamide$, Tolazamide, phenformin, Glipizide.	12
4. Anti-lipidemics, Diuretics, and diagnostic agents: **Anti-lipidemics**: Clofibrate$, nicotinic acid, boxidine **Diuretics**: Acid forming osmotic diuretics, Mercurials-Meralurides,Sulfonamides-Acetazolamide$. Chlorthiazide$, Hydrochlorthiazide, Ethacrynic acid. **Synthetic sweeteners.** Diagnostic agents Inorganic compounds- Iodoxyl, Iodophendylate. **Dyes**- Rose Bengal, Fluorescein, Aminohippuric acid$.	12
5. Hypotensive agents, General and Local Anaesthetics: **Hypotensive agents** acting on vascular smooth muscles: Nitrites, Amylnitrites, Glyceryl nitrite$, Pentaerythritol tetranitrate, Isosorbide dinitrate (MA). **General Anaesthetics**: Ether, Nitrous oxide, Halothane$, Ultra short acting Barbiturates-Thiopental sodium $. **Local anaesthetics**: Cocaine, Benzocaine$, Procaine (MA), Lidocaine$, Purgatives and cathartics: Phenolphthalein, Castor oil.	12
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.

Text Books/References / Readings	1. D. A. Williams & T. L. Lemke, *Foye's principles of medicinal chemistry* 5th edition, Lippincott Williams and Wilkins, 2006. 2. J. M. Beale & J. M. Block, *Wilson & Gisvold's Text book of Organic Medicinal & Pharmaceutical Chemistry*, Lippincott Williams and Wilkins; 2004. 3. D. J. Abraham & D.P. Rotella, Burger's Medicinal Chemistry Drug Discovery and Development (John Wiley & Sons N.Y), 7th edition, 2010. 4. D. Shriram, P. Yogeshwari, *Medicinal Chemistry*, Pearson Education, 2007. 5. G. L. Patrick: *Introduction to Medicinal Chemistry*, Oxford University Press, UK. 6th edition, 2017. 6. D. Lednicer & L.A. Mitscher, The *Organic Chemistry of Drug Synthesis*. (6 volume set) III. John Wiley & Sons, 2005. 7. H. Singh & V. K. Kapoor: *Medicinal and Pharmaceutical Chemistry,* Vallabh Prakashan, Pitampura, New Delhi, 2010. 8. G. R Chatwal, *Medicinal Chemistry* (*Organic Pharmaceutical Chemistry*), Himalaya Publishing house, 2002.

Programme: **M.Sc. Part-I (Pharmaceutical Chemistry)**

Course Code: **CHPC-411**
Title of the course: **General Physical Chemistry**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objective:	1. Introduction of various concepts on thermodynamics. 2. Introduction of electro chemistry and kinetics. 3. Learning quantum chemistry.
Course Outcome:	1. Students should be in a position to understand and explain various concepts in physical chemistry. 2. Students should be in a position to apply these concepts during the lab course in physical chemistry.

Content	*Hrs*
1. Mathematical Preparations a. Introduction to various functions and function plotting (exponential, logarithmic, trigonometric etc.), functions of many variables. Complex numbers and complex functions. b. Linear equations, vectors, matrices and determinants. c. Basic rules of differentiation and integration, Partial differentiation, location and characterization of critical points of a function, Regression methods, curve fitting. d. Introduction to series, convergence and divergence, power series, Fourier series e. Probability (permutations and combinations).	12
2. Quantum Chemistry a. Operators, Functions, Eigen value equations, Postulates. b. Schrodinger equation, application to simple system viz. free particle, particle in one dimensional, two dimensional and three-dimensional box (quantization, separation of variables, degenerate wave functions). c. Hydrogen like atoms, Schrodinger equation and its solutions, atomic orbital wave functions and interpretation. d. Hückel MO theory, Secular equations, Secular determinant, delocalization energy, charge density, π-bond order, free valence, applications to C_2H_4, C_3H_5 (radical), C_4H_6, C_4H_4, C_6H_6, C_6H_8.	20
3. Thermodynamics a. Thermodynamic properties: Gas laws, Real gasses, Boyle temperature, Critical temperature, State and path properties. Intensive and extensive properties. Exact and inexact differentials. Internal energy, enthalpy, entropy, free energy and their relations and significances. Maxwell relations. Thermodynamic equations of state b. Joule-Thomson effect. Joule-Thomson coefficient for van der Waals' gas. Joule-Thomson effect and production of low temperature, adiabatic	12

demagnetization, Joule-Thompson coefficient, inversion temperature. c. The third law of thermodynamics. Need for the third law. Apparent exceptions to third law. Application of third law. Use of thermodynamic functions in predicting direction of chemical change. Entropy and third law of thermodynamics. d. Phase equilibria: Phase rule, Discussion of two component systems forming solid solutions with and without maximum or minimum in freezing point curve. Systems with partially miscible solid phases. e. Three component systems: Graphical representation. Three component liquid systems with one pair of partially miscible liquids. Influence of temperature. Systems with two pairs and three pairs of partially miscible liquids. The role of added salts.	
4. Electrochemistry a. EMF series, The cell potential: The Nernst equation, Cells at equilibrium. Determination of thermodynamic functions. b. Decomposition potential and overvoltage, electronegativity, basic principles, completeness of deposition, Separation with controlled potentials, constant current electrolysis, composition of electrolyte, potential buffers, physical characteristics of metal deposits. c. Electroplating and electroless plating, electrosynthesis. d. Concepts of acid-base aqueous and non-aqueous solvents, hard and soft acid-base concept and applications.	8
5. Chemical Kinetics a. General introduction to various types of order of reaction including fractional order, Molecularity of the reaction. b. Introduction to reversible and irreversible reactions and reactions leading to equilibrium. Van't Hoffs equation and analysis of Gibbs free energy of equilibrium reactions. c. Collision Theory and Maxwell Boltzmann distribution of energies of colliding molecules (derivation not required). The concept of collisional cross section and reactive cross section and its significance. d. Comparative study of transition state and collision state theory (derivation not required). e. Reaction Mechanisms: elementary reactions, Consecutive elementary reactions, steady state approximation, the rate determining step and pre-equilibria f. Free radical reactions, Complex reactions such as acetaldehyde decomposition and reaction between H_2 and Br_2, Homogeneous reactions and acid-base catalysis. g. Elementary enzyme reactions. Lineweaver-Burk plot and its analysis	8
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/	1. P. W. Atkins and J. D. Paula, *Physical Chemistry*, 8th Ed., Oxford University Press, (2007) New Delhi.

References / Readings	2. G. M. Barrow, *Physical Chemistry*, 5th Ed., Tata McGraw Hill, (2016) New Delhi. 3. J. E. House, *Principles of Chemical Kinetics*, 2nd Ed., Academic Press, (2007) Elsevier Burlington, USA 4. I. N. Levine, *Quantum Chemistry*, 7th Ed., Prentice-Hall, (1999) New Delhi.

Programme: **M.Sc. Part-I (Pharmaceutical Chemistry)**

Course Code: **CHAC-411**
Title of the course: **Techniques in Analytical Chemistry - I**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objective:	1. Learning various methods of data handling in analysis. 2. Understanding the significance of sampling and calibration techniques. 3. Understanding principles and applications of various types of techniques in 4. Training the students to deduce structures based on IR, NMR, MS combined data.
Course Outcome:	1. Students will be able to analyse the role of statistical tools for determination of error and organised data management for systematic interpretation. 2. Student will be able to apply the sampling and calibration methods for obtaining reliable results. 3. Students will be able to understand basic principles and scope of different methods of Analysis 4. Students will be able to solve problems based on IR, NMR, MS combined spectral data.

Content	*Hrs*
1. Analytical Objectives and Data Handling Importance of analytical chemistry in research and industry; statistics and data handling in analytical chemistry, standard operating procedures, good laboratory practices: quality assurance, method validation and quality control.	5
2. Sampling and Calibration Techniques Sampling and sample preparation, general steps in chemical analysis, calibration of glass wares. Finding the best straight line-least square regression, correlation coefficient; Calibration curves, standard addition technique and internal standards. Chemical concentrations.	5
3. Classical methods of Analysis Gravimetry and Titrimetric methods, Principle, methodology, Advantages & Disadvantages over instrumental methods. Conditions for identifying a given reaction as method of Analysis, Classification of reactions in titrimetric analysis (Acid-Base, redox, complexometric and precipitation), Standard solutions and their preparation. Selection of Visual Indicators in titrimetric Analysis	6
4. Introduction to Electroanalytical techniques Introduction to electrochemical cell, electrode potential, Classification of electroanalytical techniques, working principles, and their applications	4
5. Introduction to Thermoanalytical techniques Principle, Instrumentation and applications of Thermogravimetric Analysis	5

(TGA), Differential Thermal Analysis (DTA), and Differential Scanning Calorimetry (DSC). Numericals based on TGA.	
6. Introduction to Chromatographic Techniques a. Principles of chromatography, classification of chromatographic techniques based on mechanism of retention, configuration, mobile and stationary phase. Efficiency of separation- plate theory (theoretical plate concept) and rate theory (van Deemter equation). b. Principles and applications of Paper chromatography, thin layer chromatography, HPTLC, Size exclusion and Ion exchange chromatography. Counter-current chromatography for isolation of natural products. c. Gas and Liquid Chromatography: Introduction; Instrumental Modules; The Separation System; Choice of Conditions of Analysis; Sample Inlet Systems; Detectors; Practical Considerations in Qualitative and Quantitative Analysis; Coupled Systems-introduction to GCMS, LCMS; Applicability-interpretation and numericals.	15
7. Introduction to Spectroscopic Techniques a. Interaction of Electromagnetic Radiation with Matter: Electromagnetic spectra, regions of spectrum, numericals. b. Ultraviolet and visible Spectroscopy: Electronic spectra and Molecular structure: types of electronic transition, Chromophore and auxochrome, absorption by isolated chromophore, conjugated chromophores, aromatic compounds, inorganic chelates. Calculating λmax for Conjugated Dienes, Trienes, polyenes, α,β-unsaturated carbonyl compounds, Numericals. Choices and effect of solvents on UV-Vis. Quantitative Calculations: Beer-Lambert Law; Mixtures of absorbing species-laws of additivity of absorbance; calibration curve for calculation of unknown; Spectrometric errors in measurement; Deviation from Beer-Lambert Law - chemical deviation, instrumental deviation; Numericals for quantitative analysis using UV-VIS spectroscopy. c. Infrared Spectroscopy: Infrared absorption and molecular structures, molecular vibrations, types of vibrations, IR spectra, overtones and bands-basis of NIR absorption. Spectra interpretation, Frequencies of functional group, Spectral Databases, Identification of unknown compounds. d. Spectrometric Instrumentation of UV-Vis and IR: Sources, monochromators, sample cells, detectors, instrumental wavelength and absorption calibration. e. Proton and Carbon NMR Spectroscopy: Theory of NMR, Instrumentation, Chemical shift, factors influencing chemical shift, solvents used in NMR, spin-spin splitting, coupling constant calculation, factors influencing coupling constant. f. Mass Spectrometry: Principle, Instrumentation and various fragmentation patterns. g. Conjoint spectrometry problems: Structural elucidation of organic molecules using IR, UV, NMR and MS. h. Raman Spectroscopy: Theory, Basic instrumentation and Structural analysis using Raman Spectra.	20

(Note: Assignment based on all above spectrometric methods should be given to student. More weightage of lectures shall be given for solving IR and NMR data problems for structure elucidation)	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. G. D. Christian, *Analytical Chemistry*, 6th Ed.; Wiley, 2004. 2. J. H. Kennedy, *Analytical Chemistry: Principles*, 2nd Ed.; Saunders College Publishing, 1990. 3. G. W. Ewing, *Instrumental Methods of Chemical Analysis*, 5th Ed.; McGraw- Hill Int., 1985. 4. W. Kemp, *Organic Spectroscopy*, 3rd Ed.; Palgrave, 1991. 5. D. A. Skoog, D. M. West, F. J. Hollar, S. R. Crouch, *Fundamentals of Analytical Chemistry*, 9th Ed.; Cengage learning, 2014. 6. F. J. Holler, D. A. Skoog, S. R. Crouch, *Principles of Instrumental Analysis*, 6th Ed.; Thomson Books, 2007. 7. H. Willard, L. L. Merritt, J. A. Dean, F. A. Settle, *Instrumental methods of Analysis*, 7th Ed.; HCBS Publishing, 2004. 8. C. N. Banwell, E. M. McCash, *Fundamentals of Molecular Spectroscopy*, 4th Ed.; Tata McGraw- Hill, 2006. 9. R. M. Silverstein, F. X. Webster, *Spectrometric identification of Organic Compounds*, 6th Ed.; Wiley, 1998. 10. H. Gunzler, A. Williams, *Handbook of Analytical Techniques*, 1st Ed.; Wiley, 2001. 11. P. S. Kalsi, *Spectroscopy of Organic Compounds*, 2nd Ed.; New Age International, 2000. 12. E. Pretsch, P. Buhlmann, C. Affolter, *Structural Determination of Organic Compounds*, 2nd Ed.; Springer, 2005. 13. L. D. Field, S. Sternhell, J. R. Kalman; *Organic Structures from Spectra*, 4th Ed.; Wiley, 2007. 14. R. A. Day, A. L. Underwood, *Quantitative Analysis*, 6th Ed.; Prentice Hall, 2001. 15. B. K Sharma, *Instrumental methods of chemical analysis*, Goel Publishing House, Meerut, 2004. 16. K. Nakamoto, *Infrared and Raman Spectra of Inorganic and Coordination Compounds*, 6th Ed.; Wiley, 2009. 17. P. J. Larkin, *Infrared and Raman Spectroscopy: principles and spectral interpretation*, 2th Ed.; Elsevier, 2018. 18. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, *Vogel's Text Book of Quantitative Chemical Analysis,* 6th Ed.; Pearson, 2009.

Programme: **M. Sc. Part-I (Pharmaceutical Chemistry)**

Course Code: **CHOE-411**
Title of the Course: **Practical Course in Organic Chemistry-I**
Number of Credits: **02** Total Hours:**60** Effective from AY: **2022-23**

Prerequisites for the course	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objective:	To translate certain theoretical concepts learnt earlier into experimental knowledge by providing hands on experience of basic laboratory techniques required for organic syntheses.
Course Outcome	1. Students will be in a position to understand stoichiometric requirements during organic syntheses. 2. Students will be in a position to understand Safe and good laboratory practices, handling laboratory glassware, equipment and chemical reagents. 3. Students will be in a position to apply the practical knowledge to perform experiments involving common laboratory techniques like reflux, distillation, steam distillation, vacuum distillation, aqueous extraction, thin layer chromatography (TLC) etc.

Content	*Hrs*
Minimum 13 experiments from the list shall be conducted.	
1. Introduction to laboratory equipments, apparatus and safety a. Use of common laboratory equipments like fume hoods, vacuum pumps, weighing balance etc. to be explained to the students. b. Introduction to various types of quick fit joints and apparatus to the students. c. Discussion of Safety Techniques: i) Disposal of chemicals ii) Usage of protective equipment's iii) First aid iv) Fire extinguishers, types of fire v) Hazards of chemicals and risk assessment	04
2. Laboratory Techniques a. Simple distillation (any one): i. Toluene-dichloromethane mixture using water condenser. ii. Nitrobenzene and aniline using air condenser. b. Steam distillation (anyone): i. Separation of *o*- and *p*- nitrophenols. ii. Naphthalene from its suspension in water, iii. Clove oil from cloves. c. Crystallisation: Concept of induction of crystallization (any one) i. Crystallisation of phthalic acid from hot water using fluted filter paper and stemless funnel. ii. Acetanilide from boiling water iii. Naphthalene from ethanol.	24

iv. Decolorisation and crystallization of brown sugar (sucrose) with animal charcoal using gravity filtration. d. Sublimation: Simple or vacuum sublimation of camphor, naphthalene, anthracene or succinic acid (any one). e. Vacuum distillation (any one): o-dichlorobenzene, diphenyl ether. Also use of nomograph should be explained. f. Thin layer Chromatography (any one): i. Separation of *o* and *p*-nitroanilines. ii. Separation of analgesic drugs iii. Separation of *o* and *p*-nitrophenols,		
3. Organic synthesis (Any Seven experiments) a. Aliphatic electrophilic substitution: Preparation of iodoform from ethanol & acetone. b. Aromatic electrophilic substitution (anyone): i. Preparation of *p*-bromoacetanilide. ii. Bromination of acetophenone to phenacyl bromide iii. Nitration of napththalene to 1-nitronaphthalene iv. Nitration of benzaldehyde to 3-nitrobenzaldehdye. c. Oxidation (any one) i. Benzoic acid from toluene. ii. Cyclohexanone from cyclohexanol. iii) Isoborneol to camphor using Jones reagent. d. Reduction (any one) i. Reduction of *o*-nitroaniline to *o*-phenylenediamine using Sn/HCl ii. Reduction of *p*-nitro benzaldehyde to *p*-nitrobenzyl alcohol using $NaBH_4$. e. Bromination of an alcohol using CBr_4/ triphenylphosphine. f. Grignard reaction: Triphenylmethanol from benzoic acid ester or benzophenone. g. Aldol condensation: Dibenzal acetone from benzaldehyde h. Acetoacetic ester condensation: Preparation of ethyl *n*-butylacetoacetate or ethyl acetoacetate. i. Cannizzaro reaction using 4-chlorobenzaldehyde as substrate. j. Friedel Craft's reaction (any one): i. using toluene and succinic anhydride ii. Resorcinol to resacetophenone, benzene and maleic anhydride to *β*-benzoylacrylic acid k. Solvent free preparation of coumarin by the Knoevenagel condensation under MW irradiation. l. Preparation of oxidizing agent (any one): Pyridinium chlorochromate-silica, pyridinium chlorochromate-alumina, MnO_2. m. Preparation of cuprous chloride.		24
4. **Isolation from natural sources (Any two)** i. Caffeine from tea powder. ii. Piperine from pepper. iii. Cinnamaldehyde from cinnamon iv. Lemongrass oil from lemongrass		8
Pedagogy:	Students should be given suitable pre- and post-lab assignments and	

	explanation revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment. Each of the experiments should be done individually by the students.	
References/Readings	1. A.I. Vogel, A., R. Tatchell , B. S. Furniss, A.J. Hannaford, *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Prentice Hall; 2011. 2. D. Pasto, C. Johnson and M. Miller, *Experiments and Techniques in Organic Chemistry*, 1st Ed., Prentice Hall, 1991. 3. L.F. Fieser, K.L. Williamson,*Organic Experiments*, 7th edition D. C. Heath, 1992. 4. K.L. Williamson, K.M. Masters, *Macroscale and Microscale Organic Experiments*, 6th Edition, Cengage Learning, 2010 5. R.K. Bansal, *Laboratory Manual in Organic Chemistry*, New Age International, 5th Edition, 2016. 6. S. Delvin, *Green Chemistry*, Sarup& Sons, 2005. 7. O.R. Rodig, C.E. Bell Jr. and A.K. Clark, *Organic Chemistry Laboratory Standard and Microscale Experiments*, Saunders College Publishing, 3rd edition, 2009. 8. J. Mohan, *Organic Analytical Chemistry*, Narosa Publishing House, 2014.	

Programme: **M. Sc. Part-I (Pharmaceutical Chemistry)**

Course Code: **CHOE-412**
Title of the Course: **Practical Course in Organic Chemistry-II**
Number of Credits: **02** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objective:	To translate certain theoretical concepts learnt earlier into experimental knowledge by providing hands on experience of basic laboratory techniques required for organic syntheses.
Course Outcome	1. Students will be in a position to adopt Safe and good laboratory practices, handling laboratory glassware, equipment and chemical reagents. 2. Students will be in a position to understand and calculate stoichiometric requirements during organic syntheses. 3. Students will be in a position to perform common laboratory techniques including reflux, distillation, vacuum distillation, aqueous extraction, thin layer chromatography (TLC).

Content	*Hrs*
Minimum 13 experiments from the list shall be conducted.	
1. Introduction to laboratory equipments, apparatus and safety a. Common Hazards in Chemical Laboratory, Risk assessment b. Accidents and Emergency procedures	04
2. Laboratory Techniques (Any Two) a. Simple distillation i. Simple distillation of thionyl chloride under anhydrous condition ii. Simple distillation under Nitrogen atmosphere b. Fractional distillation i. Chloroform-dichloromethane mixture using water condenser. ii. Toluene and cyclohexane by fractionating column. c. Vacuum distillation under inert atmosphere Dry Distillation of DMF, *o*-dichlorobenzene, $POCl_3$ d. Thin layer Chromatography i. Purification and isolation of mixture of acids by using Preparative TLC. ii. Purification and isolation of mixture of phenols by using Preparative TLC. iii. Purification and isolation of pharmaceutical drugs using Preparative TLC.	08
3. Organic Synthesis (Any Four) a. *p*-Iodonitrobenzene by Sandmeyer reaction b. Pinacol- Pinacolone rearrangement c. Hydrogenation of Maleic acid (Hydrogen balloon) d. Preparation of nitrostyrene from aldehyde e. Preparation of α,β-dibromocinnamic acid f. Reduction of nitro compounds g. Synthesis of Urea from ammonium cyanate	16
3. Solvent Free Organic synthesis (Any Two)	08

a. Reduction using ball milling technique b. Oxidation of 2° alcohol using $KMnO_4$/Alumina by grinding technique. c. Synthesis of (±)-Binol from β-naphthol d. Hunsdiecker reaction of cinnamic acid derivatives e. Beckmann rearrangement of oxime derivatives	
4. Two-step Organic Synthesis (Any Two) a. Benzamide-Benzoic acid-Ethyl Benzoate b. Phthalic anhydride – Phthalimide – Anthranilic acid. c. Methyl benzoate- *m*-nitrobenzoate- *m*-nitrobenzoic acid d. Chlorobenzene – 2, 4 – dinitrochlorobenzene – 2,4-dinitrophenol e. Acetanilide – *p*–Bromo acetanilide – *p*–Bromoaniline f. Acetophenone – Oxime – Acetanilide	16
5. **Separation, Isolation and Identification of Organic compounds (Any One)** a. Separation, purification and identification of compounds of binary mixture (Solid-Solid, Solid-liquid and Liquid-liquid) using the TLC and column chromatography, chemical tests. IR spectra to be used for functional group identification.	08
Pedagogy	Students should be given suitable pre- and post-lab assignments and explanation revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.
References /Readings	1. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Prentice Hall; 2011. 2. K. Tanaka, *Solvent-free Organic Synthesis*, Wiley-VCH, 2nd Ed., 2009 3. L. F. Fieser, K. L. Williamson "*Organic Experiments*" 7th edition D. C. Heath, 1992. 4. K. L. Williamson, K. M. Masters, *Macroscale and Microscale Organic Experiments*, 6th Edition, Cengage Learning, 2010 5. R. K. Bansal, *Laboratory Manual in Organic Chemistry*, New Age International, 5th Edition, 2016. 6. S. Delvin, *Green Chemistry*, Sarup& Sons, 2005. 7. O. R. Rodig, C. E. Bell Jr., A. K. Clark, *Organic Chemistry Laboratory Standard and Microscale Experiments*, Saunders College Publishing, 3rdedition, 2009. 8. J. Mohan, *Organic Analytical Chemistry*, Narosa Publishing House, 2014.

Programme: **M. Sc. Part-I (Pharmaceutical Chemistry)**

Course Code: **CHHE-411**
Title of the Course: **Practical Course in Pharmaceutical Chemistry- I**
Number of Credits: **02** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. To acquire hands on training in laboratory techniques. 2. To understand organic synthesis with reference to medicinal compound preparations.	
Course Outcome	1. Students will be able to understand the theoretical concepts and practical applications. 2. Students will be able to handle analytical instruments like UV-VIS spectrophotometer and carry out drug analysis.	
Content:		*Hrs*
1) Qualitative and Quantitative tests of (Any 1) (1) Purified Water as per IP Monograph (2) Ibuprofen as per IP Monograph		10
2) Titrimetric Assay of the following bulk drugs: (4 x 2 = 8) (Any 2) a) Pheniramine Maleate b) Salbutamol c) Ofloxacin		08
3) UV. Spectrophotometric Assay of the following drugs (in different dosage forms): (4 x 4= 16) (Any 4) Rifampicin, Meloxicam, Salbutamol, Ofloxacin, Isoniazid, Diazepam, Acyclovir, Bisacodyl, Tinidazole,		16
4) Synthesis of following bioactive or drug molecules (2x3=6 hours) Any 2 a) 3-Acetylcoumarin b) 2-Phenylbenzimidazole c) 2,3-Diphenyl Quinoxaline		06
5) Multistep synthesis (Any one) a) Flavone from 2-hydroxyacetophenone b) Paracetamol from Acetanilide		08
6) Dissolution experiment: To study the dissolution rate of sustained release Theophylline tablets IP.		06
7) High Performance liquid Chromatographic experiment: To develop and validate the analytical method of any one drug using high performance liquid chromatography.		06
Pedagogy	Pre-lab and Post-lab exercises. Demonstrations of experiments. Explanation of procedures.	

References /Readings	1. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, *Vogel's Textbook of Practical Organic Chemistry*, 5th Edition, Prentice Hall; 2011. 2. K. A. Connors, *Text book of Pharmaceutical analysis*, 3rd Edition, Wiley Interscience Publication, 1990. 3. J. Bassett, J. Mendhan, R. C. Denny, *Vogel's Text book of quantitative chemical analysis* revised by G.H. Jeffery , 6th Edition, Pearson Education Publication, 2007. 4. Indian Pharmacopoeia., United States Pharmacopoeia, British Pharmacopoeia. European Pharmacopoeia. 5. J. E. F. Reynolds, *Martindale-The Extra Pharmacopoeia*, 30th Edition, Pharmaceutical Press, London, 1993. 6. J. Moini, *Pharmaceutical Laboratory Procedures*, 1st Edition, Cengage Learning India Pvt. Ltd., New Delhi, 2010.	

Programme: **M. Sc. Part-I (Pharmaceutical Chemistry)**

Course Code: **CHHE-412**
Title of the Course: **Practical Course in Pharmaceutical Chemistry-II**
Number of Credits: **02** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objective:	1. To acquire hands on training in laboratory techniques. 2. To understand organic synthesis with reference to medicinal compound preparations.
Course Outcome	1. Students will be able to understand the theoretical concepts and practical applications. 2. Students will be able to handle analytical instruments like UV-VIS spectrophotometer and carry our drug analysis.

Content:	*Hrs*
1) Qualitative and Quantitative tests of (Any 1) (1) Paracetamol as per IP Monograph (2) Aspirin as per IP Monograph	10
2) Titrimetric Assay of the following bulk drugs: (2 x 4 = 8) Any 2 a) Chloramphenicol capsules IP b) Furosemide injection IP c) Ketoprofen d) Phenytoin	08
3) UV Spectrophotometric Assay of the following drugs (in different dosage forms): (4 x 2= 8) Any 2 Mefenamic acid, Furosemide, Chloramphenicol	08
4) Synthesis of following bioactive or drug molecules : (2 x 4 = 8 hours) Any 2 a) Warfarin b) 2-(*p*-Chlorophenyl)benzoxazole c) Monastrol d) Nitazoxanide	08
5) Dissolution experiment: Dissolution rate study of sustained release Diclofenac tablets IP.	06
6) Thin Layer Chromatographic experiments on Pharmaceuticals (Any 1) a) To identify the given drug amongst the paracetamol, aspirin and caffeine citrate with the help of thin layer chromatography and calculate its *Rf* value. b) To identify the given sulpha drug among the sulphadiazine, sulphamethoxazole and trimethoprim with the help of thin layer chromatography and calculate its *Rf* value.	04
7) High Performance liquid Chromatographic experiment: To demonstrate high Performance liquid chromatography and analyse Diazepam Tablets by High Pressure Liquid Chromatography.	06

8) Separation of mixture of o-nitroaniline and p-nitroaniline using column chromatography.		06
9) **Infrared Spectroscopic analysis** **Demonstration of Instrumentation and Interpretation of Representative Spectra (Any 1)** a) To differentiate between analgesic-NSAIDs :Aspirin, Ibuprofen, Paracetamol. b) To differentiate between Acetophenone, *p*-Nitroacetophenone, Benzamide		04
Pedagogy	Pre-lab and Post-lab exercises. Demonstrations of experiments. Explanation of procedures.	
References /Readings	1. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, *Vogel's Textbook of Practical Organic Chemistry*, 5th Edition, Prentice Hall; 2011. 2. K. A. Connors, *Text book of Pharmaceutical analysis*, 3rd Edition, Wiley Interscience Publication, 1990. 3. J. Bassett, J. Mendhan, R. C. Denny, *Vogel's Text book of quantitative chemical analysis* revised by G.H. Jeffery , 6th Edition, Pearson Education Publication, 2007. 4. Indian Pharmacopoeia., United States Pharmacopoeia, British Pharmacopoeia. European Pharmacopoeia. 5. J. E. F. Reynolds, *Martindale-The Extra Pharmacopoeia*, 30th Edition, Pharmaceutical Press, London, 1993. 6. J. Moini, *Pharmaceutical Laboratory Procedures*, 1st Edition, Cengage Learning India Pvt. Ltd., New Delhi, 2010	

Programme: **M.Sc. Part-I (Pharmaceutical Chemistry)**

Course Code: **CHPE-411**
Title of the course: **Practical course in Physical Chemistry-I**
Number of Credits: **02** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objective:	1. To develop experimental skills on basic lab techniques in physical chemistry 2. To acquire skills for data analysis and interpretation 3. To help the students to develop research skills
Course Outcome:	1. Students will able to explain various fundamental lab techniques. 2. Students should be in a position to apply the knowledge for their dissertation and research work.

Content	*Hrs*
Minimum 13 Experiments to be performed per Semester **Non-instrumental Experiments (any 7)** 1. To study the kinetics of hydrolysis of ethyl acetate and to determine a) Energy of activation b) Entropy of activation and c) Free energy change. 2. To determine the order of reaction between potassium persulphate and potassium iodide by graphical, fractional change and differential methods. 3. To study the three-component system such as acetic acid, chloroform; and water and obtain tie line. 4. To determine the molecular weight of polyvinyl alcohol by viscosity measurement. 5. To study the electro-kinetics of rapid reaction between SO_4^{2-} and I^- in an aqueous solution. 6. To determine the buffer capacity of acidic buffer solution. 7. To determine the partial molal volume of ethanol-water mixture at a given temperature. 8. To measure energy content of various types of plastics using bomb calorimetry 9. To determine number average molecular weight of a polymer sample with an indirect titration method. 10. To investigate basic hydrolysis of ethyl acetate at four different temperatures and find out energy of activation **Instrumental Experiments (any 6)** 11. To determine the degree of hydrolysis of salt of weak base and strong acid using conductometer.	30 30

12. To determine the dissociation constants of a tribasic acid (Phosphoric acid obtain derivative plot to get equivalence point. 13. To determine formal redox potential of Fe^{2+}/Fe^{3+} and Ce^{3+}/Ce^{4+} system obtain derivative plot to get equivalence point. 14. To study spectrophotometric titration of ferrous ammonium sulphate with potassium permanganate (or dichromate vs permanganate) 15. To determine Avogadro's number by improved electroplating. 16. To determine the zeta potential of colloidal system and investigate the effect of different surfactants on stability of the colloids 17. To verify the Kohlrausch's law for weak electrolyte by conductometry 18. To determine the transport numbers of Cu^{2+} and SO_4^{2-} ions in $CuSO_4$ solution by Hittorf's method.	
Pedagogy	Mainly pre-laboratory exercises Seminars / term papers /assignments / presentations / lab hand-out /self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. A. Finlay & J.A. Kitchener, "*Practical Physical Chemistry*", Longman. 2. F. Daniels & J.H. Mathews, "*Experimental Physical Chemistry*", Longman. 3. A.M.James, "*Practical Physical Chemistry*", Longman. 4. D.P. Shoemaker & C.W. Garland, "*Experimental Physical Chemistry*", McGraw-Hill.

Programme: **M.Sc. Part-I (Pharmaceutical Chemistry)**

Course Code: **CHPE-412**
Title of the course: **Practical course in Physical Chemistry-II**
Number of Credits: **02** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test.
Course Objective:	1. To develop experimental skills on basic lab techniques in physical chemistry 2. To acquire skills for data analysis and interpretation 3. To help the students to develop research skills
Course Outcome:	1. Students will gain knowledge of various fundamental lab techniques. 2. Students should be in a position to apply the knowledge for their dissertation and research work.

Content	*Hrs*
Minimum 13 experiments to be conducted per Semester	35
Non-instrumental Experiments (any 8)	
1. To determine the radius of a molecule by viscosity measurements.	
2. To determine ΔG, ΔH and ΔS of silver benzoate by solubility product method	
3. To investigate the adsorption of oxalic acid by activated charcoal and test the validity of Freundlich and Langmuir's isotherms.	
4. To determine the molecular weight of a given polymer by turbidimetry	
5. To study the rate of reaction between ethyl bromoacetate and sodium thiosulphate kinetically.	
6. To determine the percentage composition of a given mixture of two liquids by stalagmometer method.	
7. To study the kinetics of hydrolysis of methyl acetate and to determine a) Energy of activation b) Entropy of activation and c) Free energy change.	
8. To study the kinetics of the reaction between Potassium per sulphate ($K_2S_2O_8$), and Potassium iodide (KI), and to determine a) Energy of activation b) Entropy of activation and c) Free energy change.	
9. To determine the order of reaction for hydrolysis of ethyl acetate by graphical, fractional change and differential methods.	
10. To determine the molecular weight of polystyrene by viscosity measurement.	
Instrumental Experiments (any 5)	
11. To determine the relative strength of chloroacetic acid and acetic acid by conductometry.	25
12. To determine the degree of hydrolysis of salt of weak base and strong acid using conductometry.	

13. To determine the composition of a mixture of acetic acid, dichloroacetic acid and hydrochloric acid by conductometric titration. 14. To determine the dissociation constants of monobasic acid and dibasic acid and obtain derivative plot to get equivalence point. 15. To determine the redox potential of Fe^{2+}/Fe^{3+} system by titrating it with standard $K_2Cr_2O_7$ solution. 16. To study the electrodeposition of metal.	
Pedagogy	Mainly pre-laboratory exercises Seminars / term papers /assignments / presentations / lab hand-out /self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. A. Finlay & J.A. Kitchener, "*Practical Physical Chemistry*", Longman 2. F. Daniels & J.H. Mathews, "*Experimental Physical Chemistry*", Longman. 3. A. M. James, F. E. Prichard "*Practical Physical Chemistry*", Longman 4. D.P. Shoemaker & C.W. Garland, "*Experimental Physical Chemistry*", McGraw-Hill.

Programme: **M. Sc. Part-I (Pharmaceutical Chemistry)**

Course Code: **CHAE-411**
Title of the Course: **Practical Course in Analytical Chemistry - I**
Number of Credits: **02** Total Contact Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objectives:	1. Introduction of various experimental techniques for analysis. 2. Learning data analysis, handling and interpretation of spectra.
Course Outcomes:	1. Students will be able to explain how to determine an unknown concentration of solution. 2. Students will use statistical methods to analyse data in laboratory. 3. Students will be able to use different techniques for qualitative and quantitative estimation.

Content	*Hrs*
This course consists of 7 units of experiments in various areas of Analytical chemistry. Minimum 13 experiments which include at least 02 experiments from unit 1-6 and 01 experiment from unit 7 shall be conducted.	
Unit 1: Statistics i. Calibration of selected Volumetric apparatus ii. Calibration of selected Laboratory instruments iii. Preparation of standard solutions and standardisation.	**9**
Unit 2: Colorimetry/ UV-Visible Spectrophotometry i. Estimation of Iron from Pharmaceutical sample (capsule) by thiocyanate method ii. Estimation of phosphoric acid in cola drinks by molybdenum blue method. iii. Estimation of KNO_3 by UV spectroscopy and $K_2Cr_2O_7$ by Visible spectroscopy iv. Simultaneous determination and Verification of law of additivity of absorbances ($K_2Cr_2O_7$ and $KMnO_4$).	**9**
Unit 3: Flame Spectrophotometry and AES/AAS/ICP Spectroscopy i. Estimation of Na and K in food supplements or cosmetic products. ii. Estimation of Pb in water sample by AES/AAS/ICP. iii. Estimation of Fe and Al in Iron ore sample by AES/AAS/ICP.	**9**
Unit 4: Ion Exchange Chromatography and High Pressure Liquid Chromatography i. Separation and Estimation of chloride and bromide. ii. Separation of Anthracene and Naphthalene using reverse phase chromatography iii. Separation of Benzaldehyde and Benzyl alcohol using normal phase chromatography	**10**
Unit 5: Volumetric Titrations i. Estimation of Ca in pharmaceutical tablet. ii. Estimation of Al and Mg in antacid tablet. iii. Estimation of CaO in cement.	**10**
Unit 6: Solvent Extraction and spectrophotometry i. Extraction of Cu as copper dithiocarbamate (DTC) using solvent extraction and	**10**

estimation by spectrophotometry. ii. Determination of Ni as Dimethylglyoxime complex by spectrophotometry. iii. Determination of Silver as ion association complex with 1,10-Phenanthroline and Bromopyrogallol red.	
Unit 7: Interpretation Exercises i. Thermal studies: TG/DTA and Isothermal weight loss studies of various hydrated solids like $CuSO_4 \cdot 5H_2O$, $Ca_2C_2O_4 \cdot H_2O$, $Fe_2C_2O_4 \cdot 2H_2O$. ii. X-ray powder diffractometry: Calculation of lattice parameters from X-ray powder pattern of cubic system such as $NiMn_2O_4$, $CoFe_2O_4$ etc. iii. IR spectra of Urea, benzoic acid, Copper sulphate pentahydrate etc.	**4**
Pedagogy:	Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. J. H. Kennedy, *Analytical Chemistry Principles*, Saunders College Publishing, 2nd Ed., 1990. 2. G. D. Christian, *Analytical chemistry*, 5thEd., John Willey and Sons, 1994 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, *Vogel's Textbook of Quantitative Chemical Analysis*, 6thEd., Pearson Education Asia 2009. 4. A. J. Elias, *Collection of interesting chemistry experiments*, University press, 2002. 5. R.A. Day & A.L. Underwood, *Quantitative Analysis*, 6thEd., Prentice Hall, 2001. 6. J. Kenkel, *Analytical Chemistry for Technicians*, 3rdEd., Lewis publishers, 2002.

Programme: **M. Sc. Part-I (Pharmaceutical Chemistry)**

Course Code: **CHAE-412**
Title of the Course: **Practical Course in Analytical Chemistry - II**
Number of Credits: **02** Total Contact Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.
Course Objectives:	1. Introduction of various experimental techniques for analysis. 2. Learning data analysis, handling and interpretation of spectra.
Course Outcomes:	1. Students will be able to standardize a material to determine an unknown concentration. 2. Students will use statistical methods to analyse data in laboratory. 3. Students will be able to use different techniques for qualitative and quantitative estimation.

Content	*Hours*
This course consists of 7 units of experiments in various areas of Analytical chemistry. Minimum 13 experiments which include at least 02 experiments from unit 1-6 and 01 experiment from unit 7 shall be conducted.	
Unit 1: Statistics i. Calibration of selected Volumetric apparatus ii. Calibration of selected Laboratory instruments iii. Preparation of standard solutions and standardisation.	**9**
Unit 2: Titrimetric Analysis i. Standardisation and estimation of Chloride using precipitation titration (Mohr's method) ii. Analysis of commercial caustic soda by neutralisation titrimetric method iii. Determination of sulphates by complexometric titrations using EDTA.	**8**
Unit 3: Flame Spectrophotometry and AES/AAS/ICP Spectroscopy i. Estimation of Na and K in food supplements or cosmetic products using flame photometer. ii. Estimation of chromium in water sample by AES/AAS/ICP. iii. Estimation of nickel, molybdenum in Hastelloy C-22 using AES/AAS/ICP..	**10**
Unit 4: Natural product isolation and Ion Exchange Chromatography i. Isolation of cinnamaldehyde from cinnamon ii. Isolation of Caffeine from tea powder iii. Separation and estimation of Cadmium and Zinc	**9**
Unit 5: UV-Visible Spectrophotometry and High-Pressure Liquid Chromatography i. Estimation of KNO_3 and $K_2Cr_2O_7$ using UV- Visible spectroscopy ii. Separation of Benzaldehyde and benzoic acid using reverse phase HPLC.	**10**

iii. Quantification of naphthalene in a sample using reverse phase HPLC.	
Unit 6: Solvent Extraction and spectrophotometry i. Spectrophotometric determination of aspirin/phenacetin/ caffeine in APC tablet using solvent extraction ii. Colorimetric determination of iron with salicylic acid. iii. Determination of copper in brass sample by colorimetry.	**10**
Unit 7: Data Interpretation Exercises I. NMR/Mass spectra II. HPLC and GC chromatograph III. XRD powder pattern of cubic systems IV. Thermogram of coordination compounds	**4**
Pedagogy:	Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning.
Text Books/ References / Readings	1. J. H. Kennedy, *Analytical Chemistry Principles,* Saunders College Publishing, 2nd Ed., 1990. 2. G. D. Christian, *Analytical chemistry*, 5th Ed., John Willey and Sons, 1994 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, *Vogel's Textbook of Quantitative Chemical Analysis,* 6th Ed., Pearson Education Asia 2009. 4. J. Elias, *Collection of interesting chemistry experiments*, University press, 2002. 5. R.A. Day & A.L. Underwood, *Quantitative Analysis*, 6th Ed., Prentice Hall, 2001. 6. J. Kenkel, *Analytical Chemistry for Technicians*, 3rd Ed., Lewis publishers, 2002.

Programme: **M.Sc. Part-I (Pharmaceutical Chemistry)**

Course Code: **CHHC-412**
Title of the course: **Fundamentals of Pharmaceutical Chemistry-II**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Should have studied Pharmaceutical Chemistry at Semester I.
Course Objective:	1. To learn major classes of drugs w.r.t. IUPAC nomenclature, structure and functional groups. 2. To understand the SAR of selected drugs and their Mechanism of action. 3. To get acquainted with the synthesis of selected drug molecules
Course Outcome:	1. Students will be able to identify the examples in different classes of drugs. 2. Students will be able to write IUPAC names and Structure of drugs. 3. Students will be in a position to understand the mechanism of action of selected classes of drugs. 4. The students will have a clear understanding of concepts on SAR analysis. 5. The students will be able to apply synthetic organic chemistry knowledge in devising a synthesis for a drug.

Content	*Hrs*
Classification of Chemotherapeutic Drugs: Development of the following drugs including structure activity relationship (S.A.R.), mechanisms of action (MA), outline of synthesis ($), chemical nomenclature, generic names (GN) and side effects (SE) (outline of synthesis only of those marked$)	
1. Cholinergic and Adrenergic Agents, General Anaesthetics and Hypotensive agents Classification of cholinergic agents: Drugs acting on cholinergic nervous system: Bethanechol$, Methacholine$, Neostigmine, Pyridostigmine, Parathion, Malathion, Atropine, Dicyclomine$, Tropicamide$, Papaverine, Classification of adrenergic agents, Drugs acting on adrenergic nervous system: Methyldopa (MA,$), Guanethidine, Ephedrine, Amphetamine, Tranylcypromine, Pragyline, Norepinephrine, Epinephrine, Pronethalol, Propranalol$, Atenolol$, Metoprolol.(SAR)	12

2. **Drugs acting on the central nervous system**: Hypnotics and sedatives: Chloral hydrate, Phenobarbital$, Secobarbital, Thiopental$, Nitrazepam, (SAR) Drugs acting as anticonvulsants: Phenytoin$, phenacemide, Clonazepam, Phensuximide, Phenobarbital, (Classification of Barbiturates), Primidone, Carbamazepine$. Psychotherapeutic agents: Phenothiazines such as Chloropromazine, Chlorodiazepoxide$, Oxazepam, Diazepam$, Imipramine, Nialamide, Tranylcypromine, Pargyline. CNS stimulants: Phenmetrazine, Nikethamide$, Iproniazid, Picrotoxines, Tetrazole, Amphetamine.	12
3. **Antihistaminics, antiemetic, antiulcer drugs, Drugs used in parkinsonism and Alzhemeier's:** Diphenhydramine, Triprolidine, Cyclizine, Promethazine$(SAR), Cimetidine, Omeprazole (MA), Ranitidine, Sumatriptan, Ondansetron. Drugs used in Parkinsonism: Benzotronine mesylate, Levodopa, Carbidopa, Amantadine hydrochloride. Drugs for Alzheimer's diseases: Serine, Velnacrine (MA), Aniracetam.	10
4. **Cardiovascular drugs, antihypertensive agents**, **and antibiotics:** Digitoxin, Quinidine, Procainamide, Verapamil. Antihypertensive agents which elicit their action through autonomous nervous system previously described under 1 and 2, Clonidine, Hydralazine, ACE inhibitors- Enalapril and related drugs vasodilators such as Nitroglycerine, Isoxsuprine, Nylidrin, Antibiotics: Penicillin and semisynthetic penicillin's and Cephalosporins, Amoxicillin, Cloxacillin, Streptomycin, Chloramphenicol, Tetracycline and derivatives, Erythromycin.	10
5. Analgesics, Antipyretics and Inflammatory agents: Analgesics, antipyretics and anti-inflammatory agents: Sodium salicylate, Acetaminophen$, Phenacetin, Phenylbutazone, Oxyphenabutazone$, Naproxen$, Probenecid, Allopurinol, Profen, Diclofenac $. Narcotic analgesic agents: Morphine, Codeine, Meperidine, Methadone, Dextropropoxyphene. Non-narcotic analgesic agents: Dextropropoxyphene Levallorphan.	10
6. **Neglected Tropical diseases**. Background, overview of Neglected tropical diseases, (Poverty diseases) Human Schistosomiasis, African trypanosomiasis (Chagas), leishmaniasis, sleeping sickness. Nitroheterocycles, Benznidazole, Nifurtimox ($, MA and side-effects)	06
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be

	used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/References / Readings	1. D. A. Williams & T. L. Lemke, *Foye's principles of medicinal chemistry* 5th edition, Lippincott Williams and Wilkins, 2006. 2. J. M. Beale & J. M. Block, *Wilson & Gisvold's Text book of Organic Medicinal & Pharmaceutical Chemistry*, Lippincott Williams and Wilkins, 2004. 3. D. J. Abraham & D. P. Rotella, *Burger's Medicinal Chemistry Drug Discovery and Development*, 7th edition, John Wiley & Sons N.Y, 2010. 4. D. Shriram, P. Yogeshwari, *Medicinal Chemistry*, Pearson Education, 2007. 5. G. L. Patrick: *Introduction to Medicinal Chemistry*, Oxford University Press, UK. 6th edition, 2017. 6. D. Lednicer & L. A. Mitscher, The *Organic Chemistry of Drug Synthesis*. (6 volume set) III. John Wiley & Sons, 2005. 7. H. Singh & V. K. Kapoor, *Medicinal and Pharmaceutical Chemistry*, Vallabh Prakashan, 2010. 8. G. R Chatwal, *Medicinal Chemistry* (*Organic Pharmaceutical Chemistry*), Himalaya Publishing house, 2002.

Programme: **M.Sc. Part-I (Pharmaceutical Chemistry)**

Course Code: **CHHC-413**
Title of the course: **Drug Product Formulation, Development and Manufacture**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Should have studied Pharmaceutical Chemistry at Semester I.
Course Objective:	1. To understand the concept of drug dosage forms, types of formulations and pilot plant processes. 2. To study the drug formulation development with specific examples.
Course Outcome:	1. Students should will be able to formulate APIs. 2. Students will be able to apply this knowledge for formulation experiments in laboratory. 3. Students will be able to evaluate formulations qualitatively.

Content	*Hrs*
1. **Introduction and Classification**: Introduction to drugs, Dosage Forms & Drug Delivery system – Definitions of Common terms. Development of dosage forms: Four stage development including preformulation. Preformulation studies, objectives, factors to be considered, study protocol, including prototype development, scale up studies and commercialization. For example analysing polymorphs using ultraviolet, infra-red, solid state NMR, DSA-DTA and X-Ray Crystallography. Drug Regulation and control, pharmacopoeias-formularies, sources of drug, drug nomenclature, routes of administration of drugs products their advantages and disadvantages, need for a dosage form, classification of dosage forms & brief description, study of excipients.	15
2. **Pilot plant** Scale up techniques, Benefits of pilot plant- Broad guidelines of process development. General Consideration. Industrial manufacturing method and flow charts of sulphamethoxazole, Rifampicin, Chloramphenicol maleate, Actinobolin, BTZO43, Piperaquine, Propranolol hydrochloride.	15

3. **Pharmaceutical manufacturing operations** Brief discussion on unit operations and types of equipments/ machines used. Unit operations like size reduction, mixing/blending, drying, compression , granulation, coating etc. Three most frequently used unit operations within biopharmaceutical manufacturing, that includes chromatography, virus filtration, and tangential flow filtration (TFF), Quality by design (QbD): Fundamentals of pharmaceutical quality by design, identification of critical quality attributes, critical material attributes, critical process parameters and quality risk management.	15
4. Dosage forms-formulation components, manufacturing and QC Types of dosage forms: Liquids-monophase & biophase including ENT preparation, sprays. Semisolid eg. Ointment, creams, gels, liniment, paste, lotion etc. Solid dosage forms eg. Tablets-Types of tablets, capsules, granules, powders, pastilles, lozenges, Sterile dosage forms eg. Injectables and ophthalmic preparations. Suppositories etc. Routes of drug administration, their advantages and disadvantages. Details pertaining to manufacturing processes for variety of dosage forms as listed above. Quality control evaluation of the dosage forms for assurance.	15

Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/References / Readings	1. L. V. Allen Jr., N. G. Popovich, H. C. Ansel, *Ansel"s pharmaceutical dosage forms and drug delivery systems,* Lippincott Williams & Wilkins, 2005. 2. R. K. Khar, *Lachman/Lieberman's The Theory and Practice of Industrial Pharmacy*, 4th Edition, CBS Publishers & Distributors, 2020. 3. G. Banker, *Modern Pharmaceutics*, Marcel Dekker, Inc, 2002. 4. S. J. Carter, *Dispensing for Pharmaceuticals students*, CBS Publishers & Distributors, Delhi, 2007. 5. J. P. Remington, *Remington's Pharmaceuticals Sciences*, Mack Publishers,1990. 6. M. E. Aulton, *Pharmaceutics Science of Dosage forms and design*, Kevin Taylor Elsevier, Health Sciences Division, 2001.

Programme: **M.Sc. Part-I (Pharmaceutical Chemistry)**

Course Code: **CHHC-414**
Title of the course: **Drug Design, Discovery and Development**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Should have studied Pharmaceutical Chemistry at Semester I.
Course Objective:	1. To make the students well versed with theories of drug action. 2. To make the students understand the Structure Activity Relationship studies citing various examples. 3. To acquaint the students with the concepts of drug designing by molecular modelling. 4. To introduce various terms involved in patenting and IPR.
Course Outcome:	1. Students will be able to explain the theories of drug action. 2. Students will have a clear understanding of concepts on SAR analysis and will be able to apply Quantitative Structure Activity Relationship knowledge in drug designing. 3. Students will be able to analyze the effect of different functional groups on the biological activity of drugs. 4. The students will be able to illustrate an example of drug designing by molecular modelling. 5. The students will be able to explain the terms in patents.

Content	*Hrs*
1. **Introduction to Drug design, Lead compounds and Pro-drug Concept.** Development of new drugs: Introduction, procedure followed in drug design, the search for lead compounds, molecular modification of lead compounds, prodrugs and soft drugs, prodrug; introduction, prodrug formation of compounds containing various chemical groups, multiple prodrug formation, soft drugs; design of soft drugs.	12
2. **SAR and QSAR Studies in drug discovery** Structure-Activity Relationship (SAR): Factors effecting bioactivity, resonance, inductive effect, isosterism, bioisosterism, spatial considerations, biological properties of simple functional groups. 4-5 illustrative examples depicting structural activity relationship studies. Theories of drug activity, occupancy theory, rate theory, induced-fit theory. Quantitative structure-activity relationship (QSAR): history and development of QSAR, drug receptor interactions, the additivity of group contributions, physico-chemical parameters, lipophilicity parameters, electronic parameter, ionization constants, steric parameters, chelation parameters, redox potential, indicator-variables, quantitative models.	12

3. **QSAR Approaches in drug designing and modern methods in discovery** Hansch analysis- Advantages and drawbacks. Free-Wilson analysis, Advantages and drawbacks. Their application, relationship between Hansch and Free-Wilson analysis (the mixed approach), non-linear relationship, Introduction to other QSAR approaches- Free Topliss Method-Postulates and Illustration. Introduction to molecular modelling using computers and docking, uses of molecular modelling manual use, further computer programming.	12
4. **Designing of Enzyme Inhibitors as drugs** Structure-based drug design: Process of structure based drug design, deactivation of certain drugs necessary for T cell functioning, determination of the active site with special reference to chymotryspin, design of inhibitors**.** Design of Enzyme Inhibitors, 9-alkylpurines, 9-mercaptopurines and allopurines, active site directed irreversible enzyme inhibition, suicide enzyme inactivators.	12
5. Development of New drugs High throughput screening. Drug Design software's and its applications. Intellectual property rights, patents, industrial designs, geographical indications, trademarks, trade secrets. Patentable inventions. Patentable drugs. Role of patents in Pharmaceutical industry. Trade related aspects (TRIPS), international & regional agreements. Patent writing for drug designed. Examples of new drugs developed.(5 examples with one designing strategy)	12
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/References / Readings	1. S. S. Pandeya and J. R. Dimmock, *An Introduction to Drug Design* New Age International (P) Ltd. Publishers, 2007. 2. M. E. Wolff., Burger's Medicinal Chemistry and Drug Discovery, Vol I (Ch 9 and 14), John Wiley and Sons, New York, 1997. 3. Alen-Gringauz, *Introduction to Medicinal Chemistry*, 1st edition, Wiley-VCH,1996. 4. D. Lednicer and L. A. Mitscher, *The Organic Chemistry of Drug Synthesis*, Vol. I to V, John Wiley, 2005. 5. Alen-Gringauz, *Introduction to Medicinal Chemistry*, Wiley-VCH, 1997. 6. R.B. Silverman, *Organic Chemistry of Drug design and Drug action*, 3rd edition, Academic Press, 2014. 7. A. Leach, *Molecular Modelling: Principles and applications*, 2nd edition, Pearson India, 2001. 8. Norman Bailey, Statistical methods in Biology, 3rd edition, Cambridge University Press, 1995. 9. P. Krogsgaard-Larsen, U. Madsen, T. Liljefors *A Textbook of Drug*

	Design and Development, 2nd edition, CRC Press, 1996. 10. G. Jolles and R. H. Wooldridge, *Drug Design–Fact or Fantasy*, Academic Press, 1984. 11. E. B. Roche, *Design of Biopharmaceutical properties through prodrug and analogs,* Am. Pharm. Assoc. Academy of Pharm. Sci., 1977. 12. G. L. Patrick, *An Introduction to Medicinal Chemistry*, 2nd edition, (Indian edition), Oxford University Press, 2001 13. N.R. Subbaran, *What everyone should know about Patent*, Pharma Book Syndicate, 2005. 14. Current Patent Acts of various countries. 15. P. W. Grubb, *Patents for Chemicals, Pharmaceuticals & Biotechnology*, 4th edition, Oxford University Press, 2005.

Programme: **M.Sc. Part-I (Pharmaceutical Chemistry)**

Course Code: **CHHC-415**
Title of the course: **Biopharmaceutics and Pharmacokinetics**
Number of Credits: **04** Total Hours: **60** Effective from AY: **2022-23**

Prerequisites for the course:	Should have studied Pharmaceutical Chemistry at Semester I.
Course Objective:	1. To learn ADMET. Drug absorption drug distribution Drug Action Drug metabolism and excretion. 2. To learn how bioavailability is important in understanding the efficacy of a drug product.
Course Outcome:	1. A student will be able to relate drug absorption to bioavailability. 2. A student will be able to get an in depth knowledge of drug metabolism concept.

Content	*Hrs*
1. **Introduction:** Definitions, ADME, concentration time profile, plotting the data, different fluid compartments and blood flow rate compartment models, biological half life, elimination rate constant. Biopharmaceutics and pharmacokinetics in drug research.	08
2. **Drug Absorption, Dissolution and Distribution** GIT Absorption of drugs: Mechanism, physico-chemical, biological and pharmaceutical factors affecting drug absorption through GIT. Techniques for the GIT absorption assessment. mechanisms of drug absorption, factors affecting drug absorption: Biological, physiological, physico-chemical and pharmaceutical. Noyes-Whitney's dissolution rate law, study of various approaches to improve dissolution of poorly soluble drugs, In-vitro dissolution testing models, In-vitro-in-Vivo correlation. Factors affecting drug distribution, volume of distribution, protein binding – factors affecting, significance and kinetics of protein binding.	12
3. **Drug Metabolism and Excretion** Metabolism of drugs, Xenobiotics, Drug metabolizing organs and enzymes (microsomal & nonmicrosomal), Chemical pathways - Phase I reactions (Oxidative, reductive and hydrolytic reactions) and Phase II reactions (Conjugation), Significance of cytochrome P_{450} oxidation – reduction cycle, Factors affecting biotransformation of drugs. Renal excretion – Glomerular filtration, Active tubular secretion, Active (or) passive tubular reabsorption. Factors affecting renal excretions of drugs. Non renal excretions – Biliary, pulmonary, salivary, mammary, skin/dermal, gastrointestinal and genital excretions of drugs (Any two types).	12

4. **Bioavailability and Bioequivalency studies** Objectives and considerations in bioavailability studies, Definitions, federal requirements, methods of determination of bioavailability using blood and urinary excretion data. Protocol design for bioavailability assessment. Concept of equivalence, Methods for bioequivalence determination. Measurements of bioavailability, Determination of the rate of absorption, Bioequivalence studies and its importance. Biopharmaceutical classification of drugs, Importance of biopharmaceuticals.	12
5. Pharmacokinetics: Protein and tissue binding: Factors affecting protein binding, kinetics of protein binding, determination of rate constant and different plots (direct, scatchard and reciprocal), Implication of protein binding on pharmacokinetic parameters. Pharmacokinetic characterization of drugs: Pharmacokinetics of drugs following one/ two compartment open models with first order elimination kinetics as applied to rapid intravenous injection, Intravenous transfusion and oral administration. Determination of absorption rate constant using Wagner-Nelson, Loo Riegelman methods. Non Linear Pharmacokinetics: Various causes of non-linearity, Michaelis-Menten kinetics, In-vivo estimation of Km and Vm. Case studies. Physiologic pharmacokinetics models: Mean Residence Time; Statistical Moment Theory; Application and limitations of physiologic pharmacokinetic models. Miscellaneous Topics: Chronopharmacokinetics, Drug toxicity and forensic pharmacokinetics, kinetics of maternal-fetal drug transfer, pharmacokinetics v/s pharmacological/ clinical response, metabolic kinetics.	16
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
Text Books/References / Readings	1. M. Gibaldi, *Biopharmaceutics and Clinical Pharmacokinetics*, 4th edition, Philadelphia, Lea & Febiger, 1991. 2. D.M. Brahmankar & Sunil B. Jaiswal, *Biopharmaceutics and Pharmacokinetics: A Treatise*, Vallabh Prakasan, Pitambura, Delhi, 1998. 3. L Sharjel. & A. B. C. Yu, *Applied Biopharmaceutics and Pharmacokinetics*, 2nd edition, Connecticut, Appleton Century Crofts, 1985. 4. J. Swarbrick., Lea & Febiger, *Current Concepts in Pharmaceutical Sciences: Biopharmaceutics*, Philadelphia, 1970. 5. H. M. Abdou, *Dissolution, Bioavailability and Bioequivalence*, Mack Publishing Company, Pennsylvania, 1989. 6. R. E. Notari, *Biopharmaceutics and Clinical Pharmacokinetics- An Introduction*, 4th edition, Marcel Dekker Inc, New York and Basel, 1987. 7. J. G. Wagner and M. Pernarowski, *Biopharmaceutics and Relevant*

	Pharmacokinetics, 1st edition, Drug intelligence Publications, Hamilton, Illionois, 1971. 8. J. Swarbrick, J. C. Boylan, *Encyclopedia of Pharmaceutical Technology*, Vol. I, 2nd edition, Marcel Dekker Inc, New York, 2002. 9. S. K. Niazi, *Textbook of Biopharmaceutics and Clinical Pharmacokinetics*, BSP Books Private Limited, 2010. 10. Niazi, S. K., *Handbook of Bioequivalence Testing*, 1st edition, CRS Press, 2007.

ANNEXURE-III

Programme: M. Sc. Chemistry (Skill Based Course)

Course Code:- CHCS-501

Title of the Course: Laboratory safety, first aid and waste management (A course on transferable life skills)

Number of Credits: 02 **Total Hours: 30** **Effective from AY: 2022-2023**

Prerequisites for the Course:	Should have studied B. Sc.
Course Objective:	1. Study of various concepts related to laboratory and industrial safety. 2. Study of various methods and techniques for First aid. 3. Study of various methodologies of waste management.
Course Outcome:	1. Students will be in a position to understand how to work safely while handling chemicals in laboratory and industries. 2. Students will be in a position to help with First aid in case of accidents. 3. Students will be in a position to handle waste management.

Content	Hours
1. Laboratory safety. 1.1. Responsibilities in laboratory - Purpose and responsibilities - Basic laboratory safety practices 1.2. Chemical Managements - Introduction to chemical inventory and material safety data sheet - Chemical storage and chemical labelling - Transportation of chemicals in laboratory - Special chemical hazards 1.3. Introduction to Personal protective equipments. - Eye protection, face protection, hand protection, head protection, foot protection, protective clothing, respiratory protection and hearing protection. 1.4. Safe handling of glasswares	4
2. **Fire Safety:** 2.1. Chemistry of Fire - Fire Tetrahedron - Combustion	4

- Flame -Premixed and Diffusion Flame, Practical Examples of Premixed Flames and Diffusion Flames - Ignition - Self Heating and Spontaneous Combustion, Smoldering - Stages in a Fire - Heat Transfer - Fire Hazards of Materials - Sources of Information on Hazardous Materials 2.2. Fire Extinguishment - Classifications of Fires - Extinguishing Agents -Water, Carbon Dioxide, Halogenated Agents / Clean Agents, Dry Chemicals, Foam Extinguishing Agents, Combustible Metal Extinguishing Agents, Kitchen Fires 2.3. Introduction to Fire Extinguishers -Fire Extinguisher Use in The Workplace -Maintenance, Inspection, And Testing of portable fire extinguishers	
3. Industrial Safety. 3.1. Risk, Hazard, types of hazards -Introduction to engineering controls and administrative controls 3.2. Safety in industry - Safe/Unsafe Condition, Safe/Unsafe Acts, Near Miss - Risk Assessment (Procedure and protocols with example) 3.3. Hazardous Chemical Waste - Types of Waste, Waste minimization - Waste Management, segregation and disposal 3.4. Demonstration - Mock fire drill - Mock evacuation drill - Safety audits	7
4. Hygiene and Occupational safety - Introduction to Occupational Safety and Health, occupational hygiene - Basics of Ergonomic; Ergonomic disorders and preventive measures for improved health and safety - Selecting appropriate ergonomic chair, manual material handling	5

- Musculoskeletal exercises for lab personnel - Need for Hygiene and types of Hygiene (demonstration)	
5. Basic First Aid 5.1. Introduction to First Aid - Origin, aim and scope of first aid, Overview of the human body 5.2. First aid equipment - Contents of the first aid box - Role and responsibilities of a first aider - Assessing the situation and acting safely, effectively and promptly in an emergency 5.3. Emergency care - Assessing the Victim: primary survey, secondary survey, head-to-toe examination, monitoring vital signs - use of eyewash and showers for chemical spillage - Cardiopulmonary Resuscitation (CPR) - Airway Obstructions - Controlling Bleeding - Managing unconscious casualty: checking and monitoring breathing and circulation, life-saving priorities for unconscious adults, unconscious child, unconscious infant. 5.4. Protocols for Common injuries and their immediate care for different emergencies - Shock, Wounds and soft tissue Injuries, Burns, Head and spinal Injuries, Chest, Abdominal and Pelvic Injuries, Bone, Joint and Muscle Injuries, Extremity Injuries and Splinting, Poisoning, Bites and Stings Sudden illness, Drowning, hyperventilation, asthma, Cold and heat emergencies, Electrical Incidences, choking in adults and infants.	5
6. Sewage Treatment 6.1. Introduction to the waste treatments, Types of waste: Solid, Liquid and Gaseous - Environmental laws: The water (Pollution and control of pollution) Act, 1974 6.2. General characteristics of waste: Liquid waste - Electrical conductivity, pH, COD, BOD, TS and TDS, total suspended solids, total volatile solids, chlorides, sulphates, oil & grease. 6.3. Waste Water Treatment Technologies: A. Primary treatment methods B. Secondary treatment methods and C. Tertiary treatment methods - Sludge disposal: Methods of sludge disposal. Sources and effects of sludge on environment. 6.4. Visit to Sewage treatment plant.	5
Pedagogy	Lectures & tutorials. Seminars / assignments / presentations / demonstrations / self-study or a combination of some of these could also be used.

References /Readings:	1. C. C. Fevzi and I. Adnan, Laboratory safety handbook, 1st Edition, 2016, Sabanci University. 2. Laboratory safety manual, Environmental Health and Safety Department, University of Washington, December 2021 Edition. (www.ehs.washington.edu) 3. D. Philpott, Fundamentals of Fire Protection for the Safety Professional, 3rd Edition, 2022, Bernan Press. 4. Indian Standard- 2190:2010, Selection, Installation and Maintenance of First-Aid Fire Extinguishers — Code of Practice (Fourth Revision) (http://tricone.co.in/Downloads/selection,installation_and_maintenance_of_first-Aid_Fire_Extinguishers1_IS%201290.pdf) 5. K. R. Muller, Chemical waste handling and treatment, 1st Edition, 1986, Springer Verlag Berlin Heidelberg. 6. Prudent practices in the laboratory: handling and management of chemical hazards, the National Academic Press, 2nd Edition, 2011, National Academies Press. 7. K. Park, Park's text book of Preventive and Social Medicine, 19th Edition, 2007, Banarsidas Bhanot publishers, India 8. NIEHS Health and Safety Guide to Laboratory Ergonomics. (https://ehs.uky.edu/docs/pdf/ohs_erg_ergonomics_guide_0001.pdf) 9. M. B. Pamela, Ergonomics Foundational Principles Applications and Technologies, 1st Edition, 2021, Taylor & Francis publisher. 10. The authorized manual of St. John Ambulance, St. Andrew's Ambulance association and the British red cross society, First Aid manual, 9th Edition, 2011, Dorling Kindersley. 11. J. R. Krohmer, American college of emergency physicians First Aid manual, 5th Edition, Dorling Kindersley. 12. I. Clement, Text book on First Aid & Emergency Nursing, 1st Edition, 2012, JP brothers. 13. P. Jevon, Emergency care and First Aid for Nurses, A practical guide, 1st Edition, 2007, Churchill Living Stone. 14. M. N. Rao and A.K. Datta, Waste Water Treatment, 3rd Edition, 2017, Oxford & IBH Publishing Co. Pvt. Ltd. 15. M. J. Hammer, Sewage and waste treatment, 7th Edition, 2012, Prentice Hall India Learning Private Limited.

ANNEXURE-IV (Bridge Course)

Programme: **M.Sc. Chemistry**

Course Code: **CHCB-401 (for Part-I students)**

Title of the course: **Bridge Course in mathematical concepts for chemistry**

Number of Credits: **01** Total Hours: **15** Effective from AY: **2022-23**

Prerequisites for the course:	Should have studied B. Sc. (Chemistry)
Course Objective:	To introduce mathematical concepts to the students of MSc Part-I (Chemistry).
Course Outcome:	Students will be able to solve problems based on matrices, determinants and, differential and integral calculus in MSc Chemistry.

Content	*Hrs*
1. Calculus for thermodynamics and kinetics i. Introduction to Differentiation: Notation, Differentiating various functions, Differentiating a Sum, Product Rule, Quotient Rule, Chain Rule, Partial Differentiation: exact and inexact differentials. ii. Introduction to Integration: Notation, Rules for Integrals, Integrating various functions, Definite and indefinite Integrals.	08
2. Matrices, Determinants and vector algebra: i. Types of Matrices: Identity, reflection, rotation, inversion, distance matrix, Matrix Algebra, Matrix similarity transformation. ii. The Determinant, Minors and Cofactors, Inverse of a Matrix, Character of a matrix, Linear algebra. iii. Vectors and molecular structure.	07

Pedagogy	Mainly lectures and tutorials. Seminars/assignments/presentations/self-study or a combination of some of these can be used. ICT mode should be preferred. Sessions should be interactive to enable peer group learning.
Text Books/ References / Readings	1. Robert G. Mortimer, Mathematics for Physical Chemistry, Elsevier, 2013, 4th Ed. 2. James R. Barrante, Applied Mathematics for Physical Chemistry, Prentice-Hall, 1998, 3rd Ed.

Programme: **M.Sc. Chemistry**

Course Code: **CHCB-402 (for Part-I students)**

Title of the course: **Bridge Course in organic chemistry**

Number of Credits: **01** Total Hours: **15** Effective from AY: **2022-23**

Prerequisites for the course:	Should have studied B. Sc. (Chemistry)
Course Objective:	1. To understand various principles of organic chemistry. 2. To understand the importance of chirality in organic syntheses. 3. To understand stereoselective reactions. 4. To understand oxidation and reduction reactions.
Course Outcome:	1. Students will be able to explain basic stereochemistry. 2. Students will be able to apply knowledge of basic reaction mechanisms in organic transformation. 3. Students will be able to apply basic concepts of oxidation and reduction in organic synthesis.

Content	*Hrs*
1. Fundamentals of organic chemistry Electron movement with arrows, half and double headed arrows (Cleavage of bonds: homolysis and heterolysis) in organic reaction mechanisms; inductive effect, electromeric effect, resonance and hyperconjugation, steric hindrance, hydrogen bonding; reactivity of organic molecules: nucleophiles and electrophiles; reactive intermediates: carbocations, carbanions and free radicals; strength of organic acids and bases; aromaticity: benzenoids and Hückel's rule.	08
2. **Stereochemistry** Conformations with respect to butane and cyclohexane; interconversion of wedge formula, Newmann, Sawhorse and Fischer representations; CIP Rules: R/S configurations.	03
3. **Substitution, Elimination and addition reactions** Substitution and elimination reactions (S_N1, S_N2, E1 and E2), addition of different groups on olefins.	02
4. **Oxidation and reduction reactions**	02

Basic concepts and some examples.	
Pedagogy	Mainly lectures and tutorials. Seminars/assignments/presentations/self-study or a combination of some of these can be used. ICT mode should be preferred. Sessions should be interactive to enable peer group learning.
Text Books/ References / Readings	1. D. Nassipuri, Stereochemistry of Organic compounds - Principles and Application, Wiley Eastern Limited, New Academic Science Limited, 2013, 4th Ed. 2. E. L. Eliel, Stereochemistry of carbon compounds, Tata MacGraw Hill Publishing Company Ltd. 1990 3. J. March, Advanced Organic Chemistry: Reaction, Mechanism and Structure, Wiley, 2010, 4th Ed. 4. J. Clayden, N. Greeves, S. Warren &Wothers, Organic Chemistry, Oxford University Press, 2012, 2nd Ed. 5. I. L. Finar Stereochemistry and Chemistry of Natural products, ELBS, Longmans, Vol. 2, 1963, 3rd Ed. 6. V. M. Potapov, Stereochemistry, MIR Publishers, Moscow, 1979 7. E. S. Gould et al., Mechanism and structure in Organic Chemistry, 1965 8. F. A. Carey, Organic Chemistry, 2000, 4th Ed. 9. S. H. Pine, Organic Chemistry, McGraw-Hill International Edn. 2010, 5th Ed. 10. F. A. Carey and R.J. Sundberg, Advanced Organic Chemistry, Vol. I & II. Plenum Press, 1977 11. J. M. Harris & C.C. Wamser, Fundamentals of Organic Reaction Mechanisms, John Wiley & Sons. Inc. 1976 12. F. M. Menger, D.J. Goldsmith & L. Mendell, Organic Chemistry, A concise approach, 1975, 2nd Ed.