Central University of Punjab



Course Structure and Syllabus

M.Sc. Chemistry

(Specialization: Applied Chemistry)

Batch 2026-28

Department of Chemistry
School of Basic Sciences

Graduate Attributes for M.Sc. Chemistry (Specialization: Applied Chemistry)

Graduate attributes are the understandings, skills, and qualities that Department of Chemistry along with CUPB community agrees where the M. Sc. Chemistry (Specialization: Applied Chemistry) students should develop these characteristics during the time spent in the institution.

The Graduates will be able to identify various aspects of chemicals and their application in consumer products and industrial set-up. They have comprehensive knowledge and understanding of their subject, for application in a multidisciplinary environment. They will be effective in quality control and optimization in the industrial environment, applying critical creative and evidence based thinking to conceive innovative responses to policy, economics and project management.

The graduates will engage in professional behaviour, communicate well in the group as well as in other groups/institutions, have entrepreneurial potential. They will be able to take leadership roles in their occupations, careers and community with ethical behaviour. They will be able to contribute to a multicultural, IT revolutionized and sustainable society/policy as global citizens.

Semester I							
S. No.	**Course Code**	**Course Title**	**Course Type**	**L**	**T***	**P**	**Cr**
1	MCHM.401	Transition Metal Complexes and Reaction Mechanism	DSC	**3**	**0**	**0**	**3**
2	MCHM.402	Reaction Mechanism and Stereochemistry	DSC	**3**	**0**	**0**	**3**
3	MCHM.403	Quantum Chemistry	DSC	**3**	**0**	**0**	**3**
4	MCHM.404	Spectroscopic Techniques	DSC	**3**	**0**	**0**	**3**
5	MCHM.405	Thermodynamics, Kinetics and Electrochemistry	DSC	**3**	**0**	**0**	**3**
6	MCHM.406	Inorganic Chemistry (Practical)	SEC	**0**	**0**	**4**	**2**
7	MCHM.407	Organic Chemistry (Practical)	SEC	**0**	**0**	**4**	**2**
8	MCHM.408	Physical Chemistry (Practical)	SEC	**0**	**0**	**4**	**2**
9	XXX	Individualized Education Plan/ Tutorial*	0	**0**	**4**	**0**	**0**
Total				**15**	**4**	**12**	**21**

*Four non-credit hours (three contact hours) for Individualized Education Plan/tutorial

DSC: Discipline Specific Core Course, **SEC**: Skill Enhancement Course, **AEC**: Ability Enhancement Course, **DSE**: Discipline Specific Elective Course, **IDC**: Interdisciplinary Course, **VAC**: Value Added Course.

L: Lectures T: Tutorial P: Practical Cr: Credits

Semester II							
S. No.	**Paper Code**	**Course Title**	**Course Type**	**L**	**T***	**P**	**Cr**
1	MCHM.516	Chemistry of Clusters and Group Theory	DSC	**3**	**0**	**0**	**3**
2	MCHM.517	Organic Reagents and Photochemistry	DSC	**3**	**0**	**0**	**3**
3	MCHM.518	Molecular Spectroscopy and Electrochemistry	DSC	**3**	**0**	**0**	**3**
4	MCAC.401	Pharmaceutical Products	AEC	**3**	**0**	**0**	**3**
5	MCHM.519	Computational and Structural Chemistry (Practical)	SEC	**0**	**0**	**4**	**2**
6	MCAC.516	Advanced Applied Chemistry Practical	SEC	**0**	**0**	**4**	**2**
7	MCAC.511	Quality Control in Laboratory and Manufacturing	VAC	**2**	**0**	**0**	**2**
8		Individualized Education Plan/ Tutorial*	0	**0**	**4**	**0**	**0**
Opt Any **One (01)** Discipline Elective Courses/MOOC							
9	MCHM.521	Advanced Organic Chemistry	DSE	**3**	**0**	**0**	**3**
10	MCHM.524	Inorganic Spectroscopy and Catalysis	DSE	**3**	**0**	**0**	
11	MCHM.525	Solid State Chemistry and Statistical Thermodynamics	DSE	3	0	0	
12	MCAC.517	Applied Electrochemistry	DSE	**3**	**0**	**0**	
13	MCHM.528	Inorganic Photochemistry	DSE	**3**	**0**	**0**	
14	MCAC.518	Applied Polymer Chemistry	DSE	**3**	**0**	**0**	
15	MCAC.519	Industrial Organic Chemistry	DSE	**3**	**0**	**0**	
16	MCAC.520	Industrial Inorganic Chemistry	DSE	**3**	**0**	**0**	
17	MCAC.521	Dyes and Pigments	DSE	**3**	**0**	**0**	
18	MCAC.522	Advance Instrumental Methods	DSE	**3**	**0**	**0**	
19	MCAC.523	Applied Material Chemistry	DSE	**3**	**0**	**0**	
20	MFST.401	Food Chemistry	DSE	**3**	**0**	**0**	
22	MPC.204T	Pharmaceutical Process Chemistry	DSE	**4**	**0**	**0**	
21	XXX.XXX	Interdisciplinary Course/MOOC#	IDC	**2**	**0**	**0**	**2**
Total Credit (Hours)				**19**	**0**	**8**	**23**

Interdisciplinary Course Offered by Department for other Departments							
22	MCHM.506	Basics Perspective in Inorganic Chemistry	IDC	**2**	**0**	**0**	**2**
23	MCHM.507	Introduction to Green Chemistry and Sustainability	IDC	**2**	**0**	**0**	**2**
24	MCHM.508	Chemistry of Nanomaterials and Fabrication	IDC	**2**	**0**	**0**	**2**
25	MCHM.509	General Laboratory Practices	IDC	**2**	**0**	**0**	**2**
26	MCHM.510	Chemistry of Drug Design and Synthesis	IDC	**2**	**0**	**0**	**2**

***Opt Any One Skill Based/Skill Enhancement Course/ MOOC/NPTEL Course/Project Work for Exit with Post-Graduate Diploma in Chemistry							
27	MCHM.529	Project Report	SEC	**0**	**0**	**8**	**4**
28	MCHM.530	Chemical Laboratory Techniques	SEC	**4**	**0**	**0**	**4**
29	MCHM.531	Intellectual Properties Rights	SEC	**4**	**0**	**0**	**4**
30	MCHM.532	Modern Instrumental Methods	SEC	**4**	**0**	**0**	**4**
	MOOC Courses						
31	XXXX	Forensic Chemistry and Explosives	SEC	**4**	**0**	**0**	**4**
32	XXXX	Biomass Characterization	SEC	**4**	**0**	**0**	**4**
33	XXXX	Analytical Techniques	SEC	**4**	**0**	**0**	**4**
34	XXXX	Drugs of Abuse	SEC	**4**	**0**	**0**	**4**
	NPTEL Courses						
35	XXXX	Analytical Chemistry	SEC	**4**	**0**	**0**	**4**
36	XXXX	Food Oils & Fat : Chemistry and Technology	SEC	**4**	**0**	**0**	**4**
37	XXXX	Organic Chemistry in Biology & Drug Development	SEC	**4**	**0**	**0**	**4**
38	XXXX	Transition Metal Organometallic Chemistry: Principles to Applicatior	SEC	**4**	**0**	**0**	**4**
39	XXXX	Any other ongoing MOOC/NPTEL courses, may be taken by the studen after approval from the department	SEC	**4**	**0**	**0**	**4**

To be opted from other departments at the start of the Semester with prior consent of course coordinator and HoD.

* Four non-credit hours (Four contact hours) for Individualized Education Plan/tutorial.
**These courses are offered for students opting for exit after one year under Multiple Entry-Exit Scheme and will be given Post-Graduate Diploma in Chemistry.
***In addition to above mentioned MOOC/NPTEL courses, any other ongoing Course/MOOC/NPTEL course may be taken by the student after approval of the department.

DSC: Discipline Specific Core Course, **SEC**: Skill Enhancement Course, **AEC**: Ability Enhancement Course, **DSE**: Discipline Specific Elective Course, **IDC**: Interdisciplinary Course, **VAC**: Value Added Course.

L: Lectures T: Tutorial P: Practical Cr: Credits

During Summer vacations, students are encouraged to perform 4-6 weeks of Summer Internship/Industrial Training at reputed University/Institute/Industry. It will be a non-credit exercise for the skill development of the students.

Semester-III							
S. No.	**Paper Code**	**Course Title**	**Course Type**	**L**	**T**	**P**	**Cr**
1	MCAC.599-1	Dissertation Part-I	**SB**	**0**	**0**	**40**	**20**
		Total		**0**	**0**	**40**	**20**

Semester-IV							
S. No.	**Paper Code**	**Course Title**	**Course Type**	**L**	**T**	**P**	**Cr**
1	MCAC.599-2	Dissertation Part-II	**SB**	**0**	**0**	**40**	**20**
		Total		**0**	**0**	**40**	**20**

DSC: Discipline Specific Core Course, **SEC**: Skill Enhancement Course, **AEC**: Ability Enhancement Course, **DSE**: Discipline Specific Elective Course, **IDC**: Interdisciplinary Course, **VAC**: Value Added Course.

Examination pattern and evaluation for Masters' students

Formative Evaluation: Internal assessment shall be 25 marks using any two or more of the given methods: tests, open book examination, assignments, term paper, etc. The Mid-semester test shall be descriptive type of 25 marks including short answer and essay type. The number of questions and distribution of marks shall be decided by the teachers.

Summative Evaluation: The End semester examination (50 marks) with upto 100% descriptive type and upto 30% objective type shall be conducted at the end of the semester. The objective type shall include one-word/sentence answers, fill-in the blanks, MCQs', and matching. The descriptive type shall include short answer and essay type questions. The number of questions and distribution of marks shall be decided by the teachers. **Questions for exams and tests shall be designed to assess course learning outcomes along with focus on knowledge, understanding, application, analysis, synthesis, and evaluation.**

The evaluation for IDC, VB and entrepreneurship, innovation and skill development courses shall include MST (50 marks) and ESE (50 marks). The pattern of examination for both MST and ESE shall be same as ESE described above for other courses.

Evaluation of dissertation proposal in the third semester shall include 50% weightage by supervisor and 50% by HoD and senior-most faculty of the department. The evaluation of dissertation in the fourth semester shall include 50 marks for continuous evaluation by the supervisor for regularity in work, mid-term evaluation, report of dissertation, presentation, and final viva-voce; 50 marks (50% weightage) by an external expert shall be based on report of dissertation (25 marks), presentation (10 marks), novelty/originality (5 marks) and final viva-voce (10 marks). The external expert may attend final viva-voce through offline or online mode.

Examination pattern

Discipline Specific Core, Discipline Elective, and Compulsory Foundation Courses			IDC, VB, and Skill Based Courses	
	Marks	Evaluation	Marks	Evaluation
Internal Assessment	25	Various methods	-	-
Mid-semester test (MST)	25	Descriptive	50	Descriptive (upto 100%) Objective (upto 30%)
End-semester exam (ESE)	50	Descriptive (upto 100%) Objective (upto 30%)	50	Descriptive (upto 100%) Objective (upto 30%)

Dissertation Proposal (Third Semester)			Dissertation (Fourth Semester)		
	Marks	Evaluation		Marks	Evaluation

Supervisor	50	Dissertation proposal and presentation	Supervisor/ co-supervisor(s)	50	Continuous assessment (regularity in work, mid-term evaluation) dissertation report, presentation, final viva-voce
HoD and senior-most faculty of the department	50	Dissertation proposal and presentation	External expert	50	Report of dissertation (25), presentation (10), novelty/originality (5) and final viva-voce (10)

Marks for internship shall be given by the supervisor/internal mentor and external mentor.

Some Guidelines for Internal Assessment

1. The components/pattern of internal assessment/evaluation should be made clear to students during the semester.
2. The results of the internal assessment must be shown to the students.
3. The question papers and answers of internal assessment should be discussed in the class.
4. The internal assessment shall be transparent and student-friendly and free from personal bias or influence.

Course Title: Transition Metal Complexes and Reaction Mechanism
Paper Code: MCHM.401
Total Contact Hours: 45

L	T	P	Cr
3	0	0	3

Learning Outcome: On completion of this course the student's will able to

CLO1: Interpret the reaction mechanism, formation constant and stability of the coordination complexes.
CLO2: Interpret the electronic properties.
CLO3: Interpret the magnetic properties.

Units/ hours	Content	Mapping with CLOs
Unit-1 **10 Hours**	**Metal-Ligand Equilibria in Solution:** Stepwise and overall formation constant and their interaction, trends in stepwise constants, factors affecting the stability of metal complexes with reference to the nature of metal ion and ligand, chelate effect and its thermodynamic origin, determination of formation constants by spectrophotometry and potentiometric (pH) methods. *Group Discussion among the students on the stability of metal complex formation.*	**CLO1**
Unit-2 **10 Hours**	**Reaction Mechanisms of Transition Metal Complexes:** Introduction, potential energy diagram and reactivity of metal complexes, ligand substitution reactions, labile and inert metal complexes, acid hydrolysis, factors affecting acid hydrolysis, base hydrolysis, conjugate base mechanism, anation reaction, substitution reactions in square planar complexes, trans effect, mechanism of the substitution reaction reactions without metal ligand bond cleavage, electron transfer processes outer and inner sphere. *Demonstration of reactions mechanism of metal complexes.*	**CLO1**
Unit-3 **15 Hours**	**Electronic Absorption spectra of Metal Complexes:** Ligand field theory, nephelauxetic effect, Jahn-Teller effects, spin orbital (LS) coupling, LS and J-J coupling schemes, determination of all the spectroscopic terms of p^n, d^n, f^n ions, determination of total degeneracy of terms, order of interelectronic repulsions and crystal field strength in various fields, spin orbit coupling parameters energy separation between different j states, the effect of octahedral and tetrahedral fields on S, P, D and F terms. selection rules of electronic transitions, relaxation of the selection	**CLO2**

	rule in centrosymmetric and non-centrosymmetric molecules, Orgel diagrams, spectrochemical series. *Classroom discussion on interpretation of LS coupling and various energy level diagrams through brainstorming.*	
Unit-4 **10 Hours**	**Magnetic properties**: magnetic properties of transition metal complexes, effects of L-S coupling on magnetic properties, quenching of orbital angular momentum by crystal fields in complexes in terms of splitting, temperature independent paramagnetism (TIP). *Hands-on experience of metal complexes for magnetic properties by using Gouy`s Balance.*	**CLO3**

Mode of Transactions: Lecture, Demonstration, Lecture cum demonstration, Problem solving, Brainstorming, Tutorial.

Suggested Readings

1. Cotton, F. A., and Wilkinson, G., Murillo, C. A., Bochmann, M. (1999). *Advanced Inorganic Chemistry* (6th Edition). New York: Wiley.
2. Huheey, J. E., Keiter, E. A., Keiter, R. L., and Medhi, O. K. (2006). *Inorganic Chemistry: Principles of Structure and Reactivity*. Pearson Education India.
3. Greenwood, N. N., and Earnshaw, A. (2012). *Chemistry of the Elements*. Elsevier.
4. Miessler, G. L. and Tarr, D. A. (2011). *Inorganic Chemistry*, Pearson Education.
5. Atkins, P. (2010). *Shriver and Atkins' Inorganic Chemistry*. Oxford University Press, USA.
6. Dutta, R. L., and Syamal, A. (1993). *Elements of Magnetochemistry*. Affiliated East-West Press.
7. Drago, R. S. (1992). *Physical Methods for Chemists*. Saunders College Publishing.
8. Lee, J. D. Concise Inorganic Chemistry: Fifth Edition (2012). Elsevier.
9. Kent, B. Inorganic Chemistry: Reactions, Structures and Mechanisms (2019). NY Research Press.
10. Close, D. Principles of Inorganic Chemistry (2019). Larsen and Keller Education.

Course Title: Reaction Mechanism and Stereochemistry

L	T	P	Cr
3	0	0	3

Paper Code: MCHM.402

Total Contact Hours: 45

Learning Outcome: After the completion of the course students will be able to

CLO1: Identify various methods and intermediate species involved while determining the mechanism of organic reactions.

CLO2: Examine the mechanistic and synthetic aspects of nucleophilic, electrophilic substitution and elimination reactions.

CLO3: Explore the implications of addition to carbon-carbon/heteroatom multiple bonds for the synthesis of various molecules.

CLO4: Interpret and predict the energetically favoured conformation of cyclic and acyclic compounds, chirality and reactivity.

Units/ hours	Content	Mapping with CLOs
Unit-1 **11 Hours**	**Reaction mechanism, structure and reactivity:** Classification and determination of reaction mechanisms, kinetic and thermodynamic control, Hammond's postulate, Curtin-Hammett principle, methods of determining mechanisms. **Reactive intermediates:** Structure and reactions of carbocations, carbanions, free radicals, carbenes, nitrenes and benzynes. Neighbouring group participation, classical and non-classical carbocations, phenonium ions and norbornyl system. **Free radical reactions**: Free radical substitution mechanism at an aromatic substrate, reactivity for aliphatic and aromatic substrates at a bridgehead, Reactivity in the attacking radicals, the effect of solvents on reactivity, auto-oxidation. Hunsdiecker Reaction, Coupling of Alkynes, Acyloin Condensation, Bu3SnH promoted reaction, Coupling of alkynes and arylation of aromatic compounds by diazonium salts. *Classroom discussion on various tools used for the determination of reaction mechanisms.* *Peer Discussion on stability of the intermediates in the presence of different substituents (electron-withdrawing and electron releasing).* *Brainstorming on identification of free radical quenching reagents and role of free radicals in daily life.*	**CLO1**

Unit-2 **11 Hours**	**Substitution and Elimination Reactions** Aliphatic nucleophilic substitution reactions**:** S_N1, S_N2, S_N^i and SET mechanism. Energy profile diagram, nucleophilic substitution at an allylic, aliphatic and vinylic carbon, leaving group and reaction medium, ambident nucleophile, ion pair theory. Aromatic nucleophilic and electrophilic substitution reactions: The S_NAr, bimolecular displacement mechanism and benzyne mechanism. Aromatic electrophilic substitution: arenium ion mechanism, *ortho/para* ratio Elimination reactions: E_2, E_1 and E_1cB mechanisms, orientation of the double bond, effects of substrate structures, attacking base, leaving group and medium, mechanism and orientation in pyrolytic elimination. *Demonstration of substitution reactions with the help of ball and stick models.* *Peer discussion on the role of substituents in electrophilic and nucleophilic substitution reaction.*	**CLO2**
Unit-3 **11 Hours**	**Addition to carbon-carbon multiple bonds:** Mechanistic and stereochemical aspects of addition reactions involving electrophiles, nucleophiles and free radicals, addition of halogen polar reagents to alkenes, Regio- and chemoselectivity, hydroboration, epoxidation and hydroxylation. **Addition to carbon-hetero multiple bonds:** Structure and reactivity of carbonyl group towards nucleophilic addition. Arndt-Eistert synthesis. Mannich, Benzoin, Perkin and Michael addition, Robinson annulation. *Peer discussion of the mechanism of nucleophilic additions to carbonyl, nitrile, thiocarbonyl, carboxylic acids, esters and amides.* *Mechanistic interpretation of C-C, C-N and C-O bond formation reactions through brainstorming.*	**CLO3**

Unit-4 **12 Hours**	**Stereochemistry:** Chirality, projection formulae, configurational and conformational isomerism in acyclic and cyclic compounds; stereogenicity, stereoselectivity, diastereoselectivity, D/L, R/S, *E*/*Z* and *cis*/*trans* configurational notations, optical purity, enantiotopic and diastereotopic atoms, groups and faces, stereospecific and stereoselective synthesis, optical activity in the absence of chiral carbon (biphenyls, allenes and spiranes), chirality due to helical shape, Asymmetric Synthesis. Determination of absolute configuration. Conformational analysis of acyclic compounds and cyclic compounds such as cyclopentane, cyclohexane, cyclohexanone derivatives, decalins, 1,2, 1,3-, 1,4-disubstituted cyclohexane derivatives and D-Glucose, effect of conformation on reactivity. *Demonstration of conformational and configurational analysis, projection formulae and topicity of the molecules with the help of ball and stick models.* *Ball and stick models of biphenyls, allenes and spiranes for chirality.*	**CLO4**

Mode of Transactions: Lecture, Demonstration, Presentation, Group Discussion, Lecture cum demonstration, Problem solving, Brainstorming.

Suggested Readings

1. Clayden, J., Greeves, N., Warren, S. and Wothers, P. (2012). *Organic Chemistry,* Oxford University Press.
2. Yadav, L. D. S., Singh, J., and Singh, J. (2021). Organic Synthesis, Pragati Prakashan, India.
3. Norman, R. O. C., and Coxon, J. M. (1993). Principle of Organic Synthesis, CRC Press; 3rd edition.
4. Smith, M. B., and March, J. (2013). *March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure*. John Wiley and Sons.
5. Ahluwalia, V. K., and Parashar, R. K. (2011). *Organic Reaction Mechanisms*. Narosa Publishing House (P) Ltd.
6. McMurry, J. (1996). *Organic Chemistry*, Brooks. Cole, New York, 657.
7. Bansal, R. K. (2012). *A Textbook of Organic Chemistry*. New Age International.
8. Bansal R. K. (2010). *Organic Reaction Mechanism.* New Age International (P) Ltd.
9. Kalsi, P. S. (2010). *Organic Reactions and Their Mechanisms.* New Age International, New Delhi.
10. Lowry, T. H. and Richardson K. S. (1998). *Mechanism and Theory in Organic Chemistry,* Addison-Wesley Longman Inc., New York.
11. Morrison, R.T. and Boyd, R.N. (2011). *Organic Chemistry,* Prentice- Hall of India.
12. Mukherjee, S. M. and Singh, S. P. (2009). *Reaction Mechanism in Organic Chemistry.* Macmillan India Ltd., New Delhi.

13. Solomon, T.W.G, Fryhle, C. B. and Snyder, S. A. (2013). *Organic Chemistry*. John Wiley and Sons, Inc.
14. Sykes, P. A. (1997). *Guide Book to Mechanism in Organic Chemistry,* Prentice Hall.
15. Stein, T. H., Vasiliu, M., Arduengo, A. J. Lewis Acidity and Basicity: Another Measure of Carbene Reactivity, *J. Phys. Chem. A* 2020, 124, 29, 6096–6103.
16. Morisaki, K., Morimoto, H., Ohshima, T. Recent Progress on Catalytic Addition Reactions to *N*-Unsubstituted Imines, *ACS Catal.* 2020, 10, 12, 6924–6951.
17. Singh, M. S. (2014). Reactive intermediates in organic chemistry: Structure, Mechanism, and Reactions. John Wiley & Sons.

CUP Library E Resource:

18. Nag, A. (Ed.). (2018). Asymmetric synthesis of drugs and natural products. CRC Press.

Course Title: Quantum Chemistry

L	T	P	Cr
3	0	0	3

Paper Code: MCHM.403
Total Contact Hours: 45
Learning Outcome: After the completion of the course students will be able to

CLO1: Interpret and solve the Schrodinger equation for various systems, particle in a boundary model, Electronic and Hamiltonian operators for molecules.
CLO2: Explain the quantum chemical description of angular momentum and term symbols for a one and many-electron systems.
CLO3: Relate the Born-Oppenheimer approximation, the Pauli principle, Hund's rules, Hückel theory and the variation principle with the atomic and molecular phenomena.

Units/ hours	Content	Mapping with CLOs
Unit 1 **11 Hours**	**Fundamental Background:** Review of essential mathematical concepts required for quantum chemistry, Postulates of quantum mechanics, Eigen values and Eigen functions, operators, Schrodinger equation. **Translational, Rotational and Vibrational Motions:** - Free particle and particle in a box and its application, one-dimensional harmonic oscillator and rigid rotor, particle in a ring, particle on a sphere. *Problem solving approach to determine Eigen values and Eigen function using corresponding operator and Schrodinger equation. Brainstorming on defining and solving Schrodinger equation for different systems like particle in a box, rigid rotator, simple harmonic oscillator.*	**CLO1**
Unit 2 **11 Hours**	**Angular Momentum:** Ordinary angular momentum, generalized angular momentum, Eigen functions and Eigen values for angular momentum, Ladder operator, addition of angular momenta **Electronic Structure of Atoms:** Electronic configuration, term symbols and spectroscopic states, Russell-Saunders terms and J-J coupling schemes, Magnetic effects: spin-orbit coupling and Zeeman splitting. *Understanding multi-electron atom quantum evaluation through peer discussion and brainstorming sessions*	**CLO2**
Unit 3 **12 Hours**	. **Variation Methods:** The variation theorem and its application, linear variation principle. . *Understand the principles of variation theorem and its application through examples*	**CLO3**

Unit 4 **11 Hours**	**Born-Oppenheimer Approximation:** LCAO-MO and VB treatments of the H_2^+ and H_2, Shape of molecules, Hybridization and valence MOs of H_2O and NH_3. Determination of bond angle in sp^3, sp^2 and sp, Huckel Theory of acyclic and cyclic conjugated systems, Bond order and charge density *Application of Variation method and its uses in pi-HMO theory for acyclic and cyclic conjugated organic systems through peer learning. Application of MOT and VBT for H_2 and H_2^+ system through demonstration*	**CLO3**

Mode of Transactions: Lecture, Demonstration, Presentation, Group Discussion, Lecture cum demonstration, Problem solving, Brainstorming

Suggested Readings

1. Levine, I.N. (2014). *Quantum Chemistry*. 7th ed. Pearson Education Inc.
2. Chandra, A.K. (2017). *Introductory Quantum Chemistry*. 4th ed. Tata Mcgraw-Hill.
3. McQuarrie, D. A. and Simon, J. D. (1998). *Physical Chemistry: A Molecular Approach.* Viva Books.
4. Prasad, R.K., (2009). *Quantum Chemistry*. 4th Ed. New Age Science.
5. Murrell, J.N., Kettle S.F.A. and Tedder, J. M. (1965). *Valence Theory*. John Wiley Publishers.
6. Lowe, J. P. and Peterson, K., (2006). *Quantum Chemistry*. Academic Press.
7. Atkins, P., and Friedman, R. (2011). *Molecular Quantum Mechanics*, 5th edition, Oxford university press.
8. Atkins, P., De Paula, J., and Keeler, J. (2018). *Atkins' Physical Chemistry.* Oxford University Press.
9. Silbey, R. J. Alberty, R. A. and Bawendi, M. G. (2008). *Physical Chemistry*. Wiley-Interscience Publication.
10. Kapoor, K. L. (2011). *Text Book of Physical Chemistry*.3/5, Macmillan Publishers.
11. McQuarrie, D. A. and Simon, J. D. (2018). *Physical Chemistry: A Molecular Approach*. Viva Books.
12. Puri, B.R., Sharma, L.R. and Pathania, M.S. (2013). *Principles of Physical Chemistry.* Vishal Publishing Company.
13. Atkins, P., De Paula, J. and Keeler, J. (2018). *Atkins' Physical Chemistry. 11th ed.* Oxford University Press.

Course Title: Spectroscopic Techniques

L	T	P	Cr
3	0	0	3

Paper Code: MCHM.404

Total Contact Hours: 45

Learning Outcome: At the end of this course student will be able to

CLO1: Explore various spectroscopic techniques (UV, IR, NMR and MS) used in organic synthesis for structure elucidation.

CLO2: Predict NMR spectra and various fragment-ions/peaks in MS of a given molecular structure.

CLO3: Analyze and interpret the combined spectroscopic data (UV-Vis, IR, ^{1}H &^{13}C NMR) for structural elucidation of unknown organic molecules.

Units/ Hours	Content	Mapping with CLOs
Unit-1 **11 Hours**	**UV-Visible spectroscopy**: Introduction, role of solvents, chromophores and their interaction with UV-visible radiation. Woodward-Fieser rule for conjugated dienes and carbonyl compounds. **Infrared spectroscopy:** Infrared radiation and its interaction with organic molecules, vibrational mode of bonds, effect of hydrogen bonding and conjugation on absorption bands, interpretation of IR spectra. FTIR. *Problem solving - Identification of the structure from the given UV and FTIR data.*	**CLO1**
Unit-2 **12 Hours**	**Nuclear magnetic resonance spectroscopy**: Introduction, chemical shift and factors influencing chemical shift, reference standards and solvents. spin-spin coupling, coupling constants, long range coupling, effect of deuteration, integration of signals, interpretation of spectra, spin decoupling, double resonance and shift reagent methods, resonance of other nuclei e.g. ^{19}F, ^{15}N, ^{31}P. *The role of external magnetic field on precessional frequency: Peer discussion.*	**CLO1, CLO2**
Unit-3 **11 Hours**	**^{13}C NMR**: Introduction, Proton coupled and proton decoupled ^{13}C NMR, nuclear overhauser enhancement (NOE), DEPT techniques, 2D NMR Correlation spectroscopy (COSY), Homo COSY (^{1}H-^{1}H COSY), Hetero COSY (^{1}H-^{13}C COSY, HMQC), long range ^{1}H-^{13}C COSY (HMBC), NOESY. *Problem solving - Identification of the structure from the given ^{1}H and ^{13}C NMR data.*	**CLO1, CLO2, CLO3**

Unit-4 **11 Hours**	**Mass spectrometry**: Basic principles and brief outline of instrumentation. Ion formation: EI, CI, FAB, MALDI, ESI, metastable ion, alpha-cleavage, McLafferty rearrangement, Retro-Diels-Alder cleavage, nitrogen rule, fragmentation process of organic molecules in relation to molecular structure determination. Relative abundance of isotopes. Hyphenated Techniques: GC-MS, LC-MS. High resolution mass spectrometry (HRMS). *Problems Solving for structure elucidation using the above spectroscopic techniques*. *Interpretation of various fragmentation peaks in the mass spectrum of the given sample.*	**CLO1, CLO2, CLO3**

Mode of Transactions: Lecture, Demonstration, Presentation, Group Discussion, Lecture cum demonstration, Problem solving, Brainstorming.

Suggested Readings

1. Pavia, D. L., Lampman, G. M., Kriz, G. S., and Vyvyan, J. A. (2015). *Introduction to Spectroscopy*. Cengage Learning India Private Limited; 5th edition (14 January 2015).
2. Gross, J. H. (2017). *Mass Spectrometry: A Textbook*. Springer-Verlag Berlin Heidelberg.
3. Banwell, C. N., and McCash, E. M. (1994). *Fundamentals of Molecular Spectroscopy* (Vol. 851). New York: McGraw-Hill.
4. Kalsi, P. S. (2007). *Spectroscopy of Organic Compounds*. New Age International.
5. Kemp, W. (2019, 2nd edition). *Organic Spectroscopy*, ELBS. MACMILLAN.
6. Melinda, J.D. (2010). *Introduction to Solid NMR Spectroscopy*. Wiley India Pvt Ltd.
7. Silverstein, R. M., Webster, F. X., Kiemle, D. J., and Bryce, D. L. (2014). *Spectrometric Identification of Organic Compounds*. John Wiley and sons.
8. Pretsch, E., Bühlmann, P., Badertscher, M. (2020). Structure Determination of Organic Compounds. Springer-Verlag Berlin Heidelberg.
9. Price, W. S. (2024). Annual reports on NMR spectroscopy (Vol. 111). Elsevier.

Course Title: Thermodynamics, Kinetics and Electrochemistry
Paper Code: MCHM.405
Total Contact Hours: 45

L	T	P	Cr
3	0	0	3

Learning Outcome: At the end of this course student will be able to

CLO1: Predict the thermodynamic of mixtures, solutions and phase transformations.

CLO2: Establish and evaluate the mechanism and kinetics for reactions.

CLO3: Interpret the fast reaction monitoring for complex reactions.

CLO4: Evaluate and predict the spontaneity of a redox processes in electrochemical systems.

CLO5: Apply activity coefficient calculated of solution using Debye-Huckel theory and Ideally-Dilute solutions in chemical aspects.

CLO6: Predict and establish the thermodynamic and kinetic aspects of adsorption and catalysis.

Units/ Hours	Content	Mapping with CLOs
Unit 1 **12 Hours**	**Classical Thermodynamics and Phase Transitions:** Introduction to thermodynamics, Thermodynamics of mixing, Partial Molar Properties, Gibbs- Duhem equation, Chemical potential of liquids and solutions, Phase transition: Clausius-Clapeyron equation. **Reaction Kinetics:** Introduction, complex reactions, steady state approximation, kinetic mechanisms of chemical reactions, Arrhenius and Eyring equations and their applications, collision theories of rate constant, treatment of unimolecular reactions, steric factor, ionic reactions: salt effect. *Understanding chemical kinetics and potential surface-reaction coordinate by hands-on activity either as gaming, stochastic or molecular dynamic models*	**CLO1, CLO2**
Unit 2 **11 Hours**	**Photochemical Reactions and Processes:** Laws of photochemistry and kinetics of photochemical reactions. **Fast Reaction Kinetics:** Introduction to time-resolved techniques for absorption and emission measurements, relaxation method, study of kinetics of fast reactions by millisecond stopped-flow, nanosecond flash photolysis techniques and its application in chemistry and biology. *Learning photochemical reaction kinetics through problem solving activities. Understanding the ultrafast kinetic process and its application though examples.*	**CLO2, CLO3**
Unit 3 **11 Hours**	**Electrochemistry:** Activity, Activity coefficient; determination of activity and activity coefficients, Activity-coefficients, mean activity coefficients; Debye-Huckel treatment of dilute electrolyte solutions. **Electrochemical Cells:** Nernst equation, redox systems, electrochemical cells, application of electrochemical cell, concentration cells with and without liquid junction, thermodynamics of reversible electrodes and reversible cells, potentiometric titration. *Understanding application of electrochemistry using classroom games activity. Expanding the understanding of conductance application using peer learning.*	**CLO4, CLO5**

Unit 4 **11 Hours**	**Adsorption:** Adsorption of solids, Langmuir and Fredulich Isotherms, BET adsorption isotherm, Gibbs adsorption isotherm. **Catalysis:** Homogeneous catalysis and heterogeneous catalysis, enzyme catalysis. Michealis-Menten mechanism, Lineweaver-Burk Plot, competitive and non-competitive bindings, application of enzyme catalysis. *Application and challenges in adsorption towards environmental and nanomaterial through peer learning. Enzyme binding and catalysis through inquiry guided and gaming based learning.*	**CLO2, CLO6**

Mode of Transactions: Lecture, Demonstration, Presentation, Group Discussion, Lecture cum demonstration, Problem solving, Brainstorming

Suggested Readings

1. Engel, T., Reid, P. and Hehre, W. (2012) *Physical Chemistry*. Pearson Education
2. Puri, B.R., Sharma L.R. and Pathania, M.S. (2013) *Principles of Physical Chemistry.* Vishal Publishing Company Nash,
3. Nelson, K. A., Bawendi, M. (2008) https://ocw.mit.edu/courses /chemistry/5-60-thermodynamics-kinetics-spring-2008/video-lectures.
4. Bhattacharyya, D. and Dawlaty, J. M. (2019) Teaching Entropy from Phase Space Perspective: Connecting the Statistical and Thermodynamic Views Using a Simple One-Dimensional Model *J. Chem. Educ.,* 96 (10), 2208-2216. DOI: 10.1021/acs.jchemed.9b00134
5. Halpern A. M. and Marzzacco, C. J. (2018) Using the Principles of Classical and Statistical Thermodynamics to Calculate the Melting and Boiling Points, Enthalpies and Entropies of Fusion and Vaporization of Water, and the Freezing Point Depression and Boiling Point Elevation of Ideal and Nonideal Aqueous Solutions*, J. Chem. Educ.,95*(12), 2205-2211. DOI: 10.1021/acs.jchemed.8b00561
6. Halpern A. M. and Marzzacco, C. J. (2018) Constructing the Phase Diagram of a Single-Component System Using Fundamental Principles of Thermodynamics and Statistical Mechanics: A Spreadsheet-Based Learning Experience for Students. *J. Chem. Educ., 95* (12), 2197-2204. DOI: 10.1021/acs.jchemed.8b00560
7. Drennan, C., Taylor, E. V., (2008) https://ocw.mit.edu/courses/chemistry/5-111-principles-of-chemical-science-fall-2008/index.htm
8. Griffin, R. G., Voorhis, T. V. (2007) https://ocw.mit.edu/courses/chemistry/5-111-principles-of-chemical-science-fall-2008/index.htm
9.
10. Laidler, K. J. (2003). *Chemical Kinetics*. Pearson Education Ltd.
11. Atkins, P., De Paula, J., and Keeler, J. (2018). *Atkins' Physical Chemistry.* Oxford University Press.
12. Silbey, R. J. Alberty, R. A. and Bawendi, M. G. (2008). *Physical Chemistry*. Wiley-Interscience Publication.
13. Engel, T. and Reid, P. (2012). *Thermodynamics, Statistical Thermodynamics, and Kinetics*. Pearson Education.
14. Lakowicz, J. R. (2006). *Principles of Fluorescence Spectroscopy*. Springer.
15. Kapoor, K. L. (2011). *Text Book of Physical Chemistry*.3/5, Macmillan Publishers.

16. McQuarrie, D. A. and Simon, J. D. (2018). *Physical Chemistry: A Molecular Approach*. Viva Books.
17. Moore, J. W., and Pearson, R. G. (1981). *Kinetics and Mechanism*. John Wiley and Sons.
18. Puri, B.R., Sharma, L.R. and Pathania, M.S. (2013). *Principles of Physical Chemistry.* Vishal Publishing Company.
19. Krask, T. (2020). Establishing a Connection for Students between the Reacting System and the Particle Model with Games and Stochastic Simulations of the Arrhenius Equation, *J. Chem. Educ.,97* (7), 1951-1959 DOI: 10.1021/acs.jchemed.0c00081.
20. Changenet, P., Gustavsson, T., and Lampre, I. (2020). Introduction to Femtochemistry: Excited-State Proton Transfer from Pyranine to Water Studied by Femtosecond Transient Absorption, *J. Chem. Educ.,97* (12), 4482-4489 DOI: 10.1021/acs.jchemed.0c01056.
21. Rodriguez, J.-M. G., Harrison, A. R., and Becker N. M. (2020). Analyzing Students' Construction of Graphical Models: How Does Reaction Rate Change Over Time? *J. Chem. Educ.97* (11), 3948-3956 DOI: 10.1021/acs.jchemed.0c01036.
22. Atkins, P., De Paula, J. and Keeler, J. (2018). *Atkins' Physical Chemistry. 11th ed.* Oxford University Press.

Course Title: Inorganic Chemistry (Practical)

L	T	P	Cr
0	0	4	2

Paper Code: MCHM.406

Total Contact Hours: 60

Learning Outcome: The students will be able to

CLO1: Perform volumetric and gravimetric analysis of cations and anions within reaction mixtures.

CLO2: Standardize and titrate various inorganic compounds.

Experiments:

Introduction to good laboratory practices in chemistry.

Gravimetric Estimation

1. Determination of Ba^{2+} as its sulphate/chromate.
2. Estimation of lead as its lead sulfate.
3. Estimation of Nickel (II) as its nickel dimethyl glyoximate.
4. Estimation of Cu^{2+}as cuprous thiocyanate.

Precipitation Titrations

1. $AgNO_3$ standardization by Mohr's method.
2. Volhard's method for Cl^- determination.

Oxidation-Reduction Titrations

1. Standardization of $KMnO_4$with sodium oxalate and determination of Ca^{2+} ion.
2. Standardization of ceric sulphate with Mohr's salt and determination of Cu^{2+}, NO_2 and $C_2O_4^{-2}$ ions.
3. Standardization of $K_2Cr_2O_7$ with Fe^{2+} and determination of Fe^{3+} (Ferric alum)
4. Standardization of hypo solution with potassium iodate / $K_2Cr_2O_7$ and determination of available Cl_2 in bleaching powder, Sb^{3+} and Cu^{2+}.
5. Determination of hydrazine with KIO_3 titration.

Mode of Transactions: Demonstration, PPT, videos, Lecture cum demonstration

Suggested Readings

1. Pass, G. and Sutcliffe H. (1979). *Practical Inorganic Chemistry*. Chapman and Hall Ltd.
2. Jolly, W.L. (1961). *Synthetic Inorganic Chemistry*. Prentice Hall, Inc.
3. Nakamoto, K. (1997). *Infrared and Raman Spectra of Inorganic and Coordination Compounds: Part A and B*. John Wiley and Sons.
4. Mendham, J., Denney, R.C., Barnes, J.D. and Thomas, M. J. K. (2000). *Vogel's Textbook of Quantitative Chemical Analysis,* Pearson Education Ltd.
5. Svehla, G. and Sivasankar, B. (1996). *Vogel's Qualitative Inorganic Analysis*. Pearson Education Ltd.
6. Skoog, D.A., Holler, F.J., and Crouch, S.R. (2007). *Principles of Instrumental Analysis*. Thomson Learning.

Course Title: Organic Chemistry (Practical)

L	T	P	Cr
0	0	4	2

Paper Code: MCHM.407

Total Contact Hours: 60

Learning Outcome: At the end of this course student will be able to

CLO1: Exercise good laboratory practices including safe handling of hazardous chemicals, laboratory glassware and equipment(s).

CLO2: Apply various experimental skills for purification, isolation and recrystallization of organic molecules.

CLO3: Analyze the progress of a given reaction with various chromatographic techniques.

Experiments:

Safety and Handling of hazardous chemicals:

(i) Good laboratory practices, handling and disposal of hazardous chemicals.

(ii) Awareness about different types of glassware, heating devices, equipment(s), how to conduct organic reactions etc.

A. Techniques:

Chromatography: Thin layer chromatography (TLC): Monitoring the progress of chemical reactions, R_f values: identification of unknown organic compounds by comparing the R_f values with known standards. Column chromatography.

Purification Techniques: crystallization, distillation, sublimation.

Determination of melting point and mixed melting point.

B. Single Stage Synthesis: Synthesis of compounds and their purification, aspects such as conversion, theoretical yield and percentage yield should be paid attention.

1. Synthesis of chalcones *via* Claisen-Schmidt condensation.
2. Reduction of benzophenone to benzhydral using $NaBH_4$.
3. Conversion of benzaldehyde to cinnamic acid (Knoevenagel condensation).
4. Conversion of benzaldehyde to dibenzylidene acetone (Aldol condensation).
5. To prepare phenylpropene *via* dehydration of corresponding phenylpropanol.
6. To prepare ethyl cinnamate *via* acid catalyzed esterification of cinnamic acid.
7. Conversion of phthalic anhydride to phthalimide.
8. To synthesize arylidene analogue of Meldrum acid.
9. Synthesis of alcohol *via* addition of Grignard reagent to an aldehyde.

Mode of Transactions: Demonstration, PPT, videos, Lecture cum demonstration.

Suggested Readings

1. Harwood, L.M. and Moody, C.J. (1989). *Experimental Organic Chemistry*. Blackwell Scientific Publishers.
2. Vogel, A.I. (2003). 5th ed. *Textbook of Practical Organic Chemistry*. ELBS, Longman Group Ltd.
3. Mann, F.G. and Saunders, B.C. (2009). *Practical Organic Chemistry*. Orient Longman Pvt. Ltd.
4. Leonard, J. and Lygo, B. (1995). *Advanced Practical Organic Chemistry*. Chapman and Hall.

5. Armarego, W.L. and Chai, C. (2012). *Purification of Laboratory Chemicals*. Butterworth-Heinemann.
6. Young, J.A. (1991). *Improving Safety in the Chemical Laboratory: A Practical Guide.* Wiley Publishing.
7. Silver, J. *Let Us Teach Proper Thin Layer Chromatography Technique, J. Chem. Educ.* 2020, 97, 12, 4217–4219.
8. Tannya, R., Ibarra-Rivera**,** Delgado-Montemayor, c., Oviedo-Garza, F., Pérez-Meseguer, J., Rivas-Galindo, V. M., Waksman-Minsky, N., Pérez-López, A. (2020). *Setting Up an Educational Column Chromatography Experiment from Home*, *J. Chem. Educ.* 97, 9, 3055–3059.

Course Title: Physical Chemistry (Practical)

L	T	P	Cr
0	0	4	2

Paper Code: MCHM.408

Total Contact Hours: 60

Learning Outcome: The students will able to

CLO1: Develop skills on titrimetric analysis using conductivity meter, potentiometer and pH meter as well as buffer preparation and use.

CLO2: Hands on skills in viscometer, refractometer and spectrophotometer for different applications.

Experiments:

1. Determination of behavior and strength of a given acid/base by titrating with a base/acid conductometrically.
2. Determination of solubility and solubility product of sparingly soluble salts (e.g., $PbSO_4$, $BaSO_4$) conductometrically.
3. Determination standard electrode potential of Fe^{2+}/Fe^{3+} system by potentiometer using potassiumpermanganate
4. Preparation of buffers and measurement of their pH.
5. Determination of stability constant for Cu(II)-glycinate complex using potentiometry.
6. Determination of pK_a of acetic acid and H_3PO_4 by potentiometric titration using NaOH.
7. Determination of Surface tension of a given liquid.
8. Determination of refractive indices (RI) of given liquids and determination of the concentration from RI.
9. Verification of the Lambert-Beer's law and determination of extinction coefficient
10. Determination of stability constant of Fe(III)-salicylic acid complex by spectrophotometer.
11. To verify Freundlich and Langmuir adsorption isotherms for adsorption of acetic acid on activated charcoal.
12. Determination of partition coefficient of iodine between water and octanol and determination of equilibrium constant of tri-iodide.
13. Determination of rate constant and energy of activation of hydrolysis of an ester
14. Determination of the rate constant for the oxidation of iodide ions by hydrogen peroxide studying the kinetics as an iodine-clock reaction.
15. Determination of thermal stability of biomacromolecules.
16. Determination of rate constant and energy of activation of a chemical reaction by visible and fluorescence spectroscopy.

Mode of Transactions: Demonstration, Experimentation, handing instruments, Explanation of data.

Activity Based Learning:

1. Demonstration and application of potentiometry, conductometry, spectrophotometry, viscometer and stalagmometer.
2. Team activity of practical and observation recording for kinetic and thermodynamic parameters for chemical reactions.

Suggested Readings

1. Nad, A. K., Mahapatra, B. and Ghoshal, A. (2014). *An Advanced Course in Practical Chemistry*. New Central Book Agency (P) Ltd.
2. Maity, S., and Ghosh, N. (2012). *Physical Chemistry Practical*. New Central Book Agency (P) Ltd.
3. Elias, A. J. (2002). *A Collection of Interesting General Chemistry Experiments*. Universities Press.
4. Khosla, B. D., Garg, V. C., and Gulati A.R. (2007). *Senior Practical Physical Chemistry*. S. Chandand Sons.
5. Yadav, J. B. (2006). *Advanced Practical Physical Chemistry*. Krishna Prakashan Media.
6. Das, R. C., and Behera, B. (1983). *Experimental Physical Chemistry*. Tata McGraw-Hill.
7. James, A. M., and Prichard, F. E. (1974). *Practical Physical Chemistry*. New York: Longman.
8. Ghosh, J. C. (1990). *Experiments in Physical Chemistry*, Bharati Bhavan.

Course Title: Chemistry of Clusters and Group Theory

L	T	P	Cr
3	0	0	3

Paper Code: MCHM.516

Total Contact Hours: 45

Learning Outcome: The students will able to

CLO1: Concepts to realize point group within chemical structure, character tables and projection operator techniques.

CLO2: Application of symmetry and group theory in spectroscopy.

CLO3: Structural properties of organometallic complexes and their uses.

Units/ hours	Content	Mapping with CLOs
Unit-1 10 Hours	**Symmetry:** Symmetry elements, symmetry operations and their matrix representation, group postulates and types, multiplication tables, point group determination. *Basic discussion about types of symmetry and parameters to decide point groups in different molecules using of ball and stick models*	**CLO1**
Unit-2 10 Hours	**Group theory:** Determination of reducible and irreducible representations, character tables, construction of character tables for C_2v, C_3v, use of symmetry in obtaining symmetry of orbitals in molecules. *Group discussion to design the character tables of taking molecular examples and implication of ball and stick model tools.*	**CLO2**

Unit-3 **15 Hours**	**Metal Complexes:** Organic-transition metal chemistry, complexes with π-acceptor and π-donor ligands, 18-electron and 16-electron rules, isolobal analogy, Synthesis and important reaction of metal carbonyls. Structure and bonding of metal carbonyls, metal nitrosyl, dinitrogen and dioxygen complexes, tertiary phosphine as ligand and vibrational spectra of metal carbonyls for bonding and structure elucidation. *Discussion of various electron count rules and structural bonding parameters of organometallic compounds.*	**CLO3**
Unit-4 **10 Hours**	**Inorganic cages:** Metallocenes, metal cluster compounds, metal-metal bond, metal carbenes, carbonyl and non-carbonyl clusters, fluxional molecules, application of organometallic compounds as catalysts in organic synthesis. Cage compounds of boron: boron cage compounds, boranes, carboranes and metallocene carboranes. *Peer discussion on Cage clusters formation rules via wede`s and Mingos rules.*	**CLO4**

Mode of Transactions: Lecture, Demonstration, Lecture cum demonstration, Problem solving, Brainstorming, Tutorial.

Suggested Readings

1. Cotton, F. A., and Wilkinson, G. (1999). *Advanced inorganic chemistry* (4th edition). New York: Wiley.
2. Huheey, J. E., Keiter, E. A., Keiter, R. L., and Medhi, O. K. (2006). *Inorganic chemistry: principles of structure and reactivity*. Pearson Education India.
3. Greenwood, N. N., and Earnshaw, A. (2012). *Chemistry of the Elements*. Elsevier.
4. Lever, A.B.P. (1984) *Inorganic Electronic Spectroscopy*. Elsevier Science Publishers B.V.
5. Atkins, P. (2010). *Shriver and Atkins' inorganic chemistry*. Oxford University Press, USA.
6. Dutta, R. L., and Syamal, A. (1993). *Elements of magnetochemistry*. Affiliated East-West Press.
7. Lee, J. D. Concise Inorganic Chemistry: Fifth Edition (2012). Elsevier.
8. Kent, B. Inorganic Chemistry: Reactions, Structures and Mechanisms (12 June 2019), NY Research Press.
9. Close, D. Principles of Inorganic Chemistry (19 June 2019), Larsen and Keller Education

Course Title: Organic Reagents and Photochemistry

L	T	P	Cr
3	0	0	3

Paper Code: MCHM.517

Total Contact Hours: 45

Learning Outcome: The students will be able to

CLO1: Interpret and predict the product formation of various photochemical reactions.

CLO2: Differentiate between thermally and photochemically driven pericyclic reactions and explain about their stereochemical aspects.

CLO3: Apply various oxidizing and reducing reagents in a logical manner for their application in functional group transformation in organic synthesis.

CLO4: Explore various molecular rearrangements and name reactions for the conversion of different functional group.

Units/ hours	Content	Mapping with CLOs
Unit-1 11 Hours	**Photochemistry:** Jablonski diagram, singlet and triplet states, photosensitization, quantum efficiency, photochemistry of carbonyl compounds, Norrish type-I and type-II cleavages, Photochemistry of alkenes and enones, Paterno-Buchi reaction, Photoreduction, Di π – methane rearrangement, Hofmann-Loffler Fretag. Photochemistry of aromatic compounds, Photo-Fries reactions of anilides, Photo-Fries rearrangement, Barton Nitrite Photolysis Reaction, Barton Decarboxylation, Singlet molecular oxygen reactions. *Application of photochemical reactions in biologically important molecules through peer learning.* *Primary and secondary processes of photochemical reactions of carbonyl compounds and alkenes.*	**CLO1**
Unit-2 11 Hours	**Pericyclic chemistry:** Introduction, Phases, nodes and symmetry properties of molecular orbitals in ethylene, 1,3-butadiene, 1,3,5-hexatriene, allyl cation, allyl radical, pentadienyl cation and pentadienyl radical. **Electrocyclic reactions**: Conrotation and disrotation, 4n and 4n+2 systems. Woodward-Hoffmann rules. (i) Symmetry properties of HOMO of open chain partner (ii) Conservation of orbital symmetry and correlation diagrams. **Cycloaddition reactions**: Suprafacial and antarafacial interactions. $\pi^2 + \pi^2$ and $\pi^4 + \pi^2$ cycloadditions and stereochemical aspects. Diels-Alder reaction. Woodward-Hoffmann Selection rules. Explanation for the mechanism by (i) Conservation of orbital symmetry and correlation diagrams (ii) FMO theory. 1-3-dipolar cycloaddition reaction (Huisgen reaction). **Sigmatropic reactions**: [1,j] and [i,j] shifts; suprafacial and antarafacial, selection rules for [l, j] shifts; Cope and Claisen rearrangements; explanation for the mechanism by (i) symmetry properties of HOMO (ii) Introduction to cheletropic reactions and the explanation of mechanism by FMO theory. *Group project on the symmetry elements in FMO of 4npi and (4n+2)pi electron containing substrates.* *Quiz on FMO, correlation diagram and PMO approaches for pericyclic reactions.*	**CLO2**

Unit-3 **12 Hours**	**Oxidizing and Reducing Reagents:** Mechanism, selectivity, stereochemistry and applications of oxidation reactions, oxidation reactions using DDQ, NBS, $Pb(OAc)_4$, SeO_2, PCC, PDC, Cr and Mn based reagents, Periodic acid, OsO_4, Swern oxidation, Hydroboration-oxidation, epoxidation using peracids. Baeyer-Villiger oxidation, Sharpless epoxidation, Oppenauer oxidation. **Reducing Agents:** Mechanism, selectivity, stereochemistry and applications of catalytic hydrogenations using Pd, Pt and Ni catalysts (Lindlar, Rosenmund, Adam's catalysts), Wilkinson's catalyst, Meerwein-Pondorff-Verley reduction, dissolving metal reductions, Birch reduction, Reductions using metal hydride $NaBH_4$, Luche reduction, $NaBH_3CN$, L-selectride, K-selectride, $NaBH(OAc)_3$, $LiAlH_4$, DIBAL-H, Diimide reduction. *Peer discussion on selective use and careful handling of reducing agents.* *Demonstration on the synthesis and application of oxidizing agents like PCC. Peer discussion on green oxidizing agents.*	**CLO3**
Unit-4 **11 Hours**	**Rearrangements:** General mechanistic considerations-nature of migration, migratory aptitude, mechanistic study of the following rearrangements: Pinacol-pinacolone, Wagner-Meerwein, Benzil-Benzillic acid, Favorskii, Neber, Beckmann, Hofmann, Curtius, Lossen, Schmidt, Carroll, Gabriel–Colman, Smiles and Sommelet–Hauser rearrangements. Dakin reaction. **New synthetic reactions:** Baylis-Hillman reaction, Biginelli reaction, Mitsunobu reaction,), Buchwald-Hartwig coupling, Eishenmosher-Tanabe fragmentation, Shapiro reaction, Stork-enamine reaction, Vilsmeier–Haack reaction. *Predicting the mechanistic pathways of rearrangement reactions through peer discussion.* *Application of important name reactions for bioactive molecule synthesis through brainstorming.*	**CLO4**

Mode of Transactions: Lecture, Demonstration, Presentation, Group Discussion, Lecture cum demonstration, Problem solving, Brainstorming.

Suggested Readings

1. Clayden, J., Greeves, N., Warren, S. and Wothers, P. (2012). *Organic Chemistry.* Oxford University Press.
2. Bansal, R. K. (2012). *A Textbook of Organic Chemistry*. New Age International.
3. Carey, F. A., and Sundberg, R. J. (2007). *Advanced Organic Chemistry: Part A: Structure and Mechanisms.* Springer Science and Business Media.

4. Kalsi, P. S. (2010). *Stereochemistry Conformation and Mechanism*. New Age International.
5. Eliel, E. L., and Wilen, S. H. (2008). *Stereochemistry of Organic Compounds*. John Wiley and Sons.
6. Carey, F. A., and Sundberg, R. J. (2007). *Advanced Organic Chemistry: PartB*. Springer Science and Business Media.
7. Finar, I. L. (1996). *Textbook of Organic Chemistry*. *ELBS*, Pearson Education UK.
8. Katritzky, A. R., Ramsden, C. A., Joule, J. A., and Zhdankin, V. V. (2010). *Handbook of Heterocyclic Chemistry*. Elsevier.
9. Norman, R.O.C. and Coxon, J.M. (1998). *Principles of Organic Synthesis*. Blackie Academic and Professional.
10. Fleming, I. (2015). *Pericyclic Reactions*. Oxford University Press.
11. Singh, J. (2005). *Photochemistry and Pericyclic Reactions*. New Age International.
12. McMurry, J. (1996). *Organic Chemistry*, Brooks. *Cole, New York*, 657.
13. Masson, G., Konig, B., Yoon, T. *Photochemical Synthesis*, *Eur. J. Org. chem*., 2020, 10, 1186-1585.
14. Elford, D., Lancaster, S. J., Jones, J. A. Stereoisomers, Not Stereo Enigmas: A Stereochemistry Escape Activity Incorporating Augmented and Immersive Virtual Reality, *J. Chem. Educ.* 2021, 98, 5, 1691–1704.

Course Title: Molecular Spectroscopy

L	T	P	Cr
3	0	0	3

Paper Code: MCHM.518

Total Contact Hours: 45

Learning Outcome: The students will be able to

CLO1: Apply microwave, infrared-vibration-rotation Raman and infra-red Spectroscopy for chemical analysis and prediction of molecular structure

CLO2: Demonstrate and apply electronic absorption and emission spectroscopy of elements and simple molecules.

CLO3: Demonstrate and elucidate the physical principles of nuclear magnetic and electron spin resonance spectroscopy.

CLO4: Explore application of laser spectroscopy and photoelectron spectroscopy in materials and biomaterials.

Units/ Hours	Content	Mapping with CLOs
Unit 1 **12 Hours**	**Electronic Spectroscopy:** Electronic transition, energy of electronic transition, selection rules, the Franck-Condon principle. UV-Visible and CD spectroscopy **Photoluminescence:** Jablonski Diagram; Measurement of fluorescence and phosphorescence lifetimes, photosensitization, quenching and photodimerization, Stern-Volmer equation. **Microwave Spectroscopy:** Basic principle and instrumentation, classification of molecules, selection rule in microwave spectroscopy, rigid rotor model, effect of isotopic substitution on the transition frequencies, intensities of spectral lines, non-rigid rotor. *Problem solving approach to determine the bond length of diatomic and polyatomic molecules and effect of i*sotopic substitution *on* transition frequencies.	**CLO1, CLO2**
Unit 2 **11 Hours**	**Pure Vibrational Spectroscopy:** Basic principle and instrumentation of IR spectroscopy, Review of harmonic oscillator, selection rules, vibrational energies of diatomic molecules, zero-point energy, force constant and bond strength, anharmonicity, vibration-rotation spectroscopy, Morse potential energy diagram, P, Q, R branches, vibrations of polyatomic molecules, overtones and hot bands. **Raman Spectroscopy** - Basic principle and instrumentation of Raman spectroscopy, classical and quantum theories of Raman Effect, vibrational-rotational Raman spectra, selection rules, mutual exclusion principle, resonance Raman Spectroscopy, depolarization ratio, surface enhanced Raman spectroscopy, coherent anti-stokes Raman spectroscopy. Application of Raman spectroscopy. *Brainstorming on use of electronic, pure vibrational, pure rotational and vibrational-rotational spectroscopy in understanding chemical characteristics.*	**CLO3**

Unit 3 **11 Hours**	**Magnetic Resonance Spectroscopy:** Basic principles of NMR and ESR, instrumentation of NMR and ESR, magnetization vector and relaxation, NMR transitions, Bloch equation, relaxation effects and mechanism, effect of quadrupole nuclei, nuclear overhauser effect (NOE), multiple pulse methods, Hyperfine splitting in ESR. Application of NMR and ESR Spectroscopy. *Understanding applications of magnetic resonance spectroscopy through peer learning and brainstorming.*	**CLO4**
Unit 4 **11 hours**	**Lasers and Laser Spectroscopy:** Principles of laser action, pulsed lasers, examples of lasers: He-Ne, Nd-YAG, dye lasers. **Atomic Force Spectroscopy:** Basic principle and instrumentation, application of single molecule force spectroscopy. **Photoelectron spectroscopy**: Basic principle and instrumentation, photoelectric effect, X-ray photoelectron spectroscopy XPS. Application of XPS. *Understanding application and instrumentation of laser, photoelectron and atomic force spectroscopy through peer discussion.*	**CLO5, CLO6**

Mode of Transactions: Lecture, Demonstration, Presentation, Group Discussion, Lecture cum demonstration, Problem solving, Brainstorming.

Suggested Readings

1. Hollas, J. M. (2004). *Modern Spectroscopy*. John Wiley and Sons.
2. Lakowicz, J. R. (2006). *Principles of Fluorescence Spectroscopy*. Springer.
3. Barrow, G. M. (2007) *Physical Chemistry*. Tata McGraw-Hill Publishers.
4. Banwell, C. N., and McCash, E. M. (1994). *Fundamentals of Molecular Spectroscopy* (Vol. 851). New York: McGraw-Hill.
5. Carrington, A., and McLachlan, A. D. (1967). *Introduction to Magnetic Resonance: With Applications to Chemistry and Chemical Physics.* Chapman and Hall, London.
6. Lynden-Bell, R. M., and Harris, R. K. (1969). *Nuclear Magnetic Resonance Spectroscopy*. Appleton-Century-Crofts.
7. Reilley, C. N., Everhart, D. S., and Ho, F. F. L. (1982). *Applied Electron Spectroscopy for Chemical Analysis. Chemical Analysis, 63, 105*.John Wiley.
8. Chang, R. (1971). *Basic Principles of Spectroscopy*. McGraw-Hill.
9. Ghosh, P. K. (1983). *Introduction to Photoelectron Spectroscopy*. John Wiley and Sons, New York.
10. Günther, H. (2013). *NMR Spectroscopy: Basic Principles, Concepts and Applications in Chemistry*. John Wiley and Sons.
11. Atkins' P. (2014) Physical Chemistry, Peter Atkins and Julio Paula, Oxford University Press; 10th Ed.
12. Banwell, C. N. (2013). *Fundamentals of Molecular Spectroscopy*. Tata McGraw-Hill Education IV edition.

13. Rita Kakkar, R. (2015) Atomic and Molecule Spectroscopy: Basic Concepts and Applications, Cambridge University Press, 2015.
14. J L McHale (2008) Molecular Spectroscopy, Pearson Education India
15. McQuarrie, D. A. and Simon, J. D. (2019) *Physical Chemistry: A Molecular Approach.* Viva Books
16. Silbey, R. J. Alberty, R. A. and Bawendi, M. G. (2004) *Physical Chemistry*. Wiley-Interscience Publication.

Course Title: Pharmaceutical Products

L	T	P	Cr
3	0	0	3

Paper Code: MCAC.401

Total Contact Hours: 45

Learning Outcome: The students will be able to

CLO1: Understand the medicinal importance of various herbal products.

CLO2: Identify various commercial processes relevant in oleo chemical industry.

CLO3: Explore fats and oil as raw material for the synthesis of value added chemicals.

CLO4: Analyze various components used in perfumery and cosmetics.

Units/ hours	Content	Mapping with CLOs
Unit-1 12 Hours	**Herbal Products:** General Properties, Chemistry, Phytoconstituents and bioactive constituents and medicinal importance **Alkaloids Containing Herbal Drugs:** *Papaver somniferum* (morphine), *Rauvolfia serpentina* (reserpine), *Atropa belladonna* (atropine), *Ephedra gerardiana* (ephedrine), biosynthesis of alkaloids. **Terpenes Containing Herbal Drugs**: Lemon grass oil (citral and geraniol), *Artemisiaannua* (artemisinin) and Taxusbaccata, biosynthesis of terpenoids **Phenolics containing Herbal Drugs**: *Vitisvinifera* (resveratrol), *Pterocarpusmarsupium* (Pterostilbene) *Structures and biological activity of alkaloids and terpenoids through group presentations.* *Group project on recent advances on natural product based drug development.*	**CLO1**
Unit-2 11 Hours	**Edible Oils and Fats**: General study of the quality assessment, hydrogenation of oils, rancidity, iodine value, acid value, saponification value, Reichert-Meissel value, Polenski value and Kirschner value, adulteration of oils and fats, modifications to produce specialty fats (structured fats, nutraceuticals). Essential fatty acids: ω-3 and ω-6 fatty acids. Refining of edible oils. *Group project on chemical composition of various oils and fats.*	**CLO2**
Unit-3 11 Hours	**Soap**: Introduction, manufacturing process different types of soap and their composition, Recovery of glycerin from soap spent lye. Metathesis and co metathesis reactions of fats and oils and their application in oleo chemical industry. hydroformylation reaction, cracking of fatty acids and fatty acid esters. Detergents. Recent advances: Green surfactants *Group presentation on manufacturing process of different types of soap.*	**CLO3**

Unit-4 **11 Hours**	**Cosmetics and Perfumes:** Cosmetic necessities: Protective and antimicrobials, Astringents; safety issues of cosmetics. Storage and preparation of herbal drugs for commercial market. Essential oils and their importance in cosmetic industries. Antiperspirants, artificial and natural flavours, colours and preservatives, artificial sweeteners. *Peer learning on the recent research related to the impact of various preservatives and sugar substitutes on human health.*	**CLO4**

Mode of Transactions: Lecture, Demonstration, Presentation, Group Discussion, Lecture cum demonstration, Problem solving, Brainstorming

Suggested Readings:

1. Gunstone, F., (2004). *The Chemistry of Oils and Fats*. Blackwell Publishing Ltd, UK.
2. Rahman, A. U. (Ed.). (2006). *Studies in Natural Products Chemistry* (Vol. 33). Elsevier.
3. Jain, P.C. and Jain M. (2007). *Engineering Chemistry*. Dhanpat Rai and Sons.
4. Sharma, B. K. (1991). *Industrial Chemistry*. Krishna Prakashan Media.
5. Patrick, G. L. (2013). *An Introduction to Medicinal Chemistry*. Oxford university press.
6. Singh, H., and Kapoor, V.K., (2007). *Medicinal and Pharmaceutical Chemistry*. Vallabh Prakashan, Pitampura, New Delhi.
7. Foye, W. O. (2008). *Foye's Principles of Medicinal Chemistry*. Lippincott Williams and Wilkins.
8. Poucher, W. A. (2012). *Poucher's Perfumes, Cosmetics and Soaps: Volume 3: Cosmetics*. Springer Science and Business Media.
9. Edwards, S. E., da Costa Rocha, I., Heinrich, M., and Williamson, E. M. (2015). *Phytopharmacy: An Evidence-Based Guide to Herbal Medicinal Products*. John Wiley and Sons.
10. Daley. S. K., Cordell, G. A., Biologically Significant and Recently Isolated Alkaloids from Endophytic Fungi, *J. Nat. Prod.* 2021, 84, 3, 871–897.
11. Thomas, W. P., Pronin, S. V., New Methods and Strategies in the Synthesis of Terpenoid Natural Products, *Acc. Chem. Res.* 2021, 54, 6, 1347–1359.

Course Title: Computational and Structural Chemistry (Practical)
Paper Code: MCHM.519
Total Contact Hours: 60

L	T	P	Cr
0	0	4	2

Learning Outcomes: After completing this course, the learner will be:
CLO1: Skilled in various chemistry software needed for higher studies.
CLO2: Develop knowledge skills and understanding of structure elucidation of unknown compounds via spectral interpretation of ^{1}H, ^{13}C NMR, IR, UV and Mass spectrum.
CLO3: Select and apply the data analytics to every process and analysis in chemistry, thereby bringing in quality control to his work in hand.

Experiments:
ChemDraw, Chem-Sketch**,** Draw the structure of simple aliphatic, aromatic, heterocyclic organic compounds with substituents. Get the correct IUPAC name and prediction of ^{1}HNMR and ^{13}C-NMR signals.
Exposure to Softwares required for processing of raw FID NMR files, Molecular docking using Schrodinger/MOE Softwaresor DFT studies using Gaussian software.
Single crystal structure solving of various compounds and complexes using X-Ray Diffraction (XRD) software Olex-2.
Spectral interpretation: Interpretation of UV, IR, NMR (1D & 2D-NMR) and mass spectrum.
Combined Structure problems: Exercises of structure elucidation of unknown compounds *via* combined spectral interpretation of IR, UV-vis, ^{1}H and ^{13}C NMR and mass spectra, along with two-dimensional NMR spectroscopy.
Statistical Analysis Methods:

1. Determination of Detection limit, Quantitation limit and for instrumental method and method of analysis.
2. Determination of quality control parameters for a method of analysis.
3. Determination of Mean, Mode and Median, Skewness and Kurtosis, FWHM for chromatographic data.
4. Linear least square fitting for calibration of spectrometer
5. Non-Linear least square fitting for adsorption and kinetic data.
6. Determination of ANOVA for intralaboratory testing.
7. Error function and residual analysis of Linear and Non-linear least square fitting
8. Optimization of process and analysis using Factor analysis, Principle Component Analysis
9. Optimization of process using response surface methodology
10. Determination of charges, pKa and electrostatic free energy of enzymes and proteins using pKa calculation software.

Suggested Readings

1. Pavia, D. L., Lampman, G. M., Kriz, G. S., and Vyvyan, J. A. (2015). *Introduction to Spectroscopy*. Cengage Learning India Private Limited; 5th edition.
2. Gross, J. H. (2017). *Mass Spectrometry: A Textbook*. Springer-Verlag Berlin Heidelberg.
3. Pasto, D.P., Johnson, C., Miller, M. (2010). Experiments and Techniques in Organic Chemistry, Prentice Hall.
4. Vogel, A.I. (2003). Text Book of Practical Organic Chemistry, Pearson
5. Armarego, W. L., & Chai, C. (2012). Purification of Laboratory Chemicals. Butterworth-Heinemann.
6. Findeisen, M., (2013). 50 And More Essential NMR Experiments: A Detailed Guide. John Willey & Sons.

7. Fine, J. A., Rajasekar, A. A., Jethava, K. P., & Chopra, G. (2020). Spectral deep learning for prediction and prospective validation of functional groups. *Chemical Science*, *11*(18), 4618-4630.
8. Yorck, M.M., and Neuhold, M., (2007) Practical Data Analysis in Chemistry, 26, Elsevier Science.
9. https://www.practicaldatascience.org/html/pandas_series.html.
10. Leszczynski, J., Shukla, M. (2012) Practical Aspects of Computational Chemistry II: An Overview of the Last Two Decades and Current Trends, Springer Netherlands.

Course Title: Advanced Applied Chemistry Practical
Paper Code: MCAC.516
Total Contact Hours: 60

L	T	P	Cr
0	0	4	2

Learning Outcome: At the end of this course students will be able to

CLO1: Identify various reagents used for drying of solvents and their disposal.
CLO2: Compare various analytics for quality assessment of oils and fats.
CLO3: Separate and purify the desired product from an organic reaction.
CLO4: Characterize the synthesized organic compounds using various spectroscopic techniques
CLO5: Separate and purify the desired product from an organic reaction.
CLO6: Realize the impact of various coupling and click chemistry strategies for construction of value added chemicals.
CLO7: Biochemical, biophysical and structural characterizations of bio-macromolecules.

Experiments:

1. **Solvent Drying**: Use of sodium metal for drying of toluene and precautions while quenching the residual sodium. Drying of DCM using P_2O_5 and safe disposal of residual P_2O_5.
2. **Synthesis**: Separation and purification of organic compounds by column chromatography, percentage yield calculation (any six)
    1. Preparation of dyes: Preparation of azo dyes, Fluoroscein, Malachite green (any one)
    2. Estimation of Oils and Fats: (i) Saponification value of the given oil or fat sample (ii) Iodine value of a given oil.
    3. Extraction of essential oil: To extract the essential oils from some common plant parts.
    4. Synthesis of aromatics and perfumery compounds: Methylcinnamate, Methyl anthranilate. Benzyl acetate, Coumarin, Pyrazole, Isoxazle (any two)
    5. Synthesis of a FEMA-GRAS approved flavoring agent 4-vinylguaiacol *via* Knoevenagel-Doebner decarboxylation strategy.
    6. Green Synthesis of antipyretic drug paracetamol.
    7. Preparation of allylic alcohols *via* Baylis-Hillman reaction using DABCO as a catalyst and characterization through various spectroscopic techniques.
    8. To study Buchwald-Hartwig reaction of aryl halide with an amine using Cu-based catalyst.
    9. To study dehydration of benzylic alcohols using imidazolium based ionic liquid.
    10. Synthesis of stilbenes via Heck coupling Strategy.
    11. Synthesis of triazole via reaction of alkyne with azide (Huisgen cycloaddition).
    12. To study the synthesis of Dialntin *via* benzylic acid rearrangement.
    13. To study the Vielsmeyer Haack reaction of indole/acetophenones.

14. To study the rearrangement of benzopinacol into benzopinacolone.
15. To study the tree component coupling reaction for the synthesis of (any one)
    (i) Dihydropyrimidinone (*via* Bignelli reaction)
    (ii) Propargylamine (via A^3- coupling)

2. Advanced Instrumentation Experiments:

1. Determination of concentrations of proteins and DNA using spectrophotometer
2. Structural analysis of amino acids and proteins using CD, NMR and Fluorescence spectrometer.
3. Study of thermal denaturation (T_m and ΔH_m) of proteins and DNA using UV-Visible spectrophotometer, CD spectrometer and DSC.
4. Measurement of zeta potential and sizes of nanoparticles by DLS
5. Determination of Michaelis-Menten (K_m) constant in enzyme kinetics.
6. Particle size and hydrodynamic radii analysis for adsorbents, protein or nanoparticles
7. Measurement of affinity constant of metal complex or metal binding to protein by ITC

Mode of Transactions: Demonstration, PPT, videos, Lecture cum demonstration

Suggested Readings

1. Vogel, A.I. (2003) *Textbook of Practical Organic Chemistry*. ELBS, Longman Group Ltd.
2. Mann, F.G. and Saunders, B.C. (2009) *Practical Organic Chemistry*. Orient Longman Pvt. Ltd.
3. Leonard, J. and Lygo, B. (1995) *Advanced Practical Organic Chemistry*. Chapman and Hall.
4. Armarego, W.L. and Chai, C. (2012) *Purification of Laboratory Chemicals*. Butterworth-Heinemann.
5. Kaur, P. Kumar B. Gurjar, K.K. Kumar, R, Kumar, V, and Kumar, R. (2021) Metal- and solvent-free multicomponent decarboxylative A3-coupling for the synthesis of propargylamines: Experimental, computational and biological investigations, *J. Org. Chem.*,2020**,** *85*(4), 2231-2241.
6. Young, J.A. (1991) *Improving Safety in the Chemical Laboratory: A Practical Guide.* Wiley Publishing.
7. Van Hlde, K.E., Johnson W.C. and Ho John, P.S. (2005) *Principles of Physical Biochemistry* 2nd edition, Pearson Prentice Hall.
8. Wilson, J. M., Newcombe, R. J., and Denaro, A. R., (2016) *Experiments in Physical Chemistry*, 2nd Ed., Elsevier Science.
9. Haghi, A. K., Aguilar, C. N., Cortes, J. S. and Ascacio-Valdés, J. A. (2021) *Practical Applications of Physical Chemistry in Food Science and Technology*, Apple Academic Press.
10. Kumari, A., Anand, R., Kumari, R. (2019) *Physical Chemistry Laboratory Manual: An Interdisciplinary Approach*, I K International Publishing House Pvt. Limited.
11. Firth, J. B. (2018) *Practical Physical Chemistry*, Creative Media Partners, LLC.

Mode of Transactions: Demonstration, PPT, videos, Lecture cum demonstration

Suggested Readings

1. Vogel, A.I. (2003) *Textbook of Practical Organic Chemistry*. ELBS, Longman Group Ltd.
2. Mann, F.G. and Saunders, B.C. (2009) *Practical Organic Chemistry*. Orient Longman Pvt. Ltd.

3. Leonard, J. and Lygo, B.(1995) *Advanced Practical Organic Chemistry*. Chapman and Hall.
4. Armarego, W.L. and Chai, C. (2012) *Purification of Laboratory Chemicals*. Butterworth-Heinemann.
5. Kaur, P. Kumar B. Gurjar, K.K. Kumar, R, Kumar, V, and Kumar, R. (2021) Metal- and solvent-free multicomponent decarboxylative A^3-coupling for the synthesis of propargylamines: Experimental, computational and biological investigations, *The Journal of Organic Chemistry*,2020**,** *85*(4), 2231-2241
6. Young, J.A. (1991) *Improving Safety in the Chemical Laboratory: A Practical Guide.* Wiley Publishing.
7. Cantor, C.R. and Schimmel, P.R (1980). Biophysical Chemistry Part II: Techniques for the Study of Biological Structure and Function, W. H. Freeman & Co., New York
8. Van Hlde, K.E., Johnson W.C. and Ho John, P.S. (2005) Principles of Physical Biochemistry" 2 nd edition, Pearson Prentice Hall.
9. Wilson, J. M., Newcombe, R. J., and Denaro, A. R., (2016) Experiments in Physical Chemistry, 2nd Ed., Elsevier Science
10. Haghi, A. K., Aguilar, C. N., Cortes, J. S. and Ascacio-Valdés, J. A. (2021) Practical Applications of Physical Chemistry in Food Science and Technology, Apple Academic Press.
11. Kumari, A., Anand, R., Kumari, R. (2019) Physical Chemistry Laboratory Manual: An Interdisciplinary Approach, I K International Publishing House Pvt. Limited.
12. Firth, J. B. (2018) Practical Physical Chemistry, Creative Media Partners, LLC.

Course Title: Quality Control in Laboratory and Manufacturing
Paper Code: MCAC.511
Total Lectures: 45

L	T	P	Cr
0	0	4	2

Learning Outcome: The students will be able to

CLO1: Demonstrate and apply the various statistical tools for the quality control of the analytical results and its implications to regulatory approvals.

CLO2: Demonstrate the use of regulatory requirements in laboratory recognition in cluding USFDA Methods.

CLO3: Elucidate the good laboratory and manufacturing practices.

CLO4: Demonstrate various parameters for establishing the method validations for a particular instrument in Industrial set-up.

Units/ hours	Content	Mapping with CLOs
Unit I 11 Hours	Statistical. Method of Least squares and weighted least squares formalism. Use of certified reference materials and procedures for interlaboratory comparisons. Definition of limits of detection and sensitivity, and concept of standard addition to assess matrix effects. Uncertainty Calculations. *Statistical quality control would be understood through problem solving activity.*	**CLO1**
Unit II 12 Hours	Concept of Total Quality Management, philosophy of Good Manufacturing Practice (GMP), ISO 9000 and ISO 14798 (NABL Accreditation). Organization and personnel, responsibilities, training, hygiene, personnel records. **Premises:** Location, design, plan layout, construction, maintenance of sterile areas, control of contamination. Equipment, selection purchase specifications, preventive maintenance of equipment, cleaning of equipment. *Requirements of quality control in pharmaceutical manufacturing would be learnt through field visit.*	**CLO2**
Unit III 11 Hours	Quality control laboratory, Good Laboratory Practice(GLP), responsibilities of management, Study Director, Quality Assurance Unit, and Individual, routine controls, instruments, reagents, sampling plans, standard test procedures, protocols, non-clinical testing, controls on animal house, data generation and storage, quality control documentation, retention samples, records. Complaints and recalls, evaluation of complaints, recall procedures, related records and documents. *Good laboratory practices would be understood with card game and peer learning.*	**CLO3**
Unit IV 11 Hours	Regulatory aspects of pharmaceutical and bulk drug manufacture. DRA, FDA, CPMP, ICH guidelines. Regulatory Aspects of Environmental and Food Testing USEPA, MoEF, MoFPI, AOAC guidelines. Validation: Qualification (IQ/PQ/OQ), validation and calibration of equipment's, Evaluation of Analytical data. Drug approval process, patent application and WHO certification. *Regulatory requirements of various international and national governing bodies on quality laboratory and manufacturing would be understood through peer learning.*	**CLO2, CLO4**

Mode of Transactions: Lecture, Demonstration, Lecture cum demonstration, Problem solving, Brainstorming, Tutorial.

Suggested Readings

1. Miller, J. C., and Miller, J. N. (2010). *Statistics for Analytical Chemistry*. Pearson Education Ltd.
2. http://www.who.int/water_sanitation_health/resourcesquality/wqmchap9.pdf
3. https://www.unece.org/fileadmin/DAM/env/water/publications/documents/guidancelaboratories.pdf.
4. EURACHEM / CITAC (2012) *Quantifying Uncertainty in Analytical Measurement, EURACHEM / CITAC Guide CG 4*, 3rd Edition, https://www.eurachem.org/images/stories/Guides/pdf/QUAM2012_P1.pdf .
5. Westgard, J. O., Barry, P. L. (2016) *Basic QC Practices: Training in Statistical Quality Control for Medical Laboratories*, 4th ed., Westgard Quality Corporation.
6. Kenkel, J. (2014) *Analytical Chemistry for Technicians*, 4thed., *CRC Press.*
7. Konieczka, P., Namiesnik, J., (2018) *Quality Assurance and Quality Control in the Analytical Chemical Laboratory: A Practical Approach*, 2nd ed. CRC Press.
8. WHO (2011) *Laboratory Quality Management System Handbook*.
9. Zaman, G., (2018) *Quality Control in Laboratory,* Intech Open Publlishing.
10. Hasnain, M.S., Beg, S., (2019) *Pharmaceutical Quality by Design: Principles and Applications*, Elsevier Science.
11. Welty G., (2013) *Quality Assurance: Problem Solving and Training Strategies for Success in the Pharmaceutical and Life Science Industries*, Woodhead Publishing.
12. Haider, S. I., Asif, S. E., (2016) *Quality Control Training Manual: Comprehensive Training Guide for API, Finished Pharmaceutical and Biotechnologies Laboratories*, CRC Press.
13. Gibson, M., Schlindwein, W. S. (2018) *Pharmaceutical Quality by Design: A Practical Approach*, Wiley Publishing.
14. Gad, S. C. (2008) *Pharmaceutical Manufacturing Handbook: Regulations and Quality*, Wiley Publishing.
15. Luthra, S., Garg, D., Agarwal, A., Mangla, S. K. (2020) *Total Quality Management (TQM): Principles, Methods, and Applications*, CRC Press.
16. Montgomery, D. C., (2020) *Introduction to Statistical Quality Control*, Wiley Publishing.
17. Bunn, G. P. (2019) *Good Manufacturing Practices for Pharmaceuticals*, 7th Edition, CRC Press
18. Shewhart, W. A. (2012) *Statistical Method from the Viewpoint of Quality Control*, Dover Publication.

Course Title: Advanced Organic Chemistry
Paper Code: MCHM.521
Total Contact Hours: 45
Learning Outcome: The students will be able to

CLO1: Compare the reactivity of smaller, five and six membered heterocyclic compounds and perform their synthesis.

CLO2: Explore various reagents for functional group conversions and synthesis of organic frameworks

CLO3: Design the synthesis of alkenes and functionalized molecules utilizing phosphorus, nitrogen and sulphur ylides.

CLO4: Apply various cross-coupling reactions and organoborane based reagents for the synthesis of fine-chemicals.

Units/ hours	Content	Mapping with CLOs
Unit-1 11 Hours	**Heterocyclic Chemistry:** Systematic (Hantzsch-Widman system) and replacement nomenclature for monocyclic, fused and bridged heterocycles. **Three-membered and four-membered heterocycles**: aziridines, oxiranes, thiranes, azetidines, oxetanes. **Five membered heterocycles containing two heteroatoms (S, N, O)**: Diazoles (imidazole, pyrazole), triazoles, oxazoles and thiazoles. **Six-membered heterocycles**: Synthesis and reactions of coumarins, chromones. **Benzo-fused five-membered heterocycles**: Indoles, benzofurans and benzimidazoles. *Debate on reactivity order, basic and aromatic character of five- and six- membered heterocycles containing one and two heteroatoms.*	**CLO1**
Unit-2 11 Hours	**Reagents in organic synthesis:** Gilman's reagent, Lithium diisopropylamide (LDA), 1,3-Dithiane (Umpolung reagent), Trimethylsilyl iodide, Baker's yeast, Woodward and Prevost reagents, Crown ether, Merrifield resin, Fenton's reagents, Ziegler-Natta catalyst, Lawsson reagent, IBX, Fetizon reagent, Dioxiranes, Tebbe reagent, Corey-Nicolaou reagent and macrolactonization, Mosher's reagent. *Comparison on the reactivity and selectivity of various reagents through collaborative learning.*	**CLO2**

Unit-3 **11 Hours**	**Reaction of ylides:** Phosphorus ylide; structure and reactivity, stabilized ylides, Witting, Wittig-Horner and Wadsworth Emmons reactions-mechanistic realization; E/Z selectivity for olefin formation, Schlosser modification. Sulphur ylides; stabilized and non-stabilized ylides. Nitrogen Ylides; Stevens rearrangement, Sommelet-Hauser rearrangement. Wittig *vs* Peterson's olefination. **Enolate Chemistry**: Regio- and stereo-selectivity in enolate generation. "O" versus "C" alkylation, counter-cation and electrophiles; thermodynamically and kinetically controlled enolate formations; various transition state models to explain stereoselective enolate formation; enamines and metallo-enamines; regioselectivity in generation. *Peer group discussion on various methods to construct double bonds (including exocyclic double bonds) and respective advantages.* *Group discussion on stereoselective generation of enolates and alkylation in organic synthesis.*	**CLO3**
Unit-4 **12 Hours**	**Organometallic compounds:** Organoboranes: Preparation of organoboranes with BH_3-THF, dicyclohexylborane, disiamylborane, thexylborane, 9-BBN. Functional group transformations of organoboranes: oxidation, protonolysis and rearrangements, formation of carbon-carbon-bonds *viz* organoboranes carbonylation. Chiral Organobornaes: diisopinocampheyl borane, alpine borane. **Cross-Coupling C-C and C-N coupling reactions**: Heck coupling, Sonogashira coupling, Suzuki coupling, Buchwald Coupling, Negishi coupling, Chan-Lam coupling. *Expression of the views of the students on latest advancement in the area of organoboranes including stereochemical aspects through presentation.*	**CLO3, CLO4**

Mode of Transactions: Lecture, Demonstration, Presentation, Group Discussion, Lecture cum demonstration, Problem solving, Brainstorming

·**Suggested Readings**

1. Yadav, L. D. S., Singh, J., and Singh, J. (2017). *Organic Synthesis*, Pragati Prakashan, India.
2. Norman, R.O.C., and Coxon, J. M. (1993). *Principle of Organic Synthesis*, CRC Press; 3rd edition.
3. Ahluwalia, V. K., and Parasar R. K., (2011). *Organic Reaction Mechanism*. Narosa Publishing House (P) Ltd., New Delhi.
4. Warren, S., (2010). *Organic synthesis: The Synthon Approach*. John Wiley and Sons.
5. Carey, F. A., and Sundberg, R. J. (2007). *Advanced organic chemistry: part B*. Springer Science and Business Media.
6. Bansal, R. K. (2012). *A Textbook of Organic Chemistry*. New Age International.
7. Bansal, R. K. *Heterocyclic Chemistry*, 5th Edition, 2010, New Age International (P) Ltd., New Delhi.

8. Gilchrist, T. L., (1997). *Heterocyclic Chemistry*. Addison Wesley Longman Publishers, US.
9. Gupta R.R., Kumar M., and Gupta V., (2010). *Heterocyclic Chemistry-II Five Membered Heterocycles*. Vol. 1-3, Springer Verlag, India.
10. Joule, J. A., and Mills, K., (2010). *Heterocyclic Chemistry*. Blackwell Publishers, New York.
11. Smith, M. B., (2013). *March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure*. John Wiley and Sons.
12. Corey, E. J., and Cheng X.-M., (1989). *The Logic of Chemical Synthesis*. John Wiley and Sons.
13. Gulevich, A. V., Dudnik, A. S., Chernyak, N., and Gevorgyan, V., *Transition Metal-Mediated Synthesis of Monocyclic Aromatic Heterocycles.* Chemical Reviews, 2013, 113, 3084-3213.
14. Patil, N. T., and Yamamoto, Y., Coinage Metal-Assisted Synthesis of Heterocycles. *Chemical Reviews*, 2008, 108, 8, 3395-3442.
15. Gribble, G. W., Joule J. A. (2021). *Progress in Heterocyclic Chemistry,* Elsevier - Health Sciences Division, USA

Course Title: Inorganic Spectroscopy and Catalysis

L	T	P	Cr
0	0	4	2

Paper Code: MCHM.524

Total Contact Hours: 45

Learning Outcome: The students will be able to

CLO1: Apply properties of f-block elements to analytical and spectroscopic applications.

CLO2: Elucidate the inorganic structures using multinuclear-NMR, ESR and Mossbauer Spectroscopy.

CLO3: Demonstrate the use of radioanalytical chemistry.

Units/ hours	Content	Mapping with CLOs
Unit-1 **10 Hours**	**Lanthanides, actinides and super-heavy elements:** Coordination chemistry, magnetic and spectral properties, comparison of general properties of lanthanides and actinides, comparison with d-block elements, organo-lanthanides and actinides, analytical application of lanthanides and actinides-lanthanides as shift reagents and high temperature super conductors. *Group discussion on comparative properties and problem solving of lanthanide and Actinide elements.*	**CLO1, CLO2**
Unit-2 **15 Hours**	**Nuclear Magnetic Resonance (NMR) and Electron Spin Resonance (ESR) Spectroscopy:** **NMR**: Basic concepts of NMR with emphasis on ^{31}P, ^{19}F, ^{29}Si, ^{11}B, ^{10}B, ^{57}Se, ^{125}Te, ^{95}Mo, ^{109}Ag, ^{195}Pt, ^{119} Sn and explanation with appropriate examples. NMR study in Fluxional organometallic compounds**.** **ESR**: Basic elements of ESR, Fine structure of ESR Signals transition metal ions, Zero-field Splitting, Kramer`s Degeneracy, Hyperfine Splitting of various free radical spin polarization for atoms and transition metal ions, spin orbit coupling and significance of *g*-tensors, application of transition metal complexes (having one unpaired electron) including biological systems. *Hand on experience of inorganic complexes for resonance spectroscopy using NMR instrument and structural elucidation.*	**CLO1, CLO2**
Unit-3 **10 Hours**	**Mossbauer Spectroscopy:** Basic principles, spectral parameters and spectrum display, application of the technique to the studies of (1) bonding and structures of Fe^{2+} and Fe^{3+} compounds including those of intermediate spin, (2) Sn^{2+} and Sn^{4+} compounds- nature of M-L bond, coordination number, structure and (3) detection of oxidation state and non-equivalent MB atoms. *Peer discussion on basic parameters and technique implication for structural elucidation of iron and tin contain compounds using Mossbauer Spectroscopy.*	**CLO1, CLO2**

Unit-4 **10 Hours**	**Homogeneous Catalysis:** homogeneous catalytic hydrogenation, Zeigler-Natta catalyst and stereospecific polymerization of olefins, catalytic reactions involving carbon monoxide such as hydrocarbonylation of olefins (oxo reaction) oxo-palladation reactions, activation of C-H bond. Peer group discussion on Transition metal based industrial processes. *Peer group discussion on Transition metal based industrial processes.*	**CLO3**

Mode of Transactions: Lecture, Demonstration, Lecture cum demonstration, Problem solving, Brainstorming, Tutorial

Suggested Readings

1. Cotton, F.A. and Lippard, S.J., (1998). *Progress in Inorganic Chemistry*. Vol. 8, Wiley Internationals.
2. Lever, A.B.P., (1984). *Inorganic Electronic Spectroscopy*. Elsevier Science Publishers B.V.
3. Parish, R.V., (1990). *NMR, NQR, EPR and Mossbauer Spectroscopy in Inorganic Chemistry*. Ellis Harwood.
4. Silverstein, R.M., Bassler, G.C., and Morrill, T.C. (2002). *Spectrometric Identification of Organic Compounds*. John Wiley and Sons.
5. Abraham, R. J., Fisher, J., and Loftus, P. (1988). *Introduction to NMR spectroscopy*. Wiley.
6. Martin, M. L., Delpuech, J. J., and Martin, G. J. J. (1980). *Practical NMR Spectroscopy*. Heyden.
7. Williams, D. H., and Fleming, I. (1980). *Spectroscopic Methods in Organic Chemistry*. McGraw-Hill.
8. Greenwood, N. N., and Earnshaw, A. (2012). *Chemistry of the Elements*. Elsevier.
9. Lee, J. D. *Concise Inorganic Chemistry*, 5th Edition (2012). Elsevier.
10. Kent, B. *Inorganic Chemistry: Reactions, Structures and Mechanisms* (12 June 2019), NY Research Press.
11. Close, D. *Principles of Inorganic Chemistry* (19 June 2019), Larsen and Keller Education

Course Title: Solid State Chemistry and Statistical Thermodynamics

Paper Code: MCHM.525

L	T	P	Cr
3	0	0	3

Total Contact Hours: 45

Learning Outcome: After completion of this course, the students will be able to

Learning Outcome: After completion of this course, the students will be able to

CLO1: Physicochemical properties, defects in solid, diffraction techniques, electrical and magnetic properties of materials.
CLO2: The relationship between material structure and physical attributes associated with them.
CLO3: Advance applications of these materials.
CLO4: Explain the statistical aspects of system and relate the classical thermodynamics to quantum mechanics.
CLO5: Apprehend and apply partition function in the deduction of thermodynamic properties of chemical systems.
CLO6: Apprehend and apply Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics to the thermodynamic system.

Units/ hours	Content	Mapping with CLOs
Unit-1 **15 Hours**	**Diffraction Methods:** Basic concepts of X-ray, electron and neutron diffraction methods, structure of simple lattices and X-ray intensities, structure factor and its relation to intensity and electron density, phase identification, X-ray structure analysis, XRD and its applications, polymorphism and cocrystallization. **Semiconductor and Superconductors:** Band theory, band gap, metals and semiconductors, intrinsic and extrinsic semiconductors, p-n junctions and other applications (optical activity). *Demonstration of characterization of these solid state materials like XRD. Relevance of the various aspects of Ferrites in various areas for sustainable development through brainstorming.*	**CLO1,**
Unit-2 **10 Hours**	**Nanomaterials:** Nanoparticles: zero dimensional nanostructure, homogeneous and heterogeneous nucleation, nanoparticles and their synthesis, nanowires and nanorods: one dimensional nanostructures, thin film and two dimensional nanostructure-preparation techniques. **Magnetic Materials (Ferrites):** Introduction, structure and classification, hard and soft ferrites, synthesis of ferrites by various methods (precursor and combustion method), characterization of ferrites, magnetic properties of ferrites, applications of ferrites. *Brainstorming session on the properties of low dimension materials formation.* *Concept of Nano dimension materials for modern applications.* *Debate on semiconductor materials and their optical and conduction character for device fabrication.*	**CLO2** **CLO3**

Unit-3 **10** **Hours**	**Statistical Thermodynamics:** Statistical concepts and examples, postulates of statistical thermodynamics, configurational distribution of energy levels and states, thermodynamic probability and entropy. Partition function, molecular partition function, thermodynamic properties in terms of the molecular partition function for monoatomic gases, rotational, translational, vibrational, electronic and nuclear partition functions for diatomic molecules. *Partition function and its correlation to classical thermodynamic evaluation through brainstorming session and peer learning* **Theories of Statistical Thermodynamics:** Concept of Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics. Relation and Difference between Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics. Applications of statistical approaches to monoatomic solids, theories of specific heat for solids, chemical equilibrium, Transition state theory and Unimolecular reactions. *Demonstrating application of various statistical thermodynamic theories and Debye theory for heat capacity.*	**CLO4** **CLO5** **CLO6**
Unit 4 **11** **Hours**	**Adsorption:** Adsorption of solids, Langmuir and Fredulich Isotherms, BET adsorption isotherm, Gibbs adsorption isotherm. **Catalysis:** Homogeneous catalysis and heterogeneous catalysis, enzyme catalysis. Michealis-Menten mechanism, Lineweaver-Burk Plot, competitive and non-competitive bindings, application of enzyme catalysis. *Application and challenges in adsorption towards environmental and nanomaterial through peer learning. Enzyme binding and catalysis through inquiry guided and gaming based learning.*	**CLO7**

Mode of Transactions: Lecture, Demonstration, Presentation, Group Discussion, Lecture cum demonstration, Problem solving, Brainstorming.

Suggested Readings

1. Ashcroft, N. W., and Mermin, N. D. (1976). *Introduction to Solid State Physics*. Saunders.
2. Callister Jr., W. D., and Rethwisch, D. G. (2012). *Fundamentals of Materials Science and Engineering: An Integrated Approach*. John Wiley and Sons.
3. Anderson, J. C., Leaver, K. D., Rawlings, R. D., and Leavers, P. S. (2004). *Materials Science for Engineers*. CRC Press.
4. Keer, H. V. (1993). *Principles of the Solid State*. New Age International.
5. L. K. (2012). *Elements of Statistical Thermodynamics. Dover Publication Inc.*
6. Puri, B.R., Sharma L.R. and Pathania, M.S. (2013). *Principles of Physical Chemistry.* Vishal Publishing Company Nash.

7. Laurendeau*, N. M. (2005). Statistical Thermodynamics: Fundamentals and Applications. Cambridge University Press.*
8. *Hi*ll, T. L. (1986). *An Introduction to Statistical Thermodynamics*. Dover Publications Inc.
9. Yu, T. H. (2020). Teaching Thermodynamics with the Quantum Volume J. Chem. Educ., *97* (3), 736-740 DOI: 10.1021/acs.jchemed.9b00742.
10. Phillips, J. A., Jones, G. H., and Iski, E. V.(2019). Using a Guided-Inquiry Approach To Teach Michaelis–Menten Kinetics *J. Chem. Educ.96* (9), 1948-1954DOI: 10.1021/acs.jchemed.9b00031.
11. Bennie, S.J., Ranaghan, K. E., Deeks, H., Goldsmith, H. E., O'Connor, M. B., Mulholland, A. J., and Glowacki, D. R.(2019). Teaching Enzyme Catalysis Using Interactive Molecular Dynamics in Virtual Reality *J. Chem. Educ.96* (11), 2488-2496 DOI: 10.1021/acs.jchemed.9b00181.
12. Novak, I. (2020). Reversible Reactions: Extent of Reaction and Theoretical Yield *J. Chem. Educ.,97* (2), 443-447 DOI: 10.1021/acs.jchemed.9b0088.
13. Nelson, K. A., and Bawendi, M. (2008). https://ocw.mit.edu/courses /chemistry/5-60-thermodynamics-kinetics-spring-2008/video-lectures.

Course Title: Applied Electrochemistry

Paper Code: MCAC.517

Total Lectures: 45

L	T	P	Cr
3	0	0	3

Learning Outcome: Upon completion of the course the student would be able to

CLO1: Elucidate the working and efficiency of Commercial electrochemical cells and Mechanism of Corrosion.

CLO2: Demonstrate and apply electrochemistry of bio/chemical origin in analysis of important analytes of biological relevance.

Units/ hours	Content	Mapping with CLOs
Unit I 11 Hours	Conversion and storage of electrochemical energy, maximum intrinsic efficiency of an electrochemical converter. physical interpretation of the Carnot efficiency factor in electrochemical energy converters. power outputs. Electrochemical generators (fuel cells): hydrogen oxygen cells, hydrogen air cell, hydrocarbon air cell, alkaline fuel cell, applications of fuel cells. *Brainstorming approaches to enhance efficiency of fuel cell and electrochemical devices.*	**CLO1**
Unit II 12 Hours	Electrochemical energy storage. Properties of electrochemical energy storage: measure of battery performance, charging and discharging of a battery, Classical batteries: (i) lead acid (ii) nickel-cadmium. Modern batteries: (i) nickel-metal hydride, (ii) lithium battery. *Efficiency of energy storage devices through peer learning. Hands-on model building of electrochemical devices based on sustainable national policies.*	**CLO1**
Unit III 11 Hours	Corrosion and stability of metals. Mechanism of the corrosion of the metals; thermodynamics and the stability of metals, corrosion current and corrosion potential -Evans diagrams. Measurement of corrosion rate: Inhibiting corrosion, Passivation. Structure of passivation films, mechanism of passivation. *Brainstorming the corrosion of metals and passivation technologies of the current world.*	**CLO1**
Unit IV 11 Hours	Bioelectrochemistry. Bioelectronics, membrane potentials, simplistic theory, modern theory, electrical conductance in biological organisms: enzymes as electrodes. kinetic of electrode process. Essentials of electrode reaction. Current density, overpotential, Tafel equation, Butler Volmer equation. *Applications of bio/chemical electrochemistry for sensing analytes of medical relevance through peer learning.*	**CLO2**

Mode of Transactions: Lecture, Demonstration, Lecture cum demonstration, Problem solving, Brainstorming, Tutorial

Suggested Readings:

1. Mabbott, G. A., (2020) Electroanalytical Chemistry: Principles, Best Practices, and Case Studies, Wiley Publishers.
2. Ozkan, S.A., Kauffmann,J.-M., Zuman, P., Brett, A. M. O. (2015) *Electroanalysis in Biomedical and Pharmaceutical Sciences: Voltammetry, Amperometry, Biosensors, Applications*, Springer Berlin Hidelberg.

3. Garche, J., and Moseley, P. T. (2014) *Electrochemical Energy Storage for Renewable Sources and Grid Balancing*, Elsevier Science.
4. Ezema, F. I., and Kebede, M. A. (2019) *Electrochemical Devices for Energy Storage Applications*, CRC Press.
5. Hester, R. E., and Harrison, R. M. (2018) *Energy Storage Options and Their Environmental Impact*, RSC Publishing.
6. Job, R. (2020) *Electrochemical Energy Storage: Physics and Chemistry of Batteries*, DeGruyter Publishers.
7. Bockris, J. O. M., and Reddy, A. K. (1998). *Modern Electrochemistry 2B: Electrodicsin Chemistry, Engineering, Biology and Environmental Science* (Vol. 2). Springer Science and Business Media.
8. Srinivasan, S., (2006). *Fuel Cells: From Fundamentals to Applications*. Springer Science + Business Media LLC.
9. Bond, A. M. (1980). *Modern Polarographic Methods in Analytical Chemistry* (Vol. 4). CRC Press.
10. Zutshi, K. (2006). *Introduction to Polarography and Allied Techniques*. New Age International.
11. Monk, P. M. S., (2001). *Fundamentals of Electroanalytical Chemistry*. Wiley and Sons.
12. Vassos, B. H., and Ewing, G. W., (1983). *Electroanalytical Chemistry*. Wiley Interscience.
13. Scholtz, F. (2013) *Electroanalytical Methods: Guide to Experiments and Applications*Springer Berlin Heidelberg.

Course Title: Inorganic Photochemistry

L	T	P	Cr
3	0	0	3

Paper Code: MCHM.528
Total Contact Hours: 45
Learning Outcomes: The student will be able to
CLO1: Inorganic photochemistry and photophysical chemistry.
CLO2: The characterization of transient intermediates by ultrafast modern techniques.
CLO3: The theory of photoreaction.
CLO4: The photochemistry and photophysical chemistry of macromolecules.

Units/ hours	Content	Mapping with CLOs
Unit-1 10 Hours	**Basics of Photochemistry:** Electronic transitions, Jablonski diagram and photophysical processes, radiative transitions, absorption and emission, phosphorescence, intersystem crossing, mechanisms of singlet-triplet conversion (spin-orbit coupling), examples of ISC between states of different configurations, radiative rates, radiationless transitions, internal conversion, energy gap. *Brainstorming on identification of the various photophysical process where electronic transitions of inorganic molecules are relevant to achieve sustainable development.*	**CLO1,**
Unit-2 10 Hours	**Photochemical Mechanism:** Properties of excited states- structure, dipole moment, photochemical kinetics- calculation of rates of radiative process; bimolecular deactivation- quenching; excited states of metal complexes comparison with organic compounds, electronically excited states of metal complexes, charge transfer excitation. *Demonstration of the inorganic photochemical reactions and discussion on their potential use as a replacement for artificial photosynthesis.*	**CLO2**
Unit-3 10Hours	**Ligand Field Photochemistry:** Photosubstitution, photo-oxidation and photoreduction, ground state and excited state, energy content of the excited state, development of redox potentials of the excited states; redox reactions by excited metal complexes- energy transfer (FRET and SET), exciplex formation. *Discussion on recent variants of well-established photochemical process.*	**CLO3**
Unit-4 15 Hours	**Applications of Photochemistry:** Measurement of fluorescence and phosphorescence and lifetimes, introduction to time-resolved techniques for absorption and emission measurements, detection and kinetics of reactive intermediates, photochromic reactions and memory devices, sensors, switches and molecular machines, TiO_2 photo-catalysis, flash photolysis. *Application and challenges for the harvesting of energy via value added chemicals.*	**CLO4**

Mode of Transactions: Lecture, Demonstration, Lecture cum demonstration, Problem solving, Brainstorming, Tutorial.

Suggested Readings

1. Lakowicz, J. R., (2006). *Principles of Fluorescence Spectroscopy*, Springer.
2. Rohatgi-Mukherjee, K. K., (1986). *Fundamentals of Photochemistry*. New Age International.
3. Kryukov, A. I., and Yakuchmii, S., (1990). *Fundamentals of Photochemistry of Coordination Compounds*.
4. Kavarnos, G. J. (1993). *Fundamentals of Photoinduced Electron Transfer*. Vch Pub.
5. Valeur, B., and Berberan-Santos, M. N. (2012). *Molecular Fluorescence: Principles and Applications*. John Wiley and Sons.
6. Turro, N. J., Ramamurthy, V., and Scaiano, J. C. (2012). *Modern Molecular Photochemistry of Organic Molecules*. Wiley Publishers.
7. Ninomiya, I., and Naito, T. (2012). *Photochemical Synthesis*. Academic Press.

Course Title: Applied Polymer Chemistry

L	T	P	Cr
3	0	0	3

Paper Code: MCAC.518

Total Lectures: 45

Learning Outcomes: The student upon completion of the course would be able to

CLO1: Elucidate the different mechanisms of polymerization.

CLO2: Apply the various methods for determination of Number, weight and viscosity averaged molecular weights.

CLO3: Elucidate and demonstrate the processing of thermoplastic and thermosetting polymers.

CLO4: Apply the polymers for their use in biological and lifestyle applications.

Units/ hours	Content	Mapping with CLOs
UNIT I 13 Hours	**Polymers Synthesis and Characterization:** Classification of polymers. Types of polymerization processes: Bulk, solution, suspension and emulsion polymerization, their advantages and disadvantages. Addition, radical, ionic, coordination and condensation polymerisation; their mechanism and role of initiator, chain transfer agent, solvent and inhibitor. Effect of structure of monomer on free-radical polymerization. Polymerisation conditions and polymer reactions. Polymerisation in homogeneous and heterogeneous systems. Method for reaction rate determination using Rotating disk method and Pulsed Laser Photolysis – Size exclusion chromatography (PLP-SEC). *Learning use of various polymerization options by peer learning.*	**CLO1**
UNIT II 11 Hours	**Polymer:** Significance of molecular weight of polymer. Polydispersive average molecular weight. number, weight and viscosity average weights. Measurement of molecular weights. End group, viscosity, light scattering, osmotic and ultracentrifugation methods. Chemical and spectroscopic analysis of polymers. X-ray diffraction study. **Structure and properties:** Configuration of polymer chains. Crystal structure of polymers, morphology of crystalline polymers. Thermal analysis, tensile strength, fatigue, impact, tear resistance, hardness and abrasion resistance. *Understanding of molecular weight characteristics of polymer would be carried out through problem solving. The effect of the polymer molecular weight and crystallinity on mechanical properties would be understood though peer learning.*	**CLO2**

UNIT III **11 Hours**	**Polymer structure and physical properties:** crystalline melting point T_m, melting points of homogeneous series, effect of chain flexibility and other steric factors, entropy and heat of fusion. The glass transition temperature, T_g relationship between T_m and T_g, effects of molecular weight, diluents, chemical structure, chain topology, branching and cross linking. **Polymer Processing:** Plastics, elastomers and fibres. Compounding. Processing techniques, calendaring, die casting, rotational casting, film casting, injection moulding, blow moulding, extrusion moulding, thermoforming, foaming, reinforcing and fibre spinning. *Factors responsible for the polymer processing would be brainstormed for shaping polymers.*	**CLO3**
UNIT IV **10 Hours**	**Applications of Polymers:** Properties of polyethylene, polyvinyl chloride, polyamides, polyesters, phenolic resins, epoxy resins and silicone polymers. Functional polymers, fire retarding polymers and electrically conducting polymers. Biomedical polymers, contact lens, dental polymers, artificial heart, kidney, skin and blood cells. **Biopolymers:** The structure, function, and properties of synthetic (dextran, ficoll) and natural biopolymers (Cellulose, CMC, alginate, chitin, DNA, nucleic acids, nucleotides, proteins), conformation of nucleic acids (DNA, t-RNA, micro-RNA), molecular architecture for some biological structures such as collagen, tissue, silk, wool, and shell. Introduction to biomedical materials and drug delivery formulations. *Understanding the limitations to sustainable polymer use through peer learning. Brainstorming session on biomedical applications in drug delivery and blood.*	**CLO4**

Mode of Transactions: Lecture, Demonstration, Lecture cum demonstration, Problem solving, Brainstorming, Tutorial.

Suggested Readings

1. Billmeyer, Jr., F.W. (2007). *Textbook of Polymer Science*. Wiley.
2. Odian, G. (2004). *Principles of Polymerization*. John Wiley and Sons.
3. Cowie, J. M. G., and Arrighi, V. (2007). *Polymers: Chemistry and Physics of Modern Materials*. CRC press.
4. Takemoto, K. Inaki Y. and Ottanbrite R.M. (1997). *Functional Monomers and Polymers,* CRC Press.
5. Gowariker, V. R., Viswanathan, N. V., and Sreedhar, J. (1986). *Polymer Science*. New Age International.

6. Alcock H.R., Lambe, F.W., and Mark, J. E., (2003). *Contemporary Polymer Chemistry*, Prentice Hall.
7. Peacock, A., and Calhoun, A. (2012). *Polymer Chemistry-Properties and Applications*. Hanser Publishers, Munich.
8. Chandra, R., and Adab, A., (1994). *Rubber and Plastic Waste*. CBS Publishers and Distributors, New Delhi,
9. Bahadur, P., and Sastry, N. V., (2002). *Principles of Polymerisation*, Narosa Publishing House, New Delhi.
10. Thomas, E. (2007) https://ocw.mit.edu/courses/materials- science-and-engineering/3-063-polymer-physics-spring-2007
11. Langbeheim, E. (2020) Simulating the Effects of Excluded-Volume Interactions in Polymer Solutions *J. Chem. Educ.*97(6), 1613-1617 DOI: 10.1021/acs.jchemed.0c00003.

Course Title: Industrial Organic Chemistry
Paper Code: MCAC.519
Total Lectures: 45

L	T	P	Cr
3	0	0	3

Learning Outcomes: At the end of the course student will be able to

CLO1: Design a reaction scheme taking into consideration its green and economical aspects

CLO2: Identify various industrial manufacturing processes for value added chemicals.

CLO3: Realize the importance of green chemistry and to apply various tools of green chemistry in their future research.

Units/ hours	Content	Mapping with CLOs
Unit-1 12 Hours	**Green Chemistry**: Principles of green chemistry, atom economy, tools of green chemistry: green solvents (ionic liquids, supercritical fluids), abundant natural feedstocks/starting precursor, multicomponent reactions (MCRs), tandem/domino reactions, microwave assisted organic synthesis (MAOS), solid phase synthesis, aqueous media reactions, General introduction to Combinatorial Chemistry. *Recyclability of ionic liquids through demonstration.* *Industrial applications of green solvents: peer discussion in the classroom*	**CLO1**
Unit-2 11 Hours	**Applications of Green Chemistry:** Green synthesis of ibuprofen, design and use of CO_2-surfactants for precision cleaning in industries, environmentally preferable marine antifoulant, use of molting accelerators in place of toxic and harmful insecticides, oxidant activators to replace chlorine-based delignification process in paper and pulp industry, green chemistry process for polyester regeneration, Biocatalytic promiscuity of enzymes for C-C bond formation. Recent applications of ionic liquids as solvent and catalysts in the chemical industry. *Various green processes employed in chemical industries through group presentation.*	**CLO2**
Unit-3 11 Hours	**Industrial Organic Syntheses:** The raw material and basic processes, chemical processes used in industrial organic synthesis: production of methanol, ethanol, ethyl acetate, ammonia, sulphuric acid, acetaldehyde, acetic acid, ethylene glycol, glycerine, acetone, phenol, formaldehyde, 1,3-butadinene and styrene. *Peer discussion on industrial chemical manufacturing processes and current green alternative.*	**CLO2, CLO3**
Unit-4 11 Hours	**Detergent**: Introduction, Principal groups of synthetic detergents, Classification of surfactants; anionic, cationic, amphoteric and non-ionic detergents, alkyl/aryl/ amide sulphonates, binders and builders, fillers, eco-friendly detergents: detergents containing enzymes and zeolites. Oleochemicals as source for surfactants: Methyl ether sulfonate (MES). *Project work on the types of various detergents/surfactants present at home and their specific utility.*	**CLO2, CLO3**

Mode of Transactions: Lecture, Demonstration, Presentation, Group Discussion, Lecture cum demonstration, Problem solving, Brainstorming

Suggested Readings:

1. Anastas, P. T., and Warner, J. C. (2000). *Green chemistry: theory and practice*. Oxford university press.
2. Sauer, N. N. (2000). *Green Chemistry: Frontiers in Benign Chemical Syntheses and Processes* Ed. Anastas P. T. and Williamson T. C., (US Environmental Protection Agency). Oxford University Press: New York, NY.
3. Malhotra, S. V. (2007). *Ionic Liquids in Organic Synthesis*, Oxford University Press, US.
4. Weissermel, K., andArpe, H.J., (2010) *Industrial Organic Chemistry*. Wiley-VCH.
5. Sheldon, R.A., Arends, I., and Hannefed, U., (2007). *Green Chemistry and Catalysis*. Wiley-VCH Verlag GmbH and Co.
6. Ahluwalia, V.K and Kidwai, M. (2012) *New Trends in Green Chemistry*. Springer.
7. Scragg, A.H. (2009) *Biofuels: Production, Application and Development*, CAB International, UK.
8. Gupta, A.K., (2021) *Modern Technology of Soaps, Detergents and Toiletries* (With Formulae and Project Profiles) 2Nd Edition
9. Gaudino, E. C., Cravotto, G., Manzoli, M., & Tabasso, S. (2019). From waste biomass to chemicals and energy via microwave-assisted processes. *Green Chemistry*, *21*(6), 1202-1235.
10. Clauser, N. M., González, G., Mendieta, C. M., Kruyeniski, J., Area, M. C., &Vallejos, M. E. (2021). Biomass waste as sustainable raw material for energy and fuels. *Sustainability*, *13*(2), 794.
11. Plechkova, N. V., & Seddon, K. R. (2008). Applications of ionic liquids in the chemical industry. *Chemical Society Reviews*, *37*(1), 123-150.

Course Title: Industrial Inorganic Chemistry

Paper Code: MCAC.520

Total Lectures: 45

L	T	P	Cr
3	0	0	3

Learning Outcome: The students will be able to

CLO1: Elucidate the understanding of the semiconductors and electronics made from inorganic materials.

CLO2: Elucidate the manufacturing of various fertilizers, electroplating processes and glasses and ceramics.

Units/ hours	Content	Mapping with CLOs
Unit-1 10 Hours	**Special Materials for Electronic Industry** Recent trends in sensor technology, film sensors, Semiconductor IC technology, micro-electro mechanical systems (MEMS), nanosensors. Applications of Sensors: automobile sensors, home appliance sensor, aerospace sensors, sensors for manufacturing medical diagnostic sensors, sensors for environmental monitoring. High purity silicon, germanium, gallium arsenide (GaAs), indium phosphide (InP) etc. Preparation using zone refining, crystal growth and there use in electronic industry. High temperature materials, SiC, chromite, alumina, zirconia, magnesite etc. *Group Discussion on sensors applications in current scenario.*	**CLO1**
Unit-2 15 Hours	**Fertilizer Industries**. General principles of plant nutrition: essential plant nutrients, functions of the essential elements, classification of commercial nitrogenous fertilizers. Manufacturing of ammonium sulphate, urea, ammonium nitrate, commercial phosphatic fertilizers. Manufacturing process and properties of phosphatic fertilizers, single super phosphate, triple super phosphate. Commercial potassic fertilizers: chemicals of potassium compounds, classification, manufacturing process and properties of potassium fertilizer, potassium sulphate, mixed fertilizer. Micronutrients: role and deficiency symptom of micronutrients. Biofertilizers: classification, demands and production, present status of fertilizer industries in India. *Demonstration on industrial scale synthesis of various fertilizers and use of fertilizers and pesticides in agriculture.*	**CLO1**
Unit-3 10 Hours	**Metal Finish Technology.** Basics of electrodeposition, electroplating principles and practice, electrochemistry applied to electroplating, electroplating of metals chromium, cadmium, nickel, copper, silver, gold, purpose of metal electroplating composition and condition of plating bath, applications waste treatment and metal recovery. *Peer discussion on electroplating techniques of different transition metals and their applications in water treatment.*	**CLO2**

Unit-4 **10 Hours**	**Glass and Ceramics.** Physical and chemical properties of glasses, raw materials, manufacturing of special glasses. Ceramics and their properties, raw materials, manufacturing of ceramics, applications of colours to pottery, use of ceramics. Industrial gases: manufacturing and industrial uses of H_2, O_2, N_2, CO_2, $Cl_2$and acetylene gases. Liquefaction of gases, production of low temperature. Chemicals of utility: inorganic fine chemicals, magnesia, alumina, $AlCl_3$, calcium carbonate, sodium silicate, MnO_2, $FeSO_4$, PbO_2 and NaOH. *Brainstorming session on generation of differ gas techniques with safety features.*	**CLO2**

Mode of Transactions: Lecture, Demonstration, Lecture cum demonstration, Problem solving, Brainstorming, Tutorial

Suggested Readings

1. Keer, H. V. (1993). *Principles of the Solid State*. New Age International.
2. West, A. R. (2003). *Solid State Chemistry and its Applications*. John Wiley and Sons.
3. Sharma, B. K. (2014). *Engineering Chemistry*. Krishna Prakashan Media.
4. Lowenheim, F. A., (1978). *Electroplating,* MC Graw-Hill Book Company.
5. Gable, D., (1978). *Principal of Metal Treatment and Protection*. Pergaman Press Oxford
6. Burke, J. E., (1966). *Progess in Ceramic ScienceVol. IV*. Pergamon Press.
7. Ash, M. and Ash I., (2000). *Formulary of Paints and other Coating. Vol. I*, Chemical Publishing Press.
8. Sharma, B. K., (1997). *Industrial Chemistry*, Goel Publishing House.
9. Shukla S. D. and Pandey, G. N. (1979). *A Text Book of Chemical Technology*. Vikas Publishing House.
10. Henglein, F. A. (2013). *Chemical Technology*. Elsevier.
11. Patranabi, D. (2003). *Sensors and Tranducers*. PHI Learning Pvt. Ltd
12. Basak, R. K. (2009). *Fertilizers: A Textbook*, Kalyani Publishers.
13. Balasubramaniam, R. (2009). *Callister's Materials Science and Engineering: Indian Adaptation (W/Cd)*. John Wiley and Sons.

Course Title: Dyes and Pigments
Paper Code: MCAC.521
Total Contact Hour: 45
Learning Outcome: Upon successful completion of the course the student will be able to apply the knowledge of

CLO1: Synthetic and natural pigments in various fields.

CLO2: Synthetic and natural dyes in various fields.

CLO3: Analysis and physical properties of pigments and dyes

Units/ hours	Content	Mapping with CLOs
Unit-1 11 Hours	**Introduction of pigments:** Colour index, generic names of pigments, colour constitution number, polymorphism, properties required in a pigment and extender, dyes, pigment dyestuffs, and hue of the pigment (Bathochromic and hypsochromic shift), practices and requirement of pigments. Organic pigments - Antraquinone, Benzimidazolonedioxazines, Diazo lakes, Litholrubones, Monoazo lakes, Naphthol AS lakes, Naphthol AS, Perylenes, Phthalocyanines, Quinacridones effect pigments and biological pigments. *Different structures and properties of pigments through peer learning.* *Group project on synthesis of azo pigments.*	**CLO1**
Unit-2 11 Hours	**Classification and synthesis of dyes: Colour theory of dyes,** Various unit operations in the manufacture of intermediates and dyes, Introduction of various functional groups, synthesis of dyes, basics of azo dyes, diazotization and coupling reactions, azoic colours; vat dyes, reactive dyes, acid dyes, mono azo dye; diasazo, nitro, diphenylamine and anthraquinone dyes; acid mordant dyes, azo metal complex dyes, synthesis of different dyes. Nylon, Polyesters and Polyamides structures and names of dyes applied on each of them. *Class room debate on colour theory of dyes.* *Group presentation on synthesis of various dyes.*	**CLO2**

Unit-3 **12 Hours**	**Processing and synthesis of inorganic pigments and Raw materials for organic pigments:** Crushing and grinding, vaporization, co-precipitation, filtration, drying, flushing, calcinations/roasting, vapour phase oxidation etc. Pigments Extenders: Sources, manufacture, properties and uses of carbonates, sulphates and other extender pigments. White prime pigments: Methods of manufacturing, comparison of properties and composition of TiO2, ZnO, Zinc sulphide and lithopone, Surface treatment of TiO2 and other pigments, A brief study of coal tar distillation and the role of distillation products in the manufacture of synthetic dyes: bases and precipitants used in the colour striking. Processing of raw materials for manufacturing of dyes and pigments. *Peer discussion on inorganic and organic pigments for application in daily life application.*	**CLO1**
Unit-4 **11 Hours**	**Analysis of Dyes and Pigments**: Analysis of Dyes & Intermediates: Colour fastness, Light fastness, sublimation fastness, Paper Chromatography, Thin Layer Chromatography, Column Chromatography, Colour Matching Spectrophotometer, UV-visible Spectrophotometer. Analysis of Pigments: Crystal structure, particle size, shape and distribution, refractive index and hiding power, oil absorption, specific gravity, bulking value, reducing power, tinting strength, fastness properties such as resistance to light, heat, water, chemicals, bleeding etc. corrosion resistance, toxicity of pigments etc. *Group projects on role of dyes and pigments in paint industries.* *Peer learning on the importance of dyes in biological perspective.*	**CLO3**

Mode of Transactions: Lecture, Demonstration, Presentation, Group Discussion, Lecture cum demonstration, Problem solving, Brainstorming

Suggested Readings

1. Zollinger, H. (2003). *Colour Chemistry: Syntheses, Properties, and Applications of Organic Dyes and Pigments*. John Wiley and Sons.
2. Venkataraman, K. (Ed.). (2012). *The Chemistry of Synthetic Dyes* (Vol. 4). Elsevier.
3. Buxbaum, G. (Ed.). (2008). *Industrial Inorganic Pigments*. John Wiley and Sons.
4. Herbst, W., and Hunger, K. (2006). *Industrial Organic Pigments: Production, Properties, Applications*. John Wiley and Sons.
5. Januschewski, E., Bischof, G., Thanh, B. N., Bergmann, P., Jerz, G., Winterhalter, P., Heinz, V., Juadjur, A. Rapid UV/Vis Spectroscopic Dye Authentication Assay for the

Determination and Classification of Reactive Dyes, Monascus Pigments, and Natural Dyes in Coloring Foodstuff, *J. Agric. Food Chem.* 2020, 68, 42, 11839–11845.

6. Silva, G. T. M., Silva, K. M., Silva, C. P., Gonçalves, J. M., Quina, F.H. Hybrid Pigments from Anthocyanin Analogues and Synthetic Clay Minerals, *ACS Omega* 2020, 5, 41, 26592–26600.

Course Title: Advanced Instrumental Methods

L	T	P	Cr
3	0	0	3

Paper Code: MCAC.522

Total Lectures: 45

Learning Outcomes: The student will be able to

CLO1: Understand the current trends in the analysis prescribed by regulatory agencies

CLO2: Interpret and analyze the electrochemical and spectroscopic analysis set up requirement and information gathered.

CLO3: Justify use of a particular characterization technique of colloids, nanomaterial and analytes in solution.

CLO4: Analyze the quantitative data on proteomics and metabolomics using advanced mass spectroscopy.

Units/ hours	Content	Mapping with CLOs
Unit 1 11 Hours	Regulatory requirements of Food and Drug Administration (FDA) for food and drug analysis, Environmental Protection Agencies for air water and soil analysis and NABL. Uncertainty calculations and quality assurance. *Brainstorming and Peer learning activity on how to manage a quality assurance laboratory.*	**CLO1**
Unit 2 11 Hours	**Advanced Spectroscopic Analysis**.: UV-Vis-NIR and its applications, Confocal Raman Spectroscopy, Time Resolved Fluorescence and Fluorescence Correlation Spectroscopic Techniques and their application, *Brainstorming the application of fluorescence in quantitative information of biochemical processes.*	**CLO2**
Unit 3 11 Hours	**Amperometry/Coulometry:** Basic principles, constant current and constant potential coulometry. coulometric titrations. **Voltammetry:** Principles, voltammograms, equation of voltammogram, different waveforms–linear scan, square scan and triangular scan, cyclic voltammetry. Electron Microscopy including TEM, STEM, FESEM with dark field and bright field imaging. *Demonstration of electroanalytical techniques in quantitative analysis.* *Peer learning activity on TEM based structural analysis of nanomaterials and thin films, electrochemical methods of analysis*	**CLO3**
Unit 4 12 Hours	**Chromatographic Techniques:** HRMS and MS/MS techniques for analysis of Pesticide residue, Proteomic and Metabolomic analysis. Capillary Electrophoresis. **Advanced Mass Spectroscopy:** Ion cyclotron mass spectrometer, Ion Trap Mass Spectrometer, C-Trap and Orbitrap Mass spectrometry. *Team problem solving task on identification of protein using LC-HRMS data.*	**CLO4**

Mode of Transactions: Lecture, Demonstration, Lecture cum demonstration, Problem solving, Brainstorming, Tutorial

Suggested Readings:

1. Tao, W. A. and Zhang, Y., (2019) *Mass Spectrometry-Based Chemical Proteomics*, Wiley Publishing.
2. Issaq, H. J. (2020) *Proteomic and Metabolomic Approaches to Biomarker Discovery*, Elsevier Science Publishing.
3. Imai, K., Yau, S. L. F., (2013) *Quantitative Proteome Analysis: Methods and Applications*, Jenny Stanford Publishing.
4. Mirzaei, H., and Carrasco, M., (2016) *Modern Proteomics – Sample Preparation, Analysis and Practical Applications*, Springer Publishing.
5. Sauer, M., Hofkens, J., Enderlein, J. (2010) *Handbook of Fluorescence Spectroscopy and Imaging: From Ensemble to Single Molecules*, Wiley Publishing.
6. Jameson, D. M. (2014) *Introduction to Fluorescence*, CRC Press.
7. Paul M. W. French, P. M. W., and Elson, D. S. (2014) *Fluorescence Lifetime Spectroscopy and Imaging: Principles and Applications in Biomedical Diagnostics*, CRC Press.
8. Nikiforov, A. and Britun, N., (2018) *Photon Counting: Fundamentals and Applications*, Intech Open Publishing.
9. Skoog, D. A., West, D. M., Holler, F. J., and Crouch, S. (2019). *Fundamentals of Analytical Chemistry*. Nelson Education.
10. Rouessac, F., andRouessac, A. (2013). *Chemical Analysis: Modern Instrumentation Methods and Techniques*. John Wiley and Sons.
11. Gross, J. H. (2006). *Mass Spectrometry: A Textbook*. Springer Science and Business Media.
12. Pavia, D. L., Lampman, G. M., Kriz, G. S., and Vyvyan, J. A. (2008). *Introduction to Spectroscopy*. Cengage Learning.
13. Hollas, J. M. (2004). *Modern Spectroscopy*. John Wiley and Sons.
14. Lakowicz, J. R. (2006). *Principles of Fluorescence Spectroscopy*. Springer.

Course Title: Applied Material Chemistry
Paper Code: MCAC.523
Total Contact Hours: 45

L	T	P	Cr
3	0	0	3

Learning Outcome: The students will able to learn

CLO1: Inorganic, organic and mixed materials

CLO2: Characterization of these materials

CLO3: The relationship between material structure and physical attributes associated with them.

CLO4: Interpret and apply the conductivity of ionic and molecular conductors

CLO5: Interpret and analyse the use of materials for NLO, electronics, biomedical and energy applications

Units/ Hours	Content	Mapping with CLOs
Unit 1 11 Hours	**Magnetic Materials (Ferrites)** Introduction, structure and classification, hard and soft ferrites, synthesis of ferrites by various methods (precursor and combustion method), characterization of ferrites by Mossbauer spectroscopy, significance of hysteresis loop and saturation magnetization in ferrites, magnetic properties of ferrites, applications of ferrites. **Glasses, Ceramics, Composites and Nanomaterials:** Glassy state, glass formers and glass modifiers, applications. ceramic structures, mechanical properties, clay products. microscopiccomposites; dispersion-strengthened and particle-reinforced, fibre-reinforced composites, macroscopic composites, nanocrystalline phase, preparation procedures, special properties, applications. *Learning through spherical three dimensional models based demonstration and reconstruction of the models for ferrites.*	**CLO1, CLO2, CLO3**
Unit 2 11 Hours	Mesomorphic behaviour, thermotropic liquid crystals, positional order, bond orientational order, nematic and smecticmesophases; smectic - nematic transition and clearing temperature -homeotropic, planar and sCHMieren textures, twisted nematics, chiral nematics, molecular arrangement in smectic A and smectic C phases, optical properties of liquid crystals. dielectric susceptibility and dielectric constants. lyotropic phases and their description of ordering in liquid crystals. **Thin Films and Langmuir- Blodgett Films** Preparation techniques; evaporation/sputtering, chemical process, sol gel etc. Langmuir – Blodgett (LB) films, growth technique, photolithography, properties and applications of thin and LB films **Materials for Solid State Devices** Rectifiers, transistors, capacitors –IV-V compounds, low–dimensional quantum structure; optical properties. *Application of Langmuir-Blodgett Films and materials for solid state electronics through peer learning. Brainstorming the liquid crystals based electronics and its current applications.*	**CLO1, CLO2, CLO3**

Unit 3 **11 Hours**	Types of ionic conductors, Schottky and Frenkel Defects; Kronig-Vink Representation, thermodynamic characteristics, effect of doping on ionic conduction. Mechanism of ionic conduction, interstitial jumps (Frenkel) and vacancy mechanism with thermodynamic and geometric consideration. Superionic conductors including beta-alumina, NASCION, LISCION; phase transitions and mechanism of conduction in superionic conductors, applications of ionic conductors in fuel cell, batteries/cell, oxygen sensing. **Molecular Conductor:** TCNQ-TTF organic conductor, Peierls Theorem, Polyacetylene, Polyphenylene, Polyaniline, Oligo(phenylenevinylene)s, oligo(phenyleneethynylene)s, oligo(thiophenevinylene), oligo(thiophene), polypyrrole, etc. and their applications in sensing, batteries/cell, photovoltaic cell, actuators, biomedical application. *Understanding ionic/molecular conductors and their conduction mechanism through model construction.*	**CLO1, CLO2, CLO3, CLO4**
Unit 4 **12 Hours**	**Fullerenes, Carbon Nanotubes and Graphene:** Types and Properties, methods of preparation and separation of carbon nanotubes, applications of fullerenes, CNTs and graphene. **Nonlinear optical materials:** Non-linear optical effects, second and third order – molecular hyperpolarisability and second order electric susceptibility – materials for second and third harmonic generation. **Preparation and characterization of silica and zirconia based stationary phases: Preparation** by (a) dynamic chemical modification, in which chiral selector is adsorbed on the surface of the zirconia by physical forces, (b) permanent chemical modification, in which a CS is chemically bonded onto the zirconia surface, and (c) physical screening. Difference between zirconia and silica based stationary phases, and their application in separations by Liquid Chromatography. *Understanding the geometry of the carbon allotropes using models.*	**CLO1, CLO2, CLO3, CLO5**

Mode of Transactions: Lecture, Demonstration, Lecture cum demonstration, Problem solving, Brainstorming, Tutorial

Suggested Readings

1. West, A. R. (2014). *Solid State Chemistry and its Applications*. John Wiley & Sons.
2. Smart, L. E., and Moore, E. A. (2012). *Solid State Chemistry: An Introduction*. CRC press.

3. Callister Jr, W. D., and Rethwisch, D. G. (2012). *Fundamentals of Materials Science and Engineering: An Integrated Approach*. John Wiley and Sons.
4. Anderson, J. C., Leaver, K. D., Rawlings, R. D., andLeevers, P. S. (2004). *Materials Science for Engineers*. CRC Press.
5. Ashcroft, N. W., and Mermin, N. D. (1976*). Introduction to Solid State Physics*. Saunders.
6. Keer, H. V. (1993). *Principles of the Solid State*. New Age International.
7. Dresselhaus, M. S., Dresselhaus, G., and Eklund, P. C. (1996). *Science of Fullerenes and Carbon Nanotubes: Their Properties and Applications.* Elsevier.
8. Rao, C. N. R., and Gopalakrishnan, J. (1997). *New Directions in Solid State Chemistry*. Cambridge University Press.
9. del Alamo, J. (2007) https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-720j-integrated-microelectronic-devices-spring-2007/
10. Kimerling, L.C., Saini, S. (2006) https://ocw.mit.edu/courses/materials-science-and-engineering/3-46-photonic-materials-and-devices-spring-2006/index.htm.

Course Title: Food Chemistry

Paper Code: MFST.506

	L	T	P	Cr
	3	0	0	3

Total Hours - 45

Course Learning Outcome (CLO):

The completion of this course will enable learners to:

CLO1: Explain physicochemical properties of major and minor components of foods.

CLO2: Apply correct methods for estimating the moisture content of different foods.

CLO3: Critically analyse chemical and nutritional properties of carbohydrates, proteins and lipids.

CLO4: Critically evaluate the effect of processing on the properties of macro components of foods.

CLO5: Give recommendations on sources, functions, stability and requirements of vitamins and minerals.

Units/ hours	Content	Mapping with CLOs
UNIT I 11 hours	**Water:** Function; Types; Methods for measurement of total and available water in foods. **Carbohydrates:** Classification; Occurrence; Properties and application of important polysaccharides such as starch, cellulose, guar gum, xanthan gum, pectin, etc.; Cellulose and derivatives (MCC, CMC, MC and HPMC); Starch digestibility and Glycaemic Index **Learning Activities:** *Group discussions on role of water in food preservation*	**CLO1, CLO2**
UNIT II 11 hours	**Proteins:** Classification; Physicochemical properties of proteins; Protein structure; Forces involved in stability of protein structure; Denaturation; Functional properties; Methods of protein analysis; Sources and functions of food proteins; Protein quality and its evaluation **Learning Activities:** *Seminars on nutritive and functional properties of food proteins*	**CLO3**
UNIT III 11 hours	**Lipids:** Classification; Functions of lipids (fat/oils) in foods; Flavour defects in lipids; Role of fats in human nutrition; Health problems associated with fats; Trans fats; Recommendations for fat intake; Non-food applications of oils and fats **Learning Activities:** *Student seminars on rancidity and reversion of oils/fats*	**CLO3, CLO4**
UNIT IV 12 hours	**Vitamins and minerals**: Sources, requirements, functions stability and toxicity of vitamins; General functions of minerals; Specific functions and requirements of Ca, P, Mg, Fe, Cu, Zn, Se, etc. **Colour of foods**: Chlorophylls, curcumin, betalains, carotenoids, anthocyanins, etc.; Enzymatic and Non-enzymatic browning in foods. **Learning Activities:** *Group discussions on importance of vitamins, minerals and natural food colourants.*	**CLO4, CLO5**

Transactional Modes:
Mode of transaction shall be Lecture, presentation, Dialogue, google forms/docs, Lecture-cum-demonstration, Seminar, discussion, e-content, etc.

Tools used:
PPT, YouTube Video, Google meet, NPTEL

Suggested readings

1. FA Aladedunye and R Przybylski, Degradation and nutritional quality changes of oil during frying. *Journal of the American Oil Chemists' Society,* 86, 149-156 (2009).
2. FSSAI, Manuals published by Food Safety and Standard Authority, GOI (2016).
3. HE Khoo, A Azlan, ST Tang and SM Lim, Anthocyanidins and anthocyanins: colored pigments as food, pharmaceutical ingredients, and the potential health benefits. *Food and Nutrition Research*, 2017, 61, 1361779.
4. HK Chopra and PS Penesar, *Food Chemistry*. Narosa Publication (2010).
5. J Cmolíka and J Pokorny, Physical refining of edible oils. *European Journal of Lipid Science and Technology*,102, 472-486 (2000).
6. J Hettiarachchy, *Food Proteins and Peptides*. CRC Press (2012).
7. J Velisek, *The Chemistry of Food*. Wiley Blackwell (2014).
8. K Owusu, *Introduction to Food Chemistry*. CRC Press (2015).
9. MM Chakraborty, *Chemistry and Technology of Oils and Fats*. Prentice Hall (2003).
10. P Cheung, *Handbook of Food Chemistry*. Springer Science (2015).
11. S Bemiller, *Carbohydrate Chemistry for Food Scientists*, Woodhead Publications (2019).
12. S Damodaran and KL Parkin, *Fennema's Food Chemistry*. CRC Press (2017).
13. S Kumari, *Basics of Food Biochemistry and Microbiology*. Koros Press (2012).
14. SCM Teresa, *Starches for Food Application: Chemical Technological and Health Properties*, Academic Press (2019).
15. TAM Msagati, *Chemistry of Food Additives and Preservatives*. John Wiley and Sons (2013).
16. Z Ustunol, *Applied Food Protein Chemistry*. John Wiley and Sons (2015).

Course Title: Pharmaceutical Process Chemistry
Paper Code: MPC.204T
Course Hours: 60h

L	T	P	Credits
4	0	0	4

Learning outcome:
After completing this course, the learner will be able to:

CLO1: The strategies of scale up process of APIs and intermediate
CLO2: The various unit operations and various reactions in process chemistry
CLO3: Study the MSDS of hazardous chemicals

Units/Hours	Course Content	Content Mapping with course learning outcome
Unit 1 **12 Hours**	**Process chemistry** Introduction, Synthetic strategy, Stages of scale up process: Bench, pilot and large-scale process. In process control and validation of large-scale process. Case studies of some scale up process of APIs. Impurities in API, types and their sources including	**CLO1**

	genotoxic impurities Learning activities: Learner will be provided training involving case studies on scale up of APIs.	
Unit 2 **12 Hours**	**Unit operations** **Extraction:** Liquid equilibria, extraction with reflux, extraction with agitation, counter current extraction. **Filtration:** Theory of filtration, pressure and vacuum filtration, centrifugal filtration, **Distillation:** azeotropic and steam distillation **Evaporation:** Types of evaporators, factors affecting evaporation. **Crystallization:** Crystallization from aqueous, non-aqueous solutions factors affecting crystallization, nucleation. Principle and general methods of Preparation of polymorphs, hydrates, solvates and amorphous APIs. Learning activities: Learner will be engaged in group discussion to understand Extraction, filtration, distillation, evaporation and crystallization processes	**CLO2**
Unit 3 **12 Hours**	**Unit process- II** **Reduction** Catalytic hydrogenation, Heterogeneous and homogeneous catalyst; Hydrogen transfer reactions, Metal hydrides Case study on industrial reduction process **Fermentation** Aerobic and anaerobic fermentation, Production of Antibiotics (Penicillin and Streptomycin), Vitamins (B2 and B12), Statins (Lovastatin, Simvastatin) **Reaction Progress Kinetic Analysis** Streamlining reaction steps, route selection Characteristics of expedient routes, characteristics of cost-effective routes, reagent selection, families of reagents useful for scale-up Learning activities: Learner will be engaged in group discussion to understand unit processes for reduction, fermentation and reaction progress kinetic analysis	**CLO2**
Unit 4 **12 Hours**	**Unit Processes - III** **Reduction:** Catalytic hydrogenation, Heterogeneous and homogeneous catalyst; Hydrogen transfer reactions, Metal hydrides. Case study on industrial reduction process. **Reaction progress kinetic analysis** Streamlining reaction steps, route selection, Characteristics of expedient routes, characteristics of	**CLO2**

	cost-effective routes, reagent selection, families of reagents useful for scale-up. Learning activities: Learner will be engaged in group discussion to understand unit processes for reduction, fermentation and reaction progress kinetic analysis	
Unit 5 **12 Hours**	**Industrial Safety** MSDS (Material Safety Data Sheet), hazard labels of chemicals and Personal Protection Equipment (PPE) Fire hazards, types of fire & fire extinguishers Occupational Health & Safety Assessment Series 1800 (OHSAS-1800) and ISO-14001(Environmental Management System), Effluents and its management Learning activities: Learner will be provided Awareness about industrial safety protocols	**CLO3**

REFERENCES:

1. Process Chemistry in the Pharmaceutical Industry: Challenges in an Ever- Changing
2. Climate-An Overview; K. Gadamasetti, CRC Press.
3. Pharmaceutical Manufacturing Encyclopedia, 3rd edition, Volume 2.
4. Medicinal Chemistry by Burger, 6th edition, Volume 1-8.
5. W.L. McCabe, J.C Smith, Peter Harriott. Unit operations of chemical engineering, 7th edition, McGraw Hill
6. Polymorphism in Pharmaceutical Solids. Dekker Series Volume 95 Ed: H G Brittain (1999)
7. Regina M. Murphy: Introduction to Chemical Processes: Principles, Analysis, Synthesis
8. Peter J. Harrington: Pharmaceutical Process Chemistry for Synthesis: Rethinking the Routes to Scale-Up
9. P.H.Groggins: Unit processes in organic synthesis (MGH)
10. F.A.Henglein: Chemical Technology (Pergamon)
11. M.Gopal: Dryden's Outlines of Chemical Technology, WEP East-West Press
12. Clausen,Mattson: Principle of Industrial Chemistry, Wiley Publishing Co.,
13. Lowenheim & M.K. Moran: Industrial Chemicals
14. S.D. Shukla & G.N. Pandey: A text book of Chemical Technology Vol. II, Vikas Publishing House
15. J.K. Stille: Industrial Organic Chemistry (PH)
16. Shreve: Chemical Process, Mc Grawhill.
17. B.K.Sharma: Industrial Chemistry, Goel Publishing House
18. ICH Guidelines
19. United States Food and Drug Administration official website www.fda.gov

Course Title: Bioanalytical Techniques

L	T	P	Cr
3	0	0	3

Paper Code: MBCH.509

Total Hours - 45

Learning outcomes: Students will be able to

CLO1: Demonstrate the utility of bioanalytical techniques.

CLO2: Apply the knowledge gained in this course to understand advanced concepts of biochemistry.

CLO3: Apply and effectively communicate scientific reasoning and data analysis in both written and oral forums related to bioanalytical techniques.

Units/ hours	Content	Mapping with CLOs
Unit I 12 Hours	**Spectrophotometry, Centrifugation and Biophysical Techniques**: Beer-Lambert's law, extinction coefficient and its importance, design of colorimeter, spectrometer and spectrophotometer. Visible and UV Spectroscopy and its applications; Sedimentation velocity and RCF, differential and density gradient centrifugation, subcellular fractionation, analytical and preparative ultracentrifugation techniques. Optical rotatory dispersion (ORD), Circular Dichroism (CD), X-ray diffraction, X-ray absorption, Nuclear magnetic resonance spectroscopy. Seminars on application of the techniques in bioscience research.	**CLO1**
Unit II 10 Hours	**Gel Electrophoresis:** Agarose gel electrophoresis for DNA and RNA analysis; Rocket electrophoresis; Polyacrylamide gel electrophoresis for DNA and protein analysis; IEF and SDS-PAGE. **Chromatography:** Principles and applications of different types of chromatography. Thin layer, ion-exchange, hydrophobic-interaction, size-exclusion, Adsorption, Partition, Ion-Exchange, Chromatofocusing, Reverse Phase, and affinity chromatography. Molecular weight determination of macromolecules (in particular proteins) by size exclusion chromatography. High performance liquid chromatography. *Group discussion on the importance of gel electrophoresis and chromatography in biochemistry lab.*	**CLO1, CLO2**
Unit III 12 Hours	**Microscopy:** Principles and applications of Light, Phase-contrast and Electron- Microscopy, Scanning electron microscope, Transmission electron microscope and Immune electron microscopy. **Radioisotopic Tracer Techniques**: Detection and measurement of isotopes, Geiger–Müller, Scintillation Counter, Autoradiography, Fluorography, Applications in biology. Student seminars on application of the techniques in research and life.	**CLO1, CLO3**

Unit IV 11 Hours	**Immunological Techniques**: Measurement and Characterization of antigens and antibodies, Specificity and Cross reactivity, Precipitation and Agglutination reactions, Gel Diffusion, Immunoelectrophoresis, Ouchterlony, Radioimmunoassay, ELISA, Immunoblotting, Immunoprecipitation and co-immunoprecipitation, Application in Microscopy, Imaging-Immunohistochemistry and Flow cytometry. Peer group discussion on use of the immune-techniques in research and health care.	**CLO1, CLO3**

Suggested Readings:

1. Berg, J.M., Stryer, L., Tymoczko, J., Gatto, G. (2019). *Biochemistry*. WH Freeman. 9th ed.
2. Nelson DL, Cox MM and A. Hoskins (2021). *Lehninger's Principles of Biochemistry*, 8th ed. WH Freeman.
3. Wilson, K., Walker, J. (2018). *Principles and Techniques of Biochemistry and Molecular Biology*. 8th Edition, Andreas Hofmann and Samuel Clokie,Cambridge University Press.
4. Campbell, I. D., (2012). *Biophysical Techniques*, Oxford University Press.
5. Shourie, A., Chapadgaonkar, S.S. (2015). *Bioanalytical Techniques*. TERI, New Delhi.

Web resources:

- https://www.youtube.com/watch?v=siXdckB1HzU
- https://www.youtube.com/watch?v=WP6JpnHZJlQ
- https://www.youtube.com/watch?v=pjG4FTdMsEY
- https://nptel.ac.in/courses/102/103/102103044/
- https://nptel.ac.in/courses/102/101/102101007/
- https://www.youtube.com/watch?v=yl3EZX5kKbM
- https://www.youtube.com/watch?v=yl3EZX5kKbM
- https://www.youtube.com/watch?v=eH7UkTB7m8U
- https://www.youtube.com/watch?v=vMzs4NyVvuc
- https://www.youtube.com/watch?v=ZN7euA1fS4Y

Modes of transaction

-Lecture cum Demonstration
-Problem solving approach
-Self Learning
-Inquiry training

-Team learning

Tools used
PPT, You tube Video, Google meet, NPTEL

Interdisciplinary Courses (IDCs)

Course Title: Basic Perspectives in Inorganic Chemistry
Paper Code: MCHM.506
Total Contact Hours: 30

L	T	P	Cr
2	0	0	2

Learning Outcome: The student will able to
CLO1: Become expertise of the coordination chemistry of d-group elements and coordination of ions within living organisms.
CLO2: Know the environmental chemistry and metal hydrides as hydrogen energy source.

Units/ hours	Content	Mapping with CLOs
Unit-1 7 Hours	Chemistry of d-block elements. coordination chemistry, models and stereochemistry, theories, spectra and bonding. *Group discussion and problem solve involving characteristics of transition metals and their compounds.*	**CLO1,**
Unit-2 7 Hours	Ions role in bioscience:ionophores, porphyrin and other tetrapyrrollic macromolecules, coenzymes, neurotransmitters, metal binding to DNA. *Brainstorming discussion about essential* inorganic elements *and their compounds* in living organisms	**CLO2**
Unit-3 8 Hours	**Metals in aqueous environment:** Introduction, environmental chemistry, environmental composition, chemical processes, complexes, metal speciation of calcium, copper and mercury, their behaviour in hydrosphere. *Discussion on behaviour of metals and complexes in surrounding environmental sphere*	**CLO2**
Unit-4 8 Hours	**Hydrogen Energy:** Introduction, synthesis and structures of metal hydrides, coordination modes of hydrogen atom, hydrogen storage, H_2 evolution under solar energy, thermal energy and acidifications. *Group discussion about current requirements and challenges of renewable energy resources.*	**CLO2**

Mode of Transactions: Lecture, Demonstration, Lecture cum demonstration, Problem solving, Brainstorming, Tutorial

Suggested Readings

1. Lippard, S.J. and Berg, J.M., (1994) *Principles of Bioinorganic Chemistry*. University Science Books.
2. Cotton, F. A., and Wilkinson, G. (1988). *Advanced Inorganic Chemistry* (Vol. 545). New York: Wiley.
3. Huheey, J. E., Keiter, E. A., Keiter, R. L., and Medhi, O. K. (2006). *Inorganic Chemistry: Principles of Structure and Reactivity*. Pearson Education India.
4. Greenwood, N. N., and Earnshaw, A. (2012). *Chemistry of the Elements*. Elsevier.
5. Van-Loon G.W. and Duffy S.J. (2011) *Environmental Chemistry: A Global Perspective*. Oxford University Press.
6. Rao C.S. (2006) *Environmental Pollution Control Engineering*. New Age International Publishers, New Delhi,
7. Peruzzini, M. and Poli, R. (2005) *Recent Advances in Hydride Chemistry*, Elsevier Science B.V., Amsterdam.

Course Title: Introduction to Green Chemistry and Sustainability

Paper Code: MCHM.507

L	T	P	Cr
2	0	0	2

Total Contact Hours: 30

Learning objective: Students will be able to

CLO1: Analyze the harmful impact of traditional chemical processes on environment and health.

CLO2: Realize the relevance of Green Chemistry in the context of environment issues.

CLO3: Apply various tools of Green Chemistry for designing various reactions.

CLO4: Realize the judicious utilization of abundantly available precursors instead of depleting petroleum based feedstocks.

Units/ hours	Content	Mapping with CLOs
Unit-1 7 Hours	**Introduction:** Adverse effect of some of the current chemical practices on health and environment, concept and need of green chemistry, basic principles of green chemistry with examples– atom economy, wastage minimization, selection of starting materials etc. limitations/obstacle in the pursuit of the goals of green chemistry, types of solvent. *Relevance of the various principles of Green chemistry in various areas for sustainable development through brainstorming.*	**CLO1, CLO2**
Unit-2 7 Hours	**Emerging non-conventional techniques:** Microwave heating as energy efficient source, mechanism of microwave heating, Examples of microwave assisted organic synthesis, sono-chemistry and green chemistry. Various *emerging energy efficient tools and their heating mechanism for conducting chemical reactions through collaborative approach.*	**CLO1, CLO2 CLO3**
Unit-3 8 Hours	**Green solvents:** Ionic liquids**:** properties and advantages**,** use of ionic liquids as solvent as well as catalyst, recyclability of ionic liquids. Solvent-free synthesis. *Recyclability of ionic liquids through demonstration and discussion on their potential use as a replacement for halogenated volatile organic. solvents.*	**CLO2, CLO3**
Unit-4 8 Hours	**Value addition of abundantly available precursors:** Need for the use of renewable precursors over petroleum based feedstocks, biomass conversion (carbohydrates, lignocellulose biomass) into value added molecules. *Progress and challenges for the conversion of biomass into value added chemicals through peer group learning.*	**CLO4**

Mode of Transactions: Lecture, Demonstration, Presentation, Group Discussion, Lecture cum demonstration, Problem solving, Brainstorming

Suggested Readings

1. Ahluwalia, V.K and Kidwai, M. (2012) *New Trends in Green Chemistry*. Springer.
2. Anastas, P.T. and Warner J. C. (2000) *Green chemistry: Theory and Practical*. Oxford University Press, US.
3. Malhotra, S. V. (2007) *Ionic Liquids in Organic Synthesis*. Oxford University Press, US.
4. Ahluwalia, V.K. (2011) *Green Chemistry: Greener Alternatives to Synthetic Organic Transformations*. Alpha Science International Limited.

5. Gaudino, E. C., Cravotto, G., Manzoli, M., & Tabasso, S. (2019). From waste biomass to chemicals and energy via microwave-assisted processes. *Green Chemistry*, *21*(6), 1202-1235.
6. Clauser, N. M., González, G., Mendieta, C. M., Kruyeniski, J., Area, M. C., & Vallejos, M. E. (2021). Biomass waste as sustainable raw material for energy and fuels. *Sustainability*, *13*(2), 794.

Course Title: Chemistry of Nanomaterials and Fabrication

L	T	P	Cr
2	0	0	2

Paper Code: MCHM.508
Total Contact Hours: 30
Learning Outcome:
CLO1: The students will acquire knowledge of Nanotechnology,
CLO2: Fabrication and characterization of nanomaterials,
CLO3: Properties and applications of nanomaterials.

Units/ hours	Content	Mapping with CLOs
Unit-1 7 Hours	**Background to Nanotechnology:** Scientific revolution- Atomic structures-molecular and atomic size-Bohr radius -emergence of nanotechnology-challenges in nanotechnology. Definition of a nano system - types of nanocrystals-one dimensional (1D)-two dimensional (2D)-three dimensional(3D) nanostructured materials - quantum dots - quantum wire- multifunctional nanostructures. *Relevance of the various aspects of Nano chemistry in various areas for sustainable development through brainstorming.*	**CLO1,**
Unit-2 7 Hours	**Fabrication and Characterization of Nanomaterials:** Top-down and bottom-up approaches: chemical routes for synthesis of nanomaterials: chemical precipitation and co-precipitation; metal nanocrystals by reduction, sol-gel synthesis; microemulsions or reverse micelles, myle formation; solvothermal synthesis; thermolysis routes, microwave heating synthesis; sonochemical synthesis; electrochemical synthesis. physical methods: -inert gas condensation, arc discharge, plasma arc technique, MW plasma, laser pyrolysis, molecular beam epitaxy, chemical vapour deposition method and electro deposition. diffraction analyses, imaging techniques, spectroscopic techniques. *Variousadvanced techniques for nanomaterials characterization and their formation mechanism through collaborative approach.*	**CLO2**
Unit-3 8 Hours	**Nanomaterials and properties:** Influence of nucleation rate on the size of the crystals- macroscopic to microscopic crystals and nanocrystals - large surface to volume ratio. Metals (Au, Ag) - metal oxides (TiO_2, CeO_2, ZnO etc.) - semiconductors (Si, Ge, CdS, ZnSe) - carbon nanotubes (CNT) - ceramics and composites - dilute magnetic semiconductor- biological system - DNA and RNA - lipids - size dependent properties - mechanical, physical and chemical properties. *Concept of Nano dimension materials fabrication.*	**CLO3**

Unit-4 **8 Hours**	**Applications of Nanomaterials:** Photocatalysis- solar cell-water splitting-energy harvesting- LSPR- molecular electronics and nanoelectronics- quantum electronic devices - CNT based transistor and field emission display -biological applications - biochemical sensor-MRI agent - nanomedicine: molecular manufacturing - MEMS - NEMS - Bio-MEMS - protein nanoarrays - nano fluidics and micro fluidics -self-assembly of nanoparticles for biomedical applications-bacterial structures- cubosomes-dendrimers-DNA nanoparticle conjugates- bioactive nanomaterials-Au nanoparticles and CdSe quantum dots - molecular motors -nanoparticle and protein interactions. *Concept of Nano dimension materials for modern applications.*	**CLO3**

Mode of Transactions: Lecture, Demonstration, Presentation, Group Discussion, Lecture cum demonstration, Problem solving, Brainstorming.

Suggested Readings

1. Rao, C. N. R., Müller, A. and Cheetham, A. K. (Eds.) (2004). *The Chemistry of Nanomaterials: Synthesis, Properties and Applications*. Willy-VCH.
2. Poole, Jr., C. P. and Owens F. J. (2006). *Introduction to Nanotechnology*, Wiley-VCH
3. Mukhopadhyay, S. M., (2012) *Nanoscale Multifunctional Materials: Science and Applications*. Willy-VCH
4. Kelsall, R. W., Hamley,I. W. and Geoghegan, M. (2005). *Nanoscale Science and Technology*. 2005, John Wiley and Sons.

Course Title: General Laboratory Practices

Paper Code: MCHM.509

Total Contact Hours: 30

L	T	P	Cr
2	0	0	2

Learning Outcome: The students will acquire knowledge of

CLO1: Good laboratory practices

CLO2: Quality control and Quality assurance

CLO3: Chemical, biological and radiation hazards in laboratory and safety.

CLO4: General know how of analytical sample preparation.

Units/ hours	Content	Mapping with CLOs
Unit 1 7 Hours	**Good Laboratory Practices:** Introduction and WHO guidelines on GLP and GMP. History of GLP. Quality assurance in GLP. Quality control laboratory, responsibilities, routine controls, instruments reagents, sampling plans. *Regulatory requirement through gaming a laboratory for GLP through dramatization.*	**CLO1**
Unit 2 8 Hours	**Quality Standards and Quality Assurances:** Advantages and disadvantages of quality standards, concepts of quality control, quality assurance its functions and advantages. Standard test procedures, protocols, non-clinical testing, controls on animal house, data generation and storage, quality control documentation, retention samples, records. Complaints and recalls, evaluation of complaints, recall procedures, related records and documents. *Understanding the quality deliverability of disciplinary laboratory through team brainstorming.*	**CLO2**
Unit 3 8 Hours	**Safety and Hazard Analysis:** Chemical classification of hazards, Radiation hazard, AERB regulation for Fire and its prevention, biosafety and biohazard. Weapons of Mass destruction *Understanding National and international regulatory requirements of chemical and bio- hazards through hands-on inspection of laboratory.*	**CLO3**
Unit 4 7 Hours	**Basic Analytical practices:** Titrimetry, Gravimetric analysis, Potentiometry and Spectrophotometric analysis. Pesticides and pesticide residue extraction, Solid phase extraction etc. Trace metal sample preparations and analysis. Proteomic and metabolomic sample preparations *Understanding the selection of analytical procedures for analysis and sample preparation methods using peer learning.*	**CLO4**

Mode of Transactions: Lecture, Demonstration, Lecture cum demonstration, Problem solving, Brainstorming, Tutorial.

Suggested Readings

1. Miller, J. C. and Miller, J. N. (1998) *Statistics for Analytical Chemistry*. Wiley.
2. Skoog D. A., Holler, F. J., Crouch, S. R. (2018) Principles of Instrumental analysis Cengage Learning
3. Holler, F. J., Crouch, S. R., West, D. M., and Skoog D. A., (2014*) Fundamental of Analytical Chemistry*, 9th ed. Cengage Learning.

4. http://www.who.int/water_sanitation_health/resourcesquality/wqmchap9.pdf
5. https://www.unece.org/fileadmin/DAM/env/water/publications/documents/guidancelaboratories.pdf.
6. https://www.ugc.ac.in/oldpdf/xiplanpdf/disposalofradioactiv.pdf
7. https://www.mea.gov.in/Uploads/PublicationDocs/148_The-Weapons-Mass-destruction-And-Delivery-Systems-Act-2005.pdf
8. Westgard, J. O., Barry, P. L. (2016) *Basic QC Practices: Training in Statistical Quality Control for Medical Laboratories*, 4th ed., Westgard Quality Corporation.
9. Kenkel, J. (2014) *Analytical Chemistry for Technicians*, 4th ed., *CRC Press.*
10. Konieczka, P., Namiesnik, J., (2018) *Quality Assurance and Quality Control in the Analytical Chemical Laboratory: A Practical Approach*, 2nd ed. CRC Press.
11. WHO (2011) *Laboratory Quality Management System Handbook*.
12. Zaman, G., (2018) *Quality Control in Laboratory*, Intech Open Publlishing.
13. Hasnain, M.S., Beg, S., (2019) *Pharmaceutical Quality by Design: Principles and Applications*, Elsevier Science.

Course Title: Chemistry of Drug Design and Synthesis

L	T	P	Cr
2	0	0	2

Paper Code: MCHM.510
Total Lectures: 30
Learning Outcome: At the end of this course student will be able to
CLO1: Rationalize the basis of drug design, drug action and drug metabolism.
CLO2: Apply the knowledge to design and synthesize different drug molecules.
CLO3: Interpret the mechanism of action of different classes of drugs.

Units/ hours	Content	Mapping with CLOs
Unit-1 8 Hours	**Basics of Drug Action:** Weak interactions in drug molecules, Covalent, ion, ion-dipole, hydrogen bonding and van der Waals interactions, Drug-receptor interactions, receptor theories and drug action, Occupancy theory, rate theory, induced fit theory, macromolecular perturbation theory, activation-aggregation theory, enzyme kinetics in drug action, mechanisms of enzyme catalysis. *Apply the knowledge of drug-receptor interactions in drug design through peer learning*	**CLO1**
Unit-2 7 Hours	**Drug Design:** Introduction, Structure Activity Relationships in drug design: Qualitative versus quantitative approaches, advantages and disadvantages; rational approaches to lead discovery, bioisosterism, Insights into molecular recognition phenomenon; Structure based drug design, ligand based drug design. *Class discussion of molecular modelling in structure based and ligand based drug design approach*	**CLO2**
Unit-3 7 Hours	**Drug Metabolism:** Biotransformation of drugs, enzymes responsible for bio-transformations, microsomal and non-microsomal mechanisms; Factors influencing enzyme induction and inhibition, Factors effecting drug metabolism; Models to study drug metabolism, Adverse drug reactions; toxic reactions, allergic reactions. *Usefulness of different models to study drug metabolism through peer discussion*	**CLO2**
Unit-4 8 Hours	**Mechanism of action and synthesis of various drugs:** Introduction to parasitic and infectious diseases, Mechanism of action of anti-tuberculosis drugs, anti-HIV drugs, anti-malarial drugs, anti-leishmanial drugs and anti-cancer drugs. Mechanism of drug resistance in infectious disease. Synthesis of anti-tuberculosis, anti-HIV, anti-malarial, anti-leishmanial and anti-cancer drugs. *Recent advances on anticancer and antibiotic drug synthesis through brainstorming.*	**CLO3**

Suggested Readings

1. Patrick, G.L. (2009). *An Introduction to Medicinal Chemistry*. 4th Edition, Oxford University Press.
2. Coulson, C.J. (1994). *Molecular Mechanisms of Drug Action,* 2nd Edition, Taylor & Francis, London.

3. Silverman, R.B., Holladay, M.W. (2014). *The Organic Chemistry of Drug Design and Drug Action*, 3rd Edition, Academic Press.
4. Leach, A.R. (2001). Molecular Modelling*: Principles and Applications,* Prentice Hall.
5. Cohen, C. (1996). *Molecular Modelling in Drug Design*, Academic Press.
6. Gibson, G.G., Skett, P. (2013). *Introduction to Drug Metabolism*, 2nd edition, Springer, US.
7. Bancet, A., Raingeval, A., Lomberget, T., Borgne, M-L., Guichou, J-F., Krimm, I. Fragment Linking Strategies for Structure-Based Drug Design, *J. Med. Chem.* 2020, 63, 20, 11420–11435.
8. Flick, A. C., Leverett, C. A., Ding, H. X., McInturff, E., Fink, S. J., Mahapatra, S., Carney, D. W., Lindsey, E. A., DeForest, J. C., France, S. P., Berritt, S., Bigi-Botterill, S. V., Gibson, T. S., Liu, Y., O'Donnell, C. J. Synthetic Approaches to the New Drugs Approved during 2019, *J. Med. Chem.* 2021, 64, 7, 3604–3657.

Course Title: Project Report
Paper Code: MCAC.524
Total Contact Hours: 120
Learning Outcome: The student would be able to
CLO1: Understand the lacunas in the methodology to experimentation.
CLO2: Independently plan and execute experiments in the laboratory set-up
CLO3: Analyze and interpret the results obtained through different experiments.
CLO4: Apply expertise and specific skills in the frontier area of research.

As per the defined objectives in the research proposal, the student would carry out his experimentation to achieve these goals. The student would get experiments evaluated by the supervisor regularly, wherein the progress of the student would be evaluated. Upon achieving the objectives of the synopsis, the project report will be prepared as per the university guidelines for PG diploma in Chemistry in consultation with the supervisor. Project would be verified for plagiarism and submitted for evaluation by committee.

Course Title: Chemical Laboratory Techniques
Paper Code: MCHM.530
Total Contact Hours: 120

L	T	P	Cr
4	0	0	4

Learning Outcome: At the end of this course student will be able to
CLO1: Train the learners in the operation and maintenance of chemicals & commom apparatus used in laboratories. Familiarize them to develop skills in common laboratory techniques; train them in the procedures of procurement and storage of laboratory equipment, apparatus, glass wares and chemicals; enable them to follow appropriate disposal procedures and safety measures required for chemistry laboratories.

CLO2: Enable them to follow appropriate disposal procedures and safety measures required for chemistry laboratories. It will produce well trained Staff /Technicians to work in chemistry labs, especially Pharma industries or other small scale industries.

CLO3: To provide knowledge to perform the basic and research experiments. To impart knowledge of all safety measures in the chemistry laboratory, proper disposal of chemicals, chemical wastes and other waste materials; awareness about the handling of corrosive chemicals, lab accidents, fire extinguishers and other safety means; Knowledge of computer for proper organization and management of chemistry laboratories, minor electronic equipment, maintain lab record, inventory etc.

Units/ hours	Content	Mapping with CLOs
Unit-1 15 Hours	**Introduction of Chemistry Lab:** General introduction of chemistry laboratory, common instruction for safe working in chemical laboratories, Lab design, Storage, ventilation, lighting, fume, cupboard, arrangement of store, Safety provisions, Organization of practical work, Maintenance of laboratory, equipment/ apparatus Cleaning of laboratories and preparation room. **Introduction of Lab Apparatus:** *Glass apparatus* - Beaker, Test tube, boiling tube, funnel, separating funnel, filtration flask, round bottom flask, flat bottom flask, condenser Liebig flask, watch glass etc. measuring conical or condenser, petridish, desiccator. *Volumetric Apparatus* - Measuring cylinder, burette, pipette, Volumetric flask, analytical balance, single-pan electronic balance/ electrical analytical balance etc. *Miscellaneous apparatus*- Buchner funnel, Bunsen burner, burette stand, retort clamp, china dish/evaporating basin, wire gauze, cork borers, filter pumps, crucible, mohr clip, pipe clay triangle, pestle and mortar, sprit lamp, spatulas, thermometer, pH meter/pH paper etc**.** *and* laboratory centrifuge**.** *Apparatus for heating*: Bunsen burner, water bath, oil bath hot plate, sand bath, hot air oven, heating mantle etc**.** *Handling and storage of glass apparatus* **Solution Preparation:** Water as a solvent, types of water, solutions, components of a solution, types of solution, solubility, concentration of solutions: percentage, molarity, normality, molality (in ppm) calculation of masses and volumes for preparation of solutions solids, liquids. *Group discussion on use of chemicals and problem solving of solution of different normality/concentrations.*	**CLO1, CLO2**
Unit-2 15 Hours	1. Handling of common laboratory equipment 2. Cork boring experiment 3. Calibration of volumetric glassware 4. Weighing of chemicals using analytical balance 5. Preparation of solutions, indicators and reagents. 6. Preparation of buffer solutions and determination of their pH Values. 7. Preparation of some organic compound and determination of their boiling point and melting point. *Hand on experience of common laboratory and research equipment.*	**CLO1, CLO2**

Unit-3 **15 Hours**	**Common Laboratory Techniques:** *Refluxing:* Apparatus with interchangeable ground glass joints (Quick fit), *Filtration*: Techniques and filter media, filter paper, simple filtration, *Recrystallization*: Choice of solvent and precautions with flammable solvents, *Distillation*: recovery of solvents through partial distillation, distillation under reduced pressure, and *Determination of Boiling Point* **Chemistry Laboratory Safety:** *Fire Hazards:* Causes of fires, classification of fires, fire prevention protocols and measures, fire alarms, fire escapes, fire Extinguishers and their uses. *Chemical Hazards*: Classification and handling of hazardous chemicals, storage of chemicals, transfer from large containers *Gas Hazards:* usage of LPG and CNG safer in the laboratory, detection and handling of Gas Leakage, health hazards of gases **Use of Computer in Laboratory:** Hardware in computer, CPU, I/O devices, data input, data processing, data output, application MS office software and Internet. **Stock and Inventory Control:** Arranging stock, locating and referencing, shelf arrangement of stock, order books, inventory. **Files and Records** *Filing Systems*- Classification of files, filing methods, filing system for equipments and chemicals, filing of printed and written material, preparation of lab manuals. *Records system* : Stock records, recording stock (used and misused), record of use of listed poisons, record of use of alcohol, record of breakages, information about equipment serial numbers, record maintenance, miscellaneous records. *Activity 1:* Cleaning of laboratories and preparation room. *Activity 2*: Classification of apparatus in store. *Activity 3*: Cleaning of glassware. *Activity 4:* Organization of practical work. *Activity 5:* A brief report on Safety provisions in laboratories. *Peer discussion on Laboratory Techniques and significance of records of experimental data*	**CLO1, CLO2**

Unit-4 **15 Hours**	1. Purification of aniline by distillation method 2. Crystallization of various compounds and their TLC study 3. Column chromatographic method for separation of compounds 4. Simple acid-base titration. 5. Preparation of distilled/deionized water. 6. Preparation of inorganic double salts. 7. Experiments based on chromatography Activity 1: Classification of chemicals in laboratory/store. Activity 2: Classification hazardous chemicals based on the information given on the labels. Activity 3: Preparation of comparative chart. Activity 4: To learn the use of a carbon dioxide fire extinguisher. Activity 5: Preparation of stock register on MS-Excel. *Brainstorming discussion on various lab practicals..*	**CLO2** **CLO3**

Suggested Readings

1. Harwood, L.M. and Moody, C.J. (1989) *Experimental Organic Chemistry*. Blackwell Scientific Publishers.
2. Vogel, A.I. (2003), 5th ed. *Textbook of Practical Organic Chemistry*. ELBS, Longman Group Ltd.
3. Mann, F.G. and Saunders, B.C. (2009) *Practical Organic Chemistry*. Orient Longman Pvt. Ltd.
4. Leonard, J. and Lygo, B. (1995) *Advanced Practical Organic Chemistry*. Chapman and Hall.
5. Armarego, W.L. and Chai, C. (2012) *Purification of Laboratory Chemicals*. Butterworth-Heinemann.
6. Young, J.A. (1991) *Improving Safety in the Chemical Laboratory: A Practical Guide.* Wiley Publishing.
7. Silver, J. *Let Us Teach Proper Thin Layer Chromatography Technique, J. Chem. Educ.* 2020, 97, 12, 4217–4219.
8. Tannya, R., Ibarra-Rivera**,** Delgado-Montemayor, c., Oviedo-Garza, F., Pérez-Meseguer, J., Rivas-Galindo, V. M., Waksman-Minsky, N., Pérez-López, A. (2020) *Setting Up an Educational Column Chromatography Experiment from Home*, *J. Chem. Educ.* 97, 9, 3055–3059.

Course Title: Intellectual Property Right
Paper Code: MCHM.531
Total Lecture: 60

L	T	P	Credits
4	-	-	4

Learning Outcome: After the completion of the course students will be able to

CLO1: Understand the importance of Intellectual Property Rights, its various types and scope for the protection of his/her novel creations.

CLO2: Critically analyse the inventiveness of his/her work over the prior art available.

CLO3: Think and develop ethical values regarding copyrights

CLO4: Familiar with various agencies and treaties regarding Intellectual Property Rights

Units/ hours	Content	Mapping with CLOs
Unit-1 14 Hours	**Introduction:** Intellectual property and need for its protection, Intellectual Property Rights (IPR), Types of intellectual property; Industrial property & copyrights and related rights. IPR in India and abroad, promotion and protection concepts Impact of IPR on development, health & agriculture, IPR in biotechnology: New plant varieties, protection need and laws.	**CLO1**
Unit-2 16 Hours	**Patents**: Characteristics of patent. Patentable and non-patentable inventions in India, patent applications and their types; specification and claims, granting of patent, Transfer Commercialization Related Aspects, Indian Patent Act 1970, and amendments, Opposition to the grant of patent applications and post grant oppositions processes. **Trademarks**: Types, purpose and function of trademark, registration and protection aspects. **Industrial Designs**: Registration and protection. **Geographical Indicators:** Geographical indicators and their protection, difference between geographical indication and trademark. **Trade Secrets**: Advantages and limitations.	**CLO1, CLO2**
Unit-3 15 Hours	**Copyrights:** Copyrightable works; ownership of copyright; Exploiting Fair Use concept in copyright especially in academics and research. Infringement of copyright: **Related Rights:** Difference between copyright and related rights, celebrity rights. **Academic integrity**: Plagiarism and UGC regulations 2018, Plagiarism detection softwares.	**CLO2, CLO3**

Unit-4 **15** **Hours**	**Organizations, agencies and Treaties:** Territoriality of IPR; International Conventions in IPR; Role of World Trade Organization (WTO) and World Intellectual Property Organization (WIPO), The patent corporation treaty (PCT), GATT (General Agreement on Tariff and Trade), TRIPs (Trade Related Intellectual Property Rights) agreement, TRIMS (Trade Related Investment Measures) and GATS (General Agreement on Trades in Services).	**CLO4**

Mode of Transaction: Lecture, Demonstration, Lecture cum demonstration, Dialogue Mode, Experimentation, Problem solving, Seminar.

Suggested Readings:

1. Simran R. Gurnani. Intellectual Property Rights, C. Jamnadas & Co. (2021).
2. V K Ahuja, "Law Relating to Intellectual Property Rights", Lexis Nexis (2017).
3. *Copyright Law*, Vaver, Dav, Toronto: Irwin Law, ISBN 1-55221-034-0, 2000.
4. *Intellectual Property*, Drahos, Peter, Adlershot et.al. Darmouth, ISBN 1840147407, 1999.
5. *Intellectual Property: Patents, Copyright trademarks and allied rights*, Cornish, William R, London: Sweet and Maxwell, 4th edition, ISBN: 0421635401,1999.
6. *Intellectual Property Reading Material*, World Intellectual Property Organization, 2nd edition, ISBN: 92-805-0756-7,1998.
7. *Patents, trademarks, and related rights;* national and international protection, Ladas, Stephen P, Cambridge, MA: Harvard University Press, ISBN: 06746577756, 1975.
8. *Universal's The Patent Act* (39 of 1970) with amendments-Universal Law publishing 2005.

Course Title: Modern Instrumental Methods

L	T	P	Cr
4	0	0	4

Paper Code: MCHM.532

Total Contact Hours: 60

Learning Outcome: After the completion of the course students will knowledge on

CLO1: Principles and analytical applications of modern instrumentation.

CLO2: Principles of various chromatography and their application for purification of compounds.

CLO3: Principles of various radioanalytical methods and application of different radioisotopes in industry

CLO4: Demonstration of various imaging techniques and hands-on training on several spectroscopic techniques

Units/ hours	Content	Mapping with CLOs
Unit-1 15 Hours	**Principles and Instrumentation:** Analytical applications of following techniques: Atomic Absorption spectroscopy, Flame photometry, Inductively coupled plasma-Atomic Emission spectroscopy, Scanning Electron Microscopy. *Peer discussion on principles of modern instrumentation* *Classroom discussion on various analytical applications of modern instrumentation*	**CLO1**
Unit-2 15 Hours	**Chromatography:** Gas solid Chromatography, Gas liquid Chromatography, High performance liquid chromatography, ion exchange chromatography, paper chromatography, thin layer chromatography, column chromatography, gel permeation chromatography *Demonstration of chromatographic techniques in the laboratory* *Classroom discussion on the principles of various chromatography for purification of compounds*	**CLO2**
Unit-3 10 Hours	**Radioanalytical Methods:** X-ray diffraction methods, Neutron activation analysis, isotope dilution analysis, Radiometric titrations, particle induced X-ray Emission, Use of radioisotopes - in industry, agriculture and physicochemical studies. *Principles of various radio-analytical methods through classroom discussion* *Application of different radioisotopes in industry through peer learning*	**CLO3**
Unit-4 20 Hours	**Imaging Techniques:** Electron Microscopy including TEM, STEM, and FESEM with dark field and bright field imaging. **Industrial visits and Hands-on Training and demonstration practical based on following techniques:** HPLC, GCMS, NMR, FTIR, XRD, TGA, AAS and SEM. *Demonstration of various imaging techniques.* *Hands-on training on several spectroscopic techniques.*	**CLO3**

Mode of Transactions: Lecture, Demonstration, Presentation, Group Discussion, Lecture cum demonstration, Problem solving, Brainstorming.

Suggested Readings

1. Tao, W. A. and Zhang, Y., (2019) Mass Spectrometry-Based Chemical Proteomics, Wiley Publishing.
2. Issaq, H. J. (2020) Proteomic and Metabolomic Approaches to Biomarker Discovery, Elsevier Science Publishing.

3. Imai, K., Yau, S. L. F., (2013) Quantitative Proteome Analysis: Methods and Applications, Jenny Stanford Publishing.
4. Mirzaei, H., and Carrasco, M., (2016) Modern Proteomics – Sample Preparation, Analysis and Practical Applications, Springer Publishing.
5. Markus Sauer, M., Hofkens, J., Enderlein, J. (2010) Handbook of Fluorescence Spectroscopy and Imaging: From Ensemble to Single Molecules, Wiley Publishing.
6. Jameson, D. M. (2014) Introduction to Fluorescence, CRC Press.
7. Paul M. W. French, P. M. W., and Elson, D. S. (2014) Fluorescence Lifetime Spectroscopy and Imaging: Principles and Applications in Biomedical Diagnostics, CRC Press.
8. Anton Nikiforov, Nikolay Britun (2018) Photon Counting: Fundamentals and Applications, Intech Open Publishing.
9. Skoog, D. A., West, D. M., Holler, F. J., and Crouch, S. (2019). Fundamentals of Analytical Chemistry. Nelson Education.
10. Rouessac, F., and Rouessac, A. (2013). Chemical Analysis: Modern Instrumentation Methods and Techniques. John Wiley and Sons.
11. Gross, J. H. (2006). Mass Spectrometry: A Textbook. Springer Science and Business Media.
12. Pavia, D. L., Lampman, G. M., Kriz, G. S., and Vyvyan, J. A. (2008). Introduction to Spectroscopy. Cengage Learning.
13. Hollas, J. M. (2004). Modern Spectroscopy. John Wiley and Sons.
14. Lakowicz, J. R. (2006). Principles of Fluorescence Spectroscopy. Springer.

Semester-III							
S. No.	**Course Code**	**Course Title**	**Course Type**	**L**	**T**	**P**	**Cr**
1	MCAC.599-1	Dissertation Part-I	**SB**	**0**	**0**	**40**	**20**
		Total		**0**	**0**	**40**	**20**

SB: Skill-Based Course.

Course Title: Dissertation Part-I
Paper Code: MCAC.599-1
Total Contact Hours: 600
Course Outcome: The student would be able to
CLO1: Investigate various aspects related to the chemistry problem.
CLO2: Generate interest in frontier areas of research in chemistry.
CLO3: Analyze the literature and bring forward the research gaps and propose hypotheses and tentative solutions.

Dissertation supervisor would be allocated at the start of the semester and entire dissertation would be undertaken in discussion with the supervisor. At the end of the semester the student has to prepare a research proposal/synopsis as per the university guidelines. Upon submission of the synopsis, the research proposal shall be evaluated based on a presentation of review of literature, research gap, objective, methodology and PERT Chart for the next semester for sections of experimental work and compilation of dissertation.

Semester-IV							
S. No.	**Course Code**	**Course Title**	**Course Type**	**L**	**T**	**P**	**Cr**
1	MCAC.599-2	Dissertation Part-II	**SB**	**0**	**0**	**40**	**20**
		Total		**0**	**0**	**40**	**20**

SB: Skill-Based Course.

Course Title: Dissertation Part-II
Paper Code: MCAC.599-2
Total Contact Hours: 600
Learning Outcome: The student would be able to
CLO1: Understand the lacunas in the methodology to experimentation.
CLO2: Independently plan and execute experiments in the laboratory set-up
CLO3: Analyze and interpret the results obtained through different experiments.
CLO4: Apply their expertise and specific skills in the frontier area of research.

As per the defined objectives in the research proposal/synopsis, the student would carry out his experimentation to achieve these goals. The student would get experiments evaluated by the supervisor regularly, wherein the progress of the student would be evaluated. Upon achieving the objectives of the synopsis, the dissertation would be prepared as per the university guidelines for M.Sc. Dissertation in consultation with the supervisor. Dissertation would be verified for plagiarism and submitted for evaluation by committee.