

**Learning Outcomes-based Curriculum Framework
(LOCF)
for
(B.Sc. with Chemistry Honours/ Honours with
Research)
Undergraduate Programme
2021
(Revised 2025)**



**MANIPUR UNIVERSITY
CANCHIPUR 795003**

Course Structure	
Course	*Credit
I. Core Course (20 Papers)	120
(14 Theory papers of 4 credit each *6 Theory papers of 5 credit each)	$14 \times 4 = 56$ $6 \times 5 = 30$
Core Course Practical/Tutorial*	
(14 Practical Papers of 2 credit each *6 Tutorials of 1 credit each)	$14 \times 2 = 28$ $6 \times 1 = 6$
II. Elective Course (8 papers)	48
(a) Discipline Specific Elective (4 papers)	
**For Honours with Research (2 papers of 6 credit each)	$2 \times 6 = 12$
For Only Honours	
(4 papers of 5 credit each *4 Tutorials of 1 credit each)	$4 \times 5 = 20$ $4 \times 1 = 4$
(b) Generic Elective/Interdisciplinary Course (4 papers)	
(4 Papers of 6 credit each * Credit pattern depends on the course opted by the student)	$4 \times 6 = 24$
III. Ability Enhancement Course (4 papers)	16
(a) Ability Enhancement Course	
(2 Papers of 3 credit each 2 Tutorials of 1 credit each)	$2 \times 3 = 6$ $2 \times 1 = 2$
(b) Skill Enhancement Course	
(2 Papers of 3 credit each 2 Tutorials of 1 credit each)	$2 \times 3 = 6$ $2 \times 1 = 2$
IV. Value Addition Course	16
(8 papers of 2 credit each)	$2 \times 8 = 16$
Total	200

** Core and Elective courses with practicals will have theory, tutorial and practical, and have credit distribution of 3 credits for theory, 1 credit for tutorial and 2 credits for practical, total 6 credits.*

Core and Elective courses without practicals will have 5 credits for theory and 1 credit for tutorial, total 6 credits.

***Dissertation/ Project Part I and II courses are treated as practicals with 6 credits each.*

Course Structure at a Glance

Core Courses (CC)

Sr. No.	Name of the course	Type of course	L	T	P	Credits
CC 1	Inorganic Chemistry-I	Core course	3	1	0	4
	Inorganic Chemistry Laboratory-I	Core course	0	0	2	2
CC 2	Organic Chemistry-I	Core course	3	1	0	4
	Organic Chemistry Laboratory-I	Core course	0	0	2	2
CC 3	Analytical Chemistry	Core course	3	1	0	4
	Analytical Chemistry Laboratory	Core course	0	0	2	2
CC 4	Physical Chemistry-I	Core course	3	1	0	4
	Physical Chemistry Laboratory-I	Core course	0	0	2	2
CC 5	Green Chemistry	Core course	3	1	0	4
	Green Chemistry Laboratory	Core course	0	0	2	2
CC 6	Inorganic Chemistry-II	Core course	3	1	0	4
	Inorganic Chemistry Laboratory-II	Core course	0	0	2	2
CC 7	Physical Chemistry-II	Core course	3	1	0	4
	Physical Chemistry Laboratory-II	Core course	0	0	2	2
CC 8	Molecular Spectroscopy & Photochemistry	Core course	5	1	0	6
CC 9	Inorganic Chemistry-III	Core course	3	1	0	4
	Inorganic Chemistry Laboratory-III	Core course	0	0	2	2
CC 10	Organic Chemistry-II	Core course	3	1	0	4
	Organic Chemistry Laboratory-II	Core course	0	0	2	2
CC 11	Introduction to Quantum Chemistry	Core course	5	1	0	6
CC 12	Organic Chemistry-III	Core course	3	1	0	4
	Organic Chemistry Laboratory	Core course	0	0	2	2
CC 13	Physical Chemistry-III	Core course	3	1	0	4
	Physical Chemistry Laboratory-III	Core course	0	0	2	2
CC 14	Materials Chemistry	Core course	5	1	0	6
CC 15	Advanced Inorganic Chemistry	Core course	3	1	0	4
	Advanced Inorganic Chemistry Laboratory	Core course	0	0	2	2
CC 16	Advanced Organic Chemistry	Core course	3	1	0	4
	Advanced Organic Chemistry Laboratory	Core course	0	0	2	2
CC 17	Research Methodology	Core course	5	1	0	6
CC 18	Advanced Physical Chemistry	Core course	3	1	0	4
	Advanced Physical Chemistry Laboratory	Core course	0	0	2	2
CC 19	Spectroscopy	Core course	5	1	0	6
CC 20	Advanced Analytical Chemistry	Core course	5	1	0	6

Core Courses (Pass/Honours/Honours with Research in Chemistry)Page no

Semester VII

Core Course 15: CHM815C: Advanced Inorganic Chemistry
CHM815CP: Advanced Inorganic Chemistry Laboratory

Core Course 16: CHM816C: Advanced Organic Chemistry.....
CHM816CP: Advanced Organic Chemistry Laboratory

Core Course 17: CHM817C: Research Methodology

Semester VIII

Core Course 18: CHM818C: Advanced Physical Chemistry
CHM818CP: Advanced Physical Chemistry Laboratory

Core Course 19: CHM819C: Spectroscopy

Core Course 20: CHM820C: Advanced Analytical Chemistry.....

ELECTIVES COURSES (06 Papers) (Credit: 06 Each)

(a) Discipline Specific Electives (DSE) Courses

Semester VII

Honours with Research:

CHM801D: Dissertation/Project Part I

Only Honours

CHM802D: Polymer Chemistry

Semester VIII

Honours with Research::

CHM803D: Dissertation/Project Part II

Only Honours

CHM804D: Chemistry of Food, Nutrition and Preservation

Structure of B. Sc. Pass/Honours (Chemistry) Programme

Semester	Type	Core	DSE	GEC*	AECC	SEC	VAC
	Credits	20×6=120	4×6=24	4×6=24	2×4=8	2×4=8	8×2=16
I	CHM501C				AECCCH1	CHM501S/ CHM502S/ CHM503S	VAC-1
	CHM502C						VAC-2
II	CHM503C				AECCCH2	CHM504S/ CHM505S/ CHM506S	VAC-3
	CHM504C						VAC-4
III	CHM605C			CHM601G			VAC-5
	CHM606C						
	CHM607C						
IV	CHM608C			CHM602G			VAC-6
	CHM609C						
	CHM610C						
V	CHM711C	CHM701D/ CHM702D/ CHM703D/ CHM704D		CHM701G			VAC-7
	CHM712C						
VI	CHM713C	CHM705D/ CHM706D/ CHM707D/ CHM708D		CHM702G			VAC-8
	CHM714C						
VII	CHM815C	CHM801D/ CHM802D					
	CHM816C						
	CHM817C						
VIII	CHM818C	CHM803D/ CHM804D					
	CHM819C						
	CHM820C						

*GE Courses are to be chosen from the GE courses offered by other disciplines (Physics, Mathematics, Biochemistry, Botany and Zoology).

SCHEME FOR CHOICE-BASED CREDIT SYSTEM in B.Sc. Pass/Honours (Chemistry)

SEMESTER	COURSE CODE	COURSE NAME	Credits
I	AECCCH1	English for Communications	4
	CHM501C	Inorganic Chemistry-I	4+2=6
	CHM501CP	Inorganic Chemistry-Lab-I	
	CHM502C	Organic Chemistry-I	4+2=6
	CHM502CP	Organic Chemistry-Lab-I	
	CHM501S/ CHM502S/ CHM503S	Skill Enhancement Course	4

	VAC-1	Value Addition Course 1	2
	VAC-2	Value Addition Course 2	2
Total credits in Semester I			24
II	AECCCH2	Environmental Studies	4
	CHM503C	Analytical Chemistry	4+2=6
	CHM503CP	Analytical Chemistry Laboratory	
	CHM504C	Physical Chemistry-I	4+2=6
	CHM504CP	Physical Chemistry Lab-I	
	CHM504S/ CHM505S/ CHM506S	Skill Enhancement Course	4
	VAC-3	Value Addition Course 3	2
	VAC-4	Value Addition Course 4	2
Total credits in Semester II			24
III	CHM605C	Green Chemistry	4+2=6
	CHM605CP	Green Chemistry Laboratory	
	CHM606C	Inorganic Chemistry-II	4+2=6
	CHM606CP	Inorganic Chemistry Lab-II	
	CHM607C	Physical Chemistry-II	4+2=6
	CHM607CP	Physical Chemistry Lab-II	
	CHM601G	Generic Elective Course	4+2=6
	CHM601GP	Laboratory	
	VAC-5	Value Addition Course 5	2
Total credits in Semester III			26
IV	CHM608C	Molecular Spectroscopy & Photochemistry	5+1=6
	CHM609C	Inorganic Chemistry-III	4+2=6
	CHM609CP	Inorganic Chemistry Lab-III	
	CHM610C	Organic Chemistry-II	4+2=6
	CHM610CP	Organic Chemistry Lab-II	
	CHM602G	Generic Elective Course	4+2 =6
	CHM602GP	Laboratory	
	VAC-6	Value Addition Course 6	2
Total credits in Semester IV			26
V	CHM711C	Introduction to Quantum Chemistry	5+1=6
	CHM712C	Organic Chemistry-III	4+2=6
	CHM712CP	Organic Chemistry Lab-III	
	CHM701D/CHM702D/ CHM703D	Discipline Specific Elective	4+2=6
	CHM701DP/CHM702DP/ CHM703DP	Laboratory	
	CHM701G	Generic Elective Course	4+2=6
	CHM701GP	Laboratory	
	VAC-7	Value Addition Course 7	2

Total credits in Semester IV			26
VI	CHM713C	Materials Chemistry	5+1=6
	CHM714C	Physical Chemistry-III	4+2=6
	CHM714CP	Physical Chemistry Lab-III	
	CHM705D/CHM706D/ CHM707D	Discipline Specific Elective	4+2=6
	CHM705DP/CHM706DP/ CHM707DP	Laboratory	
	CHM702G	Generic Elective Course	4+2/=6
	CHM702GP	Laboratory	
	VAC-8	Value Addition Course 8	2
Total credits in Semester IV			26
VII	CHM815C	Advanced Inorganic Chemistry	4+2=6
	CHM815CP	Advanced Inorganic Chemistry Lab	
	CHM816C	Advanced Organic Chemistry	4+2=6
	CHM816CP	Advanced Organic Chemistry Lab	
	CHM817C	Research Methodology	5+1=6
	CHM801D/ CHM802D	Discipline Specific Elective	0+6=6 or 5+1=6
Total credits in Semester VII			24
VIII	CHM818C	Advanced Physical Chemistry	4+2=6
	CHM818CP	Advanced Physical Chemistry Lab	
	CHM819C	Spectroscopy	5+1=6
	CHM820C	Advanced Analytical Chemistry	5+1=6
	CHM803D/ CHM804D	Discipline Specific Elective	0+6=6 or 4+2=6
Total credits in Semester VIII			24
Grand Total Credits			200

CORE COURSES

These are 20 courses of 6 credits each. All courses are compulsory. These courses have the following credit pattern.

For Theory and practical based papers:

L	T	P	Cr
3	1	2	6

For Theory papers without Practical:

L	T	P	Cr
5	1	0	6

SEMESTER VII

Course Code: CHM815C: Advanced Inorganic Chemistry

(60 Hrs)

L	T	P	Cr
3	1	2	6

Learning objectives

The students will be able to:

1. Understand the concept of Coordination complexes, theories of their formation, structures and their stabilities in solution with different ligands.
2. Understand the magnetic properties of compounds and its applications.
3. Understand different types of inorganic reactions of metal complexes and their mechanism.
4. Understand the synthesis and structures of organometallic complexes.
5. Synthesise and characterise inorganic compounds, including those involving green synthetic methodology.

UNIT 1: Coordination Chemistry

(9 Hrs)

Crystal field theory and its limitations, Jahn-Teller effect in d^1 to d^5 ions in ground state, experimental evidences of metal ligand overlap, IR, NMR, EPR, intensities of d-d transition, Nephelauxetic effect, antiferromagnetic coupling, adjusted crystal field theory, Molecular orbital theory of octahedral, tetrahedral, and square planar complexes (qualitative principles involved in complexes with and without π -bonding).

UNIT 2: Magnetochemistry

(9 Hrs)

Brief review of different types of magnetic behaviour, di-, para-, ferro- and anti-ferromagnetic compounds,

spin-orbit coupling, quenching of orbital angular momenta, temperature-independent Para magnetism, measurement of magnetic susceptibility using Gouy's method, Term symbols for metal ions; Crystal field theory and its application to explain magnetic properties of coordination compounds, spin crossover; magnetic properties.

UNIT 3: Inorganic Reactions

(9 Hrs)

Mechanism of ligand substitution reactions. Theoretical approach to the substitution mechanisms. Factors affecting the reactivity of the complexes. Effect of electronic structure of the metal atom on the reactivity of complexes (based on VBT and CFT). Substitution reactions of Inorganic complexes and kinetic application of CFT on the rate of reactions (with reference to acid hydrolysis of octahedral Co(III) complexes). Mechanism of base hydrolysis of Co(III) complexes. Electron transfer reactions: Types and factors affecting electron transfer reactions. An introduction to racemisation processes of inorganic complexes.

UNIT 4: Organometallic Chemistry

(9 Hrs)

Synthesis, structure, bonding, and reactivity of complexes with CO, NO, and N₂. Organometallic reagents in organic synthesis and in homogeneous catalytic reactions (isomerisation, hydration, hydroformylation, and polymerization). Medicinal and environmental aspects of organometallic compounds. Structure and bonding (qualitative treatment only) and reactivity of π -Coordination of C-C multiple bonds (Alkene, Diene, Allyls) and Carbocyclic Polyene ligands (Cyclopentadiene, Arenes, Cycloheptatriene). Bonding in metal complexes of phosphines. Fluxionality in organometallic compounds.

UNIT 5: Metal Ligand Equilibria in Solution

(9 Hrs)

Stepwise and overall formation constants and their interaction, trends in stepwise constants, Statistical and non-statistical factors affecting the stability of metal complexes with references to the nature of metal ion and ligand, chelate effect and their thermodynamic origin. Determination of composition and stability of complex ion in solution by spectrophotometric and pH-metric methods, conditional stability constant, and their importance in complexometric (EDTA) titration.

Books Suggested:

1. F. A. Cotton, G. Wilkinson, A. Murillo, M. Bochmann; *Advanced Inorganic Chemistry*, Wiley International, 6th Ed.
 2. J.D. Lee; *Concise Inorganic Chemistry*.
 3. J.E. Huheey, E. A. Keiter, R. L. Keiter; *Inorganic Chemistry- principles of structure and reactivity*, Harper Collins College Publishers, 1993.
 4. F. Basolo, R. G. Pearson; *Mechanisms of Inorganic Reactions*, Wiley-Eastern Ltd.
- (Other books/reading materials may also be suggested).

Course Code: CHM815CP: Advanced Inorganic Chemistry Laboratory

(60 Hrs)

Synthesis and characterisation of inorganic compounds, including those involving green synthetic methodology: (at least 4 complexes are to be prepared and characterized)

- (i) Cu(acac)₂
- (ii) Tetramine copper sulphate

- (iii) Fe(acac)₃
- (iv) Hg[Ni(SCN)₄]
- (v) Nickel(II) dimethylglyoxine complex

Books Suggested:

1. F. A. Cotton, G. Wilkinson, A. Murillo, M. Bochmann; *Advanced Inorganic Chemistry*, Wiley International, 6th Ed.
2. J.D. Lee; *Concise Inorganic Chemistry*.
3. J.E. Huheey, E. A. Keiter, R. L. Keiter; *Inorganic Chemistry- principles of structure and reactivity*, Harper Collins College Publishers, 1993.
4. F. Basolo, R. G. Pearson; *Mechanisms of Inorganic Reactions*, Wiley-Eastern Ltd.
5. A. I. Vogel; *Quantitative Inorganic Analysis*, Longman Sc& Tech.
6. G. Marr, B. W. Rockett; *Practical inorganic chemistry*, Van Nostrand.
7. W.L. Jolly; *Synthesis and characterisation of inorganic compounds*, McGraw Hill, 1974.
8. D. F. Shriver, P. W. Atkins; *Inorganic Chemistry*, Oxford University Press.
9. M. T. Beck; *Chemistry of Complex Equilibria*, Van Nestrand Reinhold Company, London.
10. A. E. Martell, R. J. Motekaitis; *Determination and Use of Stability Constants*, Wiley-VCH.
11. R. L. Dutta, A. Shyamal; *Elements of Magnetochemistry*, S. Chand Co., New Delhi.
12. R. C. Mehrotra, A. Singh; *Organometallic Chemistry*, New Age International.
13. A. F. Wells; *Structural Inorganic Chemistry*, Oxford University Press.

(Other books/reading materials may also be suggested).

Course Code: CHM816C Advanced Organic Chemistry

(60 hrs)

L	T	P	Cr
3	1	2	6

Course Objectives:

1. To provide basic principles of stereochemistry and familiarize with the concepts of stereochemistry for their applications in organic molecules and compounds.
2. To familiarize basic principles of the structure and reactivity relationship and apply the fundamental knowledge of structure of organic molecules to determine its influences on reactivity of their reactions.
3. To enhance the knowledge of general organic reactions and familiarize with their reaction mechanisms. Apply the basic concepts of various reaction mechanisms in the synthesis of organic molecules and compounds.
4. To enhance the fundamental knowledge of photochemical reactions and their applications in various organic photochemical reactions.
5. To provide basic concepts of Pericyclic reactions and apply its fundamental knowledge to various organic reactions involving Pericyclic reactions.

UNIT 1: Stereochemistry

(9 Hrs)

Molecular symmetry and chirality, stereoisomerism, configurational descriptors (R, S), interconversion of

Fischer, Sawhorse, Newman and Flying wedge projections, topicity and prostereoisomerism; Principles of axial and planar chirality, allenes, alkylidene cycloalkanes, spirans, biaryls; Conformational analysis of acyclic, cyclic, and steroidal systems; Asymmetric synthesis, chiral auxiliaries, methods of asymmetric induction – substrate, reagent and catalyst controlled, resolution – optical and kinetic.

UNIT 2: Structure and Reactivity

(9 Hrs)

Acids and bases, concept of hard and soft acids and bases, symbiosis, labeling and kinetic isotope effects; Hammett equation, σ - ρ relationship, kinetic and thermodynamic control; Hammett principle, Curtin-Hammett principle, transition state and intermediates; Aromaticity, n-annulenes and hetero-annulenes, Cryptans, bonds weaker than covalent: addition compounds, inclusion compounds and rotaxanes.

UNIT 3: General reaction mechanism

(9 Hrs)

Aromatic nucleophilic substitution reaction: S_NAr, S_{RN}1 mechanism, reactivity, effect of substrate, leaving group and attacking nucleophile, diazonium salts and benzyne mechanism, Sommelet Hauser & Smiles rearrangement; *Aromatic electrophilic substitution reactions:* ortho/para ratio, ipso attack, Freidel Crafts, diazonium coupling, Vilsmeier reaction, Gattermann-Koch reaction.

Elimination reactions: E1 E2 and E1cB, Mechanism and stereochemistry of different types of elimination reactions, formation of other double bonds (C=N, C=O) and triple bonds; Addition to carbon-carbon multiple bonds, mechanistic and stereochemical aspects of addition reactions involving electrophiles, nucleophiles and free radicals, hydroboration, alkylation, epoxidation and hydroxylation.

UNIT 4: Photochemistry

(9 Hrs)

General principles, orbital symmetry consideration related to photochemical reaction, photochemistry of carbonyl groups, Norrish Type I and Type II cleavage, photochemistry of alkenes and dienes, photochemistry of aromatic compounds, photocycloaddition, photodimerization, Paterno-Buchi reaction, di- π -methane rearrangement, Barton reaction, photo reduction of carbonyl compounds.

UNIT 5: Pericyclic Reactions

(9 Hrs)

Molecular orbital symmetry, Frontier orbitals of ethylene, 1,3-butadiene, 1,3,5-hexatriene and allyl system. Woodward-Hoffmann correlation diagrams. Frontier molecular orbital and Perturbational molecular orbital approach. Electrocyclic reactions: conrotatory and disrotatory motions. Cycloadditions: antarafacial and suprafacial additions. $4n$ and $4n+2$ systems, $2+2$ addition of ketenes, 1,3-dipolar cycloadditions and cheletropic reactions. Sigmatropic rearrangements: suprafacial and antarafacial shifts of H, 3,3- and 5,5-sigmatropic rearrangements. Claisen, Cope and aza-Cope rearrangements.

Course Code: CHM816CP Advanced Organic Chemistry Laboratory

(60 Hrs)

Preparation, purification (crystallization), and thin layer chromatography (TLC) of the following compounds are to be performed.

1. Preparation of Benzylic acid starting from Benzoin.
2. Preparation of *p*-nitroaniline from acetanilide.
3. Preparation of benzylideneacetophenone.
4. Preparation of 1-phenylazo-2-naphthol by diazonium coupling method.

Books suggested:

1. J. March; *Advanced Organic Chemistry*, John Wiley & Sons, 1992.
2. E. J. Eliel; *Stereochemistry of Carbon Compounds*, McGraw Hill.
3. F. A. Carey, R. L. J. Sundberg; *Advanced Organic Chemistry, Part A and B*, Plenum Press, New York.
4. S. H. Pine; *Organic Chemistry* McGraw Hill, 1987.
5. D. Nasipuri; *Stereochemistry of Organic Compounds*, Wiley, 1994.
6. H. O. House; *Modern Synthetic Reactions*, W.A. Benjamin Inc., 1972
7. P.Y. Bruce; *Organic Chemistry*, Prentice Hall, 1998.
8. P.S. Kalsi; *Organic Reaction and their Mechanism*, New Age, 1996.

CHM817C: Research Methodology**(90 Hrs)**

L	T	P	Cr
5	1	0	6

Learning objectives

The students will be able to:

1. Understand the concept of research and different types of research in the context of chemistry
2. Develop laboratory experiment related skills.
3. Develop competence on data collection and process of scientific documentation
4. Analyze the ethical aspects of research
5. Evaluate the different methods of scientific writing and reporting
6. Use computer software, browsing of references, literature review etc
- 7.

UNIT 1: Basic Concepts of Research**(15 Hrs)**

Research-definition and types of research (Descriptive vs analytical; applied vs fundamental; quantitative vs qualitative; conceptual vs empirical).

UNIT 2: Methodology**(15 Hrs)**

Research methods vs methodology. Literature review and its consolidation; library research; field research; laboratory research. Selection of Appropriate Methodology

UNIT 3: Data Collection and Documentation of Observations**(15 Hrs)**

Maintaining a laboratory record; Data Collection, Analysis of Data, Conclusion from Data; Tabulation and Generation of graphs/information

UNIT 4: Ethics and Good Practical's and Art of Scientific Writing (15 Hrs)

Authors, acknowledgements, reproducibility, plagiarism. Writing references. Power-point presentation. Poster presentation, Scientific writing and ethics, Introduction to copyright-academic misconduct/plagiarism.

UNIT 5: Introduction to Softwares Related to Chemistry (15 Hrs)

Introduction to data analysis software - Excel and Origin. Least squares fitting. Visualization softwares: Chemdraw, ChemSketch and GaussView. Elementary structural features: bond lengths, bond angles, dihedral angles. Basic geometrical description of molecules: (i) Cartesian coordinates and (ii) Z-matrix.

References :

1. Bird, A. (2006). *Philosophy of Science*. Routledge
2. MacIntyre, Alasdair (1967). *A Short History of Ethics*. London
3. P. Chandah. (2018). Ethics in Competitive Research: Do not get scooped; do not get plagiarized.
4. E. Lewars; *Computational Chemistry: Introduction to the Theory and Applications of Molecular and Quantum Mechanics*, Springer.
5. C. J. Cramer; *Essentials of Computational Chemistry: Theories and Models*, Wiley.

(Other books/reading materials may also be suggested).

SEMESTER VIII

Core Course-18: CHM818C: Advanced Physical Chemistry (60 Hrs)

L	T	P	Cr
3	1	2	6

Learning objectives:

The students will be able to:

1. Understand microscopic Thermodynamics properties base on the behaviours of microscopic particles
2. Understand the behavior of systems that are not in thermodynamic equilibrium, particularly those involving transport processes and chemical reactions.

3. Understand the differences between classical and quantum systems, to apply quantum mechanics to statistical problems.
4. Understanding reaction rates and mechanisms, exploring factors influencing reaction speed, and applying theoretical models to predict and analyze chemical reactions.
5. Handle UV-Vis and Fluorescence Spectrometer and use for determining Quantum Yield.

UNIT 1: Statistical Thermodynamics

(10 Hrs)

Partition functions and their physical significance. Translational partition function using a particle-in-a-box model for ideal gases. Rotational partition function using the rigid-rotor model for ideal diatomic molecules. Vibrational partition function for ideal diatomic gases using the simple harmonic oscillator model. Electronic partition function for diatomic molecules. Nuclear partition function. Factorization of partition functions. Law of equipartition of energy, heat energy. Thermodynamic functions in terms of the partition function, the Seckur-Tetrode equation, and the equilibrium constant in terms of partition functions.

UNIT 2: Nonequilibrium Thermodynamics

(8 Hrs)

Entropy production, entropy production in chemical reaction, entropy production and entropy flow in open systems, Onsager's theory, validity of Onsager's equation, and its verification. The principle of microscopic reversibility and Onsager reciprocal relations, electrokinetic phenomena, diffusion, electric conduction, and coupled reactions.

UNIT 3: Quantum Statistics-I

(10 Hrs)

Brief review of Statistical Mechanics of a system of independent particles, Boltzmann distribution law, Maximization under certain constraints and Lagrangian multipliers. Quantum statistics of identical particles, Bose-Einstein and Fermi-Dirac distribution laws. Comparison of Maxwell-Bose, Bose-Einstein, and Fermi-Dirac distribution laws. Derivation of the black body radiation equation (Planck's equation) from Bose-Einstein statistics, Bose-Einstein condensation, and thermodynamic properties of an ideal Bose-Einstein gas. Fermi-Dirac distribution, Fermi level and Fermi energy, electrons in metals, electronic heat capacity.

UNIT 4: Quantum Statistics-II

(7 Hrs)

Statistical thermodynamic properties of solids, heat capacity of solids, Dulong and Petit's law, Einstein's treatment of the heat capacity of solids, and limitations of Einstein's model. Debye modification and Debye's heat capacity equation at low and high temperature limits. Limitations and modifications of the Debye theory.

UNIT 5: Chemical Dynamics

(10Hrs)

Different types of collision, collinear collision of an atom with a diatomic molecule. Potential energy surface, saddle points, reaction pathways, contour diagrams, transition state. Reaction path Hamiltonian theory, classical dynamics simulation, Rice-Ramsperger-Kassel-Marcus (RRKM) theory. Surface hopping. Experimental probes of reaction dynamics. Study of fast reactions by relaxation (temperature jump), stopped flow, flash photolysis, magnetic resonance, and shock tube techniques. Application of transition state theory to reactions in solution, oscillatory reactions, and diffusion-controlled reactions. Femtochemistry.

Course Code: CHM818CP: Advanced Physical Chemistry Laboratory

(60 Hrs)

- a) Acquisition of IR, UV-Visible, and fluorescence spectra of some organic compounds
- b) Measurement of the fluorescence quantum yields of some fluorophores with a reference fluorophore

Books Suggested:

1. D. A. McQuarrie, and J. D. Simon; *Physical Chemistry: A Molecular Approach*, Viva Books Private Limited, New Delhi.
2. P. W. Atkins; *Physical Chemistry*, Oxford University Press.
3. M. C. Gupta; *Statistical Thermodynamics*, Wiley Eastern.
4. L. K. Nast; *Elements of Statistical Thermodynamics*, Dover Publications Inc.
5. T. L. Hill; *Statistical Thermodynamics*, Addison-Wesley Publication Co.
6. R. K. Pathria; *Statistical Mechanics*, Pergamon Press, Butterworth Heinemann.
7. B. K. Agarwal, and M. Eisner; *Statistical Mechanics*, New Age International, New Delhi.
8. F. W. Sears, and G. L. Salinger; *Thermodynamics, Kinetic Theory, and Statistical Thermodynamics*, Narosa Publishing House.
9. T. Engel, and P. Reid; *Thermodynamics, Statistical Thermodynamics and Kinetics*, Pearson Education Low Price Edition.
10. R. Haase; *Thermodynamics of Irreversible Processes*, Addison-Wesley.
11. R. C. Srivastava, S. K. Saha, and A. K. Jain; *Thermodynamics: A Core Course*, Prentice Hall.
12. K. L. Kapoor; *A Textbook of Physical Chemistry, Vols. I-IV*, Macmillan India.
13. S. K. Dogra, and S. K. Dogra; *Physical Chemistry Through Problems*, New Age International.
14. L. V. Azaroff; *Introduction to Solids*, Tata McGraw-Hill, New Delhi.
15. S. Glasstone; *An Introduction to Electrochemistry*, Affiliated East West Press Private, Limited.
16. J. O. M. Bockoris, and A. K. N. Reddy; *Modern Electrochemistry*, Plenum.
17. L. I. Antropov; *Theoretical Electrochemistry*, Mir Publishers, Moscow.
18. K. J. Laidler; *Chemical Kinetics*, McGraw-Hill.

Core Course-19: CHM819C: Spectroscopy**(90 Hrs)**

L	T	P	Cr
5	1	0	6

Learning objectives:

1. To make the student learn about the basic knowledge of electromagnetic radiation and atomic spectra
2. To learn fundamentals of rotational and vibrational spectroscopic techniques
3. To learn about the electronic and laser spectroscopy

UNIT 1: Interaction of Matter with Electromagnetic Radiation**13 Hours**

Time-dependent Schrödinger equation, interaction of electromagnetic radiation with matter, solution of the total wave function, rate of change of a system from one stationary state to another stationary state, transition moment integral, Einstein's coefficients, correlation of Einstein's coefficients with experimental data, oscillator strength, and its physical significances.

UNIT 2: Atomic Spectra**12 Hours**

Elements of atomic spectroscopy, electron spin and space quantisation, orbital and spin angular momentum. Coupling of angular momenta, Spin-orbit coupling (Angular momentum operators). Atomic term symbols and spectroscopic states, Multiplet structure, atomic spectra of one-electron and two-electron systems, magnetic properties of atoms, Normal Zeeman effect.

UNIT 3: Rotational, Vibrational, and Raman Spectroscopy**25 Hours**

Spherical rotor, and asymmetric top molecules. Rigid rotor models, mathematical expressions for moment of inertia and rotational energy levels of a diatomic molecule, selection rules, and spectral transitions. Degeneracy factor. Intensity of rotational spectra, non-rigid rotor, Stark effect. Harmonic and anharmonic oscillators of a diatomic molecule, selection rules, and spectral transitions. Morse potential. Vibrational-rotational spectroscopy: P, Q, and R branches. Raman effect, Classical and Quantum theory of Raman effect, Rotational and Vibrational Raman spectra, Mutual exclusion rule, Polarization of Raman scattered light, Resonance Raman spectra, scattering, applications of Raman spectroscopy.

UNIT 4: Electronic absorption spectroscopy**10 Hours**

Franck-Condon principle and intensities of electronic spectra of diatomic molecules, quantum mechanical formulation of the Franck-Condon principle. Photoelectron spectroscopy (PES), Electron Spectroscopy for Chemical Analysis (ESCA), and Auger electron spectroscopy.

UNIT 5: Fluorescence and Laser Spectroscopy**15 Hours**

Electronically excited states; Radiative and non-radiative transitions; fluorescence, phosphorescence, and photosensitization; lifetime and quantum yield. Fluorescence anisotropy. Fluorescence quenching:

mechanism and dynamics. Radiative and non-radiative energy transfers: short-range and long-range energy transfers, Kinetics of photochemical processes. Instrumentation of steady-state and time-resolved spectrofluorimeters. Absorption and emission of light, Einstein's prediction of the probability of induced or stimulated emission, Lasing materials, Population inversion, Optical cavity, properties of laser radiation, Ruby laser, He-Ne laser, Ar⁺ laser, Nd-YAG laser, Dye laser, applications of lasers in chemical science.

Books Suggested:

1. D. A. McQuarrie; *Quantum Chemistry*, Oxford University Press.
2. D. A. McQuarrie, and J. D. Simon; *Physical Chemistry: A Molecular Approach*, Viva Books Private Limited, New Delhi.
3. P. W. Atkins; *Molecular Quantum Mechanics*, McGraw-Hill.
4. P. W. Atkins; *Physical Chemistry*, Oxford University Press.
5. A. K. Chandra; *Introductory Quantum Chemistry*, Tata McGraw-Hill.
6. C. N. Banwell, *Fundamentals of Molecular Spectroscopy*, McGraw-Hill, London.
7. Thomas Engel, *Quantum Chemistry and Spectroscopy*, Pearson Longman Low Priced Edition, New Delhi.
8. H. L. White; *Introduction to Atomic Spectra*, McGraw-Hill.
9. R. S. Drago; *Physical Methods in Chemistry*, Saunders College Publishers.
10. R. Chang, *Basic Principles of Spectroscopy*, McGraw-Hill.
11. G. M. Barrow, *Molecular Spectroscopy*, McGraw-Hill.
12. C. N. Banwell and E. M. McKash; *Fundamentals of Molecular Spectroscopy*, Tata McGraw-Hill.
13. N. J. Turro; *Molecular Photochemistry*, Benjamin.
14. C. H. J. Wells; *Introduction to Molecular Photochemistry*, Chapman and Hall.
15. K. K. Rohatgi-Mukherjee; *Fundamentals of Photochemistry*, New Age International.
16. B. Valeur *Molecular Fluorescence: Principles and Applications*; Wiley-VCH Verlag GmbH.
17. J. R. Lakowicz; *Principles of Fluorescence Spectroscopy*, Springer.

(Other books/reading materials may also be suggested).

Core Course-20: CHM820C Advanced Analytical Chemistry

(90 Hrs)

L	T	P	Cr
5	1	0	6

After completion of the course, the learner can be able to understand:

1. Statistical methods in chemical analysis
2. Theory and applications of polarography, atomic absorption spectroscopy and chromatography
3. Theory and applications of thermogravimetric analysis

UNIT 1: Statistical methods in chemical analysis (20 Hrs)

Theory of error and treatment of quantitative data, accuracy and precision, ways of expressing accuracy and precision, Normal error curve and its equation. Useful statistical tests with equation, test of significance, the F-test, the students t-test, the Chi-test, the correlation coefficient, confidence limit of the mean, comparison of two standard values, comparison of two standard values, comparison of standard deviation with average deviation, comparison of mean with true values, regression analysis (least square method).

UNIT 2: Polarography (10 Hrs)

Current-voltage relationship, theory of polarographic waves, instrumentation, qualitative and quantitative applications.

UNIT 3: Atomic Absorption spectroscopy (15 Hrs)

Atomic absorption spectroscopy, instrumentation, theory and applications, including trace elements analysis.

UNIT 4: Thermal analysis (15 Hrs)

Theory, methodology, instrumentation and applications of Thermogravimetric and Differential Thermal Analysis (TGA/DTA), and Differential Scanning Calorimetry (DSC).

UNIT 5: Chromatography (15 Hrs)

Principles of chromatography, paper, column and thin layer chromatography, ion-exchange chromatography, Gas-liquid chromatography, HPLC.

Recommended books/references:

1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6th Ed.*, Pearson, 2009. 100
2. Willard, H.H. *et al.: Instrumental Methods of Analysis*, 7th Ed. Wardsworth Publishing California, USA, 1988.
3. Christian, G.D, *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, 2004.
4. Harris, D.C.: *Exploring Chemical Analysis*, 9th Ed. New York, W.H. Freeman, 2016.
5. Skoog, D.A. Holler F.J. & Nieman, T.A. *Principles of Instrumental Analysis*
6. Mikes, O. *Laboratory Hand Book of Chromatographic & Allied Methods*, Elles Harwood John Wiley 1979.
7. Ditts, R.V. *Analytical Chemistry; Methods of separation*, van Nostrand, 1974.
8. Khopkar, S. M., *Basic Concepts of Analytical Chemistry*, New Age (Second edition) 1998

DISCIPLINE-SPECIFIC ELECTIVE COURSES*

These courses with 6 credits each have the following credit pattern.

For Theory and practical based papers:

L	T	P	Cr
3	1	2	6

For Theory papers without Practical:

L	T	P	Cr
5	1	0	6

For Dissertation/Project Part I and II:

L	T	P	Cr
0	0	6	6

*** CHM801D and CHM803D are to be elected by the students offering Honors with Research.**

CHM802D and CHM804D are to be elected by the students offering Only Honors.

SEMESTER VII

CHM801D: Dissertation/ Project Part I

L	T	P	Cr
0	0	6	6

Suggested Topics for Individual/ Team Projects

Projects may be decided by the Mentor on the basis of the Core Course CHM817C: Research Methodology.

For example, Writing a Review article on any selected (current) Subject-oriented Research Topic.

Dissertation may be assessed from the presentation of the project by the student.

L	T	P	Cr
5	1	0	6

Learning objectives:

After completion of the course, the learner can be able to understand:

1. The mechanism of polymer material formation.
2. Molecular weight and structure property relationship.
3. Characterization of polymers.

UNIT 1: Polymers and polymerization**15 Hrs.**

Polymer, monomer, examples of polymers, classification, polymerization process, degree of polymerization, addition polymers, condensation, co-polymerization. General idea about kinetics and mechanism of polymerisation reactions. Emulsion polymerisation. Stereochemistry and average end-to-end distance of polymers.

UNIT 2: Polymeric Structure and Property Relationship**15 Hrs.**

Structure of polymers - Linear, branched, cross-linked, and network polymers, crystallinity in polymer, melting temperature and glass transition temperature, Volumetric properties - molar volume, density, Van der Waals volume – Coefficient of linear thermal expansion and volumetric thermal expansion - Pressure volume temperature (PVT) relationship.

UNIT 3: Characterization of Polymers**15 Hrs.**

Number average and weight average molecular weights (molar masses) and distribution of molecular weight, polydispersity index. Theory and instrumentation of determination of molar mass by Osmometry, viscometry, light scattering and ultra-centrifugation methods. Gel Permeation Chromatography; Application of FTIR, UV-visible, NMR, and Mass Spectroscopy for identification of polymers.

UNIT 4: Conducting polymers**15 Hrs.**

Basic principles of conducting polymers, delocalized electronic states of conjugated polymers, polyanilines, polyacetylenes, polythiophene, applications of conducting polymers.

UNIT 5: Bio- polymers**15 Hrs.**

Definition, classification, starch cellulose, chitin, polypeptides, polynucleic acids, classification of natural biodegradable polymers, synthetic biodegradable polymers, polyhydroxy alkanates, polycaprolactone, poly(vinyl alcohol), polyacetic acid, application of biodegradable and biomedical polymers, contact lens, dental polymers, artificial heart, kidney, skin, and blood cells.

Recommended books/References:

1. D.W. Van Krevelen and P.J. Hoftyzen, *Properties of Polymer*, 3rd Edition Elsevier Scientific, Publishing Company Amsterdam - Oxford - Newyork. 1990.
2. J.E. Mark, Ed. AIP, *Physical Properties of Polymers*, Hand Book, Williston, Vt, 1996.
3. S K Gupta and Anil Kumar, *Reaction Engineering of Step Growth Polymerization*, Plenum Press, 1987
4. George Odian, *Principles of Polymerization*, McGraw-Hill Book Co., New York (1970).
5. W. Billmeyer, *Text book of polymer science*, 3rd Edn., 2007, Wiley- Interscience Publishers, New York.
6. J. R. Fried, *Polymer Science and Technology*, (2005), PHI publication.

SEMESTER-VIII

CHM803D: Dissertation/ Project Part II

L	T	P	Cr
0	0	6	6

Suggested Topics for Individual/ Team Projects (as given in the UGC Syllabus)

1. Synthesis of Inorganic Complexes and characterization
2. Synthesis of Organic Compounds and characterization
3. Synthesis of Aspirin.
4. Finding EMF of electrochemical cells.
5. Water analysis of nearby areas; finding out the toxic/heavy metals, anions and purification of water using simple available lab technology.
6. Study of air-pollution parameters of a given locality.

(List of Projects are suggestive. However, additional topics can be added/revised as per available facilities/as decided by the Project Guide).

Dissertation may be assessed from the presentation of the project by the student.

L	T	P	Cr
3	1	2	6

Learning objectives:

1. To know about the basic of human physiological system and food science
2. To learn about the nutrition and its importance
3. To learn about the food preservation and its utility.

Key words: Food, nutrition, preservation.

UNIT 1: Basic of human physiological system and food science**(8 Hrs)**

Digestive System: Structure and functions of G.I. tract, Process of digestion and absorption of food, Structure and functions of liver, gallbladder and pancreas. Basic concept on Food, Nutrition and Nutrients (Nutrition, Malnutrition and Health: Scope of Nutrition), Classification of Food, Classification of Nutrients.

UNIT 2: Nutrition**(10 Hrs)**

Dietary fibers (composition, properties and Minerals and trace elements (biochemical and physiological role, bioavailability and requirement with examples), Vitamines (Chemistry and biochemical role of fat soluble vitamins. A, D, E and K. Water soluble vitamins – B1, B2, B6 niacin and C, biochemical and physiological requirements, deficiency and excesses), Water (requirement, water balance), basic idea about community nutrition (objective, importance of various programmes). Minerals: inorganic elements. Macro, Micro and Trace elements – Ca, K, Na, P, Fe, Cu, fluorine, zinc and Iodine – classification, distribution in the body, functions, sources, requirements and deficiency

UNIT 3: Food preservation**(8 Hrs)**

Definition, objectives and principles of food preservation. Different methods of food preservation. Preserved Products: Jam, Jelly, Marmalade, Sauces, Pickles, Squashes, Syrups-types, composition and manufacture, selection, cost, storage, uses and nutritional aspects, Food Standards: ISI, Agmark, FPO, MPO, PFA, FSSAI.

UNIT 4: Foodborne Diseases**(10 Hrs)**

Microbial intoxication and infections: Sources of contamination of food, Types – foodborne infections, foodborne intoxications, symptoms and methods of control. Toxins in foods. Common and Recent Examples of Foodborne Outbreaks. Importance of sanitation and hygiene in relation to the spread of microorganisms. Relevance of microbiology standards for food safety. Rapid Methods of detection and recent advances.

UNIT 5: Microbial Growth in Food

(9 Hrs)

Bacterial growth curve and microbial growth in food. Factors affecting the growth of microorganisms in food, effect of environmental factors in the growth of microorganisms - pH, water activity, oxygen availability, temperature and others.

Microbial Food Spoilage: Sources of Microorganisms in Foods. Some important food spoilage microorganisms. Spoilage of specific food groups- Milk and dairy products, Meat, poultry and seafoods, Cereal and cereal products, Fruits and vegetables and Canned products.

CHM804DP: Chemistry of Food, Nutrition and Preservation

(60 Hrs)

Food Safety and Quality Control

Detection of adulterants in the following Foods: Milk, Edible Oil, Sugar, Spices, honey, Flours, Ghee, and Beverages (One method of detection for each food item).

1. To detect adulterants like dyes and large molecules in fats, oils, and ghee.
2. To detect the presence of adulterants like urea, formalin and detergent in milk.
3. To detect the adulteration of brick powder in chilli powder, Metanil yellow in turmeric.
4. To detect colouring agents in fruit juices and sweets.

List of experiments are suggestive. However, experiments may be added/revised as per the available facility.

Reference/suggested books

1. Roday S (2012): *Food Science and Nutrition*, 2nd Ed. Oxford University Press.
2. Mann J and Truswell S (2017) : *Essentials of Human Nutrition*, 5th Ed. Oxford University Press.
3. Wilson K and Walker J (2000): *Principles and Techniques of Practical Biochemistry*, 5th Ed. Oxford University Press.
4. Sadasivan S and Manikam K (2007): *Biochemical Methods*, 3rd Ed. New Age International (P) Ltd.
5. Subalakshmi, G and Udipi, SA (2006), *Food processing and preservation*, 1st Ed. New Age International (P) Ltd.
6. Srilakshmi B (2018): *Food Science*, 7th Colour Ed. New Age International (P) Ltd.
7. Swaminathan. M; *Advanced Text-Book on Food and Nutrition*, Volume I, 2nd edition. The Bangalore Printing and Publishing Co., LTD, Reprint 2015.
8. Sunetra Roday; *Food Science and Nutrition*, 2nd edition, Oxford University Press, 2013
9. Singhal, R.S. (1997) *Handbook of Indian foods of food quality and authenticity*. Cambridge Woodhead Publishing, New York..
10. Pulkit Mathur. *Text Book of Food Safety and Quality Control*.
11. Frazier William C and Westhoff, Dennis C. *Food Microbiology*, TMH, New Delhi,2004
18. Jay, James M. *Modern Food Microbiology*, CBS Publication, New Delhi, 2000

(Other books/reading materials may also be suggested).