COURSEWORK
FOR
DOCTOR OF PHILOSOPHY

(SYLLABUS)

Prepared by
Department of Chemistry
Under Faculty of Science
Gauhati University

PhD Course Work

Students admitted under Ph.D. program will have to undergo a compulsory course of 6 (six) months duration. The syllabus for Coursework in chemistry is designed by the DRC, Department of Chemistry, GU. At the end of the Coursework, the students shall have to appear in an examination to qualify for Provisional Registration. If an admitted scholar has completed the Coursework from GU (through an earlier admission) or from other recognized universities (in case of transfer), the Coursework may be treated as valid provided it has been approved by the concerned DRC. In case of Re-Admission, a scholar needs not do the Ph.D. Coursework again, if it has been successfully completed during the earlier registration. If, however, the Coursework was not completed successfully, the scholar would need to undergo the compulsory Coursework for 6 (six) months. In this case all other conditions will be in force.

Structure of the Ph.D. Coursework

i. *The Ph.D. Coursework will be of 6 months duration, and will generally start from August each year. Applicants admitted in the Spring Session will have to wait till August to begin the Coursework.*

ii. *There will be four papers in the Coursework. Each paper shall be of 6 credits, making it a total of 24 credits for the entire Coursework. Total marks in each paper shall be 100 (20 internal, 80 final examination).*

iii. *The papers will be as follows:*

- *Paper I: Research methodology (as per UGC recommendation)*
- *Paper II: Computer Application/Numerical analysis/Environmental issue or similar Course designed by the concerned department.*
- *Paper III & IV: On the relevant subject*

iv. *Course content for Paper I and II shall be framed by the concerned PG Department of\GU and will be compulsory. Paper III and IV shall be subject specific. For Paper III & IV, the concerned department may offer several courses, and the students shall exercise the option of choosing any two.*

v. *As the University has several recognized colleges/institutions outside the campus as*

centres for carrying out research activities, these sister institutes will exercise the option of framing their own course content for Paper III and IV, with the approval of the concerned DRC.

vi. *All subject-specific courses of the department and of the sister institutes will be subject to \approval of the DRC of the nodal departments.*

vii. *Sister institutes will conduct their courses in their own institutes, but the question paper setting, and evaluation process will be done by the concerned PG Department of the University.*

viii. *Upon completion of the course, students shall be required to sit for a written examination as per the syllabus designed by the concerned DRC in the concerned GU Department. Students will be declared to have successfully completed the course provided they secure the qualifying grades as indicated below.*

Qualifying Grades

- *Grade A : 90% and above*
- *Grade B : 70% and above but below 90%*
- *Grade C : 50% and above but below 70%*
- *Grade D : Less than 50%*

The minimum pass marks in each paper shall be 50%. ***Those securing below 50% (grade D) shall have to attend the course in the next session and complete the formalities with the qualifying grades.*** *Midterm and sessional test may be conducted as per the \convenience of the department and the sister institutes.*

ix. *The minimum attendance required to qualify for appearing in the* ***Final Coursework Examination is 75%.***

x. *Students admitted to the Ph.D. programme with an M.Phil. degree obtained from this University or from any other UGC recognized University or Institute will be exempted from undergoing the course work. The University shall make necessary arrangements for issuing these candidates an appropriate certificate to this effect after due verification.*

xi. Evaluation of Ph.D. Coursework will be conducted in the departments internally. Preparation of question papers and evaluation of scripts/dissertation/projects etc. will be done by the faculty members of the concerned department.

xii. The sister institutes recognized by GU will conduct sessional, internal assessment examinations etc., by themselves.

xiii. A prescribed format for certifying successful completion of the Ph.D. Coursework will be issued by the Academic Registrar to all the departments which will be used for declaration of the result.

xiv.The said certificate, after signature of the Head of the Department, will be forwarded to the Academic Registrar for counter-signature. A record of the certificates issued will be kept in the concerned department and in the office of the Academic Registrar for future reference.

xv. The Head of the concerned department will be required to submit the list of all successful Ph.D. candidates who have qualified in the Ph.D. Coursework examination along with the grades obtained to the Academic Registrar for record.

Completion of the Coursework

A scholar will have to successfully complete the Coursework within two years from the date of admission (i.e. within two academic sessions). A scholar may repeat a paper by applying to the concerned DRC and the recent marks obtained by him/her will replace the earlier marks. A scholar should successfully complete the Coursework within ***two consecutive years*** *of the admission. Failing to do so will result in cancellation of the admission. A scholar may attempt to clear a paper multiple times within these two years.*

Allotment of Research Supervisor

During the counseling of the Ph.D. Program, the DRC of the concerned department will pre-allot the scholar a supervisor. This allocation of the supervisor for a selected student shall be decided by the department in a formal manner depending on the number of students per faculty member, the available specialization among the supervisors, and the research interest of the student as indicated during the Counseling session. The final allotment of supervisor shall be done as per the pre-allotment after the successful completion of the Ph.D. Coursework.

Pre-Allotment

As the final allotment of a research supervisor to a scholar can only be completed after successful completion of the Ph.D. Coursework, a pre-allotment will be done by the concerned department for each scholar at the time of admission with the understanding that the scholar will be finally allotted to the pre-allotted supervisor after successful completion of the Ph.D. Coursework. This will help the scholar to initiate her/his research work during the Ph.D. Coursework. A research supervisor is expected to agree to supervise the pre-allotted scholar after the scholar's successful completion of the Ph.D. Coursework. However, if for some reason, the supervisor is unable to supervise the pre-allotted scholar, the supervisor will inform the respective DRC about this and the DRC will take a decision in this regard.

Programmes Specific Outcomes
1. Students will be able to create new knowledge in their chosen area of research, by enumerating the theoretical, conceptual and experimental insights of the disciplines. 2. Students will be able to justify the important objectives of their research topic, and generate or formulate appropriate hypotheses. 3. Students will develop skills to design methods for testing, record evidence/data, compare and analyse the data using statistical methods where appropriate, and critically evaluate the conclusions drawn from experimental data. 4. Students will be able solve problems and interpret their results systematically by identifying the crucial parts of a problem and formulating appropriate strategies. In the process, students will be able to critically examine the problem, and devise innovative solutions for complex problems. 5. Students will be able to provide appropriate primary literature, identify relevant topics, generate, process and retrieve scientific information related to the topic using utilise modern library search tools/databases (e.g. Scifinder, Web of Science, Science Direct, Cambridge Structural Database, etc.). 6. Drawing on the above, an environment will provided which encourages the student originality and creativity in their research

Paper I
CH 501: Research Methodology
Credits: 6 (90 h)

Objectives:

- To impart knowledge of formulation of research aims and objectives in an appropriate manner.
- To inculcate knowledge of scientific methodology in analyzing research data.
- To help the students in framing good research hypothesis.
- To acquaint the students with the online scientific databases like Scopus, Scifinder and Web of Science.
- To impart the students knowledge of good sampling techniques and record data in a proper way.
- To lead the students to do research in a right direction.
- To increase the ability of students interpretation skills.
- To lead the students to frame research thesis, journals, and research proposals for funding in a right way.

Course Outcomes:

Course Outcomes	Student Performance Indicators	Assessment Method
• Students will be able to formulate research aims & objectives in a scientific manner • Students will be able to generate good research hypothesis, devise appropriate experiments, collect and interpret the data to validate their experiments. • Students will be able to process the data using computer software, analyze the data and critically examine the hypothesis and the conclusions.	Presentation, class discussions, assigned works	Evaluation by concerned teacher by unit tests.

1. Basics of research methodology (15 h)

Foundations of Research: Meaning, Objectives, Motivation, Utility. Concept of theory, empiricism, deductive and inductive theory.Characteristics of scientific method -Understanding the language of research –Concept, Construct, Definition, Variable.Research Process.

Identification & Formulation–Research Question–Investigation Question–Measurement Issues –Hypothesis–Qualities of a good Hypothesis –Null hypothesis & Alternative Hypothesis. Hypothesis Testing –Logic & Importance.

Research Design: Concept and Importance in Research –Features of a good research design –Exploratory Research Design –concept, types and uses, Descriptive Research Designs –concept, types and uses. Experimental Design: Concept of Independent & Dependent variables.

2. Sampling and Data analysis (15 h)

Sampling: Concepts of Statistical Population, Sample, Sampling Frame, Sampling Error, Sample Size, Non Response. Characteristics of a good sample. Probability Sample –Simple Random Sample, Systematic Sample, Stratified Random Sample & Multi-stage sampling. Determining size of the sample – Practical considerations in sampling and sample size.

Data Analysis: Data Preparation –Univariate analysis (frequency tables, bar charts, pie charts, percentages), Bivariate analysis–Cross tabulations and Chi-square test including testing hypothesis of association.

Interpretation of Data and Paper Writing –Layout of a Research Paper, Journals in Chemical Science, Impact factor of Journals, When and where to publish.

Mean and standard deviation, Reliability of results (Q test), Confidence interval, Comparison of results – Students t test and F test.Correlation and Regression, Linear Regression.Non linear curve fitting.

3. Project writing (30 h)

Use of SCIFINDER, SCOPUS, WEB of Science, Online submission of manuscript etc. Each student has to submit a model project based on the format of a GOI funding agencies like UGC, CSIR, DST etc. Format for this purpose can be downloaded from the website of any of these organizations.

4. Seminar, Home assignment, Internal Assessment etc. (30 h)

Recommended Books:

1. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, Vogel's Textbook of Quantitative Chemical Analysis,6th Edition, Pearson, 2009.
2. F. J. Holler, S. R. Crouch Skoog and West's Fundamentals of Analytical Chemistry, 9th edition, **2014**
3. G. D. Christian, P. K. Dasgupta, K. A. Schug, Analytical Chemistry, 6th ed, **2014**.
4. A. K. Gupta Research Methodology Methods and Techniques, 2nd ed, **2014**.

Paper II

CH 502: Experimental Techniques

Credits: 6 (90 h)

Course Objective:

- To inculcate knowledge of theory, instrumentation and application of NMR, EPR, Mass and Fluorescence spectroscopy.
- To enable to understand theory, instrumentation and applications of HPLC and GC.
- To apprise the hand-on experience to run and maintain instruments/programs.

Course Outcome:

Course Outcome	Student Performance Indicators	Assessment Method
• Students will able to explain the theory, instrumentation and application of NMR, EPR, Mass spectrometry and Fluorescence spectroscopy. • Students will be able to explain how various chromatographic techniques can be applied to qualitative and quantitative analysis.	Presentation, class discussions, assigned works	Evaluation by unit test - I
• Explain hand-on experience to run and maintain instruments/programs	Descriptive write up	Evaluation by concerned teacher

1. Experimental Techniques (30 h)

- **Nuclear Magnetic Resonance spectroscopy (with special reference to ^{1}H-NMR):** Instrumentation, Application in Chemical Analysis - Chemical shift, Spin spin coupling. Basic idea of two dimensional and three dimensional NMR, INDOR. **(10 h)**
- **Electron paramagnetic resonance spectroscopy:** Instrumentation and Applications. **(4h)**
- **Fluorescence spectroscopy**: Instrumentation, Jablonski diagram, PET, ICT, FRET mechanisms. **(5h)**
- **High Performance Liquid Chromatography (HPLC)**: Different types of HPLC, Instrumentation, Applications. Advantages of HPLC. **(4h)**
- **Gas Chromatography:** Theory, Instrumentation, Types of detectors, injectors, and column, Applications. **(3h)**

- **Mass spectroscopy:** Instrumentation, Applications – Molecular ion, Metastable ion, Fragmentation processes. Interpretation of mass spectra. **(4h)**

2. Instrument Maintenance (30 h)

Students shall be apprised of hand-on experience to run and maintain the following instruments/programs – FT-IR, NIR, NMR, GCMS, HPLC, AAS, GC, PXRD, Thermal Analyzer and Electrochemical Analyser or any other instruments available in the institute where the course work to be done. The students shall have to write a report on the Instrumentation and Maintenance of a particular instrument. The report should be of 6 pages (Print on both side, staple only) / A4 size paper / line spacing 1.5 / font size 12 / Times New Roman.)

3. Seminar, Home assignment, Internal Assessment etc. (30 h)

Recommended Books:

1. B. Valuer, Molecular Fluorescence, Wiley-VCH, 2002
2. C.N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Edition, Tata McGraw Hill, 1994.
3. 2. D.L. Pavia, G. M. Lampman, G. S. Kriz, Introduction to Spectroscopy, 4th Ed., Brooks/Cole Cengage Learning, 2015.
4. 3. R.S. Drago, Physical Methods in Chemistry, Saunders, Thomson Learning, 1977.
5. 4. R.M Silverstein, F. X. Webster, D. J. Kiemle, D. L. Bryce, Spectrometric Identifications of Organic Compounds, 8th Edition, Wiley India Pvt. Ltd, 2015.
6. 5. W. Kemp, Organic Spectroscopy, 3rd Edition, Palgrave Macmillan, 2011.

Reference Books:

1. 1. L. D. Field, S. Sternhell, J. R. Kalman, Organic Structures from Spectra, 5th Edition, John Wiley & Sons. 2013.
2. 2. D.W.H. Rankin, N. Mitzel, C. Morrison, Structural Methods in Molecular Inorganic Chemistry, Wiley, 2013.
3. Principles of Fluorescence Spectroscopy, J R Lakowicz, Springer, 3rdEdn, 2006

Students will choose any two courses as paper-III and paper-IV out of the courses CH 503, CH 504, CH 505, CH 506 and CH 507.

CH 503: Computational Chemistry
Credits: 6 (90 h)

Objective:

- To introduce the students to programming languages such as Fortran.
- To make the students familiar with the modern ab initio approaches to the calculation of the electronic structure and properties of molecules other than a superficial level.

Course Outcomes:

Course Outcomes	Student Performance Indicators	Assessment Method
• Students will get insight into the nature and validity of a variety of approximate formalisms. • Ability to improve the problem solving skills.	Presentation, class discussions, assigned works	Evaluation by concerned teacher by unit tests.

1. Computers in Chemistry (30 h)

Getting started (Program Organization, Data types and integer constants, variables and simple input/output, selected library functions), Decision based control structures (Unconditional transfer, Conditional statements and constructs, Relational operators, Logical operators, The Block If Structure), Loops (Counted loops), Subscripted variables and Arrays, Examples.

2. Computational Techniques (30 h)

The Hartree-Fock Hamiltonian, Closed-Shell Hartree-Fock: Restricted Spin Orbitals, Introduction of a Basis: The Roothaan Equations, The Charge Density, Expression for the Fock Matrix, Orthogonalization of the Basis, The SCF Procedure, Expectation Values and Population Analysis, Model Calculations on $H_2$and HeH^+, Polyatomic Basis Sets, Contracted Gaussian Functions, Minimal Basis Sets: and HeH^+, Polyatomic Basis Sets, Contracted Gaussian Functions, Minimal Basis Sets: STO-3G, Double Zeta Basis Sets: 4-31G, Polarized Basis Sets: 6-31G* and 6-31 G**.

3. Seminar, Home assignment, Internal Assessment etc. (30 h)

Recommended Books:

1. A. Szaboo, N. S. Ostlund, Modern Quantum Chemistry, 1st Edition (Revised), **2015**.
2. David J. Tannor, Introduction to Quantum Mechanics (A time-dependent perspectives), University science Books , **2007**.
3. Ira N. Levine, Quantum Chemistry , 7th Edition, PHI Learning Pvt. Ltd., **2014**.

CH 504: Analytical Techniques

Credits: 6 (90 h)

Objectives:

- To make the students familiar with the principle, instrumentations based on
  - microscopic techniques such AFM, SEM and TEM
  - Thermo analytical techniques such as TGA, DTA and DSC.
  - X- ray diffraction techniques such as Single Crystal XRD and Powder XRD
  - Electrochemical techniques such as Cyclic Voltammetry, Chronocloumetry etc.
  - Atomic absorption and emission techniques AAS and OES, respectively.
- To make them familiar with the data supplied by those instruments.
- To develop their analytical skills.

Course Outcomes:

Course Outcomes	Student Performance Indicators	Assessment Method
• Students will understand the underlying principle of the techniques and the design of instruments. • Students will be able to know applications instruments as the analytical tools in various fields during research work. • Students will have ability to analyze the data supplied by those instruments. • Students will be able to identify the type of techniques required in a particular analysis.	Presentation, class discussions, assigned works	Evaluation by concerned teacher by unit tests.

1. Analytical Techniques-Microscopy (15 h)

Atomic Force microscopy: Principle, Instrumentation, and Applications

SEM and TEM: Principle, Instrumentation, sampling and Applications

Thermal Analysis: Basic principle of TGA, DTA, DSC Instrumentation, Applications.

2. Analytical Techniques- X Ray diffraction (15 h)

(i) Single crystal techniques Principle of X-ray diffraction, crystal structure analysis.

(ii) Powder XRD: Principle and applications

3. Analytical Techniques-: Electrochemical techniques (15 h)

Types of electrodes, Basic principle and applications of Cyclic Voltammetry, Square Wave Voltammetry, Chronocoulometry.

4. Analytical Techniques- Atomic spectroscopy (15 h)

Atomic absorption spectroscopy: Theory, Instrumentation, and Applications

Optical emission spectroscopy: Theory, Instrumentation, and Applications

5. Seminar, Home assignment, Internal Assessment etc. (30 h)

Books Recommended:

5. D. B. Murphy, M. W. Davidson, Fundamentals of Light Microscopy and Electronic Imaging, Wiley, 2013.
6. D. B. Williams, C. B. Carter, Transmission Electron Microscopy A Textbook for Materials Science, Springer, 2009.
7. P. Eaton, P. West, Atomic Force Microscopy, Oxford University Press, 2010.
8. B. D. Cullity, Elements of X-Ray Diffraction, 3rd Edition, Addison Wesley Publishing Company, Inc., 2004.
9. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, Vogel's Textbook of Quantitative Chemical Analysis,6th Edition, Pearson, 2009.
10. A. R. West, Solid State Chemistry and Application, Wiley Student Edition, 1998.

CH 505: Chemistry of Advanced Materials
Credits: 6 (90 h)

Course Objective:

- To introduce students to the interdisciplinary field of nanoscience, underlying principles of physics, synthetic strategies, characterization of materials and technological impact.

Course Outcomes:

Course Outcomes	Student Performance Indicators	Assessment Method
• Students will be able to describe the different types of materials, including nanomaterials, their properties, characterization and applications. • Students will be able to compare different qualitative and quantitative techniques for materials characterization, and enumerate their how structure-activity relationships.	Presentation, class discussions, assigned works	Evaluation by concerned teacher by unit tests.

1. Nanoscience and Nanotechnology (30 h)

Introduction to Nano (2 h)

The Science behind Nanotechnology, History of Nanoscience , Definition of Nanometer, Nanomaterial, and Nanotechnology , Classification of Nanomaterial , Nanotechnology from the Perspective of Medieval Period , Nanomaterials in nature.

Different Types of Nanostructures (3h)

Shapes and Structures of Nanomaterial, Quantum Dots , Semiconductor Nanoparticles, Carbon Nanotechnology, Nanolithography

Quantum Mechanics of Low-Dimensional Systems (5 h)

Energy Considerations: Bound States and Density of States, Quantum Confinement , Super lattices, Band Offsets , Quantum Transport in Nano clusters / Quantum Dots.

Synthesis of Nanomaterial and Device Fabrication (5 h)

Synthesis of Bulk Polycrystalline Samples , Growth of Single Crystals , Synthesis Techniques for the Preparation of Nanoparticles , Requirements for Realizing Semiconductor Nanostructures , Specialized Growth Techniques for Nanostructures, Electrostatic-Induced Growth , Thermally Annealed Quantum Wells , Semiconductor Nano crystals

Nanostructured Thin Films and Nanocomposites (3h)

Micro- and Nano scale Thin-Film Fabrication Techniques, Optical, Electrical, and Magnetic Properties of Nanostructured, Thin Films , Nano composites, Physical and Optical Properties, Metal/Dielectric-Organic Nano composites

Nanoscale Characterization Techniques (8 h)

Diffraction and Scherrer Method , Scanning Electron Microscopy, Transmission Electron Microscopy, Stoichiometry Study by Energy-Dispersive X-Ray Analysis, Scanning Probe Microscopy, Atomic Force Microscopy , Piezoresponse Microscopy, X-Ray Photoelectron Spectroscopy, XANES and XAFS, Angle-Resolved Photoemission Spectroscopy , Diffuse Reflectance Spectra, Photoluminescence Spectra, Raman Spectroscopy, DC Magnetization, Electrical Resistivity Measurements, Theory of Linear Four-Probe Method,

Recent Advances in Nanotechnology (2 h)

Designing Molecules for Nanoelectronics, Advances of Nanotechnology in Materials Science

New Trends in Nanoscience and Applications of Nanotechnology (2 h)

Applications in Material Science, Applications in Biology and Medicine, Applications in Surface Science, Applications in Energy and Environment , Applications of Nanostructured Thin Films, Applications of Quantum Dots, , Applications of Magnetic Nanoparticles.

2. Polymers: **(30 h)**

Synthesis of polymers – Addition polymerization, Condensation polymerization, Ring opening polymerization, Electrochemical polymerization and their Examples. Structure property relationship.

3. Seminar, Home assignment, Internal Assessment etc. **(30 h)**

Recommended Books

1. M.S. Ramachandra Rao, S. Singh, Nanoscience and Nanotechnology: Fundamentals of Frontiers, Wiley India. 2016.
2. G. Schmid, Nanoparticles: From Theory to Application, Wiley-VCH Verlag, 2005.
3. G. Cao, Y.Wang, Nanostructures and Nanomaterials Synthesis, Properties, and Applications 2nd Ed. , World Scientific. 2004.
4. G. Odian, Principles of Polymerization, 4th Edition, Willy Student Edition, 2004.
5. V. R. Gowarikar, N. V. Viwanathan, J. Sreedhar, Polymer Science, 1st Edition, New age International Publishers, 1986.

CH 506: Modern Methods in Organic synthesis

Credits: 6 (90 h)

Course objective:

- To understand the principles of organic synthesis
- To give a glimpse of recent trends in the development of new strategies in organic synthesis.

Course Outcomes:

Course Outcomes	Student Performance Indicators	Assessment Method
• Students will be able to explain the reactivity patterns of various types of nucleophilic and electrophilic organic reagents/molecules and their application in synthesis. • Students will be able to devise and rationalize new synthetic routes for organic compounds by applying appropriate disconnection and functional group interconversion strategies.	Presentation, class discussions, assigned works	Evaluation by concerned teacher by unit tests.

1. Retrosynthetic Analysis (10 h)

Basic principles and terminology of retrosynthesis, synthesis of aromatic compounds, one group and two group C-X disconnections, one group C-C and two group C-C disconnections, amine and alkene synthesis, important strategies of retrosynthesis, functional group transposition, important functional group interconversions.

2. Protecting Groups (4 h)

Protection and deprotection of hydroxy, carboxyl, carbonyl, carboxy amino groups and carbon-carbon multiple bonds; chemo- and regioselective protection and deprotection; illustration of protection and deprotection in peptide and carbohydrate synthesis.

3. Modern Synthetic Methods (13 h)

a) Formation of carbon-carbon bonds: As in the present syllabus (including aspects of organocatalysis)

b) Formation of carbon-heteroatom bonds: New methods for the construction of C-N, C-O, C-S and C-X bonds (including aspects related to the activation of C-H bonds)

4. **Construction of Ring Systems (20 h)**

a) Different approaches towards the synthesis of three, four, five and six-membered rings; photochemical approaches for the synthesis of four membered rings, oxetanes and cyclobutanes. Diels-Alder reaction (inter- and intra-molecular), ketene cycloaddition (inter- and intramolecular), Pauson-Khand reaction, Bergman cyclization; Nazarov cyclization, cation-olefin cyclization and radical-olefin cyclization,

b) Heterocyclic rings: Furan, pyrrole or thiophene (Knorr synthesis, Paal-Knorr synthesis), Pyrazoles, isoxazoles and pyrimidines (Claisen synthesis, Fischer synthesis), Pyridine (Hantzsch pyridine synthesis, Hofmann-Loffler-Freytag reaction), Quinolines & Isoquinolines (Conrad-Limpach reaction, Bischler-Napieralski reaction, Combes reaction, Pictet-Gams synthesis, Skraup/Doebner-von Miller reaction)

c) Inter-conversion of ring systems (contraction and expansion); construction of macrocyclic rings, ring closing metathesis.

5. Synthesis of Complex Molecules (13 h)

Total synthesis of Terpenes and alkaloids (e.g. Reserpine and morphine).

6. Seminar, Home assignment, Internal Assessment etc. (30 h)

Recommended Books:

1. S. Warren, Organic Synthesis:The Disconnection Approach, Wiley India Pvt. Ltd. 2004.
2. F. A. Cary, R. I. Sundberg, Advanced Organic Chemistry, Part A and B, 5th Edition, Springer, 2009.
3. M. B. Smith, Organic Synthesis, 2nd Edition, McGraw Hill Higher Education, 2005.
4. W. Carruthers , I. Coldham, Modern methods of Organic Synthesis, 1st South Asian Edition Cambridge University Press, 2005.

CH 507: Environmental Chemistry
Credits: 6 (90 h)

Course objective:

- To introduce students with the concerns/prospective about environment, Kyoto Protocol.
- To make students understand different aspects of environmental chemistry, chemistry of atmosphere, soil and water.

Course Outcomes:

Course Outcomes	Student Performance Indicators	Assessment Method
• Students will be able to demonstrate an understanding of environmental chemistry, viz. air, water and soil chemistry and identify the relationships between atmosphere, solar radiation and ozone formation.	Presentation, class discussions, assigned works	Evaluation by concerned teacher by unit tests.

1. Environmental Chemistry: An Introduction (8 h)

Environment & environmental chemistry, importance of the study of them. Environmental composition, chemical processes, anthropogenic effect and environmental pollution. Environment - global concern and prospective, Kyoto Protocol.

2. **Chemistry of the atmosphere (20 h)**

Atmosphere & atmospheric chemistry, importance of the atmosphere, solar influence on the chemical composition of atmosphere, photochemical and chemical reactions in atmosphere, ions and radicals in the atmosphere.

Solar radiation and plant and animal life, stratospheric ozone, ozone formation reactions, ozone destruction reactions, Montreal Protocol, antarctic and arctic ozone hole.

Inorganic air pollutants, control of particulate emissions, carbon oxides & global warming, sulpher dioxide & sulpher cycle, nitrogen oxides in atmosphere, acid rains.

Organic air pollutants : examples, smog, types of smog, photochemical smog, smog forming reactions of organic compounds mechanism of smog formation effects of smog.

3. **Soil Environmental Chemistry (16 h)**

Soil and soil formation- physical weathering and chemical weathering, soil organic matter, chemical properties of soil- cation exchange cap., pH, macro and micronutrients, leachate formation, Environmental issues associated with soils- nutrient leaching, acidification, salinity and alkalinity, metal contamination.

4. **Environmental Chemistry of Water (16 h)**

Distribution of chemical species in water, phosphorus and sulphur systems , acidity and alkalinity, chelation in water, humic matter in water-origin, formation and environmental role.

Partitioning of small organic molecules between water and soil or sediment, octanol – water partition coefficient.

Water pollution, inorganic pollutants, organic pollutants, eutrophication, radio-nuclides in aquatic environment.

5. Seminar, Home assignment, Internal Assessment etc. (30 h)

Books Recommended:

1. S.E. Manahan, Fundamentals of Environmental Chemistry, Lewis Publishers
2. G. W. Vanloon, S. J. Duffy, Environmental Chemistry, 3rd Edison, Oxford University Press