Comilla University

Department of Chemistry

Master of Science (M.S.) Program in Chemistry

Academic Session: 2023-24, 2024-25 and 2025-26

According to Bangladesh National Qualification Framework (BNQF), a Master's degree involves significantly specialized knowledge in a specific area or discipline, which is current, and at the forefront of knowledge. Critical, systematic and creative thinking skills, research practice or advance professional practice, interpersonal skills with leadership and managerial skills are critical competencies particularly within multicultural or transnational work and learning environments. The learners should be able to inform or advise, improve innovations, and share views on contemporary and new issues in related fields or professional practice to relevant audience. While the above competencies are expected as outcomes of a Master's study, the differences generally are in the output, in the form of substantial thesis, dissertation, long case study, project report, new technical solutions/practices and art forms. Master of Science (M.S.) program in the chemistry department will be offered in three modes:

(i) Master's by coursework
(ii) Master's by mixed-mode and
(iii) Master's by research.

Master of Science (Coursework) Program

Master's program will be modularized which can constitute a particular area of specialization. Master of Science (Coursework) Degree will be awarded in one of the three branches:

(i) M.S. (Coursework) in Physical Chemistry
(ii) M.S. (Coursework) in Inorganic & Analytical Chemistry
(iii) M.S. (Coursework) in Organic Chemistry

Eligibility for Admission: A student with B.Sc. (Hons.) degree in Chemistry will be eligible for admission in M.S. (Taught) program at the Department of Chemistry of Comilla University.

Program Description: A Master's by Coursework involves taught courses to a minimum of 40 credits. The duration at this level will be one year of full-time study consisting with two semesters. A student will have to choose one offered branch out of three branches of chemistry. Brach selection of students will be based on their academic merits to their undergraduate degree program. He/she must complete 40 credits to obtain his/her M.S. (Coursework) in Physical/Organic/Inorganic & Analytical chemistry. For that, he/she will have to complete at least three 3.0 credits theory courses (common courses) in the specialized field and four 4.0 credits theory courses in related branches namely Physical, Organic and Inorganic & Analytical Chemistry, three 3.0 credits laboratory courses, one 2.0 credits oral and one 4.0 credits General Education (GEd) course offered by the department. Activities of the programs will be followed according to the related academic rules and regulations of the Comilla University

Master of Science (Mixed-Mode) Program

Master's program will be modularized which can constitute a particular area of specialization. Master of Science (Mixed-Mode) Degree will be awarded in one of the three branches:

(i) M.S. (Mixed-Mode) in Physical Chemistry
(ii) M.S. (Mixed-Mode) in Inorganic & Analytical Chemistry
(iii) M.S. (Mixed-Mode) in Organic Chemistry

Eligibility for Admission: Based on the B.Sc. (Hons.) results, students having minimum CGPA of 3.5 may apply for admission.

Program Description: A Mixed-mode Master's has a minimum 20 credits taught component and a research component involving a thesis/dissertation. The duration of the program will be one and half (1.5) year consisting with three semesters. A student will have to choose one offered branch out of three branches of chemistry. Brach selection of students will be based on their academic merits to their undergraduate degree program. He/she must complete 47 credits to obtain his/her M.S. (Mixed-Mode) in Physical/Organic/Inorganic & Analytical chemistry. For that, he/she will have to complete at least three 3.0 credits theory courses (common courses) in the specialized field and four 4.0 credits theory courses in related branches namely Physical, Organic and Inorganic & Analytical Chemistry, has to complete research proposal preparation and presentation which is not credit bearing, 2.0 credits oral presentation and one 4.0 credits General Education (GEd) course offered by the department. The students will register 16.0 credits thesis (Dissertation) in third semester after completion of 2nd semester. Activities of the programs will be followed according to the related academic rules and regulations of the Comilla University.

Comilla University
Department of Chemistry
Master of Science (Coursework) in Chemistry
OBE Curriculum

Part A: Introduction

1. **Title of the Academic Program:**
   Master of Science (Coursework) in Physical/Inorganic & Analytical/Organic Chemistry
2. **Name of the University:** Comilla University
3. **Vision of the University:**
   Vision:
   - ***Centre of Knowledge for enlightened, creative, and competent human resource***
4. **Mission of the University:**
   Mission: To meet its vision, Comilla University sets its mission to-
   1. *Offer a full range of degree programs covering bachelor, masters, doctoral and professional levels to the wide variety of students across the world to acquire existing knowledge and create new;*
   2. *Ensure nationally competitive and internationally acknowledged opportunities to provide the best teaching-learning environment through continually improved curriculum;*
   3. *Enhance labs, resources and other infrastructures to usher a culture of creation and innovation amongst faculty members and students;*
   4. *Develop high levels of managerial and practical skills and leadership among students through programs, faculty-student interaction, university-industry collaboration, co-curricular and extracurricular activities, and social engagement;*
   5. *Nurture an environment, giving space to free thoughts and expressions, wisdom and creation and producing inertly enlightened, philosophically critical, and ethically sound humans to bring into positive change for entire humanity*

   Core Value: Comilla University is committed to nurture
   Integrity: The highest level of sincerity and moral, ethical, and professional conducts
   Intellectual Curiosity: Insatiable thirst for knowledge to expand intellectual horizon, go beyond the comfort zone, and bring back wonders for development.
5. **Name of the Program Offering Entity: Department of Chemistry**

6. **Vision of the Program Offering Entity:**
   - To be a leading academic department in the field of Chemistry among the national universities to fulfill the industrial and social needs.
7. **Mission of the Program Offering Entity**
   - To produce highly competent and motivated post-graduates who are fit for industry, teaching, research, and community making a significant contribution to sustainable development and well-being of the mankind.
   - Mission of the program:
     - Learning opportunities for acquiring a broad foundation of knowledge on chemical science (Physical, Inorganic & Analytical and Organic Chemistry)
     - Skill for life-long learning and professional development.
8. **Objectives of the Program Offering Entity:**
   - Objectives of M.S. (Coursework) in Physical Chemistry are to produce graduates who
     1. Have an in-depth knowledge in advanced area of physical chemistry.
     2. Have high intellectual skills and competence in solving problems in chemistry and related areas.
     3. Are responsive and adaptive to changing situation and with high design to continuously acquire new know knowledge and skills.
     4. Can independently design, perform and manage the project using acceptable methods.
     5. Can articulate ideas and finding through oral presentation and scientific writing.
9. **Name of the Degree:** M.S. (Coursework) in Physical/Organic/Inorganic & Analytical Chemistry
10. **Description of the program:**

A Master's by Coursework involves taught courses to a minimum of 40 credits. The duration at this level will be one year of full-time study consisting with two semesters. A student will have to choose one offered branch out of three branches of chemistry. Brach selection of students will be based on their academic merits to their undergraduate degree program. He/she must complete 40 credits to obtain his/her M.S. (Coursework) in Physical/Organic/Inorganic & Analytical chemistry. For that, he/she will have to complete at least three 3.0 credits theory courses (common courses) in the specialized field and four 4.0 credits theory courses in related branches namely Physical, Organic and Inorganic & Analytical Chemistry, three 3.0 credits laboratory courses, one 2.0 credits oral and one 4.0 credits General Education (GEd) course offered by the department. Activities of the programs will be followed according to the related academic rules and regulations of the Comilla University

11. **Post Graduate Attributes (based on need assessment)**

(a) In-depth knowledge and skills in the field of study

- In-depth knowledge Have in-depth knowledge on Physical/Organic/Inorganic & Analytical Chemistry.
- An appreciation of the link between theory and practice

(b) Effective communication

- Reach a high level of achievement in writing, project activities, problem-solving and communication;
- The ability to engage effectively and appropriately with information and communication technologies.
- Have a set of flexible and transferable skills for different types of employment

(c) ***Independence and creativity***:

- Have the ability to demonstrate advanced independent critical enquiry, analysis and reflection
- Have a strong sense of intellectual integrity and the ethics;

(d) Critical Judgment

- Be critical and creative thinkers, with an aptitude for continued self-directed learning;
- Be able to examine critically, synthesize and evaluate knowledge across a broad range of disciplines;

(e) Ethical and Social Responsibility

- A knowledge and respect of ethics and ethical standards in relation to a major area of study
- Be able to initiate and implement constructive change in their communities, including professions and workplaces.
- The ability to work effectively and sensitivity across all areas of society.

12. Program Educational Objectives (PEOs)

PE01	Graduate shall have expertise in a core subject area-Physical, Inorganic & Analytical and Organic Chemistry success Fundamental Knowledge.
PE02	Graduate shall have a working knowledge on various areas of chemical science and allied subject.
PE03	Graduate shall have the basic skill for Usage state of art technology used for chemical science.
PE04	Graduate will engage in professional activities with ethical practice in chemical science to enhance their own stature and simultaneously contribute to the profession and society at large.

13. Program Learning Outcomes (PLOs)

PLO1	***Advanced Knowledge***: Ability to acquire and apply knowledge and understanding of the chemical principles.
PLO2	***Chemical Methods***: Ability to demonstrate thorough knowledge, understanding and skills in application of scientific methodology to undertake and report on experimental investigation.
PLO3	***Scientific and Critical Thinking Approach***: Possess high awareness of major issues and development of chemical research and competent in initiating, developing, and pursuing scientific research.
PLO4	***Communication Skills***: Ability to present technical, scientific and chemical information and arguments clearly and correctly, in written and oral presentation.
PLO5	**Social Skills and Responsibility**: Ability to portray good interpersonal skills with high ability to work collaboratively as part of a team undertaking a range of different team roles.
PLO6	***Professionalism and Ethics***: Ability to act with integrity and good ethics in their profession and their obligation to society.
PLO7	***Lifelong Learning & Information Management***: Ability to seek new knowledge, skills and manage relevant information from various sources.
PLO8	***Entrepreneurship and Leadership Skills***: Ability to demonstrate knowledge and skills in analyzing and identifying business opportunities and to demonstrate leadership, to take action and to get others involved.

14. Mapping mission of the university with PEOs

PEOs	Mission-1	Mission-2	Mission-3	Mission-4	Mission-5
PEO1	2	1	1	-	-
PEO2	-	-	-	3	-
PEO3	-	-	-	-	3
PEO4	-	-	-	-	3

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low)

15. Mapping PLO with PEOs

PEOs	PEO-1	PEO-2	PEO-3	PEO-4
PLO1	1	-	-	-
PLO2	2	-	2	-
PLO3	1	-	-	-
PLO4	3	-	-	-
PLO5	1	-	-	-
PLO6	-	2	-	-
PLO7	-	-	-	3
PLO8	-	3	-	-

Comilla University

Department of Chemistry

Master of Science (Mixed-Mode) in Chemistry

OBE Curriculum

Part A: Introduction

1. **Title of the Academic Program:**
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2. **Name of the University:**
   Comilla University
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   4. ***Develop high levels of managerial and practical skills and leadership among students through programs, faculty-student interaction, university-industry collaboration, co-curricular and extracurricular activities, and social engagement;***
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7. **Mission of the Program Offering Entity**
   - To produce highly competent and motivated graduates who are fit for industry, teaching, research and community making a significant contribution to sustainable development and well-being of the mankind.
   - Mission of the program:
     - Learning opportunities for acquiring a broad foundation of knowledge on chemical science (Physical, Inorganic & Analytical and Organic Chemistry)
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8. **Objectives of the Program Offering Entity:**
   - Objectives of M.S. (Mixed-Mode) in Physical Chemistry are to produce graduates who
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     4. Can independently design, perform and manage chemical research using acceptable methods.
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9. **Name of the Degree:** M.S. (Mixed-Mode) in Physical/Organic/Inorganic & Analytical Chemistry
10. **Description of the program:**

A Mixed-mode Master's has a minimum 20 credits taught component and a research component involving a thesis/dissertation. The duration of the program will be one and half (1.5) year consisting with three semesters. A student will have to choose one offered branch out of three branches of chemistry. Brach selection of students will be based on their academic merits to their undergraduate degree program. He/she must complete 47 credits to obtain his/her M.S. (Mixed-Mode) in Physical/Inorganic & Analytical chemistry/Organic Chemistry Branches. For that, he/she will have to complete at least three 3.0 credits theory courses (common courses) in the specialized field and four 4.0 credits theory courses in related branches namely Physical, Organic and Inorganic & Analytical Chemistry, one research proposal preparation and presentation which is not credit bearing, one 2.0 credits oral presentation and one 4.0 credits General Education (GEd) course offered by the department. The students will register 16.0 credits thesis(Dissertation) after completion of 2nd semester of the program. Activities of the programs will be followed according to the related academic rules and regulations of the Comilla University.

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(b) Effective communication

- Reach a high level of achievement in writing, project activities, problem-solving and communication;

- The ability to engage effectively and appropriately with information and communication technologies.
- Have a set of flexible and transferable skills for different types of employment.

In addition,

The ability to clearly communicate the results of research in a format suitable for publication in the field of study; and

The ability to explain clearly and defend research findings through oral presentations, including at conference/symposium standard

(c) Independence and creativity:

- Have the ability to demonstrate advanced independent critical enquiry, analysis and reflection
- Have a strong sense of intellectual integrity and the ethics;

In addition,

The ability to undertake supervised research, including the design and conduct of investigations, in a systematic, critical and evidence-based manner, as an individual or as a member of a team;

The ability to apply and contribute skills and knowledge creativity and innovatively in a research environment

(d) Critical Judgment

- Be critical and creative thinkers, with an aptitude for continued self-directed learning;
- Be able to examine critically, synthesize and evaluate knowledge across a broad range of disciplines;

In addition,

The ability to identify problems appropriate for research and to pose research questions

The ability to make a critical analysis of the literature

The ability to analyze research data and to draw logical conclusions

(e) Ethical and Social Responsibility

- A knowledge and respect of ethics and ethical standards in relation to a major area of study
- Be able to initiate and implement constructive change in their communities, including professions and workplaces.
- The ability to work effectively and sensitivity across all areas of society.

In addition,

The ability to apply ethical standards in research in the field of study and to maintain the social and ethical responsibilities

12. Program Educational Objectives (PEOs)

PE01	Graduate shall have expertise in a core subject area-Physical, Inorganic & Analytical and Organic Chemistry success Fundamental Knowledge
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14. Mapping mission of the university with PEOs

PEOs	Mission-1	Mission-2	Mission-3	Mission-4	Mission-5
PEO1	2	1	1	-	-
PEO2	-	-	-	3	-
PEO3	-	-	-	-	3
PEO4	-	-	-	-	3

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

15. Mapping PLO with PEOs

PEOs	**PEO-1**	**PEO-2**	**PEO-3**	**PEO-4**
PLO1	1	-	-	-
PLO2	2	-	2	-
PLO3	1	-	-	-
PLO4	3	-	-	-
PLO5	1	-	-	-
PLO6	-	2	-	-
PLO7	-	-	-	3
PLO8	-	3	-	-

Comilla University
Department of Chemistry
Academic Session: 2023-24, 2024-25 and 2025-26
Semester Wise Course Distribution
Name of the Program: Master's in Physical Chemistry by Course Work
M.S. (Taught-Mode) in Physical/Inorganic and Analytical/Organic Chemistry Branch

M.S. 1st Semester (Taught-Mode)			
Course Code	**Course Title**	**Credits**	**Contact Hours/Week**
Common Specialized Courses			
0531-14-511	Computational Chemistry	3.0	03
0531-14-512	Instrumental Methods of Analysis	3.0	03
Physical Chemistry Branch* (*Any two theory courses will be offered***)**			
0531-14-513PC	Advanced Tools & Techniques in Physical Chemistry	4.0	04
0531-14-514PC	Advanced Chemical Kinetics	4.0	04
0531-14-515PC	Advanced Biophysical Chemistry	4.0	04
Inorganic and Analytical Chemistry Branch* (*Any two theory courses will be offered***)**			
0531-14-513IA	Advanced Inorganic and Material Chemistry	4.0	04
0531-14-514IA	Inorganic Spectroscopic Methods	4.0	04
0531-14-515IA	Advanced Analytical Chemistry	4.0	04
Organic Chemistry Branch* (*Any two theory courses will be offered***)**			
0531-14-513OC	Green and Sustainable Chemistry	4.0	04
0531-14-514OC	Advanced Organic Reactions and Stereochemistry	4.0	04
0531-14-515OC	Clinical Chemistry	4.0	04
Laboratory Course			
0531-14-516L	Advanced Experiments in Physical Chemistry	3.0	6.0
Total Credits: 17.0			

M.S. 2nd Semester (Taught-Mode)			
Course Code	**Course Title**	**Credits**	**Contact Hours/Week**
Common Specialized Course			
0531-14-521	Advanced Spectroscopy and Chromatography	3.0	03
Common General Education Course			
0119-14-522	Chemical Education and Pedagogy	4.0	04
Physical Chemistry Branch Courses* (*Any two theory courses will be offered***)**			
0531-14-523PC	Electroanalytical Chemistry	4.0	04
0531-14-524PC	Advanced Photochemistry	4.0	04
0531-14-525PC	Advanced Electrochemistry	4.0	04
Inorganic and Analytical Chemistry Branch Courses* (*Any two theory courses will be offered***)**			
0531-14-523IA	Advanced Bioinorganic Chemistry	4.0	04
0531-14-524IA	Computational Inorganic and Bioinorganic Chemistry	4.0	04

0531-14-525IA	Aquatic Chemistry and Biotic Environment	4.0	04
Organic Chemistry Branch Courses* (*Any two theory courses will be offered***)**			
0531-14-523OC	Advanced Methods in Organic Chemistry	4.0	04
0531-14-524OC	Chemistry of Food and Nutrition	4.0	04
Laboratory Courses			
0531-14-526L	Advanced Inorganic Laboratory: Synthesis, Structure, and Chemical Analysis	3.0	06
0531-14-527L	Advanced Organic Laboratory	3.0	06
0531-14-501	Oral Presentation	2.0	-
Total Credit: 23.0			

Note: *Students have to complete two 4.0 credits theory courses offered by the branch of chemistry in each semester.

Comilla University

Department of Chemistry

Academic Session: 2023-24, 2024-25 and 2025-26

Semester Wise Course Distribution

Name of the Program: Master's in Chemistry by Mixed Mode

M.S. (Mixed-Mode) in Physical/Inorganic and Analytical Chemistry Branch

M.S. 1st Semester (Mixed-Mode)			
Course Code	**Course Title**	**Credits**	**Contact Hours/Week**
Common Specialized Courses			
0531-14-511	Advanced Computational Chemistry	3.0	03
0531-14-512	Instrumental Methods of Analysis	3.0	03
Physical Chemistry Branch Courses* (*Any two theory courses will be offered***)**			
0531-14-513PC	Advanced Tools & Techniques in Physical Chemistry	4.0	04
0531-14-514PC	Advanced Chemical Kinetics	4.0	04
0531-14-515PC	Advanced Biophysical Chemistry	4.0	04
Inorganic and Analytical Chemistry Branch Courses* (*Any two theory courses will be offered***)**			
0531-14-513IA	Advanced Inorganic and Material Chemistry	4.0	04
0531-14-514IA	Inorganic Spectroscopic Methods	4.0	04
0531-14-515IA	Advanced Analytical Chemistry	4.0	04
Organic Chemistry Branch Courses* (*Any two theory courses will be offered***)**			
0531-14-513OC	Green and Sustainable Chemistry	4.0	04
0531-14-514OC	Advanced Organic Reactions and Stereochemistry	4.0	04
0531-14-514OC	Clinical Chemistry	4.0	04
Thesis/Research			
0531-14-500PC	Thesis (Research Proposal Preparation and Presentation)	Not Credit Bearing	Has to pass the proposal defense
Total Credits: 14.0			

M.S. 2nd Semester ((Mixed-Mode))			
Course Code	**Course Title**	**Credits**	**Contact Hours/Week**
Common Specialized Course			
0531-14-521	Advanced Spectroscopy and Chromatography	3.0	03
Common General Education Course			
0119-14-522	Chemical Education and Pedagogy	4.0	04
Physical Chemistry Branch Courses* (*Any two theory courses will be offered***)**			
0531-14-523PC	Electroanalytical Chemistry	4.0	04
0119-14-524PC	Advanced Photochemistry	4.0	04
0531-14-525PC	Advanced Electrochemistry	4.0	04
Inorganic and Analytical Chemistry Branch Courses* (*Any two theory courses will be offered***)**			
0531-14-523IA	Advanced Bioinorganic Chemistry	4.0	04
0119-14-524IA	Computational Inorganic and Bioinorganic Chemistry	4.0	04
0531-14-525IA	Aquatic Chemistry and Biotic Environment	4.0	04
Organic Chemistry Branch Courses* (*Any two theory courses will be offered***)**			
0531-14-523OC	Advanced Methods in Organic Chemistry	4.0	04
0531-14-524OC	Chemistry of Food and Nutrition	4.0	04
Oral Presentation/Viva-voce			
0531-14-501	Oral Presentation	2.0	-
Total Credits: 17.0			

Note: *Students have to complete two 4.0 credits theory courses offered by the branch of chemistry in each semester.

M.S. 3rd Semester ((Mixed-Mode))			
0531-14-500PC	Thesis (Dissertation)	16.0	-
Total Credit: 14+17+16 = 50.0			

M.S. (Coursework) in Physical Chemistry

Academic Session: 2023-24, 2024-25 and 2025-26

Course Code	**Course Title**	**Credit Hours**
0531-14-511	Advanced Computational Chemistry	4.0

(a) Rationale:

Computational chemistry deals with the advancement related with modern computer-based chemistry education. First chapter consists with advance knowledge associated to computer science. 2nd chapter deals with the potential Gaussian software, while 3rd chapter, that of material studio related Software. Final chapter illustrates the Design of materials and calculates the associated properties. All these knowledges are essential in advanced level of computational chemistry. This course is intended to provide potential development of knowledge on physical states of materials which could divert students to go through the deep knowledge of computational chemistry.

(b) Course Objectives (COs):

- To provide knowledge about advance usage of computational tasks.
- To impart advanced capability to recognize the properties of materials theoretically by assumptions.
- To deliver an understanding regarding the design as well as application of materials or the compounds.

(c) Course Contents	
1.	**Advances in computational chemistry:** Importance of Computational chemistry, application, and possibilities. Solving Chemical equation through computer software, crystal defect, unit cell, super cell, Ab Initio Electronic Structure Theory, Semi-Empirical Electronic Structure Theory, Molecular Dynamics, alloy formation, VISTA, Gaussain, material studio and their applications.
2.	**Material Studio:** CASTEP: Band structure, Core level spectroscopy, Density of states, Electron density difference, Electron localization function, electronic excitations (TD-DFT), NMR, Orbitals, Optical properties, Polarizability, Phonons, IR and Raman spectra, Population analysis, Stress.
3.	**Gaussain software:** (1) Introduction to Gaussian 09 (G09) and to GaussView (GaussView is the graphical user interface, GUI) GUI usage, Input files (Z-matrix), Output files (log or chk) Output (orbitals and surfaces), Time vs. accuracy (2) Optimizing structures; predicting IR/ Raman (3) Time-Dependent DFT and UV-Vis Spectra (4) Solvation and solution chemistry **Properties analysis:** DFT, ionization energy, chemical potential, HOMO-LOMU, Hardness, softness, reactivity, NBO analysis.
4.	**Design of materials:** Inorganic material design such as Cu_xO, ZnO, $CuFeO_2$, GaAs with the illustration of their properties. Organic material design such as Ethelene, H_2O, toluene, methyl benzene, ethyl benzene.

***(d) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to –

CLO-1: Explain by interpreting the advanced technology by computational analysis.

CLO-2: Illustrate the physical properties and molecular structure by using materials studio.

CLO-3: Explain the properties of solids, crystalline and amorphous solids with different software.

CLO-4: Describes the Ab Initio electronic structure and semi-empirical electronic structure theory

CLO-5: Use of the software such as Gaussian to design materials and their properties.

CLO-6: Describe the various compounds, and materials by using sophisticated software.

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):								
CLOs	**PLO1**	**PLO2**	**PLO3**	**PLO4**	**PLO5**	**PLO6**	**PLO7**	**PLO8**
CLO1	3	-	1	-	1	-	1	-
CLO2	3	-	1	-	-	-	1	-
CLO3	3	-	1	-	-	-	1	-
CLO4	3	-	1	-	-	-	1	2
CLO5	3	-	2	-	-	1	2	2
CLO6	3	-	1	-	-	1	2	2

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy		
CLOs	**Teaching-Learning Strategy**	**Assessment Strategy**
CLO1	Lecturing and Discussion	Summative (Mid-Semester)
CLO2	Lecturing and Video Presentation with material studio	Assignment and Presentation
CLO3	Lecturing and Power-point Presentation and Discussion	Summative (Mid-Semester)
CLO4	Lecturing and Discussion	Summative (Final Exam)
CLO5	Tutorial on Gasuaain Software	Project and Presentation
CLO6	Lecturing, Group Discussion and Student Activities	Summative (Final Exam)

(g) Learning materials

(i) Recommended Readings

- Guidebook of materials studio 2019
- Guidebook of Gaussain

(ii) Supplementary Readings

- Guidebook of VESTA
- Introduction to Solid State Physics, Charles Kittel
- Related articles (peer viewed)

Course Code	**Course Title**	**Credit Hours**
0531-14-512	Instrumental Methods of Analysis	4.0

(a) Rationale:

In order to obtain qualitative and quantitative information about the composition and structure of matter, powerful and elegant tools are necessary for applications to solve important analytical problems. Students of chemistry, biochemistry, physics, geology, the life sciences, forensic science, and environmental science must develop an understanding of these instrumental tools and their applications. Determination of trace concentration (in ppb or even lower) of specific analyte in sample is possible by instrumental methods.

(b) Course Objectives (COs):

- To be familiar about the instrumental methods
- To be able to understand about the principle and instrumentation of particular instrumental method
- To be able to apply the suitable instrumental methods for particular analyte in specific sample.

(c) Course Contents	
1.	**Instrumental Methods of Analysis:** Overview; Types of instrumental methods; Concept of an instrument; Elements of a measuring instrument; Preparation of standard and Calibration; Blanks and controls; Laboratory data acquisition and information management.
2.	**Chromatographic Methods of Analysis:** Principle and types**;** Chromatographic configuration**;** Electrophoresis**;** Gas chromatography**;** Instrument design; Sample injection system; Column configuration; Detector; Gel chromatography: Mechanism of gel chromatography, Advantages of gel chromatography, Technique of gel chromatography, Applications of gel chromatography; High-Performance Liquid Chromatography: Principle; Mobile phase consideration; Solvent delivery; Sample injection; HPLC columns; HPLC detectors; Qualitative and quantitative analysis.
3.	**Optical Methods of Analysis:** Types; Absorption methods: Ultraviolet spectrophotometry, Infrared spectrophotometry; Emission Methods: Flame photometry, Atomic absorption spectrophotometry: principles, instrumentation, interferences, electro-thermal atomizers, sample requirements, the effect of different solvents, sensitivity, qualitative and quantitative analysis, hydride vapor generation technique, cold vapor technique, advantages and disadvantages of AAS, Emission spectroscopy: Inductive coupled plasma, Dispersion and Scattering; Fluorimetry.
4.	**Electrical Methods of Analysis:** Overview**;** Standard reduction potentials; Potentiometric analysis; Reference electrode; Saturated calomel electrode; Silver-silver chloride electrode; Indicator electrodes; Potentiometric titration; Anodic stripping voltammetry; Cyclic voltammetry; Amperometry; Karl Fischer titration.
5.	**Thermal Analysis:** Thermogravimetric Analysis (TGA): Instrumentation; Derivative Thermogravimetric Analysis (DTGA); Factors affecting TGA; Application of TGA; Differential Thermal Analysis (DTA): Principle, Instrumentation; Factors affecting DTA; Applications of DTA, Differential Scanning Calorimetry (DSC); Thermometric titration

***(d) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to –

CLO-1: Describe the process of calibration and standardization process

CLO-2: Define and demonstrate the different instrumental methods of both principle and instrumentation

CLO-3: Choice suitable instrumental method for specific type of chemical analysis

CLO-4: Compare the advantages and disadvantages of different analytical methods

CLO-5: Design a scheme through selecting suitable instrumental method for real sample analysis

CLO-6: Calculate accuracy, precision and selectivity for quality assurance data

CLO-7: Evaluate the methods for selecting for specific analysis

(e) Mapping Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs):

CLOs	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	2	-	-	-	-	-	-	-
CLO2	2	-	-	-	-	-	-	-

CLO3	2	-	1	-	-	-	1	-
CLO4	2	-	1	-	-	-	1	-
CLO5	2	-	1	-	-	-	1	-
CLO6	3	-	2	-	-	-	2	-
CLO7	3	-	2	-	-	2	2	2

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping of Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy

CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lectures and Group Discussion	Summative Assessment (Midterm)
CLO2	Lectures and Group Discussion	Summative Assessment (Final Exam)
CLO3	Lectures and Group Discussion	Summative Assessment
CLO4	Video Presentation and Discussion	Summative Assessment (Midterm)
CLO5	Lectures and Group Discussion	Assignment
CLO6	Lectures and Group Discussion	Quiz
CLO7	Class Activity and Discussion	Tutorial

(g) Learning Materials

(i) Recommended Readings

- Skoog, D. A.; Holler, F.J.; Crouch, S.R., Instrumental Analysis, Thomson Brooks/Cole, a part of Cengage Learning, India

(ii) Supplementary Readings

- Instrumental Methods of Analysis, H. W. Willard, L. L. Merritt Jr., J. A. Dean and F. A. Settle Jr., D. Van Nostrand Co.
- Analytical Chemistry for Technicians, John Kenkel, Lewis Publishers, A CRC Press Company, New York
- Instrumental Approach to Chemical Analysis, A.K. Srivastava and P.C. Jahin, S. Chand & Company Ltd.
- Analytical Chemistry, Skoog, West, Holler and Crouch, CENGAGE Learning
- Modem Methods of Chemical Analysis, R. L. Pecsok, L.D. Shields, T. Cairns, and L. G. McWilliam, John Wiley & Sons.

Course Code	**Course Title**	**Credit Hours**
0531-14-513PC	Advanced Tools & Techniques in Physical Chemistry	4.0

(a) Rationale:

The course is targeted at graduate students in chemistry with preliminary knowledge of quantum/statistical mechanics and an interest in working in the fields of computational and theoretical chemistry. Participants who are already familiar with this will deepen their knowledge on the fundamental basis of the commonly used methods for solving the Schrödinger/statistical equation in the case of many interacting particles. The objective of surface analytical techniques is to review the principles of different techniques and to present examples of the application of each technique to important problems in adhesion science. The properties of crystals reflect the strong interactions that exist between the molecules/ions. Finally, the solution chemistry gathers the knowledge upon the factors affecting on concentration (CMC), its thermodynamics and application in different areas.

(b) Course Objectives (COs):

- To solve Schrodinger wave equation for atoms and their orbital structure designing with quantum number measurement
- To illustrate methods of probability theory and statistics, and particularly the mathematical tools for dealing with large populations and approximations, in solving physical problems
- To gather idea about the instrumentation and application of surface analytical techniques to the chemistry to determine the structure of molecule, synthetic route, mechanism, ions/molecular existence, *etc*.
- To understand about liquid/ionic crystals, fluid mechanics, solution theory, and various methodical uses

(c) Course Contents	
1.	**Advanced Quantum & Statistical Mechanics:** (a) Schrodinger wave equation (SWE) and eigen function; SWE in terms of Hamiltonian; Solution of SWE for H and other atoms, Dirac bracket notations, approximate solution of Schrodinger equation; perturbation method, variation method and their applications. (b) Partition function; equilibrium constant and partition function, thermal characteristics of crystalline solids; Specific heat: specific heat of solids; Einstein; Dulong and Petit's law, Debye theories & their comparison.
2.	**Surface Analytical Techniques**: Principle, instrumentation & application of- Auger electron spectroscopy (AES), X-ray photoelectron spectroscopy (XPS), low energy electron diffraction (LEED), near edge X-ray absorption fine structure (NEXAFS); surface imaging and depth profiling; concepts in imaging & localized spectroscopy, electron microscopy (SEM/SAM), imaging XPS, Auger depth profiling, scanning probe microscopy (STM/AFM).
3.	**Polarimeter for Identifying Ionic and Liquid Crystals**: Polarimeter; principle and instrumentation. Identification of ionic liquids; room temperature ionic liquids (RTILs): types and synthesis of ionic liquids/RTILs; electrochemistry and catalysis; applications: liquid crystal displays (LCD), polymeric liquid crystals (PLC). Identification of liquid crystal: thermotropic and lyotropic liquid crystals; mesophase: smectic, nematic, cholesteric; application of liquid crystals.
4.	**Techniques for Studying Aggregation:** Instrumental techniques of surfactant/micelle/aggregation identification, its solubility test: rules of thumb; Krafft temperature, cloud point; dynamic light scattering; factors affecting on CMC; thermodynamics of micellization; phase separation model, mass action model, free energy of micellization; methods for the determination of CMC of a surfactant; partial molar volume determination; graph method.

***(d) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to –

CLO-1: Solve Schrodinger wave equation using their theories and to find out quantum numbers along with orbital structures

CLO-2: Apply theories of statistical mechanics to analyze the statistical data for condensed matter systems

CLO-3: Operate surface analytical tools for predicting structure of molecule, symmetry, geometrical pattern, ions/molecular existence, *etc*.

CLO-4: Analyze the fluid mechanics, solution theory, and various methodical uses of ionic and liquid crystals
CLO-5: Calculate experimentally the CMC and binding energy for stable micelle

(e) Mapping Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs):

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	3	-	-	-	-	-	-	-
CLO2	3	-	1	-	-	-	-	-
CLO3	3	-	2	-	-	1	-	-
CLO4	3	-	-	-	-	-	-	-
CLO5	3	-	2	1	-	-	-	-

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping of Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy

CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecturing	Course preparatory quiz Midterm-I and Final Exam. (Summative)
CLO2	Lecturing & discussion	Assignment (with Rubrics) & Final Exam. (Summative)
CLO3	Lecturing & discussion	Midterm-II & Final Exam. (Summative)
CLO4	Assignment with Rubrics & discussion	Midterm-II & Final Exam. (Summative)
CLO5	Presentation & discussion	Quiz/presentation (Formative)

(g) Learning Materials

(i) Recommended Readings

- McQuarrie D. A., *Quantum Chemistry*, Viva Books, New Delhi.
- Levine I. N., *Quantum Chemistry*.
- McQuarrie Donald A., *Statistical Thermodynamics*, Viva Books, New Delhi.

(i) Supplementary Readings

- Levine I. N., *Quantum Chemistry*
- Singh S. P., Badge M. K., *Quantum Mechanics*, S. Chand & Co Ltd., N. Delhi
- Kamal Singh, Singh S. P., *Elements of Quantum Mechanics*, S. Chand & Co Ltd., Delhi
- Gupta, Kumar, Sharma, *Quantum Mechanics*, 15th ed., Jai ProkashNath& Co
- Chandra A.K., *Introductory Quantum Chemistry*, 4th ed., Tata McGraw Hill Education Pvt. Ltd
- Gupta M. C., *Statistical Thermodynamics*; New Age International Pub. New Delhi
- Rosen M. J., *Surfactants and Interfacial Phenomena*, 3rd edition, Surfactant Research Institute Brooklyn College, The City University of New York

Course Code	Course Title	Credit Hours
0531-14-514PC	Advanced Chemical Kinetics	4.0

(a) Rationale: Advanced chemical kinetics and photochemistry deals with theoretically activated complexes, composite and the use of photophysical and photochemical approaches in processes. Kinetics deals with the fundamental of TST theory including thermodynamic description of activated complex, formulation of partition function and limitation. Reaction rate theories in gas and solution phases, ionic strength, dielectric constant, and solvent effect on rates are discussed. However, photochemistry deals with the mechanism and kinetics of photochemical reactions. Finally, how to use the tools and techniques of photochemistry to examine a compound's transient absorption spectrum are discussed in details. This course will provide knowledge and skill to students about chemical kinetics, photochemistry tools and techniques which will help to contribute in research for new innovation.

(b) Course Objectives (COs):

- To investigate the transition state theory and its application in gaseous and solution phases.
- To study kinetics of reaction in solution and influence of pressure, ionic strength, solvent on reaction rates.
- To impart knowledge regarding the composite molecules and their reactions.
- To describe and explain photochemical and photophysical processes and their quantum yield expressions.
- To gather knowledge on the tools and techniques of kinetics.

(c) Course Contents

1.	**Reaction rate theory:** Review of theories: collision theory and conventional transition state theory (CTST), thermodynamic treatment of the TST, statistical treatment of TST, contour diagram, potential energy surface, some applications of the CTST, reactions between atoms and molecules, reaction between H and HBr. Unimolecular reactions: RRK, RRKM and Slater theorem.
2.	**Reactions in Solutions:** Rate determining steps in solution, Absolute reaction rate theory for solution: Activity coefficient, reaction rate and solubility. Comparison of reaction rates in gas phase and in solution. Reaction between neutral molecules: Solvation effect and influence of Dielectric constant. Reaction between ions: Single-Sphere Model and Double-Sphere Model, Frequency factor on entropy of activation, Influence of pressure, ionic strength and Dielectric constant.
3.	**Composite reactions:** Composite reactions: concept of steady state approximation and steady-state treatment, rate equations for composite reactions: decomposition of ozone, hydrocarbon oxidation and combustion of hydrocarbons, oscillatory reaction, Belousov-Zhabotinski (B-Z) reaction, a schematic representation of the B-Z reaction, chemistry of B-Z reaction, stationary flames, thermal explosion, isothermal explosion, branching chain explosion, hydrogen oxygen reaction and explosion limits.
4.	**Photophysical and Photochemical Processes:** Photophysical and photochemical process, Timescales of photophysical processes, primary quantum yield and its determination, mechanism of decay of excited singlet states, quenching, energy transfer processes. Kinetics of photochemical reaction: decomposition of HI, decomposition of O_3, photosynthesis of HCl, photosynthesis of HBr, dimerisation of anthracin, photolysis of acetone and NH_3. Photochemistry of air, troposphere, stratosphere and other spheres, decomposition of ozone layer, greenhouse effect and Osmosis & diffusion
~~5.~~	**Light sources in photochemistry:** Light sources of their standardization, measurement of emission characteristics, Techniques for study of transient species in photochemical reactions, solar energy and solar simulation, filament lamp, discharge lamp. Lasers: basic principle of laser action, various types of lasers, characteristics of laser radiation, continuous and pulsed laser. Determination of light intensity: actinometry.

6.	**Tools and Techniques of Photochemistry:** Fluorescence spectroscopy, phosphorescence spectroscopy. Flash photolysis techniques in photochemistry: pico- and femto-second photolysis, flash photolysis studies of bimolecular electron transfer and other photochemical reactions. Time resolved IR spectroscopy. Detection of short-lived species: matrix isolation and Laser induced breakdown spectroscopy (LIBS).

***(d) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to –

CLO-1: Demonstrate the concept of activation energy in the context of the transition state and be able to compute the activation energy given some experimental data.

CLO-2: Discuss the factors affecting the reaction rate in solution and gas phases. Understand and illustrate the different composite reaction rate.

CLO-3: Mention and illustrate the different composite reaction rate.

CLO-4: Discuss the mechanism and kinetics of photochemistry.

CLO-5: Investigate a compound's transient absorption spectrum using kinetic tools and techniques.

(e) Mapping Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs):

CLOs	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	3	-	1	2	-	-	-	-
CLO2	3	-	3	2	-	-	-	-
CLO3	3	-	2	2	-	-	-	-
CLO4	3	-	2	-	-	-	-	-
CLO5	3	-	3	-	-	-	-	-

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping of Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy

CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecture and Discussion	Course preparatory quiz Midterm-I & Final Exam. (Summative)
CLO2	Lecture and Discussion	Quiz/presentation (Formative) Midterm-I & Final Exam. (Summative)
CLO3	Lecture and Discussion	Quiz/presentation (Formative)
CLO4	Review Lecture and Discussion	Assignment (with Rubrics
CLO5	Review Lecture and Discussion	Midterm-II & Final Exam. (Summative) Quiz/presentation (Formative)

(g) Learning Materials

(i) Recommended Readings

- Laidler K. J., *Chemical Kinetics*, 3rd edition; Dorling Kindersely Pvt. Ltd.
- Hinshelwood C. N., *Kinetics of Chemical Change*.

(ii) Supplementary Readings

- Kundu N., Jain S. K., *Physical Chemistry*, S. Chand & Co, New Delhi.
- Eyring E., Glasstone S., Laidler Keith J., *Chemical Kinetics*, McGraw Hill Book Co, New York.
- P. Atkins, J.de Paula, *Atkins Physical Chemistry*, 10th edition; Oxford University Press.
- Christian G., *Physical Chemistry*.
- Castellan G.W., *Physical Chemistry*; 3rd edition; Narosa Pub. House, Delhi.
- Bajpai D. N., *Advance Physical Chemistry*, S. Chand & Co Pvt. Ltd, Delhi.
- A. Donald McQuarrie, Simon J. D., *Physical Chemistry*, 4th ed., Viva Books Pvt. Ltd.

Course Code	**Course Title**	**Credit Hours**
0531-14-515PC	Advanced Biophysical Chemistry	4.0

(a) Rationale:

The main theme of the study is to train highly educated professionals in the field of biophysical chemistry, intended for independent creative, scientific and research activity. Biophysical chemistry, as a field of science, is to provide physic-chemical and biochemical explanations of functions and activity of biological systems. The student is taught to independently formulate a scientific problem, suggest hypotheses and methods for its solution and perform experimental or theoretical trials to verify it. The study program focuses on an independent creative activity in the field of biophysical chemistry, includes both, theoretical and experimental work and prepares the graduates for scientific and research activity. The key parts of studies are physical-chemical and biochemical rudiments of biological processes and biomaterials.

(b) Course Objectives (COs):

- To train highly educated professionals in the field of biophysical chemistry, with sufficient experiences, intended for the independent creative, scientific and research activity
- To train the graduates in the pH-buffering, enzymatics and its theories, bioenergetics, and their mode of actions in biological system
- To gear up the research graduates in the field of ATP and its role, carbohydrate metabolism, lipid metabolism, nitrogen metabolism, glycolysis, amino acid, protein, nucleic acid, thermodynamics of macromolecules
- To develop theme of a research topic in the field of bio-colloid chemistry, nanobiotechnology, biophysical instrumental techniques, immunochemistry, and technology of biomaterials
- To use biophysical chemistry, graduates can very well employ not only in the fields of biophysical-chemical research, but also in other fields of healthcare or studies of living systems

(c) Course Contents

1.	**Noncovalent bonding and pH buffering**: Water the biological solvent, stabilizing and organizing forces of nature, acid-base equilibria, buffer solution: acidic and basic buffer, principle of pH buffering, buffering of blood, laboratory use of buffers and ionic strength.

2.	**Enzyme Kinetics:** Characteristics, mechanisms, kinetic equations, enzyme-substrate interactions, Key-Lock theory, Michael-Menten equation; Line-Weaver & Burk plot, enzyme inhibition: competitive, non-competitive and uncompetitive inhibition; pH and temperature effects on enzyme kinetics, cooperative binding, quantitative analysis of cooperative binding by Hill plot, significance of Hill plot, transport of oxygen and CO_2 (role of hemoglobin).
3.	**Bioenergetics:** Bioenergetics and thermodynamics, bioenergetic systems, mechanism of strong and utilization of energy in biological systems, coupling mechanism, phosphorylation, biochemist's standard state, ATP and its role in bioenergetics, control points in metabolic pathways, carbohydrate metabolism, lipid metabolism, nitrogen metabolism, glycolysis and limitations of thermodynamics.
4.	**Biological Macromolecules:** Introduction, structure of proteins: primary, secondary, tertiary and quaternary structures, salting in and salting out of proteins; amino acid; structure of amino acid and protein synthesis, essential & non-essential amino acids, ionic properties of amino acids and polypeptides, dual character of amino acid: Zwitter ion, isoelectric point, nucleotides and nucleic acids, base composition and base sequence of nucleic acids, biological function of protein, stability of protein conformation, factors responsible for stabilization, thermodynamic treatment of stability constant, protein binding, protein-ligand binding, binding equilibrium, color tests for protein; hydrophobic hydration and hydrophobic interaction.

***(d) Course Learning Outcomes (CLOs)*:**

Upon successful completion of this course, graduates will be able to-

CLO-1: Analyze acid-base equilibria, pH-buffering and its mode of action in biological system, enzymatic, and various relevant theories with plots

CLO-2: Demonstrate the bioenergetic systems and mechanism of energy in biological systems while the role of ATP in bioenergetics

CLO-3: Explain control points in metabolic pathways, and its thermodynamics

CLO-4: Interpret the structure, properties, stabilities, kinetics, and thermodynamics of protein, amino acid, and nucleic acid

CLO-5: Analyze ligand binding, binding equilibrium, color tests for protein and kinetics

CLO-6: Compare and evaluate physical-chemical and biochemical principles and processes industrial research

(e) Mapping Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs):

CLOs	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	3	-	2	1	-	2	-	-
CLO2	3	-	1	1	-	1	-	-
CLO3	3	-	-	-	-	-	-	-
CLO4	3	-	2	-	-	2	-	-
CLO5	3	-	1	-	-	1	-	-
CLO6	3	-	-	1	-	-	-	-

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy		
CLOs	**Teaching-Learning Strategy**	**Assessment Strategy**
CLO1	Lecture and Discussion	Course preparatory quiz Midterm-I & Final Exam. (Summative)
CLO2	Lecture and Discussion	Quiz/presentation (Formative) Midterm-I & Final Exam. (Summative)
CLO3	Lecture and Discussion	Quiz/presentation (Formative)
CLO4	Review Lecture and Discussion	Assignment (with Rubrics
CLO5	Review Lecture and Discussion	Midterm-II & Final Exam. (Summative) Quiz/presentation (Formative)
CLO6	Review Lecture and Discussion	Quiz/presentation (Formative)

(g) Learning Materials

(i) Recommended Readings

- Lehninger A.W., *Principle of Biochemistry*
- Bohinski R.C., *Modern Concept of Biochemistry*
- Nelson and Cox, *Principles of Biochemistry*, Mcmillan, 4th edition-Lchninger
- Frisell W. E., *Human Biochemistry*, Macmillan Publishing Co.
- Chang R., *Physical Chemistry with Application to Biological Systems*, Macmillan Publishing Co. Inc. 1977
- Zubay G.**,** *Biochemistry*
- Hinshelwood C. N.**,** *Kinetics of Chemical Change, Large Street Press*

(ii) Supplementary Readings

- Chang R., Physical Chemistry for the Chemical and Biological Sciences, University Science Books.
- Williams V. R. and Williams H., Basic *Physical Chemistry for Life Science*, W. H. Freeman and Co, 1967.
- Freifelder D., *Physical Biochemistry.*
- Elliott W. H., Elliott D. C., *Biochemistry*.

Course Code	**Course Title**	**Credit Hour**
0531-14-513IA	Advanced Inorganic and Materials Chemistry	4.0

(a) Rationale:

Inorganic chemistry of materials includes those parts of inorganic chemistry or the chemistry of elements that can be used to make products. It is not one single subject but consists of several widely different disciplines, such as structural chemistry, coordination chemistry, and solid state ionics, to name but a few. Society and technology are underpinned by the solid-state sciences. For example, computing (data storage, CD lasers, batteries) construction (concrete, steels) transport (catalytic converters, fuel cells, strong lightweight materials) chemicals (catalysts, sensors) medicine (artificial joints, bones, and muscle) gems (jewelry, cutting tools, lasers).

(b) Course Objectives (COs):

- To promote knowledge on synthesis, structure, properties and applications of a range of new materials.

- To impart knowledge on inorganic materials, involve molecular inorganic superconductors, polymeric coordination complexes, precursors for electronic materials.
- To convey knowledge on the nanomaterial's synthesis.

(c) Course Contents	
1.	**Technology of Materials:** Types of Matter: Structure and Bonding: chemical change; Bonding in Ionic Compounds: The Miedema Model for Intermetallics, The Pearson Model: Electronegativity Equalization, Linnett's Localized Electron Model for Molecules, Johnson's Interstitial Electron Model for Metals.
2.	**Solid State Reactions:** Types of Reactions of Solids; Kinetics of Solid State Reactions; Measuring Solid State Reaction Kinetics; The Chemistry of Ceramics and Sintering.
3.	**Chemistry of Inorganic Surfaces:** Physical Properties of Inorganic Solid Surfaces; Inorganic Colloids; Heterogeneous Catalysis; Growth of Crystalline Solids from Liquids; Converting Solids by Reaction with a Gaseous Reactant; Chemical Vapor Deposition; High-Temperature Corrosion; Surface Modification by Immobilization of Molecules.
4.	**Inorganic Morphogenesis:** Introduction to the Chemistry of Microstructure and Nanostructure; Extrinsic Properties of Materials; Fractal Dimensions; Simulations of Reaction-Diffusion Processes Using. Cellular Automata; The Chemistry of Fractal Distributions: Processes that Generate Fractal Distributions and Reactions on Fractal Surfaces
5.	**Synthesis Strategy of Inorganic Materials:** Introduction to Inorganic Synthesis; Solid State Reactions; Synthesis from Liquids: preparation from Melts, liquid Salts as Solvents, hydrothermal processes and sol-gel method; Gas-Phase Techniques.
6.	**Carbon Based Nanosystem:** Carbon nanotubes; Types of carbon nanotubes; Synthesis and application of carbon nanotubes; Graphene: structure, synthesis, properties and application.
7.	**Chemistry and Catalytic Aspects of Nanocrystals:** Chemistry occur at the nanocrystal surface; Nanostructured adsorbent; Nanoparticles as chemical reagents; Nanocomposite polymes; Application of nancrystals.
8.	**Design/Synthesis of Inorganic Materials:** Introduction to Materials Design; Requirements and Constraints; Combination Properties of Composites: sum Properties, product Properties, and morphology; Functional Materials: thermistors, varistors and Active Materials; Fabrication of Composites.

(d) Course Learning Outcomes (CLOs):

CLO-1: Demonstrate about the types of materials, bonding and structural pattern in solid state, and models or theories for predicting properties of materials.

CLO-2: Categorize the types of solid state reactions and interpret the kinetics of solid state reactions and growth of crystalline solids

CLO-3: Explore the properties of inorganic solid surfaces and inorganic colloids

CLO-4: Interpret chemical vapor deposition method and apply for solid state synthesis

CLO-5: Extract the extrinsic properties of inorganic materials and interpret the morphology control for fabricating properties of materials.

CLO-6: Develop the synthetic strategies/schemes for preparing inorganic materials.

CLO-7: Explain structure and properties of carbon based and other form of nanomaterial and their applications

CLO-8: Design a scheme/method for preparing inorganic materials of their intended use.

(e) Mapping Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs):										
CLOs	**LT**	**LD**	**PLO1**	**PLO2**	**PLO3**	**PLO4**	**PLO5**	**PLO6**	**PLO7**	**PLO8**
CLO1										
CLO2										
CLO3										
CLO4										
CLO5										
CLO6										
CLO7										
CLO8										

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)
LT: Learning Taxonomy (Appendix-1); LD: Learning Domain (Appendix-2)

(f) Mapping of Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy		
	Teaching-Learning Strategy	**Assessment Strategy**
CLO1	Lecturing and Video Presentation	Quiz and Summative Assessment (Midterm)
CLO2	Lecturing and Group Discussion	Summative Assessment (Final Exam)
CLO3	Lecturing and Group Discussion	Summative Assessment
CLO4	Video Presentation and Group Discussion	Summative Assessment (Midterm)
CLO5	Lectures and Group Discussion	Assignment
CLO6	Lectures and Group Discussion	Quiz and Summative Assessment (Mid-Semester)
CLO7	Class Activity and Discussion	Summative Assessment (Mid-Semester) and Summative Assessment (Final Exam)
CLO8	Demonstration and Student Activity (Tutorial)	Assignment and Summative Assessment (Final Exam)

(g) Learning Materials
(i) Recommended Readings
• William D. Callister, Jr. and David G. Rethwisch , Material Science and Engineering , Wiley
• Lalena, J.N. and Cleary, D. A.: Principles of Inorganic Material Design, 2nd Edition, Wiley, Printed I United States
(ii) Supplementary Readings
• Gary L. Miessler, Paul J. Fischer and Donald A. Tarr. *Inorganic Chemistry*, 5th Edition, Pearson, New York, 2014
• Bodie E. Douglas, Darl H. McDaniel and John J. Alexander. *Concepts and Models of Inorganic Chemistry*, 3rd Edition, John Wiley & Sons, Delhi, 1994

Course Code	Course Title	Credit Hour
0531-14-514IA	Inorganic Spectroscopic Method	4.0

(a) Rationale:

Inorganic spectroscopic method is an upper-level undergraduate or post-graduate course. The aim of this course is to provide students with a broad understanding of the spectroscopic methods that are available to identify structures of inorganic compounds (some techniques can also be applied for identification of organic compounds). The methods include NMR, ESR, vibrational, electronic and photoelectron spectroscopy and mass spectrometry. Instrumental design will be covered but the emphasis will be placed on the experimental methods and interpretation of spectra. Chemists are molecule makers. Whenever a new molecule is synthesized it is essential to determine its structure using spectroscopic techniques. This course is all about practical applications of spectroscopic methods for the determination of the structure of inorganic molecules.

(b) Course Objectives (COs):

- To provide knowledge regarding a broad understanding of the inorganic spectroscopic methods.
- To study the physical basis of related spectroscopic methods (vibrational, resonance, UV-Visible spectroscopy, mass spectroscopy) and their applications typical in inorganic compounds.

(C) Course Contents	
1.	**Overview of Spectroscopy**: Molecular energy levels, Population distribution, Selection rules, Time scales, Instrumentation, Fourier transforms.
2.	**Vibrational Spectroscopy**: Theory, Instrument Design, Vibrational Spectra and Symmetry Assignment of Bands to Vibrations, Fingerprints, Use of Isotopes in Interpreting Vibrational Spectra Resonance Raman Spectroscopy.
3.	**NMR Spectroscopy**: Theory, Instrument Design, 1-D Experiment, Interpretation of Spectra, 2-D Experiments and Interpretation of Spectra Information from Coupling Constants, Relaxation, Solid and Paramagnetic Compounds, Monitoring Reactions, Structure problem solving using ^{1}H and ^{13}C NMR data.
4.	**ESR Spectroscopy**: Principle; The electron Zeeman interaction, Relaxation processes, The nuclear Zeeman interaction, Isotopic hyperfine coupling, Analysis of isotopic ESR spectra, The g tensor: origin and significance, The A tensor: origin and significance, The D tensor: origin and significance, Electron-electron coupling, Hyperfine coupling, Analyzing room-temperature ESR spectra of some model metal complexes, Analyzing ESR spectra of frozen solution samples. **Nuclear Quadrupole Resonance (NQR)**: Principles and application in inorganic compounds
5.	**Mass Spectrometry**: Theory, Instrument Design, Overview of Ionization Techniques, Interpretation of Spectra, Fragmentation patterns of simple organic molecules, Retro Diels–Alder fragmentations, type 1 and McLafferty rearrangements, ortho effects.
6.	**UV-Visible Spectroscopy**: the basics, metal-metal transition, crystal field splitting, crystal field splitting in common shape, spin state, strong field model and weak field model, Jann-Teller distortion, charge transfer transition, metal-ligand transition, Ligand-centered transition.
7.	**Structure Elucidation**: Elucidation of molecular structures of some inorganic, organometallic, coordination and bioinorganic compounds putting the spectral information of the above all together.

(D) Course Learning Outcomes (CLOs):

After completion of the Course, the Student will be able to –

CLO-1: List different types of spectroscopic methods applicable for inorganic structure determination

CLO-2: Explain different spectroscopic techniques/principles to the determination of inorganic molecules.

CLO-3: Apply NMR, ESR, vibrational, electronic and photoelectron spectroscopy and mass spectrometric methods in order to elucidate the structure of inorganic compounds

CLO-4: Elucidate the structures of novel inorganic compounds/complexes with spectroscopic methods.

CLO-5: Predict and analyze the different types of novel inorganic complexes.

(e) Mapping Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs):

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	3	-	-	-	-	-	-	-
CLO2	3	-	2	-	-	-	1	-
CLO3	3	-	2	-	-	-	1	-
CLO4	3	-	2	-	-	-	1	-
CLO5	3	-	2	-	-	-	1	-
CLO6	3	-	2	-	-	-	1	-
CLO7	3	-	2	-	-	-	2	2

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping of Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy

	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecturing and Video Presentation	Quiz and Summative Assessment (Midterm)
CLO2	Lecturing and Group Discussion	Summative Assessment (Final Exam)
CLO3	Lecturing and Group Discussion	Summative Assessment
CLO4	Video Presentation and Group Discussion	Summative Assessment (Midterm)
CLO5	Lectures and Group Discussion	Assignment
CLO6	Lectures and Group Discussion	Quiz and Summative Assessment (Mid-Semester)
CLO7	Class Activity and Discussion	Summative Assessment (Mid-Semester) and Summative Assessment (Final Exam)

(g) Learning Materials

(i) Recommended Readings

- Alan K. Brisdon (1998) Inorganic Spectroscopic Methods, Oxford University Press, Oxford, Great Britain

(ii) Supplementary Readings

- Gary L. Miessler, Paul J. Fischer and Donald A. Tarr. *Inorganic Chemistry*, 5th Edition, Pearson, New York, 2014

- Bodie E. Douglas, Darl H. McDaniel and John J. Alexander. *Concepts and Models of Inorganic Chemistry*, 3rd Edition, John Wiley & Sons, Delhi, 1994
- N. N. Greenwood and A. Earnshaw, *Chemistry of the Elements,* 2nd ed., Butterworth-Heinemann, London, 1997

Course Code	**Course Title**	**Credit Hour**
0531-14-515IA	Advanced Analytical Chemistry	4.0

(a) Rationale:

In-depth theoretical treatment of chromatographic separation and underlying distribution and adsorption equilibria. Instrumentation and experimental techniques for high-resolution chromatography as well as linking of chromatography to mass spectrometry and its applications in e.g. food, drug and environmental analysis. Overview of capillary electrophoresis and field flow fractionation. Presentation of principles of green analytical chemistry and new research in this field. Critical discussions of the environmental sustainability of analytical methods and its relevance for society at large. Multivariate experimental design and different statistical analysis tools (variance analysis, principal component analysis and least squares method)

(b) Course Objectives (COs):

- To provide a thorough background in those chemical principles that are particularly important to analytical chemistry.
- To develop an appreciation for the difficult task of judging the accuracy and precision of experimental data and to show how these judgments can be sharpened by the application of statistical methods.
- To introduce a wide range of techniques that are useful in advanced analytical chemistry.
- To teach those laboratory skills that will give students confidence in their ability to obtain high-quality analytical data.

(c) Course Contents

1.	**Nature of Analytical Chemistry**: Quantitative Analytical Methods; An Integrate Role for Chemical Analysis: Feedback Control Systems; Using Spreadsheets in Analytical Chemistry; Calculations Used in Analytical Chemistry.
2.	**Errors in Chemical Analysis**: Systematic and Random Errors in Chemical Analysis; Statistical Treatment of Random Errors; Standard Deviation of Calculated Results.
3.	**Statistical Data Treatment and Evaluation**: Confidence Intervals; Statistical Aids to Hypothesis Testing; Analysis of Variance; Detection of Gross Errors.
4.	**Chemometric Measurements**: Chemoinformatics-Chemometrics-Statistics; Multivariate Data; Regression Model; Principle Component Analysis; Cluster Analysis; Factor Analysis; Experimental Design; Optimization Methods: Sequential Simplex Optimization.
5.	**Chemical Equilibria**: Chemical Composition of Aqueous Solutions; Relative Strength of Acid/Base Pairs and Buffer Capacity; Calculation of Activity Coefficients; Solving Equilibrium Calculations for Complex System.
6.	**Classical Methods of Analysis:** Comparison Between Titrimetric and Gravimetric Methods of Analysis; Titration Curves for Complex Acid/Base Systems; Application of Neutralization, Precipitation, Complexation and Redox Titrations.

7.	**Electrochemical Methods:** Potentiometry; Potentiometric Titration; Electrogravimetry and Coulometry; Coulometric Titration; Voltammetry and Amperometric Titration.
8.	**Spectrophotometric Methods**: Colorimetric Determination and Spectrophotometric Titration; Atomic Absorption Spectrophotometric Methods; Atomic Emission Spectrophotometric Methods; Plasma Emission Spectrophotometric Methods. Comparison among the Spectrophotometric Methods.
9.	**Gas Chromatography and High-Performance Liquid Chromatography**: Applications of Gas-Liquid Chromatography and Gas-Solid Chromatography; Partition Chromatography; Adsorption Chromatography; Ion Chromatography; Size-Exclusion Chromatography; Affinity Chromatography; Chiral Chromatography; Comparison of High-Performance Liquid Chromatography and Gas Chromatography.
10.	**Miscellaneous Separation Methods:** Supercritical Fluid Separations; Planar Chromatography; Capillary Array Electrophoresis; Capillary Electrochromatography; Field-Flow Fractionation.

(d) Course Learning Outcomes (CLOs):

After completion of the Course, the Student will be able to –

CLO-1: Demonstrate the different analytical methods with advantages and disadvantages.

CLO-2; Calculate the statistics of analysis and conduct statistical test to explore the decision regarding analysis.

CLO-3: Select a suitable analytical method for particular analysis to fulfill the objectives.

CLO-4: Apply volumetric, gravimetric, spectrophotometric, electrometric and chromatographic methods for particular analysis of specific sample.

CLO-5: Compare among spectrophotometric, electrometric, chromatographic methods of analysis.

CLO-6: Analyze the multivariate data by graphical interpretation.

CLO-7: Evaluate the performance of different analytical methods in terms of detection limit, selectivity and sensitivity.

CLO-8: Develop a suitable model for particular purpose of analysis.

(e) Mapping Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs):

	PLO1	**PLO2**	**PLO3**	**PLO4**	**PLO5**	**PLO6**	**PLO7**	**PLO8**
CLO1	3	-	-	-	-	-	-	-
CLO2	3	-	-	-	-	-	-	-
CLO3	3	2	2	-	-	-	1	-
CLO4	3	2	2	-	-	-	1	-
CLO5	3	2	2	-	-	-	2	-
CLO6	3	-	2	-	-	-	2	-
CLO7	3	-	2	-	-	-	2	-
CLO8	3	2	2	-	-	-	2	2

(f) Mapping of Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy		
	Teaching-Learning Strategy	**Assessment Strategy**
CLO1	Lecturing and Video Presentation	Quiz and Summative Assessment (Midterm)
CLO2	Lecturing and Group Discussion	Summative Assessment (Final Exam)
CLO3	Lecturing and Group Discussion	Summative Assessment
CLO4	Video Presentation and Group Discussion	Summative Assessment (Midterm)
CLO5	Lectures and Group Discussion	Assignment
CLO6	Lectures and Group Discussion	Quiz and Summative Assessment (Mid-Semester)
CLO7	Class Activity and Discussion	Summative Assessment (Mid-Semester) and Summative Assessment (Final Exam)
CLO8	Demonstration and Student Activity	Assignment and Summative Assessment (Final Exam)

(g) Learning Materials
(i) Recommended Readings
• Skoog, D. A., West, D. M., Holler, F.J., and Crouch, S. R. (2012): Fundamentals of Analytical Chemistry*; Cengage Learning,* India.
• Mendham, J., Dinney, R. C., Barnes, J.D., Thomas, M. and Sivasankar, B. (2009): *Vogel's Textbook of Quantitative Chemical Analysis*, 6th Edition, *Pearson*, India.
• Christian, D. (2007): Analytical Chemistry, 6th Edition, *John Wiley & Sons (Asia) Pte. Ltd*., Singapore.
(ii) Supplementary Readings
• Verma, R.M.: Analytical chemistry, 3rd Edition, *CBS Publishers & Distributors*, India
• Fifield, F.W. and Kealey, D.: Principles & Practice of Analytical Chemistry, *Wiley-Blackwell*, India

Course Code	**Course Title**	**Credit Hours**
0531-14-513OC	Green and Sustainable Chemistry	4.0

(a) Rationale:

Today's society is moving towards becoming more and more environmentally conscious. There is rising concern of environmental pollution, depleting resources, climate change, ozone depletion, heaps and heaps of landfills piling up, legislation which is getting stringent with strict environmental laws, rising cost of waste deposits, reducing the global warming and so on. We are faced with a challenge to work towards sustainable practices. Green chemistry has arisen from these concerns. It is not a new branch of chemistry but the way chemistry should be practiced. Innovations and applications of green chemistry in education have helped companies not only gain environmental benefits but at the same time achieve economic and societal goals also. This is possible because these undergraduate students are ultimate scientific community of tomorrow.

(b) ***Course Objectives (COs):***

- Raising awareness on the potential toxic effects of different chemicals and problems related to waste generation.
- Inculcating the need to practice green chemistry as it is the only way to meet the global challenges the world is facing today. Green Chemistry possesses the potential to reduce waste generation and enhances our quality of life while conferring simultaneous benefits of protecting our environment and human health.
- Providing a basis and framework for pursuing science in the most creative, innovative and responsible manner possible.
- To make academic-industrial collaborations and the potential these relationships hold in furtherance of green chemistry and rendering our planet earth greener
- Motivate students to choose discipline and career related to this field. Eventually a student practicing green chemistry can either become an industrialist or engineer or policy maker.

(c) Course Contents	
1.	**Introduction to Green Chemistry:** What is Green Chemistry? Need for Green Chemistry. Green elements in periodic table, Goals of Green Chemistry. Limitations/ Obstacles in the pursuit of the goals of Green Chemistry.
2.	**Principles of Green Chemistry:** Twelve principles of Green Chemistry with their explanations and examples and special emphasis on Designing a Green Synthesis using these principles (Prevention of Waste/byproducts; maximum incorporation of the materials used in the process into the final products, Atom Economy, calculation of atom economy, 12 principles in chemistry lab (YALE)
3.	**Practice of twelve principles and Designing a Chemical synthesis:** Prevention/ minimization of hazardous/ toxic products; reducing toxicity, Risk = (function) hazard x exposure designing safer chemicals – different basic approaches to do so; selection of appropriate auxiliary substances (solvents, separation agents), green solvents, solventless processes, immobilized solvents and ionic liquids; energy requirements for reactions – use of microwaves, ultrasonic energy; selection of starting materials; avoidance of unnecessary derivatization – careful use of blocking/protecting groups; use of catalytic reagents (wherever possible) in preference to stoichiometric reagents; designing of biodegradable products; prevention of chemical accidents; strengthening/ development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes. Energy requirements for reactions – alternative sources of energy: use of microwaves , ultrasonic energy and photochemical energy ,Selection of starting materials; should be renewable rather than depleting, Illustrate with few examples such as biodiesel and polymers from renewable resources (such as green plastic) , Avoidance of unnecessary derivatization – careful use of blocking/protecting groups, Use of catalytic reagents (wherever possible) in preference to stoichiometric reagents; catalysis and green chemistry, comparison of heterogeneous and homogeneous catalysis, biocatalysis, asymmetric catalysis and photocatalysis. Design for degradation: A product should not persist after the commercial function is over e.g. soaps and detergents, pesticides and polymers, Strengthening/ development of analytical techniques to prevent and minimize the generation

	of hazardous substances in chemical processes. Prevention of chemical accidents designing greener processes, inherent safer design, principle of ISD "What you don't have cannot harm you", greener alternative to Bhopal Gas Tragedy (safer route to carcarbaryl) and Flixiborough accident (safer route to cyclohexanol) subdivision of ISD, minimization, simplification, substitution, moderation and limitation.
4.	**Accelerating Innovations through Emerging Green Technologies**: Green Solvents, Problems associated with traditional solvents, Water as a green solvent, Ionic Liquids, Bio-based Solvents, Green Catalysts, General Introduction to Catalysis, Types of Catalysts, Green Catalyst, Nanocatalyst, super critical fluids with special reference to carbon dioxide, water as a solvent for organic reactions, PEG, solventless processes, solvents obtained from renewable resources and how to compare greenness of solvents, Green Energy, Global Warming (Climate Change), Renewable energy, Microwave Assisted Synthesis, Ultrasound Assisted Synthesis
5.	**Green Synthesis/Reactions:** Examples of Green Synthesis/ Reactions: Green Synthesis of the following compounds: Adipic acid, catechol, BHT, disodium iminodiacetate (alternative to Streckersynthesis); Green Reagents: Non-phosgene Isocyanate Synthesis, Selective Methylation using dimethylcarbonate. Microwave assisted solvent free synthesis of copper phthalocyanine. Microwave assisted reactions in water: Microwave assisted reactions in water: Hofmann Elimination, methyl benzoate to benzoic acid and Decarboxylation reaction. (Hofmann Elimination, methyl benzoate to benzoicacid, oxidation of toluene and alcohols) and reactions in organic solvents (Diels-Alder reactionand Decarboxylation reaction); Ultrasound assisted reactions: sonochemical Simmons-Smith Reaction (Ultrasonic alternativeto Iodine); Esterification, saponification, substitution reactions, Alkylations, oxidation, reduction, coupling reaction, Cannizaro reaction, Strecker synthesis, Reformatsky reaction. Surfactants for carbon dioxide – replacing smog producing and ozone depleting solvents with CO2 for precision cleaning and dry cleaning of garments. Designing of Environmentally safe marine antifoul ant. An efficient, green synthesis of a compostable and widely applicable plastic (poly lactic acid) made from corn. Healthier Fats and oil by Green Chemistry: Enzymatic Inter esterification for production of non-Trans-Fats and Oils
6.	**Green Chemistry in Pharmaceutical Industry:** Green Trends being followed in pharma Industrial Case Studies: *Ranitidine*, *Celecoxib, Ibuprofen*
7.	**Future Trends in Green Chemistry:** Oxidation reagents and catalysts; Biomimicry and green chemistry, Biomimetic, Multifunctional Reagents; mechano chemical and solvent free synthesis of inorganic complexes; co crystal controlled solid state synthesis (C2S3); Green chemistry in sustainable development.

***(d) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to –

CLO-1: Understand the twelve principles of green chemistry and will build the basic understanding of toxicity, hazard and risk of chemical substances.

CLO-2: Understand stoichiometric calculations and relate them to green chemistry metrics. They will learn about atom economy and how it is different from percentage yield.

CLO-3: Understand benefits of use of catalyst and bio catalyst, use of renewable feed stock which helps in energy efficiency and protection of the environment, renewable energy sources, importance led reactions in various green solvents.

CLO-4: Familiarizing students with the new emerging green technologies (new catalysts, solvents and energy sources) that would help them gain new insights on how pollution can be prevented through thoughtful design of chemical products and processes.

CLO-5: Appreciate the use of green chemistry in problem solving skills, critical thinking and valuable skills to innovate and find out solution to environmental problems. Thus, the students are able to realise that chemistry can be used to solve rather than cause environmental problems.

CLO-6: Green chemistry is a way to boost profits, increase productivity and ensure sustainability with absolute zero waste. Students have many career opportunities as " green" is the path to success.

CLO-7: Learn about the green trends being practiced in pharmaceutical industries through depiction of some interesting industrial case studies.

(d) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

	PLO1	**PLO2**	**PLO3**	**PLO4**	**PLO5**	**PLO6**	**PLO7**	**PLO8**
CLO1	3	-	-	2	-	-	-	1
CLO2	3	-	-	3	-	2	-	-
CLO3	3	3	3	3	-	2	1	3
CLO4	3	-	2	2	-	2	-	3
CLO5	3	-	2	2	2	2	-	3
CLO6	3	-	2	1	2	-	-	-
CLO7	3	-	-	2	-	2	-	-

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) ***Mapping of Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy***

CLOs	**Teaching-Learning Strategy**	**Assessment Strategy**
CLO1	Lecturing and Discussion	Summative (Mid-Semester-1) and Semester Final
CLO2	Lecturing and asking	Summative (Mid-Semester-1) and Semester Final
CLO3	Lecturing and Demonstration	Summative (Mid-Semester-1I) and Semester Final
CLO4	Lecturing and Students activity	Summative (Mid-Semester-1I) and Semester Final
CLO5	Lecturing and Project Based Learning	Summative (Semester Final) and Assignment
CLO6	Lecturing and Project Based Learning	Summative (Semester Final) and Assignment
CLO7	Lecturing and Group Discussion	Summative (Semester Final) and Assignment

(g) Learning Materials
(i) Recommended Readings
• Ahluwalia, V.K., Kidwai, M.R. *New Trends in Green Chemistry*, Anamalaya Publishers (2005).
• Anastas, P.T. & Warner, J.K, *Green Chemistry- Theory and Practical*, Oxford UniversityPress (1998).
• Matlack, A.S. *Introduction to Green Chemistry*, Marcel Dekker (2001).
(ii) Supplementary Readings
• Cann, M.C.and Connely, M.E. *Real-World cases in Green Chemistry*, ACS (2000).
• Lancaster, M. *Green Chemistry: An Introductory Text* RSC Publishing, Second Edition, 2010.

Course Code	**Course Title**	**Credit Hours**
0531-14-514OC	Advanced Organic Reactions and Stereochemistry	**4.0**

(a) Rationale:

Advanced organic reactions and stereochemistry describe the kinetics and advanced mechanism of esterification and ester hydrolysis, O-alkylation and C-alkylation. This course is designed to provide an idea about the nucleophilic rearrangement reactions. Stereochemistry of Allenes, Spiranes and Biphenyls are also described. Quantitative correlation between conformation and reactivity are discussed in this course. Free radical reactions mechanism also described in this course. Some important name reactions will also be addressed in this course.

(b) Course Objectives (COs):

- To provide knowledge about kinetic and non-kinetic methods of determining reaction mechanism and linear free energy relationship.
- To know the ester hydrolysis of different methods and its reaction mechanism and its synthetic uses.
- To give information about O-alkylation and C-alkylation of active methylene compounds.
- To know about different nucleophilic and free radical rearrangement reactions and its mechanism.
- To gather idea about stereochemistry of allenes, spiranes and biphenyls compounds.
- To impart knowledge about the correlation between conformation and reactivity of cyclohexane compounds.
- To give knowledge about linearly and circularly polarized light, ORD and CD curves – Cotton effect. Empirical and Semi-empirical rules.

(c) Course Contents	
1.	**Methods of determining reaction mechanism**: Kinetic & non-kinetic methods of determining reaction mechanism. Linear free energy relationships. Application and limitation of Hammett equation. Yukawa-Tsuno equation and its application. Introduction to Taft equation.
2.	**Mechanism of esterification and hydrolysis:** ($A_{AC}1$, $A_{AC}2$, $A_{AL}1$, $A_{AL}2$, $B_{AC}1$, $B_{AC}2$, $B_{AL}1$ and $B_{AL}2$) mechanisms, stereochemistry, weakness and deviations, transesterification, and its uses in synthesis.
3.	**Alkylation and Acylation**: Introduction, Types of alkylation and alkylating agents: C-Alkylation, O-Alkylation and Acylation of active methylene compounds and Applications.

4.	**Rearrangements:** Mechanisms, nucleophilic rearrangement, actual nature of migration, migratory aptitudes, memory effects, longer nucleophilic rearrangements, free radical rearrangement, dienone-phenol rearrangement, Favoriski, Fritsch-Buttenberg-Wiechell Sticglitz, Bayer-Villiger, Steven's rearrangement.
5.	**Stereoisomerism**: Axial chirality, Planar chirality and Helicity, Principles of axial and planer chirality, Stereochemistry of Allenes, Spiranes, Biphenyls, Atropisomerism.
6.	**Dynamic stereochemistry**: Conformationally rigid and mobile diastereoisomers, A single substrate with two or more conformers, Quantitative correlation between conformation and reactivity–Winstein-Eliel equations, Curtin-Hammett Principle, its application in determining the course of reaction.
7.	**Molecular Disymmetry and Chiroptical:** Polarised lights and chiroptical properties, Linearly and circularly polarized light, ORD and CD curves – Cotton effect. Empirical and Semiempirical rules-The axial haloketone rule, The octant rule, Helicity rule and Lowe's rule.

***(d) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to –

CLO-1: Write and explain the knowledge on Application and limitation of Hammett equation. Yukawa-Tsuno, Taft equation and its application.

CLO-2: Illustrate the mechanism, applications and limitations of different methods of ester hydrolysis and trans-esterification and alkylation.

CLO-3: Demonstrate the different rearrangements reactions mechanism.

CLO-4: Predict the stereochemistry of allenes, spirans and biphenyls.

CLO-5: Explore the stability of conformation. Quantitative correlation, applications reactivity, Winstein-Eliel equations, Curtin-Hammett Principle.

CLO-6: Demonstrate the ORD, CD curves, Cotton effect, Empirical and Semiempirical rules, axial haloketone rule, The octant rule, Helicity rule and Lowe's rule.

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	3	1	-	-	-	-	-	-
CLO2	3	1	-	1	-	-	-	-
CLO3	3	-	1	-	-	-	-	-
CLO4	3	-	-	-	-	-	-	-
CLO5	3	-	1	-	-	-	-	-
CLO6	3	-	-	-	-	-	-	-

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping of Course Learning Outcomes (CLOs) with Teaching-Learning & Assessment Strategy

CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecturing and Discussion	Summative (Semester Final) and Assignment
CLO2	Lecturing and asking	Summative (Mid-Semester-1) and Semester Final
CLO3	Lecturing and Demonstration	Summative (Mid-Semester-1) and Semester Final
CLO4	Lecturing and Students activity	Summative (Semester Final) and Assignment

CLO5	Lecturing and Project Based Learning	Summative (Mid-Semester-2) and Semester Final
CLO6	Lecturing and Project Based Learning	Summative (Semester Final) and Assignment

(g) Learning Materials

(i) Recommended Readings

- Peter Sykes, A Guide Book to Mechanism in Organic Chemistry,6th edition, Pearson: New York, 2016.
- Finar I. L., Organic Chemistry (Volume II), 5th edition, Pearson, New
- Elial E. L., Stereochemistry for Carbon Compounds, McGraw-Hill, 1962.

(ii) Supplementary Readings

- Kalsi P. S., Stereochemistry, Conformation and Mechanism, 4th edition.
- House. H. O., Synthetic Application of Organic Reactions.

Course Code	**Course Title**	**Credit Hours**
0531-14-515OC	Clinical Chemistry	**4.0**

(a) Rationale:

This Learning Guide is intended to serve the basic educational needs of new medical laboratory scientists who are entering the field of clinical laboratory medicine. Anyone associated with the specialty of clinical chemistry or the clinical laboratory will find this Learning Guide of interest.

***(b) Course Objectives (COs)*:**

- To acquire knowledge how the nutritional aspects are linked to various metabolic pathways involved in the growth and development of the living systems.
- To analyze how metabolic disorders lead to various diseases in human body.
- To investigate the sources of errors and ensuring the accuracy of the experiment.
- To fix up the diseases by relevant test and predict alternative way to be cured.

(c) Course Contents

1.	**Introduction to clinical chemistry:** Key concepts, Common Analytes, Combinations of Tests, Biologic Specimens, Reference Intervals
2.	**Principles of Measurement:** Key Concepts, Photometry, Absorbance, Turbidimetry and Nephelometry, Fluorescence, Potentiometry, Endpoint and Rate Reactions, Calibration
3.	**Testing Strategies to Select Fora Specific Analyte:** Key Concepts, blanking for endpoint Reactions, Use of Selected time Windows for Rate Reactions, Pretreatment, and Choosing Methods that are Highly Selective.
4.	**Accuracy:** Key Concepts, Precision and Accuracy, Assigning Values to Calibrators, Matrix Effects, Ensuring Accuracy.
5.	**Sources of Error:** Key Concepts, Three Divisions for source of Error**,** Pre-analytical Errors That Can Affect the Accuracy of a Test Result, Analytical Errors that can affect the Accuracy of a Test Result, Analyte Concentration is Higher than the measurement Range for the test**.**
6.	**Common Clinical Chemistry Tests:** Key Concepts, Electrolytes and Ions, Small Molecules and Metabolites, Proteins, Lipids and Lipoproteins, Therapeutic Drug Monitoring, Toxicology and Drugs of Abuse

7.	**Testing in Clinical Practice:** Key Concepts, Diabetes, Monitoring of Diabetes and Diabetic Complications, Cardiovascular Disease, Troponins in the Diagnosis of Myocarbial in Function, Throid Diseases, Anemia, Iroan Nutrition, Kidney Function**.**
8.	**Units of Measure:** Key Concepts, Moles Versus Mass, Enzymatic Activity, Analytes that Cannot be Expressed in Terms of Molecules or Moles.

***(d) Course Learning Outcomes (CLOs)*:**

After completion of the course, the student will be able to –

CLO-1: Understand the knowledge of the collection, preservation, and biochemical testing of clinical samples (blood, urine, CSF, *etc*.).

CLO-2: Gather critical understanding of genetic metabolic defects and their role in carbohydrate, lipid, protein, and nucleotide diseases.

CLO-3: Apply enzymatic assay protocols and compare its analysis for diagnosing illnesses, particularly hepatobiliary diseases.

CLO-4: Evaluate and interpret the laboratory results for gastric, hepatic, and pancreatic functional tests.

CLO-5: Gather depth knowledge of the diagnosis, complications, and management of major diseases, including diabetes, cancer, and organ failure.

(e) Mapping Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs):

CLOs	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO-1	3	-	-	2	-	-	-	1
CLO-2	3	-	-	3	-	2	-	-
CLO-3	3	-	-	3	-	2	1	3
CLO-4	3	-	2	2	-	2	-	3
CLO-5	3	-	2	2	2	2	-	3

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping of Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy

CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO-1	Lecture and Discussion	Summative (Mid-Semester-1)
CLO-2	Lecture and Discussion	Assignment and Presentation
CLO-3	Review, Lecture and Discussion	Assignment with Rubrics Assessment (Midterm)
CLO-4	Lecture and Discussion	Summative (Mid-Semester-2) Summative (Final Exam)
CLO-5	Review Lecture and Discussion	Summative (Final Exam)
CLO-6	Lecture and Discussion	Summative (Final Exam)

(g) ***Learning Materials***

(i) Recommended Readings

- Roberta Reed, PhD, *learning guide Clinical Chemistry,* Abbot pub.
- Christial, G. TD. Analytical Chemistry, Wiley.

(ii) Supplementary Readings

- Verma, R.M., *Analytical chemistry*, 3rd Edition, CBS Publishers & Distributors, India
- Bassett, J., Dinney, R. C., Jeffery, G. H., and Mendham, J., *Vogel's Textbook of Quantitative Inorganic Analysis*, Longman.

Course Code	**Course Title**	**Credit Hour**
0531-14-516L	Advanced Experiments in Physical Chemistry	3.0

(a) Rationale:

By carrying out laboratory work, students gain insight and are more able to solve the problems in advanced physical chemistry. Hands on training are pre-requisite to perform experiments successfully with fulfilling the intended objectives on chemistry laboratory. There are some sensitive expensive tools and techniques in chemistry which have to be acquired and be skilled through used to these tools before real life experiments. This course includes some tools and techniques covering basically physical chemistry laboratory specially on electrochemistry, catalysis, kinetics, thermodynamics, and solution chemistry.

(b) Course Objectives (COs):

- To guide you in developing efficient lab. techniques and in making your laboratory a pleasant place
- To gather knowledge in physical chemistry for analyzing and proposing methods
- To understand electrochemistry/catalysis
- To execute kinetics and physicochemical parameters experimentally in aqueous/buffer solution

(c) Course Contents

1.	Verification of Ostwald's dilution law and determination of thermodynamic dissociation constant of a weak monobasic acid conductometric/pH-metric method
2.	Verify the catalytic performance of metal salt/catalyst with the help of cyclic voltammetry (CV, LSV and DPV) and bulk electrolysis (CPE)
3.	Verification of Ostwald's dilution law and determination of thermodynamic dissociation constant of a weak monobasic acid conductometric/pH-metric method
4.	Measurement of second order rate constant of hydrolysis of CH_3-COOEt by NaOH by conductometric method
5.	Determination of CMC of a surface-active agent by conductometry/surface tension method
6.	Determination of excess thermodynamic parameters ($\Delta H^{\#E}$, $\Delta S^{\#E}$ and $\Delta G^{\#E}$) of binary liquid mixtures
7.	Verify the viscous behavior of alkanol/glycerin in water at different composition & temperature and the calculation of area of cross section
8.	Determination of intrinsic viscosity and molar mass of polystyrene by viscosity method
9.	Determination of partial molar volume of alcohol in dilute aqueous solution

(d) Course Learning Outcomes (CLOs):

Upon successful completion of this course, students will have the knowledge and skills to-

CLO1: Demonstrate the safety rules, handling of chemicals and glassware during laboratory class

CLO2: Perform electrochemical experiments in aqueous/buffer solution

CLO3: Execute kinetics experimentally to determine rate constant in aqueous/buffer solution
CLO4: Conduct physicochemical experiments in liquid-liquid solution

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	3	-	-	-	-	-	-	-
CLO2	3	-	1	2	-	2	-	-
CLO3	3	-	1	2	-	2	-	-
CLO4	3	-	1	2	-	2	-	-

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) ***Mapping of Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy***

CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecturing	Course preparatory quiz and safety awareness
CLO2	Lab. activities and data reporting	Lab. report (with Rubrics) & Midterm exam. (Formative)
CLO3	Lab. activities and data reporting	Final lab. exam. (Summative)
CLO4	Lab. activities and lab. report evaluation	Final lab. exam. (Summative)

(g) Learning Materials

(i) Recommended Readings

- Findlay A., Longmans, *Practical Physical Chemistry*, Green & Company Ltd
- Daniel, Mathews and William, *Experimental Physical Chemistry*.
- Bell and New Combe, *Experiments in Physical Chemistry*.
- Palit, *Practical Physical Chemistry*, Science Book Agency, Calcutta.
- Sharma, *Practical Physical Chemistry*, Vikas Publishing House Pvt. Ltd.
- Yadav J. B., *Advanced Practical Physical Chemistry*.
- Sharma K. K., Sharma D. S., *An Introduction to Practical Physical Chemistry*.
- Khaleque S.A., Experimental Physical Chemistry

(ii) Supplementary Readings

- Viswanathan B., Gaghavan P.S., Practical Physical Chemistry, Science Book Agency, Calcutta
- Athawale V.D., Mathur P., Experimental Physical Chemistry, New Age International Pvt. Ltd. New Delhi.

Course Code	Course Title	Credit Hours
0531-14-521	Advanced Spectroscopy and Chromatography	3.0

(a) Rationale:

This course focuses knowledge and techniques for forming and unearthing chemical structure of unknown organic compounds.

(b) Course Objectives (COs):

- To learn the principles of a few spectroscopic techniques (e.g., UV-Visible, IR, Raman, ESR, NMR, and mass spectrometry).
- To apply these spectroscopic techniques in identifying the structure of an unknown compound and in their research.
- To impart knowledge on chromatographic techniques and use these for chemical analysis.

(c) Course Contents

1.	**Nuclear Magnetic Resonance (NMR):** **^{1}H NMR Spectroscopy:** Review of basic NMR principles, instrumentation and experimental principles, advanced ideas of chemical shift, chemical exchange, effect of deuteration, stereochemistry, hindered rotation, first and second order spectra, identification of spin systems: A_2, AB, AX, AB_2, AX_2, A_2B_2, A_2X_2, ABC, ABX, ABX_2 and AMX systems. different types of couplings (one, two and three bond coupling, vicinal and germinal coupling, virtual, long range and allylic coupling), magnitude of coupling constant, factors affecting the coupling constant, Karplus equation, simplification of complex spectra (Nuclear double resonance, nuclear overhauser effect (NOE), ROE, and shifts reagents), internal rotation and the equivalence and non-equivalence of nuclear polarization, relaxation effect, spin-lattice relaxation, measurement of T_1, mechanism of spin-lattice relaxation, application of dipolar relaxation times, spin-spin relaxation, the multiple irradiation techniques, elimination of quadruple effects, multiple pulse sequence, measurement of T_2, spectral editing, signal and resolution enhancement, connectivity, solid state NMR, applications of ^{1}H-NMR in the structure elucidation of organic compounds and medical science. **^{13}C NMR Spectroscopy:** Resolution and multiplicity of ^{13}C NMR, instrumentation, chemical shifts (aliphatic, olefinic, alkyne, aromatic, heteroaromatic and carbonyl carbons), effect of substituents on chemical shifts, theoretical calculation of ^{13}C value, ^{1}H-decoupling, noise decoupling, broad band decoupling, NOE and origin of nuclear overhauser effect, off-resonance, proton decoupling, DEPT, INEPT, DANTE, structural applications of ^{13}C NMR. **Two-dimensional (2D) NMR:** Homo- and heteronuclear correlation (COSY, COLOC, HSQC, DEPT, HMBC & HETCOR experiments), measurement of the nuclear Overhauser effect (NOESY, ROSEY), J resolved 2D NMR spectroscopy (TOCSY, SECSY, EXTASY, INADEQUATE and RELAY experiments), introduction to tactics strategies of structure elucidation by one and two-dimensional NMR skeletal structure (atom connectivities) by NMR experiments, relative configuration and conformation by NMR.
2.	**NMR Spectroscopy of some other Nuclei:** ^{15}N, ^{19}F, ^{31}P and D and ^{11}B.
3.	**Mass Spectrometry:** Review of basic mass spectrometry principles and instrumentation, Ionization methods: Electron Impact (E1) & Chemical Ionization (Cl), Desorption Ionization Techniques: Fast Atom Bombardment (FAB), Secondary Ion Mass Spectroscopy (SIMS), Matrix Assisted Laser Desorption/ Lonization (MALDI), Electrospray ionization (ESI) & Thermo Spray (TS) spectra, , Field Desorption (FD) & Plasma Desorption (PD), Tandem Mass

	Spectroscopy (MS-MS/MS-MS-MS). Analyzer: Magnetic Sector, Double-Focusing, Quadruple, Ion Trap, Time-of-Flight (TOF), Fourier Trans-formation Cyclotron Resonance (FTICR or FTMS). Structural study of simple and complex organic compounds and application to macromolecules.
4.	**Advanced Chromatographic Techniques:** Theory, principles, instrumentation and applications of separation methods for chemical analysis: LC, GLC, HPLC, GC, combined techniques (GC/MS, LC/MS), GPC, Ion-exchange and supercritical fluid chromatography.

***(d) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to-
CLO-1: Explain the factors affecting the λmax, stretching frequency, chemical shift.
CLO-2: Calculate λmax value, stretching frequency, chemical shift and mass/charge ratio and natural abundances of elements.
CLO-3: Interpret of UV, IR, NMR, Raman and ESR spectroscopic techniques and Mass spectrometry.
CLO-4: Identify unknown molecules using a combination of all the spectroscopic techniques.

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

	PLO1	**PLO2**	**PLO3**	**PLO4**	**PLO5**	**PLO6**	**PLO7**	**PLO8**
CLO1	1	-	-	-	-	-	-	-
CLO2	1	-	-	-	-	-	-	-
CLO3	1	-	1	-	-	-	-	-
CLO4	1	-	-	2	-	-	-	-

(f) Mapping of Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy

CLOs	**Teaching-Learning Strategy**	**Assessment Strategy**
CLO1	Lecturing and Discussion	Summative (Mid-Semester-1) and Semester Final
CLO2	Lecturing and Students activity	Summative (Mid-Semester-1I) and Semester Final
CLO3	Lecturing and Project Based Learning	Summative (Mid-Semester-1I) and Semester Final
CLO4	Lecturing and Group Discussion	Assignment and Semester Final

(g) Learning Materials

(i) Recommended Readings

- D. L. Pavia, G. M. Lampman and G. S. C. Kriz, Introduction to Spectroscopy
- D. H. William and Ian Flemming, Spectroscopic Methods in Organic Chemistry, 4th edition
- T. C. Morril, R. S. Silverstein & G. C. Bessler, Spectrometric Identification of Organic Compounds, 4th edition.
- H. Gunther, NMR Spectroscopy
- J. K. M. Sanders and B. K. Hunter, Modern NMR Spectroscopy

(ii) Supplementary Readings

- D. Campbell and R. A. Dwek, Biological Spectroscopy
- E. A. V. Ebsworth, D. W. H. Roukin & S. Croadock, Structural Methods in Inorganic Chemistry.
- P. S. Kalsi, Spectroscopy of Organic Compounds

Course Code	**Course Title**	**Credit Hours**
0119-14-522	Chemical Education and Pedagogy	4.0

(a) Rationale:

This course is designed to introduce the concept of educational philosophy, learning theories and pedagogical approaches-teaching-learning methods with strong emphasis on gaining experience in teaching chemistry. This course provides a critical investigation of approaches associated with classroom teaching and learning practices, crossing boundaries between education, history and philosophy. The course draws on a range of cultural and societal perspectives to encourage students to explore contemporary approaches to the impact of teacher beliefs and practice on educational outcomes for students. Students are encouraged to develop their understanding and analysis of contemporary theories of educational approaches. By the end of the course, students will understand teacher beliefs and the impact upon these on classroom practices, student engagement that support or hinder successful outcomes and societal expectations of the educational system.

(b) Course Objectives (COs):

- Engage with primary, secondary, and tertiary literature in the fields of learning theory, educational theory and best practices, and STEM education research
- Apply pedagogical content knowledge (PCK) from science and chemistry education (and educational theory, in general) to weekly learning sessions.
- Reflect on their knowledge of education and pedagogy and how they develop this knowledge over the course of the semester
- Appreciate the concept of lifelong learning, and explore how their own thoughts and understanding of concepts related to teaching and learning evolve over time

(c) Course Contents

1.	Introduction Educational Theory and Chemical Education
2.	Learning Theory
3.	Embedding Graduate Attributes at the Inception of a Chemistry Major in a Bachelor of Science: Development of key skills and attributes in chemistry
4.	Constructing Active Learning in Chemistry: Concept, Cognition and Conceptions
5.	Development of theoretical Frameworks for Understanding the Learning of Chemistry
6.	Linking the Macro with the Sub-micro-Levels of Chemistry: Demonstrations and Experiments that can Contribute to Active/Meaningful/Conceptual Learning
7.	Challenging Myths About Teaching and Learning Chemistry
8.	The Learning Chemistry: The Key Role of Working Memory
9.	Educational Models and Differences between Groups of 16-years old Students in Gender, Motivation, and Achievements in Chemistry
10.	Problem Solving Through Cooperative Learning in the Chemistry Classroom
11.	Learning Company Approach to Promote Active Chemistry Learning

12.	Student's Achievement in Learning Chemistry Through the Design and Construction Approach to Laboratory Activity and Relation with their Achievements and Motivation to Learn
13.	Application of Case Study and Role Playing in Forensic Chemistry and Analytical Chemistry Education

(d) Course Learning Outcomes (CLOs):

After completion of the Course, the Student will be able to –

CLO1: Demonstrate educational and learning theory with best practices and Bangladesh perspectives.

CLO2: Outline a framework for profiling different approaches to teaching.

CLO3: Describe the assumptions, values and practices associated with different approaches to teaching in science.

CLO4: Design the curriculum to meet the educational objectives.

CLO5: Analyze reports in the STEM education and chemistry education research (CER) literature and evaluate the usefulness, applicability, and transfer of these findings to the role of academic peer leader positions (e.g., chemistry teaching interns (TIs), tutors, and workshop leaders).

CLO6: Critically evaluate the implications of the different approaches to teaching and learning to support or hinder successful outcomes and societal expectations of the educational system.

CLO7: Synthesize their own informed opinions, arguments, and ideas about chemistry education, chemistry pedagogy, teaching (from the perspective a TI), and student learning in chemistry and other STEM courses.

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

CLOs	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO-1	3	-	-	-	-	-	-	-
CLO-2	3	-	-	-	-	-	-	-
CLO-3	3	-	-	-	-	-	-	-
CLO-4	3	-	-	-	-	-	-	-
CLO-5	3	-	2	-	-	-	2	-
CLO-6	3	-	2	-	-	1	-	-
CLO-7	3	-	2	1		1	2	1

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping Course Learning Outcomes (CLOs) with Teaching-Learning & Assessment Strategy

CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecture and Discussion	Summative (Midterm)
CLO2	Lecture and Discussion	Assignment and Presentation
CLO3	Lecture and Discussion	Summative (Midterm)
CLO4	Review Lecture and Discussion	Summative (Final Exam)
CLO5	Review Lecture and Discussion	Project and Presentation
CLO6	Review Lecture and Discussion	Summative (Final Exam)

CLO7	Lecturing and Group Discussion	Assignment and Semester Final

(g) Learning Materials
(i) Recommended Readings
• Iztok Devetak, Saša Aleksij Glazˇar, (2014). Learning with Understanding in the Chemistry Classroom, Springer Science+Business Media B.V. • Tripti Saini (2017). Pedagogy Of Chemistry, Published by Bookman, Delhi, India
(ii) Supplementary Readings
• I. Eilks and A. Hofstein(eds) (2013), Teaching Chemistry-A Study Book, 213-240, Sense Publishers
• Lockey, et al. (2020). Educational Theories and Its application to advanced life support courses: a narrative review, *Resuscitation Plus*, Published by Elsevier B.V.
• Melanie M. Cooper and Ryan L. Stowe (2018). Chemistry Education Research-From Personal Empiricism to Evidence, Theory, and Informed Practice, *Chemical Reviews*, Published by American Chemical Society (ACS).

Course Code	**Course Title**	**Credit Hours**
0531-14-523PC	Electroanalytical Chemistry	4.0

(a) Rationale:

This course illustrates the basic principles and applications of modern electroanalytical methods at the advanced level. It helps students to understand the basic principles of electrochemistry involved in various electroanalytical techniques. As a consequence, they will be able to apply the electroanalytical techniques for analytical applications.

(b) Course Objectives (COs):

- To learn electrochemical cells, thermodynamics, and kinetics.
- To apply techniques like potentiometry, voltammetry, and coulometry for quantitative analysis.
- To focus on mastering the Nernst equation, analyzing mass transfer, evaluating ion-selective electrodes, and developing practical skills in modern electrochemical instrumentation for analytical, environmental, and industrial applications.

(c) Course Contents

1.	**Kinetics of Electrode Process :** Faradic and non-Faradic processes; mass transport-controlled reactions; electrode polarization and overpotential; classification of polarization phenomenon, the concept and theory of diffusion overpotential; diffusion-controlled reactions; principles and applications of polarography; basic factors in ion discharge; formulation of overall kinetic rate equation, concentration dependence of rate of a discharge step, net currents and exchange currents; heats of activation and frequency factors; activation controlled reactions; kinetics and mechanism of some simple electrode reactions.
2.	**Electrode Reactions in Cyclic Voltammetry:** Theory of cyclic voltammetry, interpretation of cyclic voltammogram; reversible, irreversible and quasi-reversible systems with single and multi-electron transfer, effects of pH, solvents and homogeneous

	chemical reactions on cyclic voltammetry; reaction mechanism: EC, E; adsorption processes; quantitative applications.
3.	**Controlled Potential Techniques of Voltammetry:** Chronoamperometry, pulse voltammetry: normal pulse, differential pulse, square-wave, and stair case voltammetry, Stripping voltammetry: stripping analysis; anodic, potentiometric and adsorptive voltammetry and potentiometry, cathodic stripping voltammetry and its applications. Flow analysis: principles, cell design, mass transport and current response, detection modes.
4.	**Electrodes of Electrochemical Cell:** Solvent and supporting electrolytes, oxygen removal, instrumentation working electrodes viz, mercury electrodes; solid electrodes, rotating disk electrodes, carbon electrodes: glassy-carbon, carbon-paste and carbon-fiber electrodes, metal electrodes, chemically modified electrodes: self-assembled monolayers, sol-gel encapsulation of reactive species, electrocatalytic modified electrode, pre-concentrating electrodes, pre-selective coatings, conducting polymers, microelectrodes: diffusion at microelectrodes, configurations of microelectrodes, composite electrodes.
5.	**Potentiometry:** Principles of on line and in-vivo potentiometric measurements using ion selective electrodes, glass electrodes, pH electrodes, glass electrodes for other cations, liquid membrane electrodes, solid state electrodes and coated wire electrodes.
6.	**Electrode Modification and Electrochemical Sensors:** Biosensors (enzyme-based electrodes), impractical and theoretical considerations, enzyme electrodes of analytical significance e.g. glucose sensors, ethanol and urea electrodes, toxin (enzyme inhibition) biosensors, tissue and bacteria electrodes. Affinity biosensors (immunosensors, DNA hybridization biosensors, solid-state devices: microfabrication of solid-state sensor assemblies, microfabrication techniques, sensor arrays.

***(d) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to –

CLO-1: Focus on enabling students to understand electrochemical cell principles, apply the Nernst equation.

CLO-2: Gather knowledge on thermodynamics and kinetics of different electrode processes.

CLO-3: Apply various electroanalytical techniques like voltammetry, coulometry and potentiometry for quantitative analysis.

CLO-4: Analyze electrode processes, interpret experimental data for qualitative/quantitative measurements, and select appropriate instrumentation for specific applications.

CLO-5: Modify the electrodes and prepare electrochemical sensors for devices.

CLOs	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	3	-	1	-	-	-	-	-
CLO2	3	2	1	-	-	1	-	-
CLO3	3	2	1	-	-	1	-	-
CLO4	3	1	1	-	-	1	-	-
CLO5	3	1	1	-	-	1	-	-

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping of Course Learning Outcomes (CLOs) with Teaching-Learning & Assessment Strategy		
CLOs	**Teaching-Learning Strategy**	**Assessment Strategy**
CLO1	Lecturing	Course preparatory quiz Midterm-I and Final Exam. (Summative)
CLO2	Lecturing & discussion	Assignment (with Rubrics) & Final Exam. (Summative)
CLO3	Lecturing & discussion	Midterm-II & Final Exam. (Summative)
CLO4	Assignment with Rubrics & discussion	
CLO5	Presentation & discussion	Quiz/presentation (Formative)

(g) Learning Materials

(i) Recommended Readings

- Joseph Wang: Analytical Electrochemistry
- A.J. Bard.: Electrochemical Methods: Fundamentals and Applications
- Peter T. Kissenger and William R. Heineman: laboratory Techniques in Electroanalytical Chemistry
- Royce W. Murray: Molecular Design of Electrode Surfaces
- A.E.G. Cass: Biosensors
- J.J. Lingane: Electroanalytical Chemistry
- Fred C. Anson: Electroanalytical Chemistry
- Mars G. Fontans and Greene: Corrosion Engineering
- J. O'M. Bockris and A.K.N. Reddy: Introduction to Electrochemistry
- B.E. Conway: Electrode Processes
- K.J. Vetter: Electrochemical Kinetics

(ii) Supplementary Readings:

- SCI/EI published articles from world prestigious journals

Course Code	**Course Title**	**Credit Hours**
0531-14-524PC	Advanced Photochemistry	3.0

(a) Rationale:

A photocatalyst is a material which absorbs light to bring it to higher energy level and provides such energy to a reacting substance to make a chemical reaction occur. Photocatalysts are typically made of metal oxides, metal sulfides, oxysulphides, oxynitrides, and composites thereof. Until the middle of the 1980s, research on photocatalysts for overall water splitting was largely devoted to $SrTiO_3$ and TiO_2. The main bottleneck of the photocatalysts can be described as follows: (1) fast photogenerated electron–holes recombination efficiency; (2) limited visible-light response ability; (3) low specific surface area.

(b) Course Objectives (COs):

- To train highly educated professionals in the field of photocatalytic materials, with sufficient experiences, intended for the independent creative, scientific and research activity
- To train a promising technique for biodegradation and pollution control

- To optimization principles for highly efficient photocatalysts include high light response and utilization ability, excellent chemical–physical stability, low cost, and environment friendliness
- The main bottleneck of the photocatalysts can be described as follows: (1) fast photogenerated electron–holes recombination efficiency (2) limited visible-light response ability; (3) low specific surface area.

(c) Course Contents	
1.	**Light Sources in Photochemistry:** Light sources of their standardization, measurement of emission characteristics, Techniques for study of transient species in photochemical reactions, solar energy/simulation, filament lamp, discharge lamp. Lasers: basic principle of laser action, various types of lasers, characteristics of laser radiation, continuous and pulsed laser. Determination of light intensity: actinometry.
2.	**Photocatalysis:** Catalyst, photocatalyst; photocatalytic activity, types of photocatalysis; homogeneous and heterogeneous catalysis. Fundamental principles of semiconductor photocatalysis; band gap of semiconductor, mechanism. Application of photocatalysis; H_2 generation form H_2O splitting, light driven CO_2 reduction, photocatalytic organic synthesis, organic pollutant degradation, antimicrobial/disinfection, limitations of photocatalytic water treatment.
3.	**Photocatalyst and Co-catalyst in H_2 Generation:** H_2 generation and water splitting; fundamental principle, main process, energy requirement, photo-corrosion, TON/TOF. Materials for H_2 generation; homogeneous/heterogeneous photocatalyst materials, development of visible-light photocatalysts; band gap engineering; semiconductor alloys, dye sensitization, combination of semi-conductors; heterojunction and Z-scheme photocatalytic system. Control the defects, size and morphology. Co-catalyst in O_2/H_2-evolution half reaction, benchmark catalyst (Pt), transition metal oxides/hydroxides, sulphides, nanocarbon based cocatalysts, graphene-based materials, nanocrystal, hydrogenase.
4.	**TiO_2 and g-C_3N_4 Photocatalysts:** TiO_2 photocatalyst; Photo-induced hydrophilicity of TiO_2, factors affecting photocatalytic activity, synthesis, surface heterojunction, surface defect on photocatalysis, modification of TiO_2, doping of TiO_2; sensitization, ligand-to-metal-charge transfer (LMCT). Graphene (g-C_3N_4); Design/synthesis, nanostructure design of g-C_3N_4, bandgap engineering; doping, copolymerization, heterojunction; type II heterojunction *vs*. Z-scheme heterojunction.
5.	**Tools and Techniques of Photochemistry:** Fluorescence and phosphorescence spectroscopy. Flash photolysis techniques: pico-/femto-second photolysis, flash photolysis for bimolecular electron transfer. Time resolved IR spectroscopy, detection of short-lived species: matrix isolation. Laser induced breakdown spectroscopy (LIBS).

***(d) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to –

CLO-1: Gather knowledge on light source and photocatalysis with mechanism

CLO-2: Design/synthesis robust photocatalysts/co-catalyst for catalytic water splitting

CLO-3: Characterize TiO_2/g-C_3N_4 and its modification

CLO-4: Analyze the role of photocatalyst in type II heterojunction *vs*. Z-scheme heterojunction
CLO-5: Use and optimize tools of photochemistry in different techniques.

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1	3	-	1	-	-	-	-	-
CLO2	3	2	1	-	-	1	-	-
CLO3	3	1	1	-	-	1	-	-
CLO4	3	1	1	-	-	1	-	-
CLO4	3	1	1	-	-	1	-	-

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping of Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy

CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecturing	Course preparatory quiz Midterm-I and Final Exam. (Summative)
CLO2	Lecturing & discussion	Assignment (with Rubrics) & Final Exam. (Summative)
CLO3	Lecturing & discussion	Midterm-II & Final Exam. (Summative)
CLO4	Assignment with Rubrics & discussion	
CLO5	Presentation & discussion	Quiz/presentation (Formative)

(g) Learning Materials

(i) Recommended Readings

- Likodimos V., *Advanced Photocatalytic Materials*, MDPI, Switzerland
- Elisa I. Garcia Lopez, Leonardo Palmisano, *Materials Science in Photocatalysis*, Elsevier
- Naushad M., Rajendran S., Lichtfouse E., *Green Photocatalysts*, Springer

(ii) Supplementary Readings:

- SCI/EI published articles from world prestigious journals

Course Code	**Course Title:**	**Credit Hours**
0531-14-525PC	Advanced Electrochemistry	3.0

(a) Rationale:

Advanced electrochemistry pacts with the electrolytic process. In the beginning of this chapter students will learn about polarization and over voltage which involved with deep understanding to explore thereby. In the 2nd chapter, deposition phenomenon as well as its process and action in daily uses will make them to construct or fabricate different energy efficient materials. Passivity and corrosion will be then discussed which is very important in both industrial and non-industrial applications to save revenue of a country. Finally, in 4th chapter, fuel and solar cell related energy materials will be explained as they are the main foundation of the energy in near future. All these knowledges are essential in both basic and advanced level of chemistry. This course is designed to furnish well developed idea about the development of energy materials which could alter the rate of a chemical reaction.

(b) Course Objectives (COs):

- To provide knowledge about advanced electrochemical processes for next generation use.
- To impart knowledge regarding the losses in socio economical corner to develop a country.
- To provide an understanding regarding the generation of energy or the minimal use of it for the betterment of society or country.

(c) Course Contents	
1.	**Polarization and Over voltage**: Electrolysis and polarization, Dissolution and deposition potentials, Concentration polarization, Decomposition voltage of aqueous solution, Over-voltage, Metal deposition over voltage, Hydrogen over voltage, Influence of (i) C.D (ii) pH and (iii) temperature on over voltage, Growth of over voltage, Theories of over voltage.
2.	**Deposition**: Physical nature of electrodeposited metals, factors influencing the deposition of metals, Throwing power, Simultaneous discharge of cations, Depolarization of metal deposition, Separation of metals by electrolysis.
3.	**Passivity and Corrosion**: Electrochemical passivity, Passivity and current density, Chemical passivity, Theories of passivity, Mechanical passivity, Corrosion of metals, H_2 evolution type corrosion, Corrosion by O_2, Corrosion in the presence of a depolarizer. Types of corrosion, Explanation of corrosion by Evans diagrams, Corrosion protection.
4.	**Electrochemical power sources**: Electrochemical cells, Type of electrochemical cells, Fuel cells, various types of fuel cells and their description in brief, working principle of a typical fuel cell, applications of fuel cells. O_2 reduction reaction in fuel cells, Electrocatalysts for the O_2 reduction reaction, Mechanism of O_2 reduction, various importance of O_2 reduction. **Solar energy:** Mechanism and applications, Basics of Semiconductor materials, semiconductor crystal growth, band structure, carrier transport properties, point defects, optical properties, and device physics of light emitting diodes and solar cells.

***(d) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to –

CLO-1: Understanding of polarization and over voltage happened during electrolytic process.

CLO-2: Describe the deposition procedure and able to apply it in practical purposes.

CLO-3: Predict and describe the passivity and corrosion in different systems

CLO-4: Describe how corrosion of metal could be decreased to protect the revenue of a country.

CLO-5: Explain the function of batteries, solar and fuel cells as well as the commonly involved underlying electrochemical reactions

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

	PLO1	**PLO2**	**PLO3**	**PLO4**	**PLO5**	**PLO6**	**PLO7**	**PLO8**
CLO1	3	-	-	2	-	-	-	-
CLO2	3	-	-	-	-	2	-	-
CLO3	3	-	-	1	-	-	-	-
CLO4	3	-	-	2	-	-	-	-
CLO5	3	-	-	2	-	-	-	-

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping of Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy		
CLOs	**Teaching-Learning Strategy**	**Assessment Strategy**
CLO1	Lecturing	Course preparatory quiz Midterm-I and Final Exam. (Summative)
CLO2	Lecturing & discussion	Assignment (with Rubrics) & Final Exam. (Summative)
CLO3	Lecturing & discussion	Midterm-II & Final Exam. (Summative)
CLO4	Assignment with Rubrics & discussion	
CLO5	Presentation & discussion	Quiz/presentation (Formative)

(g) Learning Materials

(i) Recommended Readings

- Glasstone L., *Introduction to Electrochemistry*
- Bard A. J., *Electroanalytical Methods*

(ii) Supplementary Readings:

- Atkins P.W., *Physical Chemistry*
- Eyring E., Glasstone S., Laidler Keith J., *Chemical Kinetics*, McGraw Hill Book Co, New York.
- P. Atkins, J.de Paula, *Atkins Physical Chemistry*, 10th edition; Oxford University Press.
- Bockris and Reddy, *Advanced Electrochemistry*
- Castellan G.W., *Physical Chemistry*; 3rd edition; Narosa Pub. House, Delhi.
- Bajpai D. N., *Advance Physical Chemistry*, S. Chand & Co Pvt. Ltd, Delhi.
- Donald McQuarrie, Simon J. D., *Physical Chemistry*, 4th ed., Viva Books Pvt. Ltd.
- Barrow G.M., *Physical Chemistry*, 5th edition, Tata McGraw Hill Education Pvt. Ltd.

Course Code	**Course Title**	**Credit Hours**
0531-14-523IA	Advanced Bioinorganic Chemistry	**4.0**

(a) Rationale:

Bioinorganic chemistry involves the study of metal species in biological systems. As an introduction to the basic inorganic chemistry needed for understanding bioinorganic topics, this course will discuss the essential chemical elements, the occurrences and purposes of metal centers in biological species, the geometries of ligand fields surrounding these metal centers, and ionic states preferred by the metals. Important considerations include equilibria between metal centers and their ligands and a basic understanding of the kinetics of biological metal – ligand systems.

(b) Course Objectives (COs):

The aim of this course is to present and describe bioinorganic systems through the correlation of the function, structure and activity of inorganic elements within the organisms/ biosystems.

(c) Course Contents	
1.	Introductory Concepts: Essential chemical elements, Metals in biological systems, Charge carriers, Metals in Biological coordination: Structural and trigger, metals in Electron transfer, metals in Dioxygen transport, participation in Enzyme catalysis.
2.	Metal ion Complexation in Biological context: Thermodynamics and kinetics of Complexation reaction, Electronic and Geometric structures in biological systems, Bioorganometallic Chemistry, Types of Electron transfer in biological systems, metal detoxification.
3.	Fundamentals in Biochemistry: Proteins, Amino Acid building blocks, Protein structures and Protein functions, Nucleic Acid, Zinc finger protein, Enzyme, Enzyme kinetics, Transmission of genetic information.
4.	Group I & Group II metals in biological systems: Homeostasis of Metals & Non-metals, Phosphorous as phosphates, K^+, Na^+, Cl^- ions, Ca^{2+} transport, movement of ions across membranes, Na-Pump.
5.	Iron Containing proteins and Enzymes: Myoglobin & Hemoglobin, Structural sub-units in Myoglobin & Hemoglobin, Dioxygen binding, Oxygenated and Deoxygenated hemoglobin, behavior of dioxygen bound to metal, structure of the active site in Myoglobin & Hemoglobin, Dioxygen binding curve of Myoglobin & Hemoglobin, Carbon dioxide transport, Cytochromes, Cytochrome C, Cytochrome P450, Chlorophyll, Photosystem I & II, Hemocyanin, Hemerythrin, Iron containing protein (Ferredoxin & Rubredoxin).
6.	Blue copper Proteins: Definition, Cu-Zn superoxide dismutase, Structure and active site, Plastocyanin, Structure and active site, Magnetic behavior of copper containing proteins, Apo protein, magnetically silent protein.

***(d) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to –

CLO-1: Evaluate the role of metal ions and their movements in biological systems/living organisms.

CLO-2: Analyze the interaction of metal ions with aminoacids and proteins.

CLO-3: Describe the function of metalloporphyrins of hemoglobin/myoglobin in oxygen binding by metal ions.

CLO-4: Predict the geometric structure and function of metalloenzymes and metalloproteins.

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

CLOs	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1								
CLO2								
CLO3								
CLO4								

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy		
CLOs	**Teaching-Learning Strategy**	**Assessment Strategy**
CLO1	Lecture and Discussion	Summative (Midterm)
CLO2	Lecture and Discussion	Assignment and Presentation
CLO3	Lecture and Discussion	Summative (Midterm)
CLO4	Review Lecture and Discussion	Summative (Final Exam)

(g) Learning Materials
(i) Recommended Readings
• Ivano Bertini, Harry B. Gray, Stephen J. Lippard And Joan Selverstone ValentinE, Bioinorganic Chemistry, University Science Books, Mill Valley, California
(ii) Supplementary Readings
• R.W Hay, Bioinorganic Chemistry
• S. J. Lippard and J. M. Berg, Principles of Bioinorganic Chemistry
• Hughes, Inorganic Chemistry in Biological process
• Articles from J of Inorganic biological Chemistry and relevant journals

Course Code	**Course Title**	**Credit Hours**
0531-14-524IA	Computational Inorganic and Bioinorganic Chemistry	4.0

(a) Rationale:

Electronic structure calculations of inorganic molecules can provide fundamental insight about their physical properties and chemical reactivity. When calculations are correlated to and supported by experimental data, these would be the contributory for both improved value of experimental results and improved accuracy of computational predictions. This course will provide state-of-the-art presentations of quantum mechanical and related methods and their use in describing bonding properties, energies, transition states and spectroscopic features of both inorganic and bioinorganic systems. This would be of significant value to both experimentalists and theoreticians, and anticipate that it will stimulate both further development of the methodology and its applications in many interdisciplinary fields that comprise modern inorganic chemistry.

(b) Course Objectives (COs):

- To study the computationally electronic structure of inorganic molecules, particularly transition metal systems.
- To study Ab initio, density functional theory (DFT), semi empirical self-consistent field (SCF) and molecular mechanics.
- To apply computational methods in both inorganic and bioinorganic systems and evaluate the accuracy of computational methods.

(c) Course Content	
1.	Introduction to Computational Inorganic and Bioinorganic Chemistry: Objectives and Scope of the Study.
2.	Energy Decomposition Analysis (EDA) Method
3.	Quantum Mechanical (QM) Methods

4.	Molecular Mechanical (MM) Methods
5.	Ab initio, and Semi-empirical self-consistent field (SCF) Methods,
6.	Density Functional Theory (DFT) Methods.
7.	Calculation of bonding properties, reduction potential, pKa, electronic structure of both inorganic and bioinorganic molecules and solids
8.	Spectroscopic Properties of inorganic and bioinorganic molecules: Calculation by combined quantum mechanical/molecular mechanical approaches and Time-Dependent Density Functional Theory (TD-DFT)
9.	Modeling Inorganic/bioinorganic molecules with DFT and Quantum Mechanical/Molecular Mechanical calculation; Modeling of reactivity of bioinorganic molecules
10.	Computational Studies: Chemical Evolution of Metal Sites.

***(d) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to –

CLO-1: Explain Energy Decomposition Analysis (EDA), Quantum Mechanical (QM), Molecular Mechanical (MM), Ab initio, Semi-empirical self-consistent field (SCF), and Density Functional Theory (DFT) methods.

CLO-2: To calculate bonding properties, reduction potential, pKa and electronic structure of both inorganic and bioinorganic molecules and solids.

CLO-3: To determine/locate transition states in inorganic and bioinorganic reactions.

CLO-4: To apply Quantum Mechanical (QM)/Molecular Mechanical (MM) methods to obtain structure and energies of inorganic/bioinorganic molecules.

CLO-5: To extract/compute the spectroscopic properties by combined quantum mechanical/molecular mechanical approaches and Time-Dependent Density Functional Theory (TD-DFT).

CLO-6: To evaluate the accuracy of computational methods applied in inorganic and bioinorganic systems.

CLO-7: To design/develop model/molecular modeling to predict the structure-property relationship and reactivity in both inorganic and bioinorganic systems.

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

	PLO1	**PLO2**	**PLO3**	**PLO4**	**PLO5**	**PLO6**	**PLO7**	**PLO8**
CLO1	3	-	-	-	-	-	-	-
CLO2	3	-	-	-	-	-	-	-
CLO3	3	-	2	-	-	-	1	-
CLO4	3	-	2	-	-	-	2	-
CLO5	3	-	2	-	-	-	2	-
CLO6	3	-	2	-	-	-	2	-
CLO7	3	-	2	-	-	-	2	2

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy		
CLOs	**Teaching-Learning Strategy**	**Assessment Strategy**
CLO1	Lecture and Discussion	Summative (Midterm)
CLO2	Lecture and Discussion	Assignment and Presentation
CLO3	Lecture and Discussion	Summative (Mid-Semester)
CLO4	Review Lecture and Discussion	Summative (Final Exam)
CLO5	Review Lecture and Discussion	Project and Presentation
CLO6	Review Lecture and Discussion	Summative (Final Exam)
CLO7	Project Based Learning	Project Design (Mid-Semester)

(g) Learning Materials

(i) Recommended Readings

- Esward I. Solomon, Robert A. Scott, R. Bruce King (2009). Computational Inorganic and Bioinorganic Chemistry, John Wiley& Sons Ltd, United Kingdom.

(ii) Supplementary Readings

- A. Szabo and N.S. Ostlund (1996). 'Modern Quantum Chemistry, Dover Publications, Mineola.
- R. J. Batrtlett et al. (1994). Reviews in Computational Chemistry, eds. K.B. Lipkowitz and D.B. Boyd, VCH Publishers, New York.
- W. Koch and M.C. Holthausen (2001). A Chemist's Guide to Density Functional Theory, Wiley-VCH, Weinheim.

Course Code	**Course Title**	**Credit Hours**
0531-14-525IA	Aquatic Chemistry and Biotic Environment	4.0

(a) Rationale:

Aquatic system in our surroundings is continuously changing from its natural state on which our existence depends on. It is important to know the processes that operate within and between various species and the ways in which human activities interact with the natural processes. This course will provide tools and techniques about how treat and manage aquatic system to make it environment friendly for all.

(b) Course Objectives (COs):

- To provide knowledge regarding the chemical reactions involved in water environment for regulation of chemical composition of natural waters.
- To know the water quality requirements for their intended use.
- Attempt to show how pollution affects water quality and how the aquatic system responds to human impact, especially to stress caused by chemical perturbation.

(c) Course Contents

1.	**Chemistry of Water**: Physical and chemical properties of water; Equilibrium and kinetic models for natural waters; Chemical composition of natural waters.
2.	**Acid-Base Systems in Natural Waters**; Activity and pH scale; Numerical equilibrium calculations; pH as master variables; Equilibrium calculations using a graphical approach; Ionization fractions of acids, bases, and ampholytes; Buffer intensity and neutralizing capacity, Acid-and base-neutralizing capacity.

3.	**Dissolved Carbon Dioxide:** Introduction; Dissolved carbonate equilibria (closed system); Dissolution of CO_2; pH of sea water; Conservative quantities: alkalinity and acidity; Carbon isotopes and isotope fractionation; Biogenic organic matter.
4.	**Precipitation and Dissolution:** The solubility of oxides and hydroxides, carbonates, solubility of sulphides and phosphates; The effect of inert electrolyte on solubility; Nonideality corrections; Crystal formation; The initiation and production of solid phase; Inorganic complexes in natural waters; Organic complexes in natural waters: problems of specificity; Metlal binding by polymers and at the solid-solution interface; Need for chemical speciation; Redox conditions in natural waters.
5.	**Regulation of Chemical Composition of Natural Waters:** Introduction; Acquisition of solutes; Some characteristics of river waters and ground water; Solubility of minerals; Organic Carbon: some aspects of its origin, composition and fate; Organic substance in natural waters; Interaction between organisms and abiotic environment; Sediment water interface; Biological regulation of the composition.
6.	**Water Quality Requirement:** Water quality criteria; Temperature, pH, Total alkalinity, Hardness, Dissolved oxygen; Carbon dioxide; Dissolved gas supersaturation; Ammonia; Nitrate; Nitrite; Hydrogen sulphide; Copper and other heavy metals; Chlorine; Turbidity
7.	**Ecological Perspective of Natural Water:** Pollution and Water Quality; Disturbance of balance between photosynthesis and respiration; Response of aquatic ecosystems to xenobiotic substances; Perturbation and ecosystem structure; Global chemical cycle and pollution; Global mobilization of metal ions; The biosphere and global environment.

***(d) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to –

CLO-1: Illustrate the types of chemical reactions happening into water environment.

CLO-2: Mention and interpret the significance of different water quality parameters for their intended use.

CLO-3: Analyze the acidity and basicity of aquatic system interacting with surroundings

CLO-4: Propose the suitable techniques requiring the water treatment for intended use.

CLO-5: Apply the chemical principles and models for predicting the chemical composition of aquatic habitat.

CLO-6: Solve the problem associated with aquatic pollution focusing its ecosystem.

CLO-7: Show how pollution affects water quality and analyze how the aquatic system responds to human impact, especially to stress caused by chemical perturbation.

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

	PLO1	**PLO2**	**PLO3**	**PLO4**	**PLO5**	**PLO6**	**PLO7**	**PLO8**
CLO1	3	-	-	-	-	-	-	-
CLO2	3	2	-	-	-	-	-	-
CLO3	3	-	1	-	-	-	-	-
CLO4	3	-	-	-	-	-	-	-
CLO5	3	-	-	-	-	-	-	-
CLO6	3	-	-	-	-	-	1	
CLO7	3	-	-	-	-	-	1	2

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy		
CLOs	**Teaching-Learning Strategy**	**Assessment Strategy**
CLO1	Lecturing and Discussion	Summative (Mid-Semester & Final Exam)
CLO2	Demonstration and Group Work	Assignment and Presentation
CLO3	Demonstration and Case Study	Summative (Final Exam)
CLO4	Lecturing and Group Discussion	Summative (Final Exam)
CLO5	Demonstration and Flip Learning	Formative (Project and Presentation)
CLO6	Problem Based Learning (PBL) with Class Activity	Summative (Final Exam)
CLO7	Demonstration and Project Base Learning	Formative (Project and Presentation)

(g) ***Learning Materials***
(i) Recommended Readings
• Stumn, W and Morgan, J.J., *Aquatic Chemistry*, John Wiley & Sons, New York.
(ii) Supplementary Readings
• Boyd, C. and Tucker, C. S., *Pond Aquaculture Water Quality Management*, Kluwer Academic publishers, New York.
• Hobbie, J. E., *Estuarine Science*, Island Press, California.
• Schnoor, J. L., *Environmental Modeling*, John Wiley & Sons, New York
• Manahan, S., *Fundamentals of Environmental Chemistry*, Lewis, New York.

Course Code	**Course Title**	**Credit Hours**
0531-14-523OC	Advanced Methods in Organic Chemistry	4.0

(a) Rationale:

This course is designed to provide a knowledge on the reactive intermediates, protecting groups of different functional groups, disconnection approach and stereoselective synthesis.

(b) Course Objectives (COs):

- To give information about reaction intermediates carbenes, nitrenes, arynes and its application.
- To know Phosphorous, nitrogen and sulphur yields and its reaction mechanism and its synthetic uses.
- To give information about Enamines, heterocyclic enamines & Umpolung.
- To know about target, synthons and synthetic equivalents, disconnection approach, functional group interconversions (FGI).
- To gather idea about disconnection approach of one and two groups.
- To impart knowledge about protection and deprotection of alcohol, amines, carbonyl groups and carboxylic acids.
- To give knowledge about Enantioselective synthesis (Chiral approach) reactions and use of calculations of optical purity and enantiomeric excess.

(c) Course Contents	
1.	**Reactive Intermediates in organic synthesis**: Methods of generation and reactivity and applications: a) Carbenes, nitrenes, arynes reactions. b) Phosphorous, nitrogen and sulphur yields. c) Enamines, heterocyclic enamines & Umpolung.
2.	**Protecting groups:** a) Protection of alcohols by ether, silyl ether and ester formation b). Protection of 1,2-diols by acetal, ketal and carbonate formation c) Protection of amines by acetylation, benzoylation, benzyloxycarbonyl, t-butyloxycarbonyl, fmoc and triphenyl methyl groups. d) Protection of carbonyls by acetal, ketal and thiol acetal (Umpolung) groups. e) Protection of carboxylic acids by ester and ortho ester (OBO) formation.
3.	**Disconnection approach**: An introduction to target, synthons and synthetic equivalents, disconnection approach, functional group interconversions (FGI). Criteria for selection of target. One group C-X and two group disconnections in 1,2,1,3 -,1,4-& 1,5- difunctional compounds, Retro- synthesis of Alkene, acetylenes and aliphatic nitro Alcohols and carbonyl compounds, amines, the importance of the order of events in organic synthesis, chemoselectivity, regioselectivity. Diels Alder reaction, Michael addition and Robinson annulation. Retro- synthesis of aromatic Heterocycles and 3, 4, 5 and 6 membered carbocyclic and heterocyclic rings. Reversal of polarity (Umpolung).
4.	**Designing organic synthesis:** Designing organic synthesis involving one step disconnections: disconnection of simple alcohols, olefins and ketones. Two group disconnections: β-Hydroxy carbonyl compounds, α, β-unsaturated carbonyl compounds and 1,3-dicarbonyl compounds.
5.	**Newer methods of Stereoselective synthesis:** Introduction and Stereoselective and stereospecific reactions. Enantioselective synthesis (Chiral approach) reactions. Sharpless epoxidation, Diels-Alder selective synthesis, homotopic, heterotopic, enatiotopic and diastereotopic atoms, groups and faces. Asymmetric synthesis: use of calculations of optical purity and enantiomeric excess.

***(d) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to –

CLO-1: Explore the preparation, stability and reactions of reactive intermediates carbine, nitrene and benzyne.

CLO-2: Illustrate the mechanism of formation and reactions phosphorous, sulphur ylieds, enamine and Umpolung.

CLO-3: Demonstrate the mechanism of protection and de-protection of different functional groups.

CLO-4: Predict the designing organic synthesis by disconnection approach.

CLO-5: Explore the newer methods of stereoselective synthesis and homotopic, heterotopic, enantiotopic.

CLO-5: Diastereotopic atoms, groups, faces and asymmetric synthesis: use of calculations of optical purity and enantiomeric excess.

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):								
	PLO1	**PLO2**	**PLO3**	**PLO4**	**PLO5**	**PLO6**	**PLO7**	**PLO8**
CLO1	3	1	-	-	-	-	-	-
CLO2	3	1	-	1	-	-	-	-
CLO3	3	-	1	-	-	-	-	-
CLO4	3	-	-	-	-	-	-	-
CLO5	3	-	1	-	-	-	-	-
CLO6	3	-	-	-	-	-	-	-

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping of Course Learning Outcomes (CLOs) with Teaching-Learning & Assessment Strategy		
CLOs	**Teaching-Learning Strategy**	**Assessment Strategy**
CLO1	Lecturing and Demonstration	Summative (Mid-Semester-1) and Semester Final
CLO2	Lecturing and Demonstration	Summative (Mid-Semester-1) and Semester Final
CLO3	Lecturing and Students activity	Summative (Mid-Semester-1I) and Semester Final
CLO4	Lecturing and Project Based Learning	Summative (Semester Final) and Assignment
CLO5	Lecturing and Discussion	Summative (Semester Final) and Assignment

(g) Learning Materials
(i) Recommended Readings
• T. W. Greene and P. G. M. Wuts, Protective groups in organic synthesis, 2nd Ed., John Wiley and Sons, 1991.
• Gould E. S. Mechanism and Structure in Organic Chemistry, New impression edition, 1969.
• Warren S. & Wyatt. P., Organic Synthesis: The Disconnection Approach, 2nd edition.
(ii) Supplementary Readings
• Roberton J., Protecting Group Chemistry, 1st edition, Oxford Chemistry Primers, 1995.
• Nasipuri. D., Stereochemistry Organic Compounds, 2nd edition (revised)

Course Code	Course Title	Credit Hours
0531-14-524OC	Chemistry of Food and Nutrition	4.0

(a) Rationale:

Food sciences use chemistry, microbiology and biochemistry to help produce lasting, nutritious, and easily accessible food. Studying food sciences may help achieve a greater understanding of the development of food systems and how to create sustainable food resources for future generations. Food security is one of the major concerns of our time. The production of adequate and nutritious food for everyone, using the available recourses in a sensible and sustainable manner is a key priority worldwide, especially considering the expected effects of climate change on food production. Students who are seeking to develop a career within the food industry and related sectors and offers the opportunity to obtain a unique internationally recognized qualification from a global leader in the fields of food production, safety and food security as well as quality of food. With an ever-increasing global population, the world's food production and supply chains are under increased pressure, and issues relating to quality of food, food safety and food security are of key concern for all.

(b) Course Objectives (COs):

- To enable to gain the specialized knowledge, understanding, skills and attitudes necessary to contribute effectively and ethically to strategic decision making, opinion forming and operational management for the sustainable development of food chemistry and food supply systems.
- To provide an understanding regarding the basic principles of food chemistry.
- To provide an optimum environment for students to gain an understanding of the chemical bases of food component reactivity and functionality.
- To provide an opportunity for students to test various approaches for manipulating the chemical and/or functional properties of foods.
- To develop the specialist skills and combine food science, technology and nutrition to meet the challenges facing the industry.

(c) Course Contents

1.	**Food Chemistry and Nutrition:** Food Chemistry – definition, scope and importance of water in food, physical properties of water and ice. Water activity and relative vapour pressure. Relative vapour pressure and food stability. Principles of colorimetry, spectrophotometry, fluorometry, atomic absorption spectroscopy and chromatographic methods- HPLC and GC. Essential nutrients: sources, deficiency diseases; requirements and recommended dietary allowances, Digestion, absorption, transport and metabolism of nutrients in human system, Water in foods, Types of water in foods: Water Activity-Definition, measurement of water activity, role and importance of water activity in foods.
2.	**Carbohydrates:** Definition and importance, classification, sources, functions, physico-chemical properties, functional properties of sugars and polysaccharides in foods**.** Dietary fibre and food applications. Effect of processing on nutritional quality of carbohydrates. **Minor food constituents:** Minerals, vitamins, pigments, flavours and anti-nutritional compounds. Changes in vitamins and minerals during storage and processing. **Prebiotics and probiotics:** usefulness of probiotics and prebiotics in gastro intestinal health and other benefits, beneficial microbes; prebiotic ingredients in foods; types of prebiotics and

	their effects on gut microbes, resistant starch, fructo-oligosaccharides as probiotic food components.
3.	**Proteins, amino acids and Lipids:** Definition and importance, classification, sources, functions, physico-chemical properties and functional properties of proteins. Browning reactions in foods. Protein concentrates, isolates and hydrolysates and their applications. **Lipids**: Definition and importance, classification, sources, functions, physical and chemical properties, functional properties, rancidity and reversion, types of rancidity, factors leading to rancidity and reversion, changes in lipids during storage and processing.
4.	**Principles of food preservation:** Preservation by use of high temperature- heat resistance of microorganisms and their spores, thermal death time, TDT curve, decimal reduction time, D-value, Z-value and F-value. Determination of thermal process,12 D concept. Preservation by retorting and pasteurization. Low temperature preservation of foods- effect of chilling and freezing on microorganisms. Preservation by curing and drying- effect of water activity; microbiology of dried foods. **Contamination.** Preservation and spoilage of different food items– vegetables and fruits, meat and meat products, fish and other seafood, eggs, poultry and milk and milk products. Spoilage of canned foods- causes of spoilage, classification of canned foods based on acidity; aerobic and anaerobic spoilage of canned foods. Spoilage of dried and cured products. Spoilage of oils, bottled beverages, spices, etc. **Food Safety.** Introduction to food safety: Definition of food safety, food safety issues, factors affecting food safety. Safe food and importance of safe food, Food Contamination; Types of food contamination, harmful effects and control. **Food Adulteration.** Definition, common adulterated foods and harmful effects of adulterants.
5.	**Food Laws and Standards:** FDA regulations, USDA regulations, EPA, EFSH regulations, *Codex Alimentarius* Commission, Food Safety and Standards Regulations for different products, the Prevention of Food Adulteration Act,1954, Export and Import Laws and Regulations, Export (Quality Control and Inspection) Act, 1963., etc. Packaging and labelling laws, regulations. Concept of food traceability for food safety, traceability, Food safety and Standards Act 2006: Role of national and international regulatory agencies- food safety rule in Bangladesh. International Organization for Standards (ISO) and its standards for food quality and safety- ISO 9000 series, ISO 22000, ISO 15161, ISO 14000.
6.	**Basic Concept of Packaging**, definition, importance and scope of packaging foods, criteria for packing foods. Functions and design of food package, package development, current status and trends in food packaging. **Packaging Materials and Containers**: Origin of packaging materials; different types; properties, advantages and disadvantages of each material- glass containers, metal cans-tinplate, aluminum, TFS; aluminum foil.

***(d) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to –

CLO-1: Demonstrate a systematic or coherent understanding of the fundamental concepts, principles and processes underlying the academic field of food chemistry including food components, nutrition, processing and importances of foods, nutrition's.

CLO-2: Procedural knowledge that creates different types of professionals in the field of food science and related fields such as food industry, teaching, research, product quality, consumer goods industry, food products, cosmetics industry, etc.

CLO-3: To study the application of food processing and preservation principles and technologies in the processing, preservation, extension of shelf life and value addition of fruit and vegetable products.

CLO-4: Food law and how global trends in trade, regulation and policy influence the sustainability and wider impact of the food chain.

CLO-5: Student will be able to understand the need for packaging food, understand the various functions of food packages as influenced by their characteristics, understand the health implications of food-package interactions**.**

(d) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

	PLO1	**PLO2**	**PLO3**	**PLO4**	**PLO5**	**PLO6**	**PLO7**	**PLO8**
CLO1	3	-	-	2	-	-	-	1
CLO2	3	-	-	3	-	2	-	-
CLO3	3	3	3	3	-	2	1	3
CLO4	3	-	2	2	-	2	-	3
CLO5	3	-	2	2	2	2	-	3
CLO6	3	-	2	1	2	-	-	-

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) ***Mapping of Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy***

CLOs	**Teaching-Learning Strategy**	**Assessment Strategy**
CLO1	Lecturing and Demonstration	Summative (Mid-Semester-1) and Semester Final
CLO2	Lecturing and Demonstration	Summative (Mid-Semester-1) and Semester Final
CLO3	Lecturing and Students activity	Summative (Mid-Semester-1I) and Semester Final
CLO4	Lecturing and Project Based Learning	Summative (Semester Final) and Assignment
CLO5	Lecturing and Group Discussion	Summative (Semester Final) and Assignment

(g) Learning Materials

(i) Recommended Readings

- Fennema OR.1996. *Food Chemistry*. Marcel Dekker.
- Belitz HD.1999. *Food Chemistry*. Springer Verlag.

- Bamji MS, Rao NA & Reddy V. 2003. *Textbook of Human Nutrition*. Oxford & IBH.

(ii) Supplementary Readings

- Swaminathan M. 1974. *Essentials of Foods and Nutrition*. Vol. II. Ganesh & Co.

Course Code	**Course Title**	**Credit Hour**
0531-14-526L	Advanced Inorganic laboratory: Synthesis, Structure, and Chemical Analysis	**3.0**

(a) Rationale:

Advanced inorganic: synthesis, structure, and chemical analysis course was designed that uses scaffolded, inquiry-based lab experiments and project-based learning in order to enhance students' learning. The laboratory experiments also included opportunities for cooperative and collaborative learning through student group work and feedback. To further develop students' independent research

skills, project-based learning is incorporated in the second part of the course in which students develop a research proposal based on independent literature research and the laboratory techniques they learned

from the course in order to increase their problem-solving and critical thinking skills.

(b) Course Objectives (COs):

- To provide hands-on experience of the synthesis and characterization of variety inorganic compounds and nanocrystals.
- To provide guidelines in order to develop experimental design for assessing environmental quality such as water quality assessment through project-based learning
- To guide to develop to demonstrate their ability to use literature and computational resources to accurately retrieve and record simple chemical and physical data.

(c) Course Contents

1.	Synthesis of Copper(II) Acetate Monohydrate
2.	Preparation of Metal Complexes of Saccharin
3.	Preparation of a Liquid Crystalline Complex Aroylhydrazinatonickel(II)
4.	Insert atmospheric technique for synthesis of nancrystals
5.	Determination of Dissolved Oxygen (DO) and Biological Dissolved Oxygen (BOD) and Chemical Oxygen Demand (COD) of specific water environment

(d) Course Learning Outcomes (CLOs):

After completion of the Course, the Student will be able to –

- CLO-1: To synthesize and characterize the synthesized compound/s with some important physical properties such as melting point and spectral (such as UV-Visible, IR etc.) analysis
- CLO-2: To carry out simple multistage chemical calculations quickly and accurately, the ability to lay out an answer so that the reasoning at each stage of the calculation is clear and easy to follow.
- CLO-3: To examine a typical result from an experiment and perform a series of tasks to explain and contextualize that result.

- CLO-4: Design a scheme and synthesis of intended chemical compound/s such as complex, nanocrystals with identification and use of standard piece of laboratory equipment and to handle any chemicals used in conjunction with that equipment.
- CLO-5: To develop a project with specific aim and objectives such as water quality assessment for its intended use.

(e) Mapping Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs):

CLOs	LT	LD	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1										
CLO2										
CLO3										
CLO4										
CLO5										

(f) Mapping of Course Learning Outcomes (CLOs) with Teaching-Learning & Assessment Strategy

	Teaching-Learning Strategy	Assessment Strategy
CLO1	Demonstration and Laboratory Activities	Laboratory Final Exam (Summative)
CLO2	Case-Base Study and Group Activities	Quiz(Formative) and Mid-Semester
CLO3	Scaffolding and Laboratory Activities	Laboratory Final Exam (Summative)
CLO4	Cooperative Learning	Mid-Semester (Project Design)
CLO5	Project Based Learning	Project Evaluation (Summative)

(g) Learning Materials

(i) Recommended Readings

- Geoffry and Haydn Sutcliffe (1974). *Practical Inorganic Chemistry-Preparations, Reactions and instrumental methods*, Scinec Paperbacks.
- Szfran, Z., Pike, R. M. and Mono, M. S., *Microscale Inorganic Chemistry*, John Wiley & Sons, New York.
- V.I. Spitsyn (1987). Practical Inorganic Chemistry, MIR Publisher, Moscow.

(ii) Supplementary Readings

- Chun Chu,a Jessica L Dewey,b Weiwei Zheng. An Inorganic Chemistry Laboratory Technique Course using Scaffolded, Inquiry-Based Labs and Project-Based Learning, Department of Chemistry, Syracuse University, Syracuse, New York 13244, United States and Duke Learning Innovation, Duke University, Durham, North Carolina 27708, United States.
- Pass, G., Sutcliffe, H. (1974). The preparation of some manganese compounds. In: Practical Inorganic Chemistry. Springer, Dordrecht.

Course Code	Course Title	Credit Hours
0531-14-527L	Advanced Organic Laboratory	**3.0**

(a) Rationale:

This course is comprised with various preparation techniques, purification and identification of organic compounds, and the estimation, determination, and analysis of various organic materials. In addition, development of knowledge and skill on the separation techniques of different mixture and extraction of organic compounds.

(b) Course Objectives (COs):

- To equip students on various preparation techniques, purification, and identification of organic compounds
- To develop expertise students in the estimation, determination, and analysis of various organic compounds
- To provide knowledge and hands-on-training on the separation techniques of different mixtures of organic compounds and extraction of organic compounds from real world samples.

(c) Course Contents

1.	Crystallization, extraction, distillation and drying of organic compounds / reagents.
2.	Fractional distillation: ethanol from sugar; extraction from solution.
3.	Multistep organic synthesis: a) synthesis of nitrophenols, paracetamol; b) preparation of sulphanilamide and other sulphur drugs; c) synthesis of benzyllic acid from benzoin via benzil formation; d) preparation of acridone from anthranilic acids; e) methyl orange and salicylic acid from aspirin (some other synthesis may also be included if facilities are made available).
4.	Preparation of ketals, esters: fats and detergents; reactions of aldehydes and ketones and heterocyclic compounds like coumarins, beta keto esters, cyclohexene from cyclohexanol
5.	Chromatographic method - TLC, column chromatography, paper chromatography.
6	Assay of drugs and raw materials: a) ephedrine hydrochloride; c) penicillin/ ampicilline capsule; d) cotrimoxazole tablet /syrup; e) aspirin tablet etc. (some other suitable compounds if they are available. Use of UV-Vis and IR spectrometers.
7	Resolution of recemic compounds (acids/bases).
8	Oxidation: selective oxidation; oxidation of primary and secondary alcohol and aldehyde.
9	Reduction: sodium borohydride reduction of benzil and other compounds containing carbonyl groups.
10	Hydroboration: hydroboration of unsaturated hydrocarbons.
11	Phase Transfer Catalysis: Use of PTC in different types of reactions.
12	Reaction kinetics: hydrolysis of *tert*-butyl chloride etc.

***(d) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to –

CLO-1: Demonstrate the various preparation techniques, purification, and identification of various types of organic compounds.

CLO-2: Estimate/determine and analyze various organic compounds.

CLO-3: Perform the separation techniques of different mixtures of organic compounds.

CLO-4. Extract specific organic compounds from real world samples.

(e) Mapping Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs):										
CLOs	**LT**	**LD**	**PLO1**	**PLO2**	**PLO3**	**PLO4**	**PLO5**	**PLO6**	**PLO7**	**PLO8**
CLO1										
CLO2										
CLO3										
CLO4										

(f) Mapping of Course Learning Outcomes (CLOs) with Teaching-Learning & Assessment Strategy		
	Teaching-Learning Strategy	**Assessment Strategy**
CLO1	Demonstration and Laboratory Activities	Laboratory Final Exam (Summative)
CLO2	Case-Base Study and Group Activities	Quiz (Formative) and Mid-Semester
CLO3	Scaffolding and Laboratory Activities	Laboratory Final Exam (Summative)
CLO4	Cooperative Learning	Mid-Semester (Project Design)
CLO5	Project Based Learning	Project Evaluation (Summative)

(g) Learning Materials
(i) Recommended Readings
• Vogel's Text Book of Practical Organic Chemistry, ELBS with Longman, 5th edition
• Fiesser, L.F. and Williamson, K.L., *Organic Experiments*, D.C. Health & Company Lexington, Toronto
• Clark F. Most, *Experimental Organic Chemistry*
(ii) Supplementary Readings
• Louis F. Fieser, Kenneth L. Williamson, *Organic Experiments*, D. C. Health & Company Lexington, Massachusetts, Toronto (4th edition)

Course Code	**Course Title**	**Credit Hours**
0531-14-501	Oral Presentation	2.0

(a) Rational/ Summary:

Communication skill is now a day is very vital for professionalism. For academic, industrial and research purposes communication of scientific results and view as well as social communication is very important. This course aims to make the students capable of making proper communication, particularly in their subject matters.

(b) Course Objectives (COs):

- Train the students to prepare a professional assignment.
- Acquire skills in professional presentation.
- Acquaint students with a proficient oral examination and critical thinking.
- Train them to make a PowerPoint presentation.

***(c) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to –

CO1. Prepare a professional assignment on specific topics
CO2. Prepare for academic presentation
CO3. Make logic for the scientific statement on Chemistry
CO4. Prepare for a professional presentation, instant critical thinking, and problem-solving
CO5. Make an argument in front of the viva board and defend the viva board

Teaching- Learning and Assessment Strategies:

There will be no formal face-to-face teaching-learning activities for the oral presentation. Students will learn throughout the semester from the respective related class lecture and discussions with teachers and among themselves. Respective course teachers will provide the topics to each individual student for their presentation before the final presentation. Students will be evaluated and grades will be given on the basis of the marks given by the members of the examination committee.

Course Code	**Course Title**	**Credit Hours**
0531-14-500PC/0531-14-500OC/ 0531-14-500IA	Thesis (Research Proposal and Presentation)	3.0

(a) Rationale:

Students conduct original research in accordance with their ability and background, and under the supervision of a research faculty.

(b) Course Objectives (COs):

- Demonstrate up-to-date and in-depth knowledge of their area(s) of specialization.
- Apply practical or computational techniques/skills for chemical investigations.
- Conduct directed chemical research, develop experimental protocols and interpret results.
- Communicate effectively the results of scientific research in writing and by oral presentation.

***(c) Course Learning Outcomes (CLOs)*:**

Upon successful completion of this course, graduates will have the knowledge and skills to-

- Work independently, to handle and use appropriate instrumentation, interpret data, and complete given tasks in a research setting, and to prepare a written report.
- Communicate more effectively in speaking and writing, both about their newly acquired knowledge and knowledge in general.
- Recognize deficiencies in knowledge existing in chemistry, and to plan and mount a research study to address these deficiencies.
- More critically assess data presented in textbooks, the primary literature or other sources, e.g., electronic data bases, patents.
- In general, to appreciate research in relation to science, the definition of problems in research, and how the corpus of scientific knowledge is able to expand through the overall research effort for the betterment of humankind.

Course Code	Course Title	Credit Hours
0531-14-500IA	Thesis (Dissertation)	**16.0**

(a) Summary:

There will be two components of the Dissertation. Components –I will be ***research proposal preparation and presentation*** and/or comprehensive examination (if any) which is not credit bearing but has to pass the proposal defense and or comprehensive examination (if any) and another component will be the dissertation with defined credit values 16. Dissertation/thesis has to submit as per prescribed format. For the fulfillment of knowledge in chemistry and related subjects, and for getting hands on experience in critical thinking and problem solving, it is very essential to carry out a thesis.

(b) Course Objectives (COs):

- To conduct research and fulfill the objectives of the study with proper methodologies.
- Make the students expert in academic research.
- Give them in hand opportunity to do their own research with the help of a supervisor.
- Make them able to collect the data and analyze them to make a conclusion.
- Help them to be skilled in writing an academic research report.
- Make them able to communicate the scientific results in written, orally and representatively.

***(c) Course Learning Outcomes (CLOs)*:**

After completion of the Course, the Student will be able to –

CLO-1: Work independently, think critically and develop problem solution.

CLO-2: Interpret data, and complete given tasks in a research setting, and to prepare a written report.

CLO-3: Communicate more effectively in speaking and writing, both about their newly acquired knowledge and knowledge in general.

CLO-4: Recognize deficiencies in knowledge existing in chemistry, and to plan and mount a research study to address these deficiencies.

CLO-5**.** Practice norms and ethics for data manipulation, and scientific and academic research.

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

CLOs	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8
CLO1								
CLO2								
CLO3								
CLO4								
CLO5								

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

BNQF (Level-9/Master's): A Mixed-mode Master's has a minimum 20 credits taught component and a research component involving a thesis/dissertation. A student's assessment is based on his/her performance in both the components.

Learner Profile (Master's): At this level, a learner will show a high mastery of knowledge in specific field/field of study/work and professional practice exemplifying **strong theoretical knowledge**, **critical thinking**, and **creative and innovative skills**. S/he will be able to generate new solutions to problems and conduct research under minimal supervision. S/he will possess a strong sense of ethics aligned to national

aspirations and global citizenship. S/he will be able to function in an environment of broad degree of autonomy.

Level 9: Master's
A learner successfully completing programs at this level will be able to:

Learning Outcome Domains	Level Descriptors
Fundamental Skills	1. Demonstrate a systematic understanding of advanced knowledge and skills which may be at the forefront of a field/fields of study, discipline or practice; 2. Analyze general and advanced range of specialized theories, concepts, principles and complex information and method within a field of study, discipline or practice; 3. Apply knowledge and skills to manage complex matters; 4. Synthesis complex information, concepts, theories and problems in a field of study or practice as a basis for research; 5. Carry out semi-specialized research and/or apply practical skills, tools or techniques which are informed by the forefront latest development in the subject or discipline to solve and manage complex problems or solve issues in a field/fields of study or practice; and 6. Competently use a wide range of suitable software ICTs to enhance study, research and/or work/practice.
Social Skills	1. Communicate clearly the knowledge, skills, ideas, critique and conclusion/rationale using appropriate methods to experts, specialists and peers and non-expert range of audience both in Bangla and advanced English; 2. Work with different people in learning and working community and other groups and networks; 3. Function effectively as a member of a community; and 4. Demonstrate advanced knowledge of cultural, governmental, and environmental issues at a regional and international level, in relation to issues within Bangladesh and actively participating in and advocating for changes/solutions for the betterment of the nation
Thinking Skills	1. Be independent and individually responsible for work, professional practice, systems, processes and decision-making on complex problematic matters or issues within the academic, professional or technical settings (a field of study and/or professional practice and/or in multi-disciplinary context); and 2. Demonstrate significant autonomy, leadership qualities, interpersonal skill and responsibilities - (planning, resource management, supervision and problem solving) in managing work within a team and others.
Personal Skills	1. Demonstrate self-advancement through continuous academic and/or professional development; 2. Observe legal, ethical and professional codes of practice; and 3. Demonstrate appreciation of cultural diversity in Bangladesh in contributing to the society.

Modularized Qualifications Based on Standards and Learning Outcomes

All higher education qualifications will be modular or unitized, based on benchmarked standards and learning outcomes. As such, all teaching and learning activities carried out by a student will be quantified and measured. A qualification is formed by individual courses allowing a student to cumulatively achieve the minimum graduating credits for the relevant qualification level. A course is characterised by its learning outcomes that are translated into credit that is measured by student learning time. This credit will be the academic currency, which a graduate of the Bangladesh higher education sector may carry with her/him for the purposes of career or educational advancement. For the purpose of this Framework, the general measure of one credit is 40 notional hours. The calculation of notional hours is based on class contact time and self-learning time of a student in addition to the class contact time.

(For lecture, tutorial, seminar 1-hour face to face learning per week for 14 weeks, for lab, studio or clinical work 1.5-hour face to face learning per week for 14 weeks and for industrial/workplace learning 2 hours per week for 14 weeks is equivalent to 1 credit)

The proposed notional hours for each of the learning activity include assessment, self-learning and preparatory work.

Instructions for Preparing Questions:

- Course learning outcomes, teaching learning activities and assessment methods are properly aligned in each course of the program.
- Cover all topics in CLOs in question paper. Keep in your mind that since there is choice of questions, if students select required questions as if all CLOs are attained automatically.
- Maintain the lower order learning to higher order learning assessment in question paper.

1). Evaluation Strategy

Each theoretical course offered should be composed of either 50 (for 02 credits) or 100 (03 credits) marks. Grades will be calculated as per the university grading structure and individual students will be evaluated based on the following criteria with respective weights.

Descriptions	Evaluation (%)
Class Test/PowerPoint Presentation	10%
Assignment/Quiz/Tutorial test	05%
Mid Semester Examination (At least 2 mid-semester examinations). An average of all examinations will be calculated.	20%
Class Attendance	05%
Semester-Final Examination: An Average of the marks given by the internal and external examiners will be calculated.	60%
Total:	**100%**

Each Lab course offered should be composed of either 50 (for 02, 1.5 credits) or 100 (for 03 credits) marks. Grades will be calculated as per the university grading structure and individual students will be evaluated based on the following criteria with respective weights.

Descriptions	Evaluation (%)
Midterm	20%
Lab Attendance	10%
Lab Report	10%
Semester-Final Examination: An Average of the marks given by the internal and external examiners will be calculated.	60%
Total:	**100%**

Thesis Evaluation:

Thesis Evaluation (Marks: Supervisor, Examiner 30)			
	Excellent	**Good**	**Poor**
Thesis Title *Title of the needs to match with the objectives and should reflect the activities and expected outcomes.*	Project Title matches very perfectly and reflects the overall activities of the project	Project Title matches with objectives but do not reflect the overall activities of the project	Project Title does not match with the activities of the project
Background *Student should present a brief background on the significance of the project and the current research related to the topic.*	Background and significance of project fully explained	Background or significance given but not explained	No background or significance of project given
Purpose for choosing project *Student should share personal reasons for choosing this project*.	Purpose for choosing project explained	Purpose for choosing project mentioned	No purpose for choosing project given
Hypothesis *Student should state and explain the hypothesis.*	Hypothesis is clearly stated in the correct form, demonstrates a cause-and-effect relationship, and is testable	Hypothesis stated but not in the correct form	No hypothesis stated
Methodology and Experimental Procedure *Student should summarize the experimental procedure, including pictures.*	Experimental procedures thoroughly described and picture(s) present	Experimental procedures described and picture(s) present	Experimental procedures not described and no pictures presented

Presentation of Results *Student should use data tables to show the results of the experiment.*	Data tables present, properly titled and labeled, and thoroughly explained	Data tables present, properly labeled, and described	Data tables present but not described OR not properly labeled
Discussion and Conclusion *Student should explain whether the results support or refute the hypothesis and explain their conclusions.*	Hypothesis supported or refuted and conclusions demonstrate deep understanding of the project	Hypothesis supported or refuted and conclusions are thoughtful	Surface level conclusions reached but no mention of original hypothesis

2). Grading Scale and Grades

Letter Grade and Grade point: Total marks obtained in each course, oral (viva-voce) examination and practical courses shall be converted into LG (Letter Grade) and GP (Grade point) as follows:

Numerical Grade	Letter Grade		Grade point	Interpretation
80% and above	A+	(A Plus)	4.00	Outstanding
75% to less than 80%	A	(A regular)	3.75	Excellent
70% to less than 75%	A-	(A minus)	3.50	Very Good
65% to less than 70%	B+	(B Plus)	3.25	Good
60% to less than 65%	B	(B regular)	3.00	Satisfactory
55% to less than 60%	B-	(B minus)	2.75	Below Satisfactory
50% to less than 55%	C+	(C Plus)	2.50	Average
45% to less than 50%	C	(C regular)	2.25	Pass
40% to less than 45%	D	.....	2.00	Poor
Less than 40%	F	.....	0.00	Fail

2) Grade Point Average (GPA) and Cumulative Grade Point Average (CGPA)
Grade Point Average (GPA) / Cumulative Grade Point Average (CGPA) will be calculated up to the second decimal points. If the third decimal point is 0.5 or above it shall be rounded up to following second decimal points.
3) Course Withdrawal
4) Incomplete (I) courses
5) Retake
6) Grade Improvement

IMPROVEMENT/F-REMOVAL OF GRADES

(I) F-REMOVAL: A student having earned 'F' grade in any course in any semester shall be required to remove the 'F' grade. Removal of 'F' grade in any course is permitted only for two (2) times excluding the regular examination. This has to be done within his academic tenure.

(ii) IMPROVEMENT: A student having earned letter grade **'B-' (GP- 2.75)** or below in any course may be allowed to improve the grade by appearing in the semester-final examination with the next available batch[7]. S/he can avail this opportunity only once for a course. In such case the best GPA from the improvement or the regular examination of the concern subject shall be calculated for tabulation.

(iii) No improvement shall be allowed in ^{8th} semester.

(iv) For appearing in the improvement examination, a student shall have to pay fees for the course prescribed for the purpose.

(v) A student willing to improve grade should apply to the controller of examination through the chairman of the department within 01 (one) week after the publication of the results of the semester.

(vi) No improvement shall be allowed in continuous assessment (mid-term/class-test/assignment/ fieldwork/ monograph/ project/ practical/case-study/term-paper/quiz test/etc.).

(vii) The concerned (current) examination committee to that semester will take necessary actions to arrange the improvement examinations, tabulation and posting of marks.

8) Dropout

If a student re-admitted twice in any semester fails to earn minimum required credits[6] for promotion shall be dropped out from the program.