Curriculum

Graduate
Session: 2023-2024

Department of Chemistry

Shahjalal University of Science and Technology
Sylhet, Bangladesh

Department of Chemistry
Shahjalal University of Science & Technology
Sylhet-3114, Bangladesh
Curriculum for MS Program
Session: 2023-24

1. **Title of the Academic Program: Master of Science (MS) in Chemistry**
2. **Name of the University: Shahjalal University of Science & Technology, Sylhet-3114, Bangladesh**
3. **Vision of the University:** *To be a leading university of excellence in Science and Technology with a strong national commitment and significant international impact.*
4. **Mission of the University:**

- To advance learning and knowledge through teaching and research in science and technology.
- To serve as a center for knowledge creation, technological innovation and transfer among academia, industry, and society.
- To assist in transferring Bangladesh a country with sustainable economic growth and equitable social development.

5. **Name of the Program offering Entity: Department of Chemistry, SUST**
6. **Vision of the Department of Chemistry, SUST:**
   The Department of Chemistry, SUST endeavors to be a nationally recognized model for producing chemistry graduates to compete in and contribute to the needs of time-demanding and technology-centered chemistry world.
7. **Mission of the Department of Chemistry, SUST:**

M1. To achieve the highest possible standards of teaching and research in chemistry and allied subjects by providing a high quality of education that will allow graduates to be active, productive, engaged members of society on local, national and international levels.
M2. To prepare students as successful professionals for employment in any of the vast array of chemistry-related industries including: Chemical, Pharmaceuticals, Biotechnology, Environmental, and Quality Control-Quality Assurance sectors.
M3. To achieve personal academics by use of modern educational technology in secondary and tertiary level, independent thought, collegial exchange of ideas and high ethical standards.
M4. To develop the students as effective researchers on fundamental and applied problems and promoting the development of innovative interdisciplinary research programs (**For mix mode**)

8. **Objectives of the Department of Chemistry, SUST:**

Providing high-quality education: Chemistry departments aim to provide students with a strong foundation in the principles and practices of chemistry, and to equip them with the skills and knowledge needed to pursue careers in various fields related to chemistry.
Conducting research: Chemistry departments conduct research to advance our understanding of chemical reactions, properties, and structures. They aim to develop new technologies, materials, and medicines that can benefit society.
Promoting scientific discovery: Chemistry departments aim to promote scientific discovery by developing new theories and hypotheses, and testing them through experimentation and analysis. They also strive to disseminate their findings through publications, conferences, and other forms of communication.
Fostering interdisciplinary collaboration: Chemistry departments often work closely with other departments and disciplines, such as biology, physics, and engineering, to solve complex scientific problems that require a multidisciplinary approach.
Engaging with the community: Chemistry departments aim to engage with the broader community through outreach programs, public lectures, and other educational activities. They aim to promote a greater understanding and appreciation of chemistry, and to inspire the next generation of scientists.

9. **Name of the Degree**

Master of Science (MS) in Chemistry is awarded in four different branches of Chemistry, namely:

Master of Science in Physical Chemistry
Master of Science in Inorganic Chemistry
Master of Science in Organic Chemistry
Master of Science in Analytical and Environmental Chemistry

10. **Description of the Program:**

Master's degree in Chemistry is a postgraduate program that focuses on advanced course works and research in the field of chemistry. Department of Chemistry, SUST graduate program offers three distinct pathways to a Master's degree: Master's by Coursework, Master's by Mixed Mode (with options for a dissertation), and Master's by Research.
Both Master's by Coursework and Master's by Mixed Mode (with options for a dissertation), are further classified in four groups of specialization, namely Physical Chemistry, Inorganic Chemistry, Organic Chemistry and Analytical and Environmental Chemistry. For Master's by Coursework, the duration is one year and for Master's by Mixed Mode , it is one and half year.
The curriculum of a Master's in Chemistry program includes advanced courses in organic, inorganic, physical, and analytical chemistry, as well as specialized courses in areas such as biochemistry, materials science, and environmental chemistry, and some others special courses related to chemistry. Students are also expected to engage in research projects, which may involve laboratory work, data analysis, and scientific writing.
After completing a Master's in Chemistry, graduates can, pursue various career paths, including research and development in academia, government, or industry, teaching at the college level, or working in fields such as pharmaceuticals, materials science, or environmental science. Many students also use the Master's degree as a stepping stone towards pursuing a Doctoral by Research. in Chemistry or related fields.

The degree offers in three different categories:

i. Master's by Coursework (Taught Program) (1 Year, 2 Semesters)
ii. Master's by Mixed Mode (with options for a dissertation (1.5 Years, 3 Semesters)
iii. Master's by Research (2 years, 4 semesters)

11. **Graduate Attributes (GA):**

Graduate attributes refer to the skills, knowledge, and qualities that students are expected to have acquired upon completing their degree program. For a chemistry graduate, some of the key graduate attributes would include:
GA1. Subject Specific Knowledge: In-depth knowledge of all major areas of Chemistry
GA2. Analytical and critical thinking: Have the ability to analyze data and information, evaluate arguments and evidence, and draw logical conclusions. They should be able to think critically to solve chemistry problems.
GA3. Scientific literacy: Deep understanding of the scientific method, including design experiments, collect and analyze sample, interpret results.
GA4. Communication skills: Able to communicate effectively with different audiences, including scientific peers, policymakers, and the general public. They should be able to write and speak clearly and use appropriate scientific language and terminology.
GA5. Teamwork and collaboration: Able to work effectively as part of a team, collaborating with other scientists and professionals to achieve common goals. They should be able to contribute their own ideas, listen to others, and work towards consensus.
GA6. Ethics and professionalism: Understand the ethical principles and standards of their profession, and be able to demonstrate professionalism.
GA7. Adaptability and lifelong learning: Able to adapt to new situations and technologies, and be willing to learn and acquire new knowledge and skills throughout their career. They should have a growth mindset and be able to embrace change and uncertainty.

12. **Program Educational Objectives of the Department of Chemistry, SUST (PEO):**

Objectives of the MS program in Chemistry

It is given that all students obtaining a certified degree in chemistry should be well trained in chemical concepts and laboratory practices. However, to be effective and productive scientists, students need to master a variety of skills that

go beyond course content alone. The objectives or learning targets of the curriculum are categorized in the following dimensions:

- *Knowledge and Understanding*
- *Skills and Processes, and*
- *Values and Attitudes*

To meet these goals, the following are the program objectives:

PEO1. Help the students to be enriched with the advanced knowledge, processes and procedures of the major areas of chemistry; and particularly specialized in a field among the physical, inorganic, organic, analytical and environmental.

PEO2. Make the students able to demonstrate high level analytical and critical thinking skills to solve conceptual and quantitative problems in chemistry through the application competencies achieved in all four major fields of chemistry.

PEO3. Develop skill to demonstrate safe and acceptable skills in laboratory procedure, experimental design and to expose students to modern instrumentation and laboratory techniques used in chemical analysis (**and research**).

PEO4. Help the students to acquire the expertise with the necessary tools to carry out chemistry research independently and in team and to prepare them for doctoral or higher studies in chemistry or related fields.

PEO5. To enhance the skill for communicating scientific results effectively in written, oral and in interactive presentation.

PEO6. Help students develop curiosity and interest in making scientific investigations, personal integrity and to realize the roles of chemist on industrial, environmental social and economic aspects nationally and globally.

PEO7. Acquaint students with moral and ethical values to handle the research findings, maintaining the secrecy of Intellectual Properties (IP) and development of patriotism.

13. PEO to Mission Statement Mapping

Mission/ PEO	PEO1	PEO2	PEO3	PEO4	PEO5	PEO16	PEO7
M1	X	x	x	x	x	x	x
M2	X	x	x		x	x	
M3	X	x	x			x	x
M4	X	x	x	x	x	x	x

14. Program Learning Outcome for MS in Chemistry (POs)

POs	Learning Attribute	PO statement *After successful completion of the program, graduate will be able to-*	BNQF Domain
PO1	*Advanced Knowledge of Chemistry*	Explain and apply the advanced knowledge and expertise in the field of chemistry, including physical, inorganic, organic, and analytical & environmental chemistry.	Fundamental
PO2	*Laboratory Equipment and Sophisticated Instrumental Skills*	Design and carry out qualitative and quantitative chemistry experiments, synthesis, isolation and characterize the materials, analyze the results using statistical and computational methods. Familiarity with a range of experimental techniques and methodologies, including the latest advances in instrumentation and technology	Fundamental
PO3	*Critical Thinking and Problem-Solving Skills*	Demonstrate strong problem-solving and critical thinking skills, integrate concepts and ideas and skills to perform qualitative and quantitative analysis and analytical reasoning.	Thinking and Problem-solving
PO4	*Research Skill* ***(For Thesis group)***	Search and explore the chemistry literature and scientific resources to design, execution and report on independent research projects in the field of chemistry, demonstrate mastery of laboratory techniques and data analysis as individuals, and collaboratively to explore new knowledge in chemistry and allied fields. Collaborate effectively with other scientists and professionals from related fields.	Fundamental and Thinking
PO5	*Communication, ICT, and digital Fluency*	Use knowledge and proficiency to communicate the results of scientific work in oral, written and electronic visual formats and be able to prepare logical, organized and concise written articles or reports; able to use modern devices and platforms for general, social and professional communication.	Social
PO6	*Employability and Entrepreneurships*	Plan and manage activities required for professional development in chemical and related industries; have the skills to work in interdisciplinary research/industries; be competence in keeping up with global innovations and developments in chemistry and in related fields; Prepare for further study or research at the PhD level, or find gainful employment in academics, industry and government organizations and develop entrepreneurships and professional career.	Personal
PO7	*Professional Integrity and Leadership*	Demonstrate professional integrity, safety, and environmental stewardship and display effective cooperation with others on projects in various learning and work environments. Be realize the interdisciplinary nature of chemistry and be able to collaborate effectively with other scientists and professionals from related fields.	Personal
PO8	*Environment and sustainability*	Realize the environmental protection and work/laboratory safety and integrate the rules of chemist and impact of chemical solutions in societal and environmental contexts and realize the needs for sustainable development of society and country.	Social
PO9	*Ethics and morality*	Aware of the ethical and social implications of scientific research and apply ethical principles in research and professional practice. Demonstrate the moral and professional ethical values to handle the research findings, data manipulation and maintaining the secrecy of Intellectual Property (IP).	Personal
PO10	*Life-long Learning*	Understand the current trends, developments, and issues in the field of chemistry, and the ability to stay abreast of new advances.	Personal

15. Mapping of the Mission Statement of the Department with PEO

Mission/ PEO	PEO1	PEO2	PEO3	PEO4	PEO5	PEO16	PEO7
M1	**x**	**x**	**x**	**x**	**x**	**x**	**X**
M2	**x**	**x**	**x**		**x**	**x**	
M3	**x**	**x**	**x**	**x**	**x**	**x**	**X**
M4	**x**	**x**	**x**			**x**	**X**

16. Program Objectives (PEO) to Program Learning Outcome (PO) Mapping:

PO	PEO1	PEO2	PEO3	PEO4	PEO5	PEO16	PEO7
PO1	X						
PO2		x					
PO3			x				
PO4				x			
PO5					x		
PO6						x	X
PO7						x	x
PO8	X	x	x	x	x	x	x
PO9							x
PO10						x	

17. Mapping of Courses with Program Learning Outcomes (POs)

Sr. No	Course Code No	Course Title	Program Learning Outcomes (POs)									
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	CHE 0531 5121	Electrochemical Methods	**3**	**3**	**3**					**1**		**1**
2	CHE 0531 5122	Surface Chemistry and Spectroscopy	**3**	**3**	**3**							**3**
3	CHE 0531 5123	Molecular Photochemistry	**3**		**3**	**3**	**1**		**3**		**2**	
4	CHE 0531 5224	Advanced Chemical Kinetics	**3**		**3**	**3**				**2**	**1**	**1**
5	CHE 0531 5225	Advanced Electrochemistry	**3**	**3**	**3**					**1**		**1**
6	CHE 0531 5226	Biophysical Chemistry	**3**		**3**					**1**		**1**
7	CHE 0531 5227	Chemical Energy	**3**	**3**	**3**						**2**	**3**
8	CHE 0531 5220	Advanced Physical Chemistry Lab		**3**	**1**							
9	CHE 0531 5131	Inorganic Materials Chemistry	**2**		**1**							
10	CHE 0531 5132	Inorganic Spectroscopic Methods	**2**		**2**	**2**	**1**	**1**				
11	CHE 0531 5233	Advanced Bioinorganic Chemistry	**2**		**3**			**1**				
12	CHE 0531 5234	Advanced Crystallography and Group Theory	**3**		**1**							
13	CHE 0531 5235	Frontiers Solid-state Materials	**3**	**1**	**1**							
14	CHE 0531 5130	Advanced Inorganic Chemistry Lab		**3**	**3**							
15	CHE 0531 5141	Advanced Heterocyclic and Organometallic Chemistry	**3**		**1**							
16	CHE 0531 5142	Advanced Biochemistry	**3**		**2**							
17	CHE 0531 5243	Advanced Spectroscopy and Stereochemistry	**3**		**2**					**1**		**1**
18	CHE 0531 5244	Supramolecular Chemistry	**3**		**2**							
19	CHE 0531 5245	Advanced Natural Products Chemistry	**3**		**2**	**3**						
20	CHE 0531 5240	Advanced Organic Chemistry Lab		**3**		**2**						**1**
21	CHE 0531 5151	Analytical Spectroscopy	**3**									
22	CHE 0531 5152	Advanced Environmental Chemistry	**3**	**2**							**2**	
23	CHE 0531 5253	Waste Management and Treatment	**3**									
24	CHE 0531 5254	Sustainable Chemistry and Bio Nanotechnology	**3**								**2**	
25	CHE 0531 5150	Advanced Analytical and Environmental Chemistry Practical		**3**							**2**		**2**
26	CHE 0531 5262	Topics on Nanoscience and Nanotechnology	**2**	**3**								
27	CHE 0531 5200	Course Viva	**2**		**3**		**2**					**1**
28	SPS 0417 5180	In Plant Training						**3**	**1**			**2**
29	SPS 0111 5170	Research methodology for chemistry			**3**	**2**	**1**			**3**	**1**	**1**
30	CHE 0531 5310	Thesis			**3**		**3**		**1**			**2**

18. Course Structure:

1. Program duration: one (1) year for Master's by Coursework; one year (1) & six (6) months for Master's by Mixed Mode

Numbers of Semesters: Two (2) Semester for Master's by Coursework, three (3) Semesters for Master's by Mixed Mode

2. Admission Requirements (for Master's by Mixed Mode): Based on the B.Sc. (Hons.) results, top students having minimum CGPA of 3.0 may apply for admission.

3. Graduating Credits: **40 (**Master's by Coursework) **/44 (**Master's by Mixed Mode**)**

4.Total Class week in each semester will be as follows:

Classes and Preparatory weeks:	14 weeks
Final Examination:	04 weeks
Total:	18 weeks

5. **Minimum CGPA requirements for graduation: 2.00**

Description of the Program

MS in Chemistry is offered in three main streams, Master's by Coursework and Master's by Mixed Mode.
The details for both groups are as follows:

I) Master's by Coursework:

MS degree will be awarded in Master of Science in Chemistry (Coursework) from the chemistry department of SUST under the following terms and conditions.

Eligibility for admission: A student with B.Sc. (Hons.) Degree in Chemistry from SUST will be eligible for admission into MS by Coursework at the Department of Chemistry.

Duration of the course: The duration of the course will be one year (two semesters).

Section selection: A student will have to choose one Special branch out of four branches of chemistry Physical, Inorganic, Organic, and Analytical and Environmental Chemistry.

Semester and Credit: A student will have to complete **40.0** credits to obtain his/her MS degree in MS by Coursework. A student enrolled in this program must register for a minimum of 10 (ten) credits and a maximum of 20 (twenty) credits per semester. A student can complete the necessary courses (theory and lab) either in MS 1st Semester or in MS 2nd Semester (providing the availability of the courses) offered by the Department. MS Degree will be given as

specialized in Physical/Inorganic/Organic/Analytical & Environmental Chemistry with MS by Coursework.

Selection of courses:

1. Theory courses (27 credits): will have to complete at least 4.0 credits **four** (at least two in each semester) theory courses in the specialized branch in related branch in Physical, Inorganic, Organic, and Analytical & Environmental Chemistry. In addition of that, Topics on Nanoscience and technology, 4.0 credits, and **Research Methodologies for chemistry (3.0 credits).** Besides these courses, the students will have to study **one** course of 4.0 credit from the other group. The evaluation will be based on term test, assignment, quiz, class attendance and semester final examinations. The marks will be distributed as attendance 10%, term test, assignment, quiz, etc., 30% and rest of 60% final examination.

2. Laboratory courses (4×2=8.0 credits): Students will have to complete 04 (Four) advanced practical courses from (one from each specialized branch). The teachers will design the contents of the laboratory courses. At least 2 teachers will be assigned in laboratory courses.

3. In plant training (2.0 credits): In plant Training Program will be completed at TICI (Training Institute for chemical Industries) by the joint collaboration of Chemistry Department, Shahjalal University of Science and Technology, Sylhet and Training Institute for Chemical Industries, Sarkarkhana, Polash, Narsingdi-1611, Bangladesh. Teacher (2-3) will be assigned for this course. The department will select an industry/ laboratory or training institute so that students can get practical training regarding technologies.

4. Course Viva (CHE 5200, 3.0 credits): At the end second semester, the examination committee will arrange a viva board to evaluate the performance of the students. Here GEd courses is (2+3=5) 12.5%

II) Master's by Mixed Mode:

MS degree will be awarded in Chemistry (mixed mode) from the chemistry department of SUST under the following terms and conditions.

Eligibility for admission: Based on the B.Sc. (Hons.) results, top students having minimum CGPA of 3.00 may apply for admission.

Section selection: At first a student will search a supervisor. In appropriate cases a co-supervisor will also be engaged with the student. The students will choose a branch (Physical/Inorganic/Organic/Analytical & Environmental) consulting with his/her own branch related supervisor .

Semester and Credit: A Student must complete offered **44** credits in three semesters and he/she enrolled in this program must register for a minimum of 8 (eight) credits and a maximum of 16 (sixteen) credits per semester.

Selection of courses:

1. Theory courses (27 credits): Course wise teachers will be engaged. Students will take four compulsory courses (4.0 credits of each) from their own branch of specialization, and one course of 4.0 credits from the other groups. In addition to that, two compulsory theory courses, Research methodology for chemistry (3.0 credits) and Topics on Nanoscience and technology (4.0 credits) must be taken.

2. Research Methodologies for chemistry (3.0 credits): A student belongs to thesis group will take this theory course.

3. In plant training (2.0 credits): In plant Training Program will be completed at TICI (Training Institute for chemical Industries) by the joint collaboration of Chemistry Department, Shahjalal University of Science and Technology, Sylhet and Training Institute for Chemical Industries, Sarkarkhana, Polash, Narsingdi-1611, Bangladesh. Teacher (2-3) will be assigned for this course. The department will select an industry/ laboratory or training institute so that students can get practical training regarding technologies.

4**. Course Viva (CHE 5200, 3.0 credits):** At the end of second semester, the examination committee will arrange a viva board to evaluate the performance of the students.

7.Thesis (CHE 0531 5310, 12.0 credits): Students will start their thesis works from the beginning of the MS 1st semester and they will register for this course at the third semester. Research ethics should be followed.

GEd (2+3=5) 11.7%

Evaluation:

The marks distribution of a given course will be as follows:

Class Attendance	10%
Assignments and Mid-Semester Examinations	20%
Quiz, Assignment, etc.	10%
Final Examination	60%

Assessment and Attainment of COs:

There should be at least two mid-semester examinations for every course. The course teacher may decide the relative marks distribution between the assignments, tutorial, and mid-semester examinations, however at least 50% of contribution should come from the mid-semester examinations. The course teacher may decide the relative marks distribution between the assignments, tutorial, and mid-semester examinations. The course teacher of each course will design the distribution of COs for the Class test, mid-semester, and final exam in the course plan that will be submitted to the department prior to the start of class. A copy of this course plan will also be provided to the chairman of the examination committee so that it can be used during the moderation of the questions so that the attainment of all the COs will be confirmed throughout all the assessments.

Course Structure for MS in Chemistry

Description of course structure	Master's by Mixed Mode	Master's by Coursework
Four (04) theory courses from the own Branch of specialization	4.0 × 4 = 16.0	4.0 × 4 = 16.0
One (01) theory course from other branches of choice	4.0 × 1 = 4.0	4.0 × 1 = 4.0
Four (04) Lab courses from four branches	-	2.0 × 4 = 8.0
Compulsory Two(02) theory courses:		
Topics on Nanoscience and Nanotechnology (CHE 0531 5262)	4.0	4.0
Research methodology for chemistry (SPS 0111 5170)	3.0	3.0
In-plant Training in TICI (SPS 0417 5180)	2.0	2.0
Course Viva (CHE 0531 5200)	3.0	3.0
Thesis (CHE 0531 5310)	12.0	-
Total credits:	**44.0**	**40.0**

List of Courses offered by the four branches for MS program in Chemistry

Branch	**Course Code**	**Course Title**	**Course type**	**Credit**
Courses of Physical Chemistry Branch	CHE 0531 5121	Electrochemical Methods	Core Theory	4.0
	CHE 0531 5122	Surface Chemistry and Spectroscopy	Core Theory	4.0
	CHE 0531 5123	Molecular Photochemistry	Core Theory	4.0
	CHE 0531 5224	Advanced Chemical Kinetics	Core Theory	4.0
	CHE 0531 5225	Advanced Electrochemistry	Core Theory	4.0
	CHE 0531 5226	Biophysical Chemistry	Core Theory	4.0
	CHE 0531 5227	Chemical Energy	Core Theory	4.0
	CHE 0531 5220	Advanced Physical Chemistry Lab	Core Lab	4.0
Courses of Inorganic Chemistry Branch	CHE 0531 5131	Inorganic Materials Chemistry	Core Theory	4.0
	CHE 0531 5132	Inorganic Spectroscopic Methods	Core Theory	4.0
	CHE 0531 5233	Advanced Bioinorganic Chemistry	Core Theory	4.0
	CHE 0531 5234	Advanced Crystallography and Group theory	Core Theory	4.0
	CHE 0531 5235	Frontiers Solid-state Materials	Core Theory	4.0
	CHE 0531 5130	Advanced Inorganic Chemistry Lab	Core Lab	4.0
Courses of Organic Chemistry Branch	CHE 0531 5141	Advanced Heterocyclic and Organometallic chemistry	Core Theory	4.0
	CHE 0531 5142	Advanced Biochemistry	Core Theory	4.0
	CHE 0531 5243	Advanced Spectroscopy and Stereochemistry	Core Theory	4.0
	CHE 0531 5244	Supramolecular Chemistry	Core Theory	4.0
	CHE 0531 5245	Advanced Natural Products Chemistry	Core Theory	4.0

	CHE 0531 5240	Advanced Organic Chemistry Lab	Core Lab	4.0
Courses of Analytical Chemistry Branch	CHE 0531 5151 CHE 0531 5152 CHE 0531 5253 CHE 0531 5254 CHE 0531 5150	Analytical Spectroscopy Advanced Environmental Chemistry Waste Management and Treatment Sustainable Chemistry and Bio Nanotechnology Advanced Analytical and Environmental Chemistry Practical	Core Theory Core Theory Core Theory Core Theory Core Lab	4.0 4.0 4.0 4.0 4.0
Compulsory Courses for Skill Enhancement	SPS 0111 5161 CHE 0531 5262	Chemistry Education Topics on Nanoscience and Nanotechnology	GEd Theory Core Theory	3.0 4.0
Compulsory Capstone Courses	SPS 0417 5180 CHE 0531 5200	In Plant Training Course Viva	GEd Exposer Core Viva	2.0 3.0
Special Skill enhancement/ Capstone Courses for Thesis Group	SPS 0111 5170 CHE 0531 5280 CHE 0531 5310	Research methodology for chemistry Comprehensive in Chemistry research Thesis	GEd Capstone Core Capstone Core Capstone	3.0 3.0 12.0

By Course work

M1:Two courses (8) + Nano (4)+ Research method (3)+Two lab (4) +TICI (2) =21

M2:Three courses (12)+Two lab (4) +Oral (3) =19

By Mix mode

M1:Two courses (8) + Nano (4)+ Research method (3)+ TICI (2) =17

M2:Three courses (12)+Two lab (4) +Oral (3) =15

Detailed Semester wise Course Structure for Physical Chemistry Branch

Semester I			
Course Code	**Course Title**	**Credits**	
		Mixed Mode	Master's by Coursework
CHE 0531 5121 **CHE 0531 5122** **CHE 0531 5123**	Electrochemical Methods Surface Chemistry and Spectroscopy Molecular Photochemistry	4.0×2 = 8.0	4.0×2 = 8.0
CHE 0531 5162	Topics on Nanoscience and Nanotechnology	4.0	4.0
CHE 0531 5130 **CHE 0531 5150**	Advanced Inorganic Chemistry Lab Advanced Analytical and Environmental Chemistry Practical		2.0×2=4.0
SPS 0111 5170	Research methodology for chemistry	3.0	3.0
SPS 0417 5180	In Plant Training	2.0	2.0
Total credits in Semester I		**17**	**21**

Semester II			
Course Code	**Course Title**	**Credits**	
		Mixed Mode	Master's by Coursework
CHE 0531 5224 **CHE 0531 5225** **CHE 0531 5226** **CHE 0531 5227**	Advanced Chemical Kinetics Advanced Electrochemistry Biophysical Chemistry Chemical Energy	4.0×2 = 8.0	4.0×2 = 8.0
***Optional Courses**	**One theory course from other branches** One theory course from any branch than Physical Chemistry branch (Either in 1st or 2nd semester)	No course Or 4.0	No course Or 4.0
CHE 0531 5220 **CHE 0531 5240**	Advanced Physical Chemistry Lab Advanced Organic Chemistry Lab		2.0×2=4.0
CHE 0531 5200	Course Viva	3.0	3.0
	Total credits in Semester II	**15**	**19**
Total credits in Semester I & II (Program completion for Master's by Coursework)			**21+19=40**

Semester III		
Course Code	**Course Title**	**Credits** (Mixed Mode)
CHE 0531 5310	Thesis	12.0
Total credits in Semester I, II, III (Program completion for Mixed Mode)		**(17+15+12) = 44.0**

Detailed Semester wise Course Structure for Inorganic Chemistry Branch

Semester I			
Course Code	**Course Title**	**Credits**	
		Mixed Mode	Master's by Coursework
CHE0531 5131 **CHE0531 5132**	Inorganic Materials Chemistry Inorganic Spectroscopic Methods	4.0×2 = 8.0	4.0×2 = 8.0
CHE 0531 5162	Topics on Nanoscience and Nanotechnology	4.0	4.0
CHE0531 5130 **CHE0531 5150**	Advanced Inorganic Chemistry Lab Advanced Analytical and Environmental Chemistry Practical		2.0×2=4.0
SPS 0111 5170	Research methodology for chemistry	3.0	3.0
SPS 0417 5180	In Plant Training	2.0	2.0
Total credits in Semester I		**17**	**21**

Semester II			
Course Code	**Course Title**	**Credits**	
		Mixed Mode	Master's by Coursework
CHE0531 5233 **CHE0531 5234** **CHE0531 5235**	Advanced Bioinorganic Chemistry Advanced Crystallography and Group theory Frontiers Solid-state Materials	4.0×2 = 8.0	4.0×2 = 8.0
***Optional Courses**	**One theory course from other branches** One theory course from any branch than Inorganic Chemistry branch (Either in 1st or 2nd semester)	No course Or 4.0	No course Or 4.0
CHE0531 5220 **CHE0531 5240**	Advanced Physical Chemistry Lab Advanced Organic Chemistry Lab	-	2.0×2=4.0
CHE0531 5200	Course Viva	3.0	3.0
	Total credits in Semester II	**15**	**19**
Total credits in Semester I & II (Program completion for General Group)			**21+19=40**

Semester III		
Course Code	**Course Title**	**Credits (Thesis group)**
CHE0531 5310	Thesis	12.0
	Total credits in Semester I, II, III (Program completion for Thesis Group)	**(17+15+12) = 44.0**

Detailed Semester wise Course Structure for Organic Chemistry Branch

Semester I			
Course Code	**Course Title**	**Credits**	
		Mixed Mode	Master's by Coursework
CHE 0531 5141 **CHE 0531 5142**	Advanced Heterocyclic and Organometallic Chemistry Advanced Biochemistry	4.0×2 = 8.0	4.0×2 = 8.0
CHE 0531 5162	Topics on Nanoscience and Nanotechnology	4.0	4.0
CHE 0531 5130	Advanced Inorganic Chemistry Lab	-	2.0×2=4.0

CHE 0531 5150	Advanced Analytical and Environmental Chemistry Practical		
SPS 0111 5170	Research methodology for chemistry	3.0	3.0
SPS 0417 5180	In Plant Training	2.0	2.0
Total credits in Semester I		**17**	**21**

Semester II			
Course Code	**Course Title**	**Credits**	
		Mixed Mode	Master's by Coursework
CHE 0531 5243 **CHE 0531 5244** **CHE 0531 5245**	Advanced Spectroscopy and Stereochemistry Supramolecular Chemistry Advanced Natural Products Chemistry	4.0×2=8.0	4.0×2=8.0
***Optional Courses**	**One theory course from other branches** One theory course from any branch than organic Chemistry branch (Either in 1st or 2nd semester)	No course Or 4.0	No course Or 4.0
CHE 0531 5220 **CHE 0531 5240**	Advanced Physical Chemistry Lab Advanced Organic Chemistry Lab		2.0×2=4.0
CHE 0531 5200	Course Viva	3.0	3.0
	Total credits in Semester II	**15**	**19**
	Total credits in Semester I & II (Program completion for General Group)		**21+19 = 40.0**

Semester III		
Course Code	**Course Title**	**Credits (**Mixed Mode**)**
CHE 0531 5310	Thesis	12.0
Total credits in Semester I, II, III (Program completion for Thesis Group)		**(17+15+12) = 44.0**

Detailed Semester wise Course Structure for Analytical and Environmental Chemistry Branch

Semester I			
Course Code	**Course Title**	**Credits**	
		Mixed Mode	Master's by Coursework
CHE 0531 5151 **CHE 0531 5152**	Analytical Spectroscopy Advanced Environmental Chemistry	4.0×2=8.0	4.0×2=8.0
CHE 0531 5162	Topics on Nanoscience and Nanotechnology	4.0	4.0
CHE 0531 5130 **CHE 0531 5150**	Advanced Inorganic Chemistry Lab Advanced Analytical and Environmental Chemistry Practical		2.0×2=4.0
SPS 0111 5170	Research methodology for chemistry	3.0	3.0
SPS 0417 5180	In Plant Training	2.0	2.0
Total credits in Semester I		**17**	**21**

Semester II			
Course Code	**Course Title**	**Credits**	
		Mixed Mode	Master's by Coursework
CHE 0531 5253 **CHE 0531 5254**	Waste Management and Treatment Sustainable Chemistry and Bio Nanotechnology	4.0×2=8.0	4.0×2=8.0
***Optional Courses**	**One theory course from other branches** One theory course from any branch than the analytical & environmental Chemistry branch (Either in 1st or 2nd semester)	No course Or 4.0	No course Or 4.0
CHE 0531 5220 **CHE 0531 5240**	Advanced Physical Chemistry Lab Advanced Organic Chemistry Lab	-	2.0×2=4.0
CHE 0531 5200	Course Viva	3.0	3.0

	Total credits in Semester II	**15**	**19**
Total credits in Semester I & II (Program completion for Master's by Coursework**)**			**21+19=40**

Semester III		
Course Code	**Course Title**	**Credits (**Mixed Mode**)**
CHE 0531 5310	Thesis	12.0
Total credits in Semester I, II, III (Program completion for Thesis Group)		**(17+15+12) = 44.0**

*** Optional course can be taken in 1st or 2nd semester**

Description of all courses (Course Profile)

Course No: **CHE 0531 5220**	Credit: 2.0 (8h/week)	Year: MS	Semester: Second
Course Title: **Advanced Physical Chemistry Lab**		Course Type: Core Lab	

Course Rationale:
This course is designed to give learners advanced laboratory experience with a strong focus on developing skills to develop and analyze data based on electrochemical, kinetics and spectroscopic experiments.

Course Objectives:
The objectives of this course are to:
- Provides training in advanced physical chemistry laboratory techniques.
- The investigation provides an introduction to research methods: a group of 3-4 students are given a theme or problem and some apparatus; they must devise, build and execute experiments using less guidance than for the standard experiments. Data analysis and structured report writing are key components of the course.

Course Content
Students will perform the following experiments:
1. Study of primary salt effect on the base catalyzed hydrolysis of ethyl acetate and determination of the activation energy of the reaction by conductometric method.
2. Study of the primary salt effect on the oxidation of iodide using persulphate and determination of activation energy of the reaction.
3. Spectroscopic determination of the pKa value of methyl orange indicator.
4. Determination of activation energy of base catalyzed hydrolysis of ethyl acetate conductometrically.
5. Study of ionic strength effect on base catalyzed hydrolysis of ethyl acetate.
6. Study of primary salt effect on the formation of colloidal sulphur by the reaction of thiosulphate with an acid and determination of the activation energy of the reaction.
7. Cyclic Voltammetric Study of ferrocyanide/ferricyanide Redox Couple

Course Learning Outcomes (COs):
After the successful completion of the course, students will be able to:
CO1. Determine the primary salt effect on the base catalyzed hydrolysis of ethyl acetate and determination of the activation energy of the reaction by conductometric method
CO2. Study the primary salt effect on the oxidation of iodide using persulphate and determination of activation energy of the reaction
CO3. Apply the spectroscopic method to determine the value of the pKa of an indicator
CO4. Apply conductivity measurements in studying the kinetic parameters
CO5. Apply the basics of cyclic voltammetry with a well-behaved electroactive species

Mapping of Course Learning Outcomes (COs) with POs
3: Strongly aligned 2: Moderately Aliened 1: Weakly Aliened

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1		3								
CO2		3								
CO3		3								
CO4		3								
CO5		2	1							

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Demonstration on data handling and graphical representation	Assessment in the lab, report evaluation
CO2	Lecture demonstration	Assessment in the lab, report evaluation
CO3	Group discussion, Instrumental demonstration.	Assessment in the lab, report evaluation
CO4	Lecture demonstration , Group discussion	Assessment in the lab, report evaluation
CO5	Group discussion, Instrumental demonstration.	Assessment in the lab, report evaluation

Books Recommended:

1. P. W. Atkins, Physical Chemistry
2. K.J. Laidler, Reaction Kinetics
3. Steinfeld, Francisco & Hase, Chemical Kinetics and Dynamics

Course No: **CHE 0531 5121**	Credit: 4.0	Year: MS	Semester: First
Course Title: **Electrochemical Methods**		Course Type: Core Theory	

Course Rationale: This course is designed to give learners the advanced concepts of modern aspects of electrochemistry and electrochemical methods. This course will help the MS students to gain advances on electrochemistry

Course Objectives:

The objectives of the course are to:

- Familiarize the students with principle of electrochemistry
- Understand double layer capacitance
- Make them able to differentiate between Faradaic and non Faradaic processes
- Understand Kinetics of electron transfer reaction
- Understand electrochemical Impedance spectroscopy
- Understand outersphere and innersphere reactions

Course Content:

1. Overview of Electrode processes: Electrochemical cells, Faradaic and non Faradaic processes, Ideal polarized and non polarized electrodes, Electrical double layer, Double layer Capacitance and Charging current in electrochemical measurements, Factors affecting rates of electrode reactions, Electrochemical cells and resistance, Double layer structures, Surface excess. Various types of potentials: standard potential, formal potential, applied potential, half wave potential, half-peak potential, concentration over potential, activation overpotential. Nernst equation of adsorbed species.

2. Mass transfer controlled reactions: Modes of mass transfer: Diffusion and migration, Steady state mass transfer, Transient response, coupled reversible and irreversible reactions.

3. Kinetics of Electrode reactions: Dynamic equilibrium, Arrhenius equation, Transition state theory, Butler-Volmer and Nernst models of electrode kinetics, Transfer co-efficient and Tafel plot, Approximate forms of i-η equation, Exchange current density, rate determining electron transfer, multistep processes, polarization and overpotential, Determination number of electron, exchange current density, standard rate constant and potential dependent rate constant.

4. Basic potential step methods: Chronoamperometry, Cottrel's equation, Steady state voltammetry, Planner and spherical electrode, Diffusion controlled reactions, Single step and multistep reaction analysis. Chronoamperometry of adsorbed species.

5. Potential sweep methods: Linear sweep voltammetry, Cyclic voltammetry, measurements of reversibility, Quasireversible reactions. Coupled reactions (EE, CE, EC, ECE mechanism, Voltammetry of adsorbed species, Votammetric determination of heterogeneous rate constant.

6. Bulk electrolysis: Controlled current and controlled potentials methods, Current efficiency, current- time behavior, Flow electrolysis, coulometric measurements, thin layer electrochemistry.

7. Hydrodynamic electrodes: Concept of rotating disk electrode. Levich and Kouteky-Levich equations, Channel Electrodes, determination of Renolds number, Mechanism study: Nitrate reduction reaction, Oxygen reduction reaction.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Explain fundamentals of Electrochemistry
CO2. Execute research works with electrochemical work stations
CO3. Resolve various problems related to voltammetry, I-E curve, bulk electrolysis etc.
CO4. Perform electrokinetic experiments based on Chronoamperometry, Voltammetry, EIS etc.
CO5. Characterize electron transfer reactions by means of different physical parameters

Mapping of Course Learning Outcomes (COs) with POs
3: Strongly aligned 2: Moderately aligned 1: Weakly aligned

COs	Program Learning Outcomes (POs)									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3									
CO2			3							
CO3			3					1		1
CO4	3		2							
CO5		3	1							

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

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture demonstration	Class test (Short Q and MCQ)
CO2	Lecture demonstration	Quiz,
CO3	Lecture demonstration, animated VDO clips, Question-Answer session	Class test (Short Q and MCQ)
CO4	Lecture demonstration, Group discussion	Essay test, problem solving
CO5	Lecture demonstration Group discussion for problem analysis	Essay type test, problem solving

Books Recommended:

1. P.W. Atkins, Physical Chemistry
2. A. J. Bard, Electroanalytical Methods
3. L. Glasston, Introduction to Electrochemistry
4. R.G. Compton et at., Understanding Voltammetry (Imperial College Press)

Course No: **CHE 0531 5122**	Credit: 4.0	Year: MS	Semester: First
Course Title: **Surface Chemistry and Spectroscopy**		Course Type: Core Theory	

Course Rationale:

This course is designed to give learners the advanced understanding of surface phenomena and techniques which will help the students to solve problems related to these topics.

Course Objectives:

The objectives of this course are to:

- Familiar with the concepts of surface chemistry
- Teach how to characterize a surface with surface sensitive techniques
- Analyze principles of kinetics and mechanisms of surface reactions
- Be acquainted with the techniques to find the composition of a surface

Course Content:

Surface Sensitivity & Surface Specificity: General Sensitivity Problems, surface sensitive technique, Inelastic Mean Free Path (IMFP) of electrons, UHV (Ultra High Vacuum (UHV), Effects of Gas Pressure.

Adsorption of Molecules on Surfaces: Kinetics of adsorption, Adsorption Isotherms, Langmuir, Hinshelwood, BET, Tempkin, Elley-Rideal etc. Adsorption with dissociation, Competitive adsorption, Non ideal adsoroption Thermodynamics and statistical mechanics of adsorption.

Surface reactions: Unimolecular surface reactions, Inhibition and Activation. Bimolecular surface reactions, Reactions between two adsorbed molecules, Reaction between a adsorbed molecule and a gas molecule, Adsorption of two gases without mutual displacement, Inhibition, Activation Energies.

Surface Analytical Techniques: Auger Electron Spectroscopy (AES); Principle, instrumentation, application. X-ray Photoelectron Spectroscopy (XPS); Principle, instrumentation, application. Infrared Spectroscopy; IR Spectroscopy of various forms, e.g. RAIRS, MIR, Electron Energy Loss Spectroscopy (EELS), Applications of Vibrational spectroscopy, LEED (low energy electron diffraction); principles and application, NEXAFS Near edge X-ray absorption fine structure analysis; basic principle and application.

Surface Imaging and Depth Profiling: Basic Concepts in Imaging & Localised Spectroscopy, Electron Microscopy (SEM & TEM), Imaging XPS, SIMS Imaging & Depth Profiling, Auger Depth Profiling, Scanning Probe Microscopy (STM/AFM).

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Outline the principles and problems of surface sensitivity and surface specificity

CO2. Describe the kinetics different adsorption isotherms and apply the knowledge of statistical mechanics in adsorption

CO3. Explain the mechanism of uni and bio molecular surface reactions

CO4. Demonstrate the fundamental and practical aspects of many surface analytical techniques

CO5. Execute the modern surface imaging technique for sample analysis

Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately Aliened 1: Weakly Aliened

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3									
CO2			3							
CO3	3									
CO4										3
CO5		3	2							

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture Demonstration	Class test (Short Q and MCQ)
CO2	Lecture Demonstration	Quiz, assignment
CO3	Lecture Demonstration, Question-Answer session	Class test (Short Q and MCQ)
CO4	Lecture Demonstration, Group discussion	Short and Broad Q
CO5	Lecture Demonstration, Group discussion for problem analysis	Short and Broad Q

Books Recommended:

1. Rita Kakkar, Atomic and Molecular Spectroscopy
2. Yip-Wah Chung, Practical Guide to surface science and spectroscopy.
3. Anwar Ul-Hamid, A Beginners' Guide to Scanning Electron Microscopy

Course No: **CHE 0531 5123**	Credit: 4.0	Year: MS	Semester: First
Course Title: **Molecular Photochemistry**		Course Type:	Core Theory

Course Rationale:

This course aims to give the inside idea and to analyze the internal molecular dynamics of electronic transition based on quantum chemical approach especially for organic molecules that is needed for the further study at research levels. This also makes a bridge between higher researches with their previous knowledge.

Course Objectives

The objectives of this course are to:

- Acquaint students with the fundamentals of Molecular Photochemistry
- Make the students familiar with Molecular wave function, the structure, electronic configuration, molecular states, and spin state using quantum molecular operators
- Acquire the concept of chemical dynamics, transition between states, and probability of transition, vibronic coupling and motion
- Provide the knowledge inter conversion of Electronic states with orbital mixing
- Analyzed the electronic spectrum of radiative and non radiative transition of organic molecule

Course Content:

1. Photochemistry- An overview: Photochemical Reactions, Electronic excitation and de-excitation of molecules, State energy diagram: Electronic and spin examples. Calibration point of Molecular motion and Molecular dimensions. Calibration point for molecular energies and reaction dynamics. The nuclear geometry of electronically excited states. An energy surface description of molecular photochemistry

2. Electronic orbital, Configurations and States: Molecular wave function and molecular states. The Born-Oppenheimer Approximation. The spirit of the use of quantum molecular operators. The construction of electronic states from electronic configurations. Visualization of electron spin. Electronic energy differences between Singlet and Triplet States. Experimental measurement of Orbital energy.

3. Transition between states: Chemical Dynamics as Transition between stares: chemical dynamics, Quantum dynamics. Transition between stares: Evaluation of Transition Probability, Nuclear Motion, Vibronic states. Singlet-Triplet inter conversion

4. Radiative Transitions- The absorption and emission of light: Absorption and emission spectra of molecules. The nature of light: Electromagnetic waves and Oscillating electronic dipoles. Shape of absorption and emission spectra. State mixing, Breakdown of the single orbital configuration and pure multiplicity Approximations. Spin-Orbit coupling and spin forbidden radiations. Experimental examples of orbit-spin forbidden radiative transitions. Flash Spectroscopy. Excited state structures and dipole moments. Radiative transition involving more than one molecules: Charge transfer absorption, Excimers and Exciplexes. Delayed Fluorescence and Phosphorescence. Emission from 'Upper' Excited singlet and triplet; The Azulene Anomaly.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Describe and explain Electronic excitation and de-excitation, State energy diagram, Molecular motion and Molecular dimensions, reaction dynamics, nuclear geometry of electronically excited states

CO2. Explain the transition probability along with orbital mixing and geometry of excited state

CO3. Explain the Absorption and emission spectrum of spin allowed spin forbidden states, triplet sublevel, and delayed fluorescence **CO4.** Apply state mixing, Spin-orbit coupling, and orbital symmetry in transition between states in molecules

CO5. Handle experiments of Photo electron spectroscopy and Flash spectroscopy

Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately aligned 1: Weakly aligned

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3									
CO2			3							
CO3			3							
CO4										
CO5							3		2	

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture, PPT Demonstration	Class test (Short Q and MCQ)
CO2	Lecture, PPT Demonstration, Discussion	Quiz, assignment
CO3	Lecture, animated VDO clips, Question-Answer session	Class test (Short Q and MCQ)
CO4	Lecture, PPT presentation, Group discussion	Essay type test, problem solving
CO5	Lecture, Demo experiment of VDO clips, Group discussion for problem analysis	Essay type test, problem solving

Books Recommended:

1. Modern Molecular Photochemistry: N.J. Jurro
2. Elements of Organic Photochemistry: D. O. Crown and R.L. Drikoz
4. El-Sayed H, Excited States, ed len E.C. New York Academic Press.
5. Theory and Interpretation of florescence and Phosphorescence: R. Becleer

Course No: **CHE 0531 5224**	Credit: 4.0	Year: MS	Semester: Second
Course Title: **Advanced Chemical Kinetics**			Course Type: Core Theory

Course Rationale:

This course is designed to provide the learners insight into different aspects of advanced level of chemical kinetics so that learners can get maximum benefits for learning and doing research in the area of chemical kinetics, polymerization process and thermal decomposition.

Course Objectives:

The objectives of this course are to:

- Acquire knowledge about kinetics and reaction monitoring system for advanced complex reactions
- Gain necessary knowledge for experimentation and application of complex kinetic reactions
- Develop skills in the design and analysis of experiments to study chemical kinetics, including the determination of rate constants and activation energies
- Understand the reaction dynamics and optimized condition for polymerization and combustion process
- Develop communication skills to effectively present and discuss research findings in chemical kinetics

Course Content:

1. Fast reactions: Flow method, Flash photolysis, Relaxation method: Temperature Jump, Pressure Jump, Periodic potential method, Relative method, Production of free radicals and techniques.

2. Reaction in solution: Single sphere and double sphere activated complex, ion-dipole and dipole-dipole reactions, Influence of hydrostatic pressure: van't Hoff's equation, volumes of activation.

3. **Autocatalysis and Oscillating reaction**: Lotka-Voltera mechanism, Brusselator, The oregonator, Bistability, Chemical chaos.

4. Catalysis in gaseous systems: Chain mechanisms, Catalysis by ions of variable valency, activation of Molecular hydrogen.

5. Decomposition reactions: Goldfinger-Letort rules, Molecular process, Inhibition mechanism, combustion of hydrocarbon, Hydrogen-oxygen reactions, Gas phase combustion.

6. **Thermodynamics and Kinetics of Polymer**: Polymer solutions, the thermodynamics of polymer solution, Polymerization reactions: Stepwise polymerization, Chain polymerization, Cationic polymerization, Anionic polymerization, Emulsion polymerization.

7. **Molecular reaction dynamics:** The dynamics of molecular collisions, reactive collisions, experimental probes of reactive collisions, Potential energy surfaces: The symmetrical potential energy barrier, General features of early potential energy barriers for exothermic and endothermic reactions, Reactions with a collision complex and a potential energy well.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Defining range of fast and slow reactions and ways for monitoring the mechanism

CO2. Explain the variation of reactions in solution and gas phase, the factors affecting the reactions in solution, van't Hoff's equation, the effects of solvent and solution nature on the reactions

CO3. Defining the aoutocatalytic and oscillation reactions with understanding the mechanism and reasons behind some typical oscillation reactions including Lotka-Voltera mechanism, Brusselator, The oregonator, Bistability, Chemical chaos

CO4. Explain the processes of decomposition systems in laboratory and industries and deducing the mechanisms of various combustion and decomposition reactions

CO5. Explain and apply the mechanism and thermodynamics of various polymerization reactions and Explain the molecular reaction dynamics, collision theory, potential energy barriers and optimized kinetic conditions for successful chemical reactions

Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately aligned 1: Weakly aligned

COs	Program Learning Outcomes (POs)									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3									
CO2	3		2							
CO3	3		1							
CO4	1								1	1
CO5	2							1		

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

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture	Class test (Short Q and MCQ)
CO2	Lecture, Discussion	Quiz, assignment
CO3	Lecture, Question-Answer session	Class test (Short Q and MCQ)
CO4	Lecture, Group discussion	Test, problem solving
CO5	Lecture, Group discussion for problem analysis	Test, problem solving

Books Recommended:

1. P.W. Atkins, Physical Chemistry
1. 2 Margaret Robson Wright, An Introduction to Chemical Kinetics
2. Santosh K. Upadhyay, Reaction Dynamics
3. K. J. Laidler, Chemical Kinetics

Course No: **CHE 0531 5225**	Credit: 4.0	Year: MSc	Semester: Second
Course Title: **Advanced Electrochemistry**		Course Type: Core Theory	

Course Rationale: This course is designed to give learners the advanced concepts of modern advancements on electrochemistry and electrochemical methods. This course will help the MSc students to understand critical reasoning on advanced electrochemistry

Course Objectives:

The objectives of this course are to:

- Familiarize the students with principle of electrochemistry
- Understand double layer and electrode - solution interface
- Identify difference between Faradaic and non Faradaic processes
- Understand corrosion process and fuel cells
- Study irreversible ET reactions with hydrodynamic electrode
- Explain principles of various electrochemical techniques

Course Content:

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

5. Principles and applications of various electrochemical techniques: (i) Different types of voltammetry: Cyclic voltammetry, Linear sweep voltammetry, Normal pulse voltammetry, Differential pulse voltammetry and Square-wave voltammetry, (v) Steady-state voltammetry, Kinetics and reaction mechanism studies using steady-state voltammetry, Ring-disk electrode (RDE), Rotating ring-disk electrode (RRDE), Levich equation, Koutecky-Levich equation, Tafel plot.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Delineate fundamentals of Electrochemistry
CO2. Explain how to perform research works with electrochemical work stations
CO3. Resolve various problems related to voltammetry, I-E curve, RDE etc.
CO4. Perform ET kinetic experiments based on Chronoamperometry, Voltammetry, EIS etc.
CO5. Correlate electron transfer reactions with various physical parameters

Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately aligned 1: Weakly aligned

	Program Learning Outcomes (POs)									
COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3									
CO2			3							
CO3			3					1		1
CO4	3		2							
CO5		3	1							

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	**Teaching-Learning Strategies**	**Assessment Strategies**
CO1	Lecture demonstration	Class test (Short Q and MCQ)
CO2	Lecture demonstration	Quiz
CO3	Lecture demonstration, animated VDO clips, Question-Answer session	Class test (Short Q and MCQ)
CO4	Lecture demonstration, Group discussion	Essay test, problem solving
CO5	Lecture demonstration Group discussion for problem analysis	Essay type test, problem solving

Books Recommended:

1. P.W. Atkins, Physical Chemistry
2. A. J. Bard, Electroanalytical Methods
4. L. Glasstone, Introduction to Electrochemistry
5. Bockris and Reddy, Advanced Electrochemistry

Course No: **CHE 0531 5226**	Credit: 4.0	Year: MS	Semester: Second
Course Title: **Biophysical Chemistry**		Course Type: Core Theory	

Course Rationale: The course on biophysical chemistry is designed to provide students with a comprehensive understanding of the physical and chemical principles underlying the behavior of biological molecules and systems.

Course Objectives:

The objectives of this course are to:

- Understanding the principles of thermodynamics and kinetics and their application to biological systems
- Develop an understanding of the physical and chemical properties of biological macromolecules, such as proteins, nucleic acids, and lipids
- Understanding the principles of biophysical techniques
- Understanding the relationship between structure and function in biological molecules and systems.
- Developing an appreciation for the interdisciplinary nature of biophysical chemistry and its importance in fields such as biochemistry, biotechnology, and drug discovery
- Acquiring the skills necessary to design and carry out experiments in biophysical chemistry, including data collection, analysis, and interpretation

Course Content:

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

2. Biomolecules: Building block molecules of biomolecules, amino acid structures, polypeptides, ionic properties of amino acids and polypeptides, nucleotides and nucleic acids, base composition and base sequence of nucleic acids, simple idea about carbohydrates and lipids.

3. Proteins: Classifications, primary, secondary, tertiary and quaternary structure of globular proteins, salting in and salting out of proteins, chemistry of ion exchange and chromatographic technique in isolation/purification of protein, characterization of proteins, molecular weight determination of proteins by PAGE and get filtration techniques

4. Enzymes: Nomenclature, cofactor, principle of catalysis, enzyme catalyzed reactions having one substrate, M-M equation, K_m and V_m values determination, pH and temperature effects on catalysis, competitive, non-competitive and uncompetitive inhibition of catalysis, Transport of oxygen and CO_2 (The role of hemoglobin)

4. Bioenergetics: ATP and its role in bioenergetics, control points in metabolic pathways, carbohydrate metabolism, the energetic of the citric acid cycle, lipid metabolism, oxidative phosphorylation, nitrogen metabolism.

5. Specificity and modification of proteins/ enzymes: Trypsin, chymotrypsin, elastase, carboxypeptidase, aminopeptidase, cynanogen bromide cleavage, -SH, -S-S-, $-NH_2$, $-SCH_3$ group modification.

6. Biological membrane: Constituents and structure, the fluid mosaic model, factors affecting the physical properties of membranes, the theory and thermodynamic of biological transport, energy coupling mechanisms in biological transport, molecular mechanism of biological transport.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Explain the fundamental principles of thermodynamics and kinetics, and apply these principles to the analysis of biological systems
CO2. Understand of the physical and chemical properties of biological macromolecules and their role in biological processes
CO3. Design and interpret experiments using biophysical techniques

CO4. Appreciate for the interdisciplinary nature of biophysical chemistry and its importance in fields such as biochemistry, biotechnology, and drug discovery

Mapping of Course Learning Outcomes (COs) with POs
3: Strongly aligned 2: Moderately aligned 1: Weakly aligned

	Program Learning Outcomes (POs)									
COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3									
CO2	3									
CO3			3					1		1
CO4	3		2							

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs/POs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture demonstration	Class test (Short Q and MCQ)
CO2	Lecture demonstration	Quiz,
CO3	Lecture demonstration, animated VDO clips, Question-Answer session	Class test (Short Q and MCQ)
CO4	Lecture demonstration , Group discussion	Essay test, problem solving

Books Recommended:
1. A.W. Lehninger: Principle of Biochemistry
2. R.C. Bohinski: Modern Concept of Biochemistry
3. G. Zubay: Biochemistry
4. D. Freifelder: Physical Biochemistry
5. R.K. Scopes: Protein Puripication
6. C.N. Price & R.A. Dwek: Principles and Problems in Physical Chemistry for Biochemists
7. W.H. Elliott & D.C. Elliott: Biochemistry

Course No: **CHE 0531 5227**	Credit: 4.0	Year: MS	Semester: Second
Course Title: **Chemical Energy**		Course Type: Core Theory	

Course Rationale: This course is Aim to understand the fundamental concepts of energy-matter relation, the effective and efficient operations to design, re-design, and development of sustainable processes and materials for particular energy conversions and storage.

Course Objectives
The objectives of this course are to:
- Facilitate necessary knowledge about science of energy conversion
- Acquire knowledge about carbon free energy
- Interpret the applications of functional materials about energy storage
- Gain ideas energy harvesting from renewable sources
- Facilitate necessary knowledge about fuel cells

Course Content:
Basics of energy: Energy and Power, Kinds of energy, origin of energy, conversion of energy and corresponding efficiency, renewable and nonrenewable energy, Properties of a good fuel, Galvanic cell, free energy.
Carbon based fuel: Formation of fossil fuel, Types of fossil fuel, Heat of combustion of various hydrocarbons and their calorific values, Octane number, advantage and disadvantage of fossil fuels, biodiesel, biogas.
Alternative fuel: Hydrogen synthesis via photochemical and electrochemical water splitting, Carbon neutral fuel, mechanisms: Oxygen reduction reactions, hydrogen peroxide oxidation and reduction reactions, Ammonia oxidation reactions, Ascorbic acid oxidation and CO_2RR; Turn over frequency & Tafel analysis of HER, OER and ORR at an electrode surface.
Fuel cell: Fundamentals of fuel cell, PEMFC, DMFC, alkaline fuel cells, phosphoric acid fuel cells, molten carbonate fuel cells, solid oxide fuel cells, reversible fuel cells, hydrogen fuel cells, microbial fuel cells, functional membranes for fuel cells.

Solar cell: Fundamentals of solar cells, types of solar cells (Amorphous Silicon solar cell, Biohybrid solar cell, Dye sensitized solar cell, thin film solar cell), Evaluation of cell performance.
Energy storage materials and battery: Concept of rechargeable and non-rechargeable batteries Lead storage battery, Lithium-ion battery, charge storage in capacitor, charge-discharge phenomenon of battery and capacitor.

Course Learning Outcomes (COs):
After the successful completion of the course, students will be able to :
CO1. Describe the ways of energy conversion
CO2. Explain how energy could be generated from carbon free sources
CO3. Illustrate the difference among various energy devices.
CO4. Explain the ways chemical electrochemical energy generation
CO5. Interpret the kinetics of various energy related reactions and fabricate small fuel cells for real life applications

Mapping of Course Learning Outcomes (COs) with POs
3: Strongly aligned 2: Moderately aligned 1: Weakly aligned

	Program Learning Outcomes (POs)									
COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3									
CO2								2		
CO3	3									
CO4	3									3
CO5		3	3							

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture, Group discussion, Question-Answer session	Class test (Short Q and MCQ)
CO2	Lecture, Group Discussion, Question-Answer session	Quiz, Assignment
CO3	Lecture, Group Discussion, Question-Answer session	Essay type test
CO4	Lecture, Group Discussion, Question-Answer session	Class test (Short Q and MCQ)
CO5	Lecture, Group Discussion, Question-Answer session	Essay type test

Books Recommended:
1. Physical Chemistry (7th Edition), P.W. Atkins, Oxford University Press Inc., New York, 2002
2. Handbook of Electrochemical Energy, Editors: Cornelia Breitkopf, Karen Swider-Lyons, ISBN: 978-3-662-46657-5
3. Electrochemical Methods: Fundamentals and Applications 2nd edition, Allen J. Bard & Larry R. Faulkner
4. Chemical Energy Storage, 1st Edition by Robert Schlögl, ASIN : 3110264072
   Publisher : De Gruyter; 1st edition (December 13, 2012)

Course No: CHE **0531 5130**	Credit: 2.0	Year: MS	Semester: First
Course Title: **Advanced Inorganic Chemistry Lab**		Course Type: Core Practical	

Course Rationale:
This course is designed mainly to prepare the student practically skilled in the techniques involved in the separation of different ionic species from a mixture and synthesizing, purifying, and examining the various inorganic compounds in a normal and inert atmosphere.

Course Objectives:
The objectives of this course are to:
- Impart knowledge on the separation of ionic complexes and identify them by UV-Visible spectroscopy
- Prepare and characterize multiple Coordination Complexes in a normal and inert atmosphere.

Course content:
1. Ion exchange separation of ionic complexes and identify them by spectrophotometry

2. Preparation and identification of the copper (II) bipyridine complex
3. The synthesis and characterization of a macrocyclic complex
4. Preparation and spectroscopic characterization of an Iron dinitrogen complex
5. Synthesis and spectroscopic characterization (UV, IR) of metal salen complex
6. Preparation of carbonatotetraamine cobalt(III) nitrate $[Co(NH_3)_4CO_3]NO_3$ and its characterization using conductometric and spectroscopic techniques.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Prepare and use a different solution of various ingredients of inorganic compounds accurately for inorganic compounds' synthesis using necessary reagents

CO2. Separate ionic complexes by UV-Visible spectroscopy in the supplied sample

CO3. Synthesize and characterize the Coordination Complexes by physical, conductometric, and spectroscopic methods

CO4. Prepare, separate, and analyze inorganic complexes in a normal and inert atmosphere and characterize them

Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately Aligned 1: Weakly Aligned

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1		2	3							
CO2		3	3							
CO3		3	3							
CO4		3	3							

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Apparatus demonstration and presenting MSDS	Lab Performance (group)
CO2	Lectures, experiment demonstration	Lab Reports, Viva Voce
CO3	Lectures for characterizations	Lab Performance, Viva Voce
CO4	Lectures and experiment demonstration	Lab Performance (individual), Written Examination

Books Recommended:

1. G. Pass and H. Sutcliffe, *Practical Inorganic chemistry*
2. Robert J. Angelici, *Synthesis, and Technique in Inorganic Chemistry*
3. J. Derek Woolins, Inorganic Experiment

Course No: CHE **0531 5131**	Credit: 4.0	Year: MS	Semester: First
Course Title: **Inorganic Materials Chemistry**		Course Type: Core Theory	

Course Rationale:

This course aims to provide real-life use of different materials in terms of a chemist's point of view, how they are fabricated, and the advanced research done in these fields. The different optical and electrical characteristics of materials will be discussed here and their correlation with the properties of these materials will be explained.

Course Objectives:

The objectives of this course are to:

- Learn about the optical properties of some large complexes, especially their second and third-order nonlinear properties
- Discuss the electrical and magnetic properties of materials and their influence on the semiconduction properties of materials
- Explain the liquid crystalline properties of materials and how to change their optical properties
- Express the synthetic and separation techniques involving zeolites

Course Content:

Metal containing materials for nonlinear optics: Some basic concepts of nonlinear optics. Nonlinear optical properties of organometallic and coordination compounds.

Metal containing liquid crystals: Classes, physical properties, and characterization. Metal complexes as liquid crystals. Mesomorphic coordination complexes of bidentate and polydentate ligands.

Electronic and magnetic properties of inorganic materials: Introduction to band theory, band structure, and electronic properties- metals, insulators and semiconductors, Interactions in binuclear compounds; magnetic chain compounds, long-range ordering in molecular compounds. Conductors and superconductors based on metal complexes.

Luminescent Materials: Luminescent metal complexes of transition metal and lanthanides. Biological and medicinal chemistry of metal complexes.

Zeolites: Intercalation in layer materials and solid electrolytes: zeolites, zeolite structures, the properties of zeolites, intercalation chemistry in zeolites.

Metal oxide-based materials: Structure, optical, catalytic, and sensor applications.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Describe the nonlinear optical properties of materials and explain their correlation with the structure of these compounds

CO2. Explain the relationship of bandgap with electrical and magnetic properties of materials and express the liquid crystalline properties of different materials

CO3. Design materials for drug delivery assessment study

CO4. Apply their knowledge to separate products after reactions based on size and use the steric effect of zeolite to control suitable reactions

CO5. Explain the luminescent properties of metal complexes and their application in the medicinal sector

Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately Aligned 1: Weakly Aligned

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	2		1							
CO2	2		1							
CO3	2		1							
CO4	3									
CO5	2		1							

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture, Discussion	Class test (Short Q and MCQ)
CO2	Lecture, Discussion	Class test (Short Q and MCQ)
CO3	Lecture and demonstration	Class test
CO4	Lecture and demonstration	Class test
CO5	Lecture, PPT Demonstration, Group discussion for problem analysis	Class Test (Problem-Solving)

Books recommended:

1. Inorganic materials chemistry, Mark A Weller, Oxford Science Publications, 1995.
2. Inorganic Spectroscopic Methods, Allan K. Brisdon, Oxford Science Publications, 1998.
3. Inorganic materials chemistry, Duncan W Bruce and Dermot O'Hare, 2nd Edition, John Wiley & Sons, Inc., 1997.
4. Nano-Optics, Satoshi Kawata, Motichi Ohtsu and Masahiro Irie, Springer, 2002.

Course No: **CHE 0531 5132**	Credit: 4.0	Year: MS	Semester: First
Course Title: **Inorganic Spectroscopic Methods**		Course Type: Core Theory	

Course Rationale:
This course aims to give an understanding of spectroscopic methods for inorganic compounds which will be needed for further study at research levels. This is also to make a bridge with their previous knowledge of this.

Course Objectives:
The objectives of this course are to:
- Acquaint students with the principles of various spectroscopic methods
- Make the students understand the application of these methods for inorganic compounds
- Train to determine molecular structures of inorganic and organic compounds based on the above spectral information
- Make them skilled to identify and characterize an unknown compound

Course content:
1. Vibrational spectroscopy: The basics, symmetry, and vibrational bands, infrared experiments - group frequencies, fingerprints, analysis of mixtures.
2. Raman spectroscopy: The basics, Raman applications, depolarization measurements, complementary nature of Raman, and IR spectroscopy.
3. Resonance spectroscopy: The basics, are chemical shift, chemical environment, integration, coupling, magnetic versus chemical equivalence, decoupling, non-spin-1/2 systems, exchange processes, and relaxation processes. Nuclear quadrupole resonance (NQR)–The principle and applications. Electron spins resonance- The principle and applications.
4. UV-visible spectroscopy: The basics, metal-metal transitions, crystal field splitting, crystal field splitting into common shapes, spin states, strong field model and weak field model, selection rules, Jahn-Teller distortions, charge transfer transitions, metal-ligand transitions, ligand-centered transitions.
5. Luminescence spectroscopy: Basics and application.
6. Mass spectrometry: Basics, ionization methods, electron impact, fast atom bombardment, chemical ionization, interpretation of mass spectra, accurate mass measurements, isotopic pattern, and fragmentation patterns. McLafferty Rearrangement
7. Determination of molecular structures of inorganic and organic compounds based on the above spectral information.

Course Learning Outcomes (COs):
After the successful completion of the course, students will be able to:
CO1. Explain different spectroscopic methods used in the study of inorganic and organic compounds
CO2. Apply the methods to determine the structure of a compound
CO3. Explain various properties of an inorganic compound
CO4. Monitor the progress of a reaction
CO5. Interpret spectral data of unknown compounds

Mapping of Course Learning Outcomes (COs) with POs
3: Strongly aligned 2: Moderately Aligned 1: Weakly Aligned

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	2				1					
CO2			1	2						
CO3			2			1				
CO4				2		1				
CO5				2		1				

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategy	Assessment Strategy
CO1	Lecture, PPT Demonstration	Class test (Short Q and MCQ)
CO2	Lecture, PPT Demonstration, Discussion	Quiz, assignment
CO3	Lecture, Question-Answer session	Class test (Short Q and MCQ)
CO4	Lecture, PPT presentation	Semester end exam, problem-solving
CO5	Lecture, PPT presentation	Semester end exam, problem-solving

Books Recommended:

1. Inorganic materials chemistry, Mark A Weller, Oxford Science Publications.
2. Inorganic Spectroscopic Methods, Allan K. Brisdon, Oxford Science Publications.
3. Inorganic materials chemistry, Duncan W Bruce and Dermot O'Hare.
4. Nano-Optics, Satoshi Kawata, Motichi Ohtsu, and Masahiro Irie.
5. Interpretation of mass spectra (Benjaunia), F. W. Mc Lafferty.
6. Introduction to Spectroscopy (Sanndus Golden Snburet Series), Pavia
7. Spectro reactive identification of Organic Compounds (John Williamson), Silverstein, Bassler, Morrid.

Course No: CHE **0531 5233**	Credit: 4.0	Year: MS	Semester: Second
Course Title: **Advanced Bioinorganic Chemistry**		Course Type: Core Theory	

Course Rationale:
This course is designed to achieve knowledge on essential elements, metalloporphyrin and their involvement in O_2 and CO_2 transport in humans, biological electron transfer and energy transfer, proteins, enzymes, metalloenzymes, enzyme function, and inhibition, and to widely comprehend the chemistry of metal ions in medicine and human health.

Course Objectives:
The objectives of this course are to:
- Offer graduate students a thorough knowledge of essential metal ions in humans and important features of the structure and functions of hemoglobin and myoglobin, photosynthesis, metabolism, and nitrogen fixation
- Prepare the students to understand the significance and dynamics of coordination chemistry in the biological environment
- Improve the knowledge to apply for evaluating the reactivity of a metal center and electron transfer and energy transfer in biological systems
- Advance the systematic and critical thinking about protein, enzyme, enzyme action and inhibition, metalloenzyme functions and applications, metal overload and toxicity, and biological catalysis
- Recognize different diseases such as cancer, heart disease, and HIV, and apply knowledge for material design and synthesis for therapeutic, diagnostic, and theragnostic interventions in medicine and pharmaceutical platforms

Course content:
Introduction: Inorganic chemistry is behind the requirement of biological cells for metals such as Zn, Fe, Cu, Mo, S, Se, etc.
1. Binding of metal ions to proteins: (a) Metal-dependent lyases and hydrolases. carboxypeptidases A, Purple acid phosphatase (metal-dependent), carbonic anhydrase. (b) Zink binding domains. (c) Calcium and Calcium-binding proteins. (d) Copper binding proteins, and (e) manganese binding proteins.
2. Special cofactors and metal clusters: (a) Electron transfer protein, (b) cobalamin, and (c) Molybdenum cofactors enzyme.
3. Transport and storage of iron: (a) Transport and storage of iron with oxygen, and (b) Obtaining iron from organisms
4. Oxygen metabolism: (a) Reactivity of oxygen and its reduced forms, (b) Dioxygen carriers, (c) Enzymes that get rid of superoxides, (d) Enzymes that utilize peroxides, and (e) Oxygen activating enzymes, cytochrome P-450
5. Interactions of DNA with metal salts and complexes:
6. Metals and Health: (a) Metals-based drugs, Cisplatin, Carboplatin, Platinum anticancer drugs, Radiopharmaceuticals, MRI, Contrast agents, anti-infective drugs for skin HIV, AIDS, etc., and (b) Metal toxicity Cu overload, iron overload, mercuric ion reductases, Lead and porphobilinogen synthases.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Recognize the roles of essential trace elements, Na, K, Ca, Mg, Co, Mo, Se, etc. in humans

CO2. Correlates the structure and functions of porphyrin ring systems in essential biological processes. Significance of electron transfer and energy transfer in biological systems

CO3. Realize the iron intake, storage, and mobilization in humans and organisms; oxygen and CO_2 transfer and metabolism, and the importance of electron transfer by heme and non-heme iron

CO4. Elucidate the enzymes, metalloenzymes, enzyme action and inhibition, and their functions as biocatalysts

CO5. Recognize fetal disease and prevention by application of metal- and metal complex-based systems in medicine and therapy, diagnosis, and theragnostic

Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately Aligned 1: Weakly Aligned

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3									
CO2			3							
CO3	2		3							
CO4	2		3			1				
CO5	2		3			1				

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategy	Assessment Strategy
CO1	Lecture, discussion, group study	Assignment, Class assessment, term test, final semester examination (Short Q and MCQ)
CO2	Lecture, discussion, group study, assignment	Final semester examination (Short Q and MCQ)
CO3	Lecture, discussion, group study, assignment	Assignment, Class assessment, and term test (Short Q and MCQ)
CO4	Lecture, discussion, group study, assignment	Final semester examination (Short Q, MCQ, Quiz, Explanation)
CO5	Lecture, discussion, group study, assignment	Final semester examination (Short Q, MCQ, Quiz, Explanation)

Books Recommended:

1. R.W Hay, Bioinorganic Chemistry
2. S. J. Lippard and J. M. Berg, Principles of Bioinorganic Chemistry
3. Sally Solomon, Introduction to General, Organic, and Biological Chemistry - McGraw Hill
4. Hughes, Inorganic Chemistry in Biological process
5. J. E. Huheey, Inorganic Chemistry
6. Y. Satake, S. Mido, Bioinorganic Chemistry
8. Douglas, McDaniel, and Alexander: Concepts and Models of Inorganic Chemistry
9. Articles from J of Inorganic biological Chemistry and relevant journals
10. J.B. Taylor and P. D. Kennewell, Modern Medicinal Chemistry, Ellis Horwood, NY,- 1st ed.

Course No: CHE **0531 5234**	Credit: 4.0	Year: MS	Semester: Second
Course Title: **Advanced Crystallography and Group theory**			Course Type: Core Theory

Course Rationale:

Students are expected to understand and explain the structures, geometries, and properties of atoms, molecules, and compounds at atomic and molecular levels.

Course Objectives:

The objectives of this course are to:

- Acquire knowledge of crystal structures, morphology, and properties
- Explain elaborately the symmetric properties and point groups of molecules and compounds
- Provide clear knowledge of space groups and apply this knowledge to spectroscopic and bonding concepts.
- Understand the space groups of molecules and compounds and the relationship between space groups, point Groups, and physical properties

Course Content:

Crystallography: Crystals and lattices, disorder, Crystal systems and geometry, Classification of unit cells, Restrictions imposed by symmetry on unit cell dimensions, Crystal systems, Limitations on symmetry in crystals, Hermann-Mauguin notation, Bravais lattices, Distinction between Trigonal and Hexagonal systems, Crystal planes and indices, Law of rational indices, Interplanar spacings.

Symmetry: Symmetry Elements and Operations, Point groups, List of 32 Point Groups, Properties, and Representations of Groups, Translational Matrices, Representations of Point Groups, Reducible and Irreducible Representations, reduction formula, Character Tables, symmetry labels.

Applications of group theory to vibrations spectroscopy: Polarity, Chirality, Molecular vibrations, Infrared, and Raman spectroscopy.

Applications of group theory to structures and bonding: The symmetries of molecular orbitals, Symmetry-adapted linear combinations, fundamental and construction of molecular orbital theory. Linear, angular, planner, pyramidal, and octahedral complexes.

Space groups and equivalent positions: Translational Symmetry Elements, Screw axis, Glide plane, Space groups, the relationship between Space groups, Point Groups and physical properties, Equivalent positions, Wyckoff Sites.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Interpret crystal structures and properties using various crystallographic parameters

CO2. Explain symmetric properties and identify point groups of molecules and compounds

CO3. Understand the group theory for molecules and compounds through symmetry operations to understand the nature of molecules

CO4. Apply group theory knowledge in understanding structures, spectroscopic, and bonding of molecules and compounds

CO5. Illustrate Space groups and equivalent positions and understand the relationship between Space groups, Point Groups, and physical properties

Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately Aligned 1: Weakly Aligned

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3									
CO2	3									
CO3	3									
CO4	3									
CO5	3		1							

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture using PPT and demonstration of practical data	assignment
CO2	Lecture using PPT and demonstration of practical data	Class test (Short Q and MCQ)
CO3	Lecture using PPT and model demonstration	Final Exam (Short Q, MCQ, Quiz, Explanation)
CO4	Lecture using PPT and model demonstration	Class test (Short Q and MCQ), presentation
CO5	Lecture using PPT and Group discussion	Final Exam (Short Q, MCQ, Quiz, Explanation)

Books Recommended:

1. Haas et al. Duke University, Inorganic Chemistry
2. Kieran C. Molloy; Group theory for chemists Fundamental theory and applications
3. Donald E. Sands; Introduction to Crystallography
4. Peter Atkins, Tina Overton; Inorganic Chemistry 5th edition
5. James E. Huheey, Inorganic Chemistry 4th edition

Course No: CHE **0531 5235**	Credit: 4.0	Year: MS	Semester: Second
Course Title: **Frontiers Solid-state Materials**			Course Type: Core Theory

Course Rationale:

This course aims to gain knowledge on the design, synthesis, characterizations, properties, and applications of various solid-state materials.

Course Objectives:

The objectives of this course are to:

- Acquire knowledge on the synthesis of materials
- Gain knowledge on the characterizations of materials
- Understand structures and properties of materials
- Explain the structure-property relationships of materials
- Use the materials in various applied fields

Course Content:

A. Synthesis and crystal growth of materials: The formation of bulk material: Methods of direct synthesis, Solution and hydrothermal methods, High and low-temperature reactions, Solid solution methods, Sol-gel methods, Sealed tubes, and special atmospheres. Chemical deposition, Phase diagrams, and synthesis

B. Physical Methods for Characterizing Solids: Powder X-ray diffraction, uses of powder x-ray diffraction, The Rietveld Method, single crystal X-ray diffraction, neutron diffraction, electron microscopy, extended x-ray absorption fine structure (EXAFS), thermal analysis.

C. Structures and properties of various materials: Strategy for the synthesis of Noncentrosymmetric (NCS) materials, monoxides of the metals, higher oxides and complex or mixed oxides, metal nitrides, carbonates, nitrates, sulfates, phosphates, halides, and oxyhalides, rechargeable battery materials.

D. Chalcogenides, intercalation compounds, and metal-rich phases: Layered MS_2 compounds and Intercalation, Chevrel phases, and chalcogenide thermoelectrics.

E. Framework structures: Structures based on tetrahedral oxoanions; Aluminophosphates, Phosphates, and silicates. Structures based on octahedral and tetrahedral; Clays, pillared clays, and layered double hydroxides, Advance in inorganic framework chemistry. Metal-organic frameworks (MOFs) and Polyoxometalates (POMs).

F. Perovskites materials and their related phases: Structures, properties, and applications of

G. Metal–metal bonded compounds and clusters: Formation and criteria of the metal-metal bond clusters, Electron count, and Structure and isolobal analogies.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Distinguish the design and various synthesis methods of materials

CO2. Explain different characterization techniques of solid-state materials

CO3. Describe properly the crystal structures of various types of materials and understand the bonding nature within compounds

CO4. Recognize the various physical and chemical properties of materials and applications in different technological fields

CO5. Explain the structure-properties relationships of the solid-state materials

Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately Aligned 1: Weakly Aligned

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	1								
CO2	3	1								
CO3	3									
CO4	3									
CO5	3		1							

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture using PPT and discussion	assignment by quiz
CO2	Lecture using PPT and open discussion	Class test (Short Q and MCQ)
CO3	Lecture using PPT and compare with previous lectures	Final Exam (Short Q, MCQ, Quiz, Explanation)
CO4	Lecture using PPT and demonstration of practical data	Class test (Short Q and MCQ), presentation
CO5	Lecture using PPT and demonstration practical data, Group discussion	Semester end Exam ; problem solving

Books Recommended:

1. Lesley E. Smart, Elaine A. Moore; Solid State Chemistry
2. Peter Atkins, Tina Overton; Inorganic Chemistry 5th edition
3. Mark T. Weller; Inorganic Materials Chemistry, Oxford Chemistry premiers
4. Anthony R. West; Solid State Chemistry and its Applications, Second Edition
5. Donald E. Sands; Introduction to Crystallography
6. James E. Huheey, Inorganic Chemistry 4th edition
7. Douglas, McDaniel, and Alexander: Concepts and Models of Inorganic Chemistry
8. Ch. Elschenbroich, A. Salzer: Organometallics
9. P.Shiv Halasyamani and Kenneth R. Poeppelmeier; Noncentrosymmetric Oxides, *Chem. Mater.* 1998, *10,* 2753-2769
10. Kang Min Ok, Eun Ok Chi, and P. Shiv Halasyamani; Bulk characterization methods for non-centrosymmetric materials: second-harmonic generation, piezoelectricity, pyroelectricity, and ferroelectricity
11. Kang Min Ok and P. Shiv Halasyamani; Distortions in Octahedrally Coordinated d0 Transition Metal Oxides: A Continuous Symmetry Measures Approach

Course No: CHE **0531 5240**	Credit: 2.0	Year: MS	Semester: Second
Course Title: **Advanced Organic Chemistry Lab**		Course Type: Core Practical	

Course Rationale:

Aim to acquire knowledge of various preparation techniques, purification and identification of organic compounds, and the estimation, determination, and analysis of various organic materials. In addition, other goals are to develop knowledge of the separation techniques of different mixture as well as improve skills in the extraction of organic compounds

Course Objectives:

The objectives of this course are to:

- Acquire knowledge of various preparation techniques, purification, and identification of organic compounds
- Make them expertise students in the estimation, determination, and analysis of various organic compounds
- Develop knowledge of the separation techniques of different mixtures of organic compounds
- Make them demonstrate as well as improve skill in the extraction of organic materials

Course Content:

1. Preparation of benzilic acid from benzaldehyde.
2. Preparation, Purification & Identification of dibenzalacetone.
3. Preparation of 4, 4 - diphenyl but - 3 - ene - 2 - one from ethylacetoacetate or preparation of 1, 1 -diphenyl -1 - propanal using Grignard reagent.
4. Preparation of 4,5-dialkoxy-1,2-dibromobenzene from catechol.
5. Estimation of Carboxylic acid by the iodometric method.
6. Determination of Polyhydric alcohols by the iodometric method.
7. Determination of the concentration of an aqueous phenolic solution by bromination method.
8. Analysis of vitamin C.
9. Qualitative and quantitative analysis of sugar.
10. Separation of a mixture of organic compounds by column chromatography using suitable solvents and detection of separated compounds with thin layer chromatography.
11. Extraction:
    (a) Acid-base extraction
    (b) Solid-liquid extraction

(c) Isolation of caffeine from tea

N.B. Experiments may be added or removed from the above list if necessary.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Demonstrate the various preparation techniques, purification, and identification of organic compounds, such as benzaldehyde, dibenzalacetone, 4,4-diphenylbut-3-ene-2-one, 4,5 –dialkoxy-1,2-dibromobenzene, etc.

CO2. Outline the estimation, determination, and analysis of various organic compounds

CO3. Perform the separation techniques of different mixtures of organic compounds

CO4. Accomplish the extraction of organic materials

Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately Aligned 1: Weakly Aligned

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1		3		2						1
CO2		3								1
CO3		3		1						1
CO4		3		2						1

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture, Group work, Question-Answer session	Class test (Short Q and MCQ)
CO2	Lecture, Group work, Question-Answer session	Quiz, Assignment
CO3	Lecture, Group work, Question-Answer session	Essay type test, Assignment
CO4	Lecture, Group work, Question-Answer session	Class test (Short Q and MCQ)

Books Recommended:

1. Organic Syntheses, 1932, 12, 22, DOI: 10.15227/orgsyn.012.0022
2. H. T. Clarke, B. Haynes, E. C. Brick, G. C. Shone, E. Arnold, *Handbook of Organic Analysis, Qualitative and Quantitative*, 5th edition
3. R. L. Shriner, R. C. Fuson and D. Y. Curtin, *Systematic Identification of Organic Compounds*, John Wiley & Sons, Inc. New York, London, Sydney, 5th edition
4. Vogel's Text Book of Quantitative Chemical Analysis, John Wiley & Sons Inc.
5. Scott D. Murray and Peter J. Hansen, *J. Chem. Educ.* 1995, 72, 9, 851, https://doi.org/10.1021/ed072p851

Course No: CHE **0531 5141**	Credit: 4.0	Year: First	Semester: First
Course Title: **Advanced Heterocyclic and Organometallic Chemistry**			Course Type: Core Theory

Course Rationale:

This course provides an introduction to the broad field of heterocyclic organic chemistry by reviewing the major classes of heterocyclic compounds in terms of nomenclature, structure, properties, preparations, and reactions. This course also aims to provide the students with a thorough understanding of the relationship between the structures, chemical bonding, and chemical properties of organometallic chemistry.

Course Objectives:

The objectives of this course are to

- Acquiring knowledge about the structure, properties, nomenclature, chemical reactions, and the role of three, four, five, and six-membered **saturated** and **unsaturate**d (aromatic and non-aromatic) heterocyclic compounds. Developing the ability to interpret the transformation of heterocyclic compounds
- Impart knowledge of the designing of synthetic routes for different heterocyclic compounds
- Form an image of the use of heterocyclic compounds in pharmaceuticals, cosmetics, and household chemicals
- Give knowledge on the synthesis, structure, and bonding of Organo copper, organozinc, organo-boron, and organotin compounds
- Introduce content from the fundamentals to advanced aspects of transition metal organometallic chemistry. Convey knowledge of the reactions of organometallic compounds and their mechanisms such as insertion, oxidative addition, and reductive elimination
- Application of metal-catalyzed different coupling reactions
- Study the carbene, nitrene, and enamine intermediate and their application in organic synthesis

Course Content:

1. Heterocyclic Chemistry:

(i) Introduction: Physiological and industrial significance of heterocyclic compounds, classification, and systematic nomenclature.

(ii) Compounds with three- and four-membered heterocyclic rings containing Nitrogen, Oxygen, and Sulphur: Synthesis, physic-chemical properties and uses of oxiranes and oxetans, thirans and thietans, aziridines and azetidines.

(iii) Compounds containing a five-membered ring with two heteroatoms: Nitrogen-nitrogen (pyrazole and imidazole groups and related compounds), nitrogen-oxygen (oxazole and isooxazole), and nitrogen-sulfur (thiazole, isothiazole, and related compounds).

(iv) Condensed Five-membered rings with one heteroatom: Synthesis and physico-chemical properties of indoles, benzofurans, benzothiophenes, and carbazoles.

(iv) Compounds containing a six-membered ring with two heteroatoms: Pyrimidines, pyrazines, oxazines, thiazines, dioxins, and their analogs.

(v) Compounds containing seven-membered rings: Azepines, diazepines, oxazepines, thiazepines, and related compounds.

(v) Saturated heterocyclics with one and two heteroatoms.

2. Organometallic Chemistry:

(i) Preparations, structures, properties, and applications of Organo- copper, Organo zinc, organo-boron, and organo-tin reagents.

(ii) Transition metal catalysts in organic synthesis: Introduction to organometallic chemistry of transition metals. Organopalladium Chemistry, and Organo-Platinum compounds: Metal Catalyzed Coupling Reactions: Suzuki coupling, Heck coupling, Stille coupling, Sonogashira coupling, Kumada coupling, and related cross-couplings. Alkene metathesis.

(iii) Reaction intermediates in organic synthesis regarding carbenes, ketenes, and enamines.

Course Learning Outcomes (COs):

Upon completion of this course, the students will be able to

CO1. Explain the importance of heterocyclic compounds in biological systems, pharmaceuticals, and other industrial applications. Distinguish the molecular structure, classification

CO2. Explain and apply the reactions for Syntheses, reactions, and properties of three and four-membered heterocyclic compounds containing Nitrogen, Oxygen, and Sulphur and condensed five-membered heterocyclic compounds with one hetero atom

CO3 Discuss and explain the chemistry and mechanistic aspects of five and six-membered aromatic heterocyclic compounds containing two hetero atoms and identify their the chemical and physical properties

CO4 Rationalize the synthesis, structure, bonding, properties, and reactivity of organo-copper, organo zinc, organo boron, tin, and transition metal organometallic compounds. Illustrate the reactivity of selected organometallic compounds such as organo cuprates, organo-boron, and tin and show how these may be used as a tool for the synthesis of complex molecules

CO5 Apply the following reagents for coupling and other reactions for organic synthesis: Grignard reagent, Organolithium, organocuprates, carbenes, nitrenes, enamines, and their application in organic synthesis

Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately Aligned 1: Weakly Aligned

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3									
CO2	3									
CO3	3									
CO4	3		1							
CO5	3									

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture, PPT demonstration	Class test, (Short Q and MCQ), Quiz
CO2	Lecture, Demonstration with the model, Discussion	Quiz, Assignment, Mid –term-1 exam.
CO3	Lecture, animated VDO clips, Question-Answer session	Mid-Term-2 exam., Assignment
CO4	Lecture, Group discussion	Problem-solving, Assignment, Final Assessment
CO5	Lecture, PPT presentation, group discussion for problem analysis	Problem-solving, Final Assessment

Books Recommended:

1. E. H. Rodd, Chemistry of Carbon Compounds (Heterocyclic Compounds) IV A, B, C.
2. A. R. Katritzky, Advances in Heterocyclic Chemistry, vols. I-X.
3. J. Joule and G. Smith, Heterocyclic Chemistry. Fifth Edition.
4. R. K. Bansal, Heterocyclic Chemistry.
5. Stanley H. Pine, Organic Chemistry, Fifth Edition, McGraw-HILL.
6. Francis Carey and Richard J. Sundberg, Advanced Organic Chemistry, Part B, Third Edition.
7. T. L. Gilchrist, Heterocyclic Chemistry.

Course No: CHE **0531 5242**	Credit: 4.0	Year: MS	Semester: Second
Course Title: **Advanced Spectroscopy & stereochemistry**		Course Type: Core Theory	

Course Rationale: Applications of spectroscopy are essential for a variety of fields, including analytical chemistry, biochemistry, materials science, and medical imaging. The course aims mainly at structural elucidation of known or unknown compounds using common advanced spectroscopic techniques. Stereochemistry is the study of the relative spatial arrangement of atoms in molecules and how this affects their properties and reactivity. Understanding stereochemistry is an important factor for understanding the behavior of many important classes of chemical compounds, including pharmaceuticals, natural products, and polymers and useful for understanding reaction pathways.

Course objectives:

Objectives of the course are to:

- Acquire the common features and applications of the following spectroscopies: including UV-Vis, IR, NMR, and Mass spectrometry
- Make them able to select the appropriate techniques among the different spectroscopic techniques and be able to make a proper analysis of organic structures and to apply them for medical and other fields.
- Give the idea about the optical isomerism of compounds devoid of chiral center like biphenyls and allenes
- Internalize the basic principles of ORD and CD; Develop the ability to analyze and interpret ORD and CD spectra, including understanding the relationship between spectra and molecular structure and conformation
- Make them familiar about the basic principles of stereochemistry, including the relationships between stereochemistry and molecular structure, and the influence of stereochemistry on chemical reactivity and reactivity for asymmetric synthesis

Course Content:

1. Spectroscopy

(i) NMR spectroscopy: ^{1}H-, ^{13}C-, ^{19}F- and ^{31}P-NMR spectroscopy: Basic principles, chemical shift, spin-spin coupling and its patterns, spin decoupling. 2D NMR, COSY, HETCOR, DEPT, NOESY, and NOE. Application of ^{1}H- and ^{13}C-NMR for structural and reaction study.

(ii) Mass spectrometry: Introduction to different modern techniques of mass spectra, e.g., GC-MS, LC-MS, TOF MS, FAB MS. Elucidation of the structure of important organic compounds using combined spectral analysis.

2. Stereochemistry

(i) Stereochemistry of fused ring systems: Conformations, relative stability and molecular dissymmetry in (i) Bicyclic systems e.g., Decalin, 2-Decalol, (ii) Polycyclic systems e.g., Perhydrophenanthrene, Perhydroanthracene.

(ii) Optical rotation and optical rotatory dispersion: Chiroptical Properties (i) Relation between rotation and configuration, atomic asymmetry, conformational asymmetry. (ii) Circular birefringence and circular dichroism (CD). Optical rotatory dispersion (ORD), Cotton effect. Description of ORD curves, Differences between ORD and CD, Rotatory dispersion of ketones. Sector rules: the axial Haloketone rule, the Octant rule, Application of these in determining the structure, conformation, and configuration of different compounds.

(iii) Stereochemistry of reaction mechanism: Asymmetric synthesis**,** Introduction, R/S stereo descriptors, Stereoselective syntheses: nucleophilic attack on acyclic chiral carbonyl compounds (Cram's rule),

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Explain common features and applications of the following spectroscopies: including UV-Vis, IR, NMR, and Mass spectrometry

CO2. Select the appropriate techniques among the different spectroscopic techniques and be able to make a proper analysis of organic structures and to apply them for medical and other fields

CO3. Explain the optical isomerism of compounds devoid of chiral center like biphenyls and allenes

CO4. Internalize the basic principles of ORD and CD; Develop the ability to analyze and interpret ORD and CD spectra, including understanding the relationship between spectra and molecular structure and conformation

CO5. Explain the basic principles of stereochemistry, including the relationships between stereochemistry and molecular structure, and the influence of stereochemistry on chemical reactivity and reactivity for asymmetric synthesis

Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately Aligned 1: Weakly Aligned

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3		2							
CO2			3							
CO3	3		2							
CO4	3		2							
CO5	3		2							

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture, PPT Demonstration, Open discussion	Class test (Short Q and MCQ)
CO2	Lecture, PPT Demonstration, Discussion, Open discussion	Class test (Quiz, Short Q)
CO3	Lecture, PPT Demonstration, Question-Answer session	Class test (Short Q and MCQ), Assignment
CO4	Lecture, PPT Demonstration, animated VDO clips, Group discussion	Final Exam (Short &broad Q, Explanation)
CO5	Lecture, PPT presentation, Group discussion	Final Exam (Short &broad Q, Explanation)

Books Recommended

1. William and Flemming (McGraw Hill), Spectroscopy of Organic Compounds.
2. D. Pavia Lampen and Kniz, Introduction to Spectroscopy.

3. Silverstien, Bassien and Morril, Spectrometric Identification of Organic Compounds
4. P. S. Kalsi, Stereochemistry of Organic Compounds
5. D. Nasipuri, Stereochemistry of Organic Compounds
6. E. E. Eliel, S. H. Wilen, and L. N. Mander, Stereochemistry of Organic Compounds 7.I. L. Finar, Organic Chemistry, Vol. 2

Course No: CHE **0531 5142**	Credit: 4.0	Year: MS	Semester: First
Course Title: **Advanced Biochemistry**		Course Type: Core Theory	

Course Rationale:
This course aims to provide progress in understanding the core principles and topics of Biochemistry, which are involved in the chemistry of the biological system.

Course Objectives:
The objectives of this course are to :
- Acquaint students with the molecular logic of living organisms and the history of life
- Make them familiar with the metabolic concepts and bioenergetics
- Acquire the concepts of glycolysis, gluconeogenesis, pyruvate oxidation, and TCA cycle
- Make them understand the electron transport and oxidative phosphorylation
- Provide the knowledge of catabolism of triacylglycerol, amino acids, and Urea cycle
- Recognize the basics of oxidation of fatty acids
- Make them familiar with the biosynthesis of fatty acids and amino acids and nucleic Acids
- Recognize the concept of hormones, and their regulation, function & mechanism

Course Content:
1. Introduction: Definition, branches, biochemistry as the molecular logic of living organisms. Origin and history of life, chemical evolution of life.
2. Bioenergetics and Metabolism: (i) Metabolic concepts, bioenergetics. (ii) Glycolysis, pyruvate oxidation, and TCA cycle. Electron transport and oxidative phosphorylation. Gluconeogenesis. (iii) Catabolism of triacylglycerol, *β*-oxidation of saturated, monounsaturated, polyunsaturated, and odd-chain fatty acids. (iv) Catabolism of amino acids and the Urea cycle. (v) Outline the biosynthesis of fatty acids and amino acids.
3. Introduction to Heredity and Nucleic Acids: The structure of genetic materials. Replication and transcription of DNA, mutation. Genetic code, protein biosynthesis, and its regulation.
4. Hormones: Classification, the function of hormones, and general mechanism of hormone action. Hormone regulation and action with special reference to insulin and testosterone. Birth control.

Course Learning Outcomes (COs):
After the successful completion of the course, students will be able to:
CO1. Describe and recognize the molecular logic of living organisms and the origin and history of life, the chemical evolution of life, the metabolic concepts, and bioenergetics
CO2. Describe and explain the catabolism of glycolysis, pyruvate oxidation and TCA cycle, triacylglycerol, amino acids and Urea cycle, fatty acids oxidations, electron transport, and oxidative phosphorylation
CO3. Describe and demonstrate the anabolism of Gluconeogenesis, fatty acids, and amino acids
CO4. Explain and analyze the structure of genetic materials, Replication and transcription of DNA, mutation, genetic code, protein biosynthesis, and its regulation
CO5. Describe and recognize hormones classification, function, general mechanism, regulation, and action with special reference to insulin and testosterone

Mapping of Course Learning Outcomes (COs) with POs
3: Strongly aligned 2: Moderately Aligned 1: Weakly Aligned

COs	**Program Learning Outcomes**									
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3									
CO2	3									
CO3	3									
CO4	3		2					1		
CO5	3		2							1

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	**Teaching-Learning Strategies**	**Assessment Strategies**
CO1	Lecture, PPT Demonstration	Class test (Short Q)
CO2	Lecture, Demonstration with the model, Discussion	Quiz, assignment
CO3	Lecture, Question-Answer session	Class test (Short Q)
CO4	Lecture, Group discussion	type test, problem-solving
CO5	Lecture, PPT presentation, Group discussion for problem analysis	type test, problem-solving

Books Recommended
1. Lehninger, Nelson and Cox, Principles of Biochemistry.
2. S. Solomon, General, Organic and Biological Chemistry.

Course No: CHE **0531 5244**	Credit: 4.0	Year: MS	Semester: Second
Course Title: **Supramolecular Chemistry**		Course Type: Elective Theory (Core)	

Course Rationale: For chemistry students it is very important to have the knowledge on contemporary topics of chemistry. This course is aimed to give the fundamental knowledge of supramolecular chemistry, which basically deals with spatial organization of discrete molecules through non-covalent interactions.

Course Objectives:
The objectives of this course are to:
- Acquaint students with the development of supramolecular chemistry, nature of supramolecular interactions, and supramolecular host-guest compounds
- Make the students familiar with cation- and anion-binding and molecular hosts
- Understand the fundamentals of the formation of host-guest compounds in the solution and in the solid-state
- Acquire the concepts of the formation of network solids such as zeolites, layered solids, intercalates, Werner clathrates and metal organic frameworks
- Make them familiar with the role of self-assembly in supramolecular architecture
- Provide the knowledge of different supramolecular mimics used in biological processes

Course Content:
Concepts of Supramolecular Chemistry: Definition and development of supramolecular chemistry, Classification of supramolecular host–guest compounds, Receptors, Coordination and the lock and key analogy, Binding constants, Cooperativity and the chelate effect, Preorganisation and complementarity, Thermodynamic and kinetic selectivity, Nature of supramolecular interactions, Solvation and hydrophobic effects, Supramolecular chemistry of life.
Cation- and Anoin-Binding Hosts: Crown ethers, Podants, Cryptands, Spherands, Calixarenes, Corands, Macrocycles, Biological anion receptors, Inert metal-containing receptors, Ion pair receptors.
Molecular Hosts and Molecular Guests in Solution: Introduction, Cyclodextrins, Cucurbiturils, Cyclophanes, Cryptophanes, Carcerands and Hemicarcerands.
Solid-State Host-Guest Compounds: Clathrates, Urea and thiourea clathrates, Cyclotriveratrylene.
Network Solids: Introduction, Zeolites, Layered solids and intercalates, Hoffman inclusion compounds and Werner clathrates, Coordination polymers and metal organic frameworks (MOFs).
Self-Assembly: Introduction, Proteins and foldamers, Biochemical self-assembly, Self-assembly in synthetic systems, Self-assembling coordination compounds, Self-assembly of closed complexes by hydrogen bonding, Catenanes and

rotaxanes, Helicates and helical assemblies.
Biological Mimics and Supramolecular Catalysis: Introduction, Cyclodextrins as enzyme mimics, Corands as ATPase mimics, Cation-binding hosts as transacylase mimics, Metallobiosites, Haem analogues, Ion channel mimics, Supramolecular catalysis.

Course Learning Outcomes (COs):
After the successful completion of the course, students will be able to:
CO1. Describe supramolecular chemistry, their development and the nature of supramolecular interactions
CO2. Explain different types of hosts and guests and their formation of supramolecular compounds in solution and solid-state
CO3. Discuss the concepts of network solids, self-assembly in supramolecular architecture and different mimics used as supramolecular catalysts in the biological processes
CO4. Interpret different factors, effects, hosts and guests necessary for the formation of supramolecules
CO5. Illustrate the concepts of network solids, self-assembly and biological mimics as catalysts in supramolecular chemistry

Mapping of Course Learning Outcomes (COs) with POs
3: Strongly aligned 2: Moderately Aligned 1: Weakly Aligned

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3		1							
CO2	3		1							
CO3	3		1							
CO4			3							
CO5			3							

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture, PPT Demonstration, Group Discussion	Class test (Short Q and MCQ), Quiz
CO2	Lecture, PPT Demonstration, Group Discussion	Class test (Short Q and MCQ), Quiz
CO3	Lecture, PPT Demonstration, Group Discussion	Class test (Short Q and MCQ), Quiz
CO4	Lecture, PPT Demonstration, Open Discussion	Assignment, Final Assessment
CO5	Lecture, PPT Demonstration, Open Discussion	Assignment, Final Assessment

Books Recommended:

1. J. W. Steed and J. L. Atwood, *Supramolecular Chemistry*, 3rd Ed., 2022, John Wiley & Sons Ltd.
2. J. M. Lehn, *Supramolecular Chemistry: Concepts and Perspectives*, 1995, Wiley-VCH, Weinheim, Gemany.
3. K. Ariga and T. Kunitake, *Supramolecular Chemistry–Fundamentals and Applications*, 2006, Springer-Verlag, Berlin, Germany.

Course No: CHE **0531 5245**	Credit: 4.0	Year: MS	Semester: Second
Course Title: **Advanced Natural products Chemistry**		Course Type: Core Theory	

Course Rationale:
A vast area of our daily life is involving the use of different types of large-size natural molecules called natural products. These natural products cover food supplements, vitamins, medicines, and even different hormones. This course aims to deal with the chemical and other related properties, preparation, and analysis of those natural product molecules.

Course Objectives:
The objectives of this course are to:

- Acquaint the students with the advanced ideas of important classes of compounds of natural products chemistry
- Facilitate necessary knowledge of the structure, biosynthesis, occurrence, analysis, and pharmaceutical perspectives
- Teach about the structural elucidation of Steroids and Hormones
- Provide knowledge on the properties and structural elucidation of alkaloids, terpenoids
- Give the students ideas and knowledge on antibiotics
- Help to expose knowledge of Carotenoids, Flavonoids, Xanthones, and Porphyrins.
- Develop knowledge of Vitamins
- Impart knowledge on the biosynthesis of terpenoids, steroids, and flavonoids

Course Content:
1. A broad concept leading to the formation of different types of Naturally Occurring Substances.
2. **Alkaloids:** Elucidation of the Structures of Morphine and Quinine.
4. **Terpenoids:** Chemistry of higher terpenoids concerning Zingiberene, Phytol, α-Pinene, and Squalene.
5. **Antibiotics:** Chemistry of Streptomycin and Penicillin.
6. **Chemistry of Steroids** with special reference to Cholesterol; Stereochemistry of Steroids; Introduction to saponins. Study of Hormones: Chemistry of sex hormones (Testosterone and Estrogen); Non-steroidal hormone (Thyroxin) and Adernel cortical hormone (Cortisone).
7. **Natural pigments:** Introduction and classification; basic idea about Carotenoids, Flavanoids, Xanthones, and Porphyrins; Chemistry of Carotenes; Characterization of flavonoids by degradation experiments concerning Quercetin.
8. **Vitamins:** Introduction, Chemistry of Thiamine, Riboflavin, Ascorbic acid, and Calciferol.

Course Learning Outcome (COs):
After the successful completion of the course, students will be able to:
CO1. Explain the importance of natural compounds. Elucidate the structure of alkaloids, terpenoids, and antibiotics by chemical as well as physical methods
CO2. Explain and apply the basic chemistry of different types of steroids and hormones; saponin
CO3. Explain the constituents of Carotenoids, Flavonoids, Xanthones, and Porphyrins
CO4. Analyze the functions of vitamins and the Physiological significance of Vitamin
CO5. Plan a synthetic route for the synthesis of exemplary natural products, able to know biosynthesis & learn advanced methods of structural elucidation of compounds of natural origin

Mapping of Course Learning Outcomes (COs) with POs
3: Strongly aligned 2: Moderately Aligned 1: Weakly Aligned

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3		2							
CO2	3		2							
CO3	3		2							
CO4	3		2	2						
CO5	3		2	3						

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture, PPT Demonstration, Group Discussion	Class test (Short Q and MCQ), Quiz
CO2	Lecture, PPT Demonstration, Group Discussion	Class test (Short Q and MCQ), Quiz
CO3	Lecture, PPT Demonstration, Group Discussion	Class test (Short Q and MCQ), Quiz
CO4	Lecture, PPT Demonstration, Open Discussion, Question-Answer session	Problem-solving assignment, Final Assessment
CO5	Lecture, PPT Demonstration, Group discussion for problem analysis	oral, Final Assessment

Books Recommended:

1. L. Finar, Organic Chemistry, Vol. 2

2. Agarwal, Chemistry of Organic Natural Products, Vol. I and II
3. Natural Products Chemistry, P. S. Kalsi, Kalyani Publishers, New Delhi.
4. Natural Product Chemistry, K.B.G. Torssell, J. Wiley and sons New York.

Course No: **CHE 0531 5151**	Credit: 4.0	Year: MS	Semester: First
Course Title: **Analytical Spectroscopy**		Course Type: Core Theory	

Course Rationale:
This course is aim to provide advanced knowledge on Analytical Spectroscopic methods that will be needed to be a professional analyst for different chemical analysis both in research as well as industrial sectors.

Course Objectives
The objectives of this course are to:

- Acquaint students with the specific knowledge of analytical spectroscopic techniques.
- Accumulate basic ideas and advanced information about specific application of these analytical spectroscopic techniques environmental pollution and remedial measures
- Acquire theoretical knowledge and precision of different techniques and their real time analysis capacity.
- Foster the analytical and critical thinking on the utilization of the techniques in proper way
- Make them familiar with sample specific chemical analysis as per ISO standard which will be helpful after completion of the degree

Course Content:
Fundamentals of spectroscopy: Refreshment of basic principles, the interaction of matter and energy, concise knowledge on various spectroscopic methods (eg. UV-Visible, IR, NMR and Mass spectrophotometry) and its application.
Atomic Absorption Spectroscopy: Atomization, Flame Atomization, Graphite Furnace Atomizers, Volatile Hydrides, Sources for Atomic Absorption Spectroscopy (AAS), Principle of AAS, Background Correction, Interferences, Applications of AAS in water and soil analysis.
Atomic Emission Spectroscopy: Flame Emissive Spectrometry: Instrumentation, Analytical Measurement and Applications. Plasma Emission Spectroscopy:
Inductively Coupled Spectrometry: Principle, Instrumentation; Sources (Inductively Coupled Plasma ICP, dc Plasma DCP), isotopic interferences and remedy (eg. Arsenic analysis by ICP), Applications.
X-Ray diffraction spectroscopy: X-Ray Processes, Instrumentation, Powder diffraction methods and its application, Electron Microprobe, X-Ray Diffraction Analysis, Applications.
Fluorometry: Principle of Fluorescence, Chemical Structure and Fluorescence, Fluorescence Quenching, Relationship Between Concentration and Fluorescence Intensity, Fluorescence Instrumentation, Spectrofluorometer.
Chromatographic and attached mass spectrometry techniques: Advanced chromatographic methods (GC, LC and HPLC) for pharmaceutical and pollutant analysis, Mass spectroscopy in chromatographic analysis, fundamentals of mass spectroscopy, mass analyzer, GC-MS and its application: gas chromatographic techniques in environmental pollutant, food, pesticides and forensic analysis, analytical requirements of samples for this techniques. Mass Spectrometer as a detector.
Forensic analysis using Analytical spectrophotometric techniques: Fundamentals of forensic analysis, methods used for forensic analysis, precision and accuracy related to analysis.

Course Learning Outcomes (COs):
After the successful completion of the course, students will be able to:
CO1. Compare different spectroscopic techniques for application purposes, explain the mechanism of different spectroscopic techniques
CO2. Explain the principle of AAS and will be able to utilize in specific field of pollutant analysis
CO3. Express and utilize knowledge of ICP spectrometry for trace elemental analysis and other analysis purposes
CO4. Explain the principle and application of XRD for structural as well as other analysis purposes
CO5. Express advanced separation processes (GC-MS), acquire skill related to forensic analysis and will be able to utilize the taught methods for industrial application purposes as well as research oriented works.
Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately Aliened 1: Weakly Aliened

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3									
CO2	3									
CO3	3									
CO4	3									
CO5	3									

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture, PPT presentation related to lecture materials, Demonstration	Class test (Short Q and MCQ)
CO2	Lecture, Demonstration with theoretical problem solving, Discussion and make students thinking in real problem solving phenomena.	Quiz, assignment
CO3	Lecture, animated VDO clips, workshop type interactive discussion, Question-Answer session	Class test (Short Q and MCQ)
CO4	Lecture, Group discussion	Essay type test, problem solving
CO5	Lecture, PPT presentation, Group discussion for problem analysis.	Essay type test, problem solving

Books Recommended:
1. William Schrenk, Analytical Spectroscopy
2. Raymond P.W. Scott, Analytical Spectroscopy
3. Kamlesh Bansal, Analytical Spectroscopy
4. Robert D. Braun, Introduction to instrumental analysis
5. Galen W. Ewing, Instrumental methods of chemical analysis
6. Skoog, West, Holler, Analytical chemistry
7. A. Braithwaite and F.J.Smith, Chromatographic methods

Course No: **CHE 0531 5152**	Credit: 4.0	Year: MS	Semester: First
Course Title: **Advanced Environmental Chemistry**		Course Type: Core Theory	

Course Rationale:
This course is aim to provide advanced knowledge on Environmental Chemistry that will be needed for environmental problem handling and management purposes.

Course Objectives
The objectives of this course are to:

- Acquaint students with the specific knowledge of chemistry for keeping environment safe and sound
- Accumulate basic ideas and advanced information about environmental pollution and remedial measures
- Acquire theoretical reason of environmental hazards, and to utilize this for future handling of environmental issues
- Foster the critical thinking on the local and international environmental issues and to handle these to make the earth sustainable for all
- Make students deal with pollutant remedial strategies suitable for our Bangladesh perspective as well as internal

Course Content:
The Atmosphere and Atmospheric Chemistry: Importance of the atmosphere, physical characteristics of the atmosphere, stratification of the atmosphere and its impact on the environment, atmospheric mass transfer, meteorology and weather, Temperature inversion, plume behavior, Chemical and photochemical reactions in the atmosphere, particles in the atmosphere, chemical processes for the particle matter formation, particulate materials and their impact on health, Global climate and microclimate, air quality standards and methods of measurement of air quality, chemical fate and transport in the atmosphere, climate change and anthropogenic effect.
The Geosphere and Geochemistry: Physical forms of the geosphere, internal processes (eg Earthquake, volcanos

surface processes) Sediments, Clays, Geochemistry, weathering, environmental aspects of geosphere, surface earth movement, phenomena at the land/ocean interface, threat of risin sea levels, environmental effects of mining and mineral extraction, Origin and internal structure of lithosphere, Minerals, rocks and rock system, the plate tectonic system, igneous rocks, metamorphic rocks, weathering and erosion, geological time and history, earthquakes, volcanic eruption and other geological hazards, earth resources.

Chemistry of Hydrosphere and Aquatic Microbial Biochemistry: Fundamentals of Aquatic chemistry**,** Global historical cycle and water, basic hydrological concepts, planetary scale circulation, regional and local infiltration, evaporation and evapotranspiration, runoff and stream flow, ground water hydrology stream and catchments hydrology, Aquatic biochemical processes, Factors affecting bacterial metabolism, microbial oxidation and reduction, Microbial transformations of carbon,

Soil and Agricultural Environmental Chemistry: Soil and Agriculture, water and air in soil, the inorganic components of soil, organic matter in soils, soil humus, acid-base and ion exchange reactions in soils, soil losss and degradation, saving the land (agroforestry and soil preservation), Components of biosphere, man, animals and plant kingdoms in ecological balance of the environment, food and nutrition in health and biological processes, food contaminants for human and animals, effects of drugs, enzyme actions, pest and pesticides, environmental toxicology, forests and desertification, effects of toxic elements on biota and enzymes, biological effects of Cd, Pb, Hg, As, CO, NO_x, SO_2.

Toxicological chemistry and Environmental Toxicology: Fundamentals of toxicology, ATSDR Toxicological profiles**,** Synergism, potentiation and Antagonism, Dose respiknse relationship, Nonlethal effects, reversibility and sensitivity, Hypersensitivity and hyposensitivity, Teratogenesis, Mutagensis, carcinogenesis and effects, In vivo and in Vitro toxicity, Toxic elements and elemental forms (O_3, White phosphorous, heavy metals and their biochemical effects), Toxic inorganic compounds (eg. Cyanide, CO, NOx, HF, interhalogen compounds and halogen oxides, organometallic compound and their toxicity etc), toxicology of organic compounds (eg Alkene and alkyne hydrocarbons, Benzene and aromatic hydrocarbons, phenols and derivatives, organo nitrogen compounds, organohalogen compounds, organohalide pesticides, toxic natural products, non degradable plastics etc. Ecotoxicology,

Bio-technology and its application in Environmental protection: Introduction, Biotechnology and pollution control, Bio-remediation, Biological de-odorisation, contaminated land and bioremediation, aerobes and effluents.

Techniques for determination and measurement of environmental parameters: Some important specific environmental pollutant will be addressed like(eg As, Pd, Se)., reviewing the past, present and finding solution for future generation.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Express different terms of environmental segment and chemicals species and their chemistry related to these segments, their formation and impacts on environment. Also Explain the mechanism of reactions within environmental segments including microbial mediation to transport pollutant.

CO2. Explain the causes of water pollution and will be able to take steps for keeping water bodies free from pollution and Also Express d the causes of soil pollution, and will be able to take steps for remedial measure related to these.

CO3. Express and the knowledge related to toxicology and their pathways and consequences on our health.

CO4. Explain the role and application of biotechnology as a safe environmental techniques to remediate pollutants

CO5. Handle and analyze the data and their management of some pollutants.

Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately Aliened 1: Weakly Aliened

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3									
CO2	2							2		
CO3	3									
CO4	3									
CO5	2	2								

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture, PPT presentation related to lecture materials, Demonstration	Class test (Short Q and MCQ)
CO2	Lecture, Demonstration with theoretical problem solving, Discussion and make students thinking in real problem solving phenomena.	Quiz, assignment
CO3	Lecture, Review article session on recent topics on environmental hazards, workshop type interactive discussion, Question-Answer session	Class test (Short Q and MCQ)
CO4	Lecture, Group discussion	Semester end test, problem solving
CO5	Lecture, PPT presentation, Group discussion for problem analysis.	Semester end test, problem solving

Books Recommended:

1. Colin Baird, Environmental Chemistry
2. Stanely E. Manahan, Environmental Chemistry , 9th edition
3. J. W. Moore, Environmental Chemistry
4. I. F. Fergussow, Environmental Chemistry
5. S. S. Dara, A text book of Environmental Chemistry and Pollution control
6. C. S. Rao, Environmental pollution control Engineering
8. Ernest Hodgson, A Textbook of Modern Toxicology, 3rd Edition

Course No: **CHE 0531 5253**	Credit: 4.0	Year: MS	Semester: Second
Course Title: **Waste Management and Treatment**			Course Type: Core Theory

Course Rationale:

This course is aimed to provide up to date knowledge about different types of Waste and their management strategies followed by sustainable treatment

Course Objectives:

The objectives of this course are to:

- To get on broader understanding on various aspects of solid waste management practiced in different municipalities
- Introduce the new approaches toward recovery of products from solid waste to compost and biogas, incineration and energy recovery
- Foster students about the importance of water treatment both in domestic as well as industrial sector, problems and remedial measures to tackle these economically and environmentally friendly manner
- Help to increase the consciousness about the concept of zero waste philosophy and thereby to implement it in industrial sectors
- Ensure the protection of the environment through and effective waste management system
- Explain the hazards of waste management and treatment options of some risky waste and their worldwide treatment philosophy

Course Content:

Introduction: Human Impact on environment and pollution phenomena, chemical fates and transport, importance of waste management and treatment, zero waste philosophy.

Solid waste: Types of solid wastes; pollution, treatment and disposal methods, municipal solid wastes, industrial wastes, hazardous wastes, Sources of solid wastes and waste treatment, Waste reduction and minimization, Recycling and re-use strategy, Physical and chemical methods of waste treatment- an overview, biological factors involved in waste treatment, methods of waste disposal-composting, sanitary land filling, thermal processes-incineration, pyrolysis, Green waste treatment by photolysis and sonolysis, Biodegradation of wastes, Disposal site and proper steps to dump wastes.

Waste Water treatment and management: Sources of waste water, properties of waste water, water treatment for municipal use, industrial use and disposal, water conditioning and treatment for different purposes. Different treatment processes (primary, secondary and tertiary), Industrial waste water treatment: removal of solids, removal of metals,

removal of dissolved Organics and Inorganics, Sludge, Water disinfection. Comparison among different filtration techniques.

Gaseous waste and pollutants management: Sources of gaseous pollutants, Types and classification of air pollutants: particulate, hydrocarbons, carbon monoxide, oxides of sulfur, oxides of nitrogen, photochemical oxidants, Gaseous waste and pollutants in Portland cement, glass, fiber glass, petroleum refineries, iron and steel and acid manufacturing industries, pharmaceutical. Fly ash management in coal burning industries.

Integrated waste Management strategy: Overview of current Water and Waste-Water Management, Effluent treatment plant and its importance in industrial sector, Water Regulations, Solid-Waste Reduction and Minimization, Risk Assessment and Management, Hazardous Waste Management, treatment and disposal of hazardous chemical waste-physical, chemical and biological processes, off-side disposal and co-disposal, security concerns of handling hazardous waste, Air quality management concept, Abatement of NOx, Sox and particulate matter from stationary and mobile sources, Selective catalytic reduction versus low NOx burner technologies, Flue gas de-sulpherization techniques, 3-way catalyst and importance of vehicle pollutant reduction, Controlling devices for gaseous contaminants.

Resource recovery from waste: Characterization of waste for resource recovery, treatment of mining waste and their management, energy harnessing from biomass and fuel cell based on organic waste.

Nuclear Waste Management: Nuclear wastes and consequences of un-treated waste, spent fuel and their proper management, short-lived and long-lived radioactive waste management techniques and their improvement. Nuclear waste management-Bangladesh perspectives.

Biological Treatment of Solid and Hazardous Waste: Bioreactors; anaerobic decomposition of solid waste; principles of biodegradation of toxic waste; inhibition; co-metabolism; oxidative and reductive processes; slurry phase bioreactor; in-situ remediation

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Explain basic concepts on waste characterization and of solid waste management, beginning from source generation to waste disposal in a system of municipality organizational structure.

CO2. Interpret various technological applications for processing of waste and their disposals in various ways.

CO3. Design the ways to convert waste to energy productions in the perspectives of sustainable development.

CO4. Apply basic concepts in hazardous waste management and integrated waste management for urban areas

CO5. Demonstrate the waste water characterization and its management practiced in various cities of Bangladesh.

Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately Aliened 1: Weakly Aliened

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3									
CO2	3									
CO3	3									
CO4	3									
CO5	3									

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture, PPT presentation related to lecture materials, Demonstration	Class test (Short Q and MCQ)
CO2	Lecture, Demonstration with theoretical problem solving, Discussion and make students thinking in real problem solving phenomena.	Quiz, assignment
CO3	Lecture, animated VDO clips, workshop type interactive discussion, Question-Answer session	Class test (Short Q and MCQ)
CO4	Lecture, Group discussion	Essay type test, problem solving
CO5	Lecture, PPT presentation, Group discussion for problem analysis.	Essay type test, problem solving

Books Recommended:

1. Jacqueline Vaughn, Waste Management
2. John Pichtel, Waste Management Practices
3. Stanley E. Manahan, Environmental Chemistry, 9th eidition
4. Howard S. Peavy Donald Rowe, Environmental Engineering
5. James L. Pyle, Chemistry and Technological Backlash
6. A. K. De, Environmental Chemistry

Course No: **CHE 0531 5254**	Credit: 4.0	Year: MS	Semester: Second
Course Title: **Sustainable Chemistry and Bio Nanotechnology**		Course Type: Core Theory	

Course Rationale: This course is aim to provide advanced knowledge on Chemistry for maintaining Sustainable development and also to provide knowledge of some greener chemical routes for sustainable industry.

Course Objectives

The objectives of this course are to:

- Acquaint students with knowledge of chemistry for fulfilling the requirements of sustainable development
- Accumulate basic ideas and advanced information about greener routes of synthesis
- Acquire theoretical reason of environmental hazards, and to utilize this for future handling of waste less chemistry
- Foster critical thinking on safe and sustainable energy for the future generation
- Acquire knowledge on bio nano technology as a safer option for maintaining sustainable development

Course Content:

Sustainability and sustainable development: Definition of sustainability, importance of sustainable development and role of chemistry towards sustainable development, UN SDG Goals and their achievement strategies, Current situation of Sustainable development worldwide, Further improvement or innovative suggestions related SDG**.**

Resources and Sustainable Materials: Minerals in the Geosphere, Classification and evaluation of Mineral Resources, Extraction & hazards related to some mining, Mining site rehabilitation, Management of metal resources and nonmetal resources, safe disposal options of metallurgical waste.

Green Chemistry and Industrial Ecology: Principles of Green Chemistry, reduction of risks related to hazardous materials, synthetic chemistry versus Green Chemistry, Feedstocks, Stoichiometric and catalytic reagents, various solvents and their merits and demerits, industrial ecosystem, industrial metabolism, materials flow and recycling in an industrial ecosystem, The Kalundborg industrial ecosystem as an ideal model, economic advantages of green chemistry. Solvent free Chemistry: Alternative approach to solvent Chemistry, exploring solvent free reactions, microwave assisted chemical synthesis, ionic liquids as an alternative solvents, supercritical fluids and their application in green chemistry, supported catalyst and reagents for green chemistry.

Sustainable Energy: Energy problem, Nature of energy, Sources of energy used in the atmosphere, Energy devices and conversions, Green Technology and energy conversion Efficiency, Renewable energy sources, Petroleum and natural Gas, Geothermal Energy, Nuclear Energy, Biomass Energy, bio-fuel and its future and new route of synthesis, Fuel Cells and its hope and limitations.

Nano Structured Materials and Bio nanotechnology: Chemistry of Nano materials, Scaling laws applied to, nanotechnology, Nanoparticle Morphology and Electronic Structure, Properties of Nano materials, Synthesis of Nano materials (Top down and bottom up techniques), Characterization Techniques of Nano materials, Bio-nano technology, biological machines, Application of Nanotechnology, Nano materials in catalysis, Nano technology in environmental problem abatement (waste water treatment and gaseous pollutant reduction, drug delivery), State of the art in nanotechnology, Safety issues of Nanotechnology, hazards in nano technology and its remediation.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Describe and explain the significance sustainable chemistry to maintain sustainable development

CO2. Explain the importance of green chemistry as a sustainable method and its application

CO3. Address the energy issues and importance of safer methods to tackle next generation energy mitigation strategy. and the knowledge related to supercritical fluid and ionic liquid for environmental applications purposes.

CO4. Express the fundamentals of nano science and technology to utilize it next

CO5. Express the role and application of biotechnology as a safe environmental techniques

Mapping of Course Learning Outcomes (COs) with POs
3: Strongly aligned 2: Moderately Aliened 1: Weakly Aliened

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3									
CO2	3									
CO3	3									
CO4	2							2		
CO5	3									

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture, PPT presentation related to lecture materials, Demonstration	Class test (Short Q and MCQ)
CO2	Lecture, Demonstration with theoretical problem solving, Discussion and make students thinking in real problem solving phenomena.	Quiz, assignment
CO3	Lecture, animated VDO clips, workshop type interactive discussion, Question-Answer session	Class test (Short Q and MCQ)
CO4	Lecture, Review journal articles on up to date isses related to sustainable chemistry and Group discussion	Essay type test, problem solving
CO5	Lecture, PPT presentation, Group discussion for problem analysis.	Essay type test, problem solving

Books Recommended:

1. Manahan, Stanley E , Environmental Chemistry, 9th ed.
2. C. Baird and M. Cann, Environmental Chemistry, 3rd ed.
3. J. C Jones, Atmospheric Pollution
4. Rashmi Sanghi and MM Srivastaba, Green Chemistry-Environmental Friendly Alternatives
5. Jeremy Ramsden, Essentials of Nanotechnology
7. J. Richard Wilson, Minerals and Rocks
8. J.C Jones, Thermal Processing of Waste

Course No: **CHE 0531 5150**	Credit: 2.0	Year: MS	Semester: 1st
Course Title: **Advanced Analytical and Environmental Chemistry Practical**			Course Type: Core Practical

Course Rationale: This course is aim to provide students hand on pragmatic skill on Analytical methods and instrument for characterization and analysis of environmental sample.

Course Objectives

The objectives of this course are to:

- Accumulate advanced information practical skill on ISO standard sample collection and processing for environmental sample analysis
- Acquaint students with the specific skill of analytical spectroscopic techniques
- Acquire hand on skill on precision and accurate determination techniques maintaining legislative stringint restrictions
- Foster the analytical and critical thinking on the utilization of the techniques along with repetition of data for publication in international journal format

Course Content:

Collection of samples: Direct collection of samples from different surface and underground water spot from in and around the campus and subsequent Measurement of some water quality parameters eg. Suspended solid, dissolved solid, total solid, acidity, alkalinity, hardness, iron content etc. by various analytical techniques.

Experimental set up: Collection of same samples from industrial polluted zone from Sylhet city and determination of Dissolved oxygen (DO), Biochemical oxygen demand (BOD), Chemical Oxygen Demand (COD) of these samples.

Rock or soil analysis: Collection of some soil and rock samples from in and around campus and Estimation of ion-exchange capacity and other metal contents of soil by various analytical techniques.

Estimation of cholesterol from the supplied edible oil/butter by spectrophotometric method: Estimation will be based on different trademark butter or oil samples and their characterization will be completed individually by students.

Comparative examination of some heavy metal levels: Pb, Cr from polluted samples and their estimation will be doe by using spectroscopic methods.

Experiment based on different adsorption models: Langmuir and Freundlich curve fitting analysis will be designed by the students with their own for some adsorptive removal of heavy metals using biosorbents.

Thermodynamic and Kinetic study of adsorptive removal of pollutant: sample pollutants like Pb and Cr from polluted samples collected before.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Collect and process the sample in a ISO specific method followed by calibration of proper instrument

CO2. Compare different spectroscopic techniques for application purposes, also will be able to handle individually different spectroscopic techniques

CO3. Utilize instrument for pollutant analysis

CO4. Express and utilize knowledge of different analytical techniques for trace elemental analysis and other biochemical analysis purposes

CO5. Explain the data and represent in a proper way to publish in a international journal

Mapping of Course Learning Outcomes (COs) with POs
3: Strongly aligned 2: Moderately Aliened 1: Weakly Aliened

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1		3								
CO2		3								
CO3		3								
CO4		2						2		
CO5		2								2

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture, Demonstration in field level sampling safety and hazardous of direct sampling of environmental pollutant.	Assessment in the lab
CO2	Lecture, Practical Demonstration of instrument set up tips to take care instrument properly.	Quiz, on spot assignment during experimental analysis.
CO3	Demonstration on Data handling and graph drawing (hand and software aided graph practice) for result presentation	Assessment of report along with computer aided graph interpretation.
CO4	Group discussion, trouble shooting of instrumental error.	Assessment based on PPT and Oral presentation of the students.
CO5	Journal article reviews, problem analysis	Evaluation of overall report writing in a scientific journal style and final Power point presentation of students.

Books Recommended:

1. Skoog, West, Holler, Analytical chemistry
2. A. Braithwaite and F.J.Smith, Chromatographic methods
3. David Harvey, Analytical Chemistry 2.1

Course No: SPS 0111 5161	Credits: 3.0	Year: MS	Semester: First

Course Title: **Chemistry Education**	Course Type: GEd Theory

Rational of the course: Chemistry teaching in University, collage, and other educational institutes is very popular to chemistry graduate. This course is to make the students skilled and interested for Chemistry education profession and to trained them on educational pedagogy and realated theory and principles.

Course Objectives:

The objective of the courses are to:

- Make the students knowladgable about the ways to prepare the mind of the learner for meaningful learning
- Train them on lecture preparation and presentation
- Make famlear with active learning through interactive lecture demonstration
- Give them idea about misconception in chemistry and develop refined knowledge and different type of laboratory teaching and learning
- Make them accustom to team work and cooperative learning and problem based learning and way to be critical chemist

Course Content:

Preparing the mind of the learner, Pre-lectures, Chemorganisers and Independent learning for unwilling.
Pedagogy and Activity of Teaching: captivating class, lecture challenges, lecture basics, lectures by using board and visual aids. Learning objectives of graduate: Skills, Knowledge and attitude. Bloom's Taxonomy and cognitive knowledge. Active learning: Q & A, Discussion, Interactive lecture demonstration (ILD), Group work, Misconception, refinement of concept, Lecture demonstration. Cooperative learning: Essential elements of cooperative learning, team base learning, the solution of chemistry related real life problem (Environmental, Industrial, chemical techniques or theory development, analysis) by team base learning (TBL).
Laboratory teaching and learning: traditional laboratory experiments, problem based laboratory experiments and Problem based learning (PBL) module (e.g. CFC replacement for green chemistry, suspicious death investigation).
Critical chemists: Learning through critical thinking, reading, constructing arguments, understanding arguments and making judgments. Assessment format.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Explain the students' background to deliver the meaningful learning in Chemistry and required contents of an informative lecture and to present properly in chemistry
CO2. Apply the problem based learning to solve any real life chemistry related problem.
CO3. Think any chemistry topic logically to get findings and teach the students to create new concept.
CO4. Work and cooperative learning to work with unfamiliar co-workers and environment
CO5. Format the assessment and the way of fairest assessment to drive the learning deeply and understanding and overcome of the misconception of chemistry

Mapping of Course Learning Outcomes (COs) with POs
3: Strongly aligned 2: Moderately Aliened 1: Weakly Aliened

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2								
CO2			3							
CO3				3						
CO4					2					
CO5		2				2	3			

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture, PPT Demonstration, Demonstration with model, Discussion	Class test (Short Q and MCQ) Quiz, assignment
CO2	Lecture, animated VDO clips, Question-Answer session	Class test (Short Q and MCQ)
CO3	Lecture, Group discussion	Essay type test, problem solving
CO4	Lecture, Group discussion	Essay type test, problem solving
CO5	Lecture, PPT presentation, Group discussion for problem analysis, Group discussion	Essay type test, problem solving

Books Recommended:

1. Sirhan G, Gray C, Johnstone AH, Reid N. Preparing the mind of the learner. University Chemistry Education. 1999;3(2).
2. Forehand M. Bloom's taxonomy: Original and revised. Emerging perspectives on learning, teaching, and technology. Retrieved from http://projects. coe. uga. edu/epltt. 2005 Aug.
3. Overton TL. Creating critical chemists. University Chemistry Education, Journal of the Tertiary Group of the Royal Society of Chemistry, 1 (1). 1997:28-30.
4. Kelly OC, Finlayson OE. Providing solutions through problem-based learning for the undergraduate 1st year chemistry laboratory. Chemistry Education Research and Practice. 2007;8(3):347-61.
5. Flynn P, Vermette PJ, Mesibov D, Smith RM. Captivating classes with constructivism: practical strategies for pre-service and in-service teachers. Institute for Learning Centered Education; 2007.
6. Kee TP, Ryder J. Developing critical and communication skills in undergraduates through chemistry. University Chemistry Education. 1997;1(1):1-4.
7. Belt ST, Evans EH, McCreedy T, Overton TL, Summerfield S. A problem based learning approach to analytical and applied chemistry. University Chemistry Education. 2002;6(2):65-72.

Course No: **CHE 0531 5162**	Credit: 4.0	Year: MS	Semester:1st
Course Title: **Topics on Nanoscience and Nanotechnology**			Course Type: Core Theory

Course Rationale: Design and development of nanostructured materials have gained potential interest due to their intrinsic properties for the last three decades. This course is aimed to give the basic knowledge on the important topics of nanoscience and nanotechnology.

Course Objectives

The objectives of this course are to:

- Acquaint students with the development, classification, and properties of nano-sized materials
- Understand the fundamentals of the different characterization techniques of nanomaterials
- Make the students familiar with the synthesis and properties of nanoparticles, nanorods, nanowires, nanotubes, and nanofibers
- Acquire the concepts of the formation of nanostructured polymers
- Familiarize students with nanolithography techniques and nanomanipulation
- Provide basic knowledge of nano-bio technology

Course Content:

Introduction: History and scope of nanomaterials, Definition of nanomaterials, Nano-size and related properties: Electronic, optical, magnetic and catalytic properties. Classification of nanostructured materials.
Characterization: Characterization of nanomaterials using SEM, TEM, Confocal Microscopy, AFM, DLS, XRD, and XPS techniques.
Nanoparticles: a) Metal nanoparticles: Synthesis, properties and application of nanoparticles b) Metal oxide nanoparticles: Synthesis, properties and applications of copper oxide, iron oxide, aluminium oxide, and titanium oxide nanoparticles.
Nanorods and nanowires: Synthesis, properties and application of gold, silver, zinc oxide, and titanium oxide nanorods and nanowires.
Nanotubes and nanofibers: Classification, synthesis, properties and application.
Nanostructured polymers: Introduction, Macromolecular structural control, Polymer conformational control, Morphology of block copolymers, Nanostructures based on bulk phase separation, Nanostructures based on lyotropic mesophases, Core crosslinked systems, Shell-crosslinked systems, Nanocages, Nanostructures from polymerized

surfactant assemblies.

Nanolithography and nanomanipulation: Introduction, Template fabrication, Deposition, Fabrication of nanostructures in the templates e.g., electrodeposition, sol-gel method, and chemical vapor deposition (CVD) method, scanning probe based anodic oxidation as a tool for the fabrication of nanostructures, Oxidation of metallic substrates, Use of scanning probe microscopy in Dip Pen nanolithography, Use of scanning probe microscopy in nanomanipulation.

Nano-bio technology: Introduction, Nanomachines based on biomolecules.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Describe development, classification, and properties of nano-sized materials along with their characterization techniques

CO2. Discuss synthetic procedures and the application of the different types of nanomaterials

CO3. Explain nanolithography techniques, nanomanipulation, and nano-bio technology

CO4. Interpret different synthetic protocols and properties of nanomaterials according to their nature, shape, and size

CO5. Illustrate the concepts of different techniques of nanolithography, nanomanipulation, and nanomachines based on biomolecules

Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately Aliened 1: Weakly Aliened

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	2		3							
CO2	2		3							
CO3	2		3							
CO4			3							
CO5			3							

Mapping Course Learning Outcomes (COs) with the Teaching-Learning and Assessment Strategy

CO	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture, PPT Demonstration, Animated Video clips, Open Discussion	Class test (Short Q and MCQ), Quiz
CO2	Lecture, PPT Demonstration, Open Discussion	Class test (Short Q and MCQ), Quiz
CO3	Lecture, PPT Demonstration, Open Discussion	Class test (Short Q and MCQ), Quiz
CO4	Lecture, PPT Demonstration, Open Discussion	Assignment, Final Assessment
CO5	Lecture, PPT Demonstration, Open Discussion	Assignment, Final Assessment

Books Recommended:

1. C. N. R. Rao, A. Muller, and A. K. Cheetham, *The Chemistry of Nanomaterials*, 2004, Wiley-VCH, Weinheim, Germany.
2. B. S. Murty, P. Shankar, B. Raj, B. B. Rath, and J. Murday, *Textbook of Nanoscience and Nanotechnology*, 2013, Universities Press (India) Private Limited, Hyderabad, India.
3. T. Pradeep, *Nano: The Essentials*, 2007, Tata McGraw-Hill Publishing Company Ltd., New Delhi, India.
4. W. C. Sanders, *Basic Principles of Nanotechnology*, 2019, CRC Press Taylor & Francis Group, USA.

Related research articles.

Course No: **SPS 0111 5170**	Credit: 3.0	Year: MS	Semester: 1st
Course Title: **Research methodology for chemistry**		Course Type: Capstone (Core)	

Course Rationale: For research students it is very important to have fundamental concepts of research methodology for chemistry. This course is aimed to gather the detailed knowledge about finding out a research problem and the methods of solving the problems in a systematic way.

Course Objectives

The objectives of this course are to:

- Acquaint students with the meaning of research, objectives and motivation of research, significance and importance of doing research, process of research, and the criteria of a good research
- Make the students familiar with the methods of reviewing literature from different sources
- Acquire the knowledge of formulating research problem and design and planning of a research
- Understand how to collect data and their analysis and interpretation
- Achieve the skill of writing a research report
- Accumulate the knowledge of required computer softwares and chemical safety issues for chemistry research
- Familiarize students with patents and its registration procedure

Course Content:

Introduction: What does research mean? Objectives and motivation of research. Types of research. Research approach and its significance. Difference between research methods and research methodology for chemistry. Scientific method of research. Importance of knowing how research is done. Process of research. Criteria of a good research.

Literature survey: Need for reviewing literature. Introduction to chemical abstracts and Beilstein: subject index, substance index, author index, formula index and other indices with examples. Web resources and E-journals: E-books, Search engines- Google scholar, Chemical industry, ChemSpider, Science Direct, SciFinder, Scopus, ACS, RSC, Wiley online library, etc.

Formulating a research problem: Research problem. The importance of formulating a research problem. Considerations in selecting a research problem. Steps in formulating a research problem. The formulation of research objectives.

Research design and planning: Meaning and necessity. Features of a good design. Important concepts relating to research design. Different research designs. Basic principles of experimental designs. Planning of research.

Data collection and analysis: Collection of data from different experimental and instrumental methods. Analysis and interpretation of collected data toward the solution of formulated research problem.

Report writing: Significance of report writing. Different steps in writing a report. Layout of the research report. Types of reports. Oral presentation. Mechanics of writing a research report. Precautions for writing research reports.

Basic knowledge of computer systems: Softwares and their application. Programming languages. General awareness of software packages and other scientific applications. Application and uses of common softwares in chemistry-Origin, SigmaPlot, ChemSketch, and ChemDraw. Checking plagiarism.

Concepts of chemical safety: Chemical safety and ethical handling of chemicals. Safe working procedure and protective environment. Emergency procedure and first aid. Laboratory ventilation, safe storage and use of hazardous chemicals. Procedure for working with substances that pose hazards, flammable or explosive hazards. Procedures for working with gases at pressures above or below atmosphere. Safe storage and disposal of waste chemicals, recovery, recycling and reuse of laboratory chemicals.

Patents: What is patent? Ethical and moral issues for filing patents. Methods of writing and filing a patent for registration.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Explain the meaning of research, objectives and motivation of research, research approach and its significance, difference between research methods and research methodology for chemistry, scientific method of research, importance of knowing how research is done, criteria of a good research, and literature survey

CO2. Describe the process of designing and planning research after formulating the research problem, the methods of collecting research data and their analysis and interpretation toward writing a research report and the registration of patents

CO3. Discuss the necessity of computer softwares and chemical safety issues for chemistry and allied fields

CO4. Analyze and interpret data and information with the use of the necessary technology, adapt situation for decision making, work individually or with a team, criticize any problem, and produce free, creative and inductive thinking

CO5. Apply the step by step knowledge of research methodology to solve a chemical research problem

Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately Alienied 1: Weakly Aliened

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1			3	1						
CO2				3					1	
CO3					1			3		
CO4			3	2						
CO5				3	1					2

Mapping Course Learning Outcomes (COs) with the Teaching-Learning and Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Lecture, PPT Demonstration, Group Discussion	Class test (Short Q and MCQ), Quiz, Assignment
CO2	Lecture, PPT Demonstration, Group Discussion	Class test (Short Q and MCQ), Assignment
CO3	Lecture, PPT Demonstration, Group Discussion	Class test (Short Q and MCQ), Assignment
CO4	Lecture, PPT Demonstration, Open and Group Discussion	Seminar, Final Assessment
CO5	Lecture, PPT Demonstration, Open and Group Discussion	Seminar, Final Assessment

Books Recommended:

1. C. R. Kothari, *Research methodology for chemistry-Methods and Techniques*, 2nd Ed., 2004, New Age International (P) Ltd., India
2. A. M. Novikov and D. A. Novikov, *Research methodology for chemistry-From Philosophy of Science to Research Design*, 2013, CRC Press Taylor & Francis Group, USA
3. R. Kumar, *Research methodology for chemistry*-A Step-by-Step Guide for Beginners, 3rd Ed., 2011, Sage Publications Inc., New Delhi, India
4. U. K. B. Dubey and D. P. Kothari, *Research methodology for chemistry-Techniques and Trends*, 2022, CRC Press Taylor & Francis Group, USA
5. A. L. Durham, *Patent Law Essentials-A Concise Guide*, 5th Ed., 2018, ABC-CLIO, LLC, California, USA
6. A. N. Goldstein, *Patent Law for Scientists and Engineers*, 2005, CRC Press Taylor & Francis Group, USA
7. Research articles of different interests

Course No: **SPS 0417 5180**	Credit: 2.0	Year: MS	Semester: First
Course Title: **In Plant Training**		Course Type: Exposer (GEd)	

Course Rationale:

This course is to give practical experiences of the work environment of the chemical industry to the students. The student will gather hands on experience in different chemical industries.

Course Objectives

The objectives of this course are to:

- Expertise students on the real industrial duties
- Prepare them for their future carrier in suitable industry
- Acquiring hands-on experience in industry-specific tasks and processes

Course Content:

Each student will be assigned to take residential training for the duration of one month at Training Institute for Chemical Industries (TICI), Narsingdi

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Students will get in depth knowledge of chemical industry and get the opportunity to apply theoretical knowledge to practical problems

CO2. Connect with industrial authority and may secure jobs for the future

CO3. Build professional connections and relationships with industry professionals

CO4. Expose to potential job opportunities and a better understanding of the job market

CO5. Recognize the current trends and latest technologies

Mapping of Course Learning Outcomes (COs) with POs

3: Strongly aligned 2: Moderately Aligned 1: Weakly Aligned

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1							2			1
CO2						3				
CO3						3				
CO4						3	1			
CO5							1			2

Assessment Method:

This intensive residential training will be conducted by the TICI authority, and two teachers of the Department will be assigned as guides. During their straining h/she will follow the chemical process and the related mater in real industry environment in a real pilot plan. The evaluation of the training will be done by the academics of the TICI and a formal mark sheet will be provided by the TICI authority. After the visit, the student will submit a report to the examination committee give a presentation, that will be evaluated jointly by the committee and the final score will be made by the combination of it with that of TICI's evaluation report.

Course No: **CHE 0531 5280**	Credit: 3.0	Year: MS	Semester: Second
Course Title: **Comprehensive in Chemistry research**		Course Type: Capstone (Core)	

Course Rationale:

This course is designed for research students to achieve knowledge on searching the literature, presentation of the research outputs, and attaining critical thinking on the designing of new research.

Course Objectives

The objectives of this course are to:

- Make them understand the research background, theme, methodology, and impact of the research from the presentation.
- Familiarize students with searching literature from various high-quality reputed journals.
- Acquire guidelines for the preparation of research presentations.
- Explain elaborately and systematically the data acquisition and research outputs.
- Attain critical thinking on the designing of new research.
- Gain knowledge on the solving of critical problems.

Course Content:

Research presentation and abstract preparation: Assigned course teachers will present their research through several classes. After the research presentation, the enrolled students will prepare the abstract for each lecture/presentation and send it to the assigned course teachers.

Preparation of research presentations: Every course teacher will provide recently (within the last three years) published 5 (five) articles from high-quality reputed journals (ACS, Willey, RSC, Nature Publishing Group, ELSEVIER, Science Magazine (AAAS), Taylor and Francis, and Springer Link) to each student. Then, students will prepare the presentations elaborately and systematically for each given article.

Presentation of research outputs: Students will present the research outputs and appear viva-voice based on the given articles.

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Recognize the research background, theme, methodology, and impact of the research from the researcher presentation and be able to write concisely the abstract of the research.
CO2. Become familiar with the searching literature from various high-quality reputed journals.
CO3. Acquire guidelines for the preparation of research presentations
CO4. Explain elaborately and systematically the data acquisition and research outputs.
CO4. Attain critical thinking on the designing of new research and gain knowledge on the solving of critical problems in research.

Mapping of Course Learning Outcomes (COs) with POs
3: Strongly aligned 2: Moderately Aligned 1: Weakly Aligned

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1				3					1	
CO2				2	2					
CO3				1	3					
CO4				3						
CO5			2	2						

Mapping Course Learning Outcomes (COs) with the Teaching-Learning & Assessment Strategy

COs	Teaching-Learning Strategies	Assessment Strategies
CO1	Research paper presentation, PPT Demonstration	Abstract writing
CO2	Online searching, PPT Demonstration	Individual performances in class
CO3	Lecture, PPT Demonstration	PPT Presentation
CO4	Lecture, PPT Demonstration, Open and Group Discussion	Presentation and Viva-voice
CO5	Lecture, PPT Demonstration, Open and Group Discussion	Seminar and Final report writing

Books Recommended:

1. Research articles of the Assigned course teachers
2. Articles from high-quality reputed journals (ACS, Willey, RSC, Nature Publishing Group, ELSEVIER, Science Magazine (AAAS), Taylor and Francis, and Springer Link)

Course No: **CHE 0531 5200**	Credit: 3.0	Year: MS	Semester: Second
Course Title: **Course Viva**		Course Type: Capstone (Core)	

Course Rationale

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.

Course Objectives:

The objectives of this course are to:

- 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

Course Content:

Students will be assigned specific topics based on the whole curriculum of the MS program. Students will prepare a detailed assignment (approximately 1000 words) based on their assigned topics and give an oral presentation before the exam committee. Besides the selected topic, the student will be asked any question on the basic topic studied throughout the program.

Course Learning Outcomes (COs):

After the successful completion of the course, students 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

Mapping of Course Learning Outcomes (COs) with POs
3: Strongly aligned 2: Moderately Aligned 1: Weakly Aligned

COs	Program Learning Outcomes									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	2				2					
CO2					3					
CO3			2		2					
CO4			3		1					1
CO5			3							1

Teaching- Learning and Assessment Strategies:

There will be no formal face-to-face instruction for the course. 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 individually or combinedly.

Assessment Rubric:

	Excellent (33p)	Proficient (25p)	Satisfactory (20p)	Poor (15p)
Content Of the Presentation	-The facts are clear, understandable -Students discuss the subject in great details -Student describes in detail about their topic -Students indicate what they have learned	-The facts are clear, understandable -Students discuss the subject with some details -Student outlines their topic -Students show what they have learned	-The facts are OK -Student discuss the subject with a few details -Student do not outline their topic –Student's misconceptions are still seen	-The facts were not correct -Students discuss the subject with very minimal details -Students do not outline what they have learnt -Students still sound confused on this topic
Presentation and Delivery	-The presentation was very creative -Good posture -Eye contact with the audience most of the time -Appropriate gesture and expression -Deliverance with confidence	-The presentation was somewhat creative -Good posture -Frequent eye contact with the audience -Appropriate gesture and expression	-The presentation was OK. -Intermittent good posture –Occasional eye contact with the audience –Appropriate gesture and expression	-The presentation was not good. -Poor posture -Seldom eye contact with the audience -Not enough easy during presentation
Answering to the Question making logical Arguments	-Answers All the questions asked properly -Makes logical argument nicely	-Answers Most of the questions asked properly -Makes logical argument	-Answers Some of the questions asked correctly -Makes logical vey weekly	-No Satisfactory Answer for most of the Questions asked -Unable to make logical argument

Course No: **CHE 0531 5310**	Credit: 12.0	Year: MS	Semester: Third
Course Title: **Thesis**		Course Type: Capstone (Core)	

Course Rational:

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. This course ensures the students' attainment of different skills like cognitive, effective, communication, collaboration, working in a group, data collection, and manipulation, maintaining ethical matters, etc.

Course Objectives:

The objectives of this course are to:

- 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

Course Learning Outcomes (COs):

After the successful completion of the course, students will be able to:

CO1. Think critically and develop the solution to design a research project utilizing the common lab experiences
CO2. Incorporate knowledge and ideas to plan a good research project
CO3. Communicate the scientific results in written, orally and representatively
CO4. Practice norms and ethics for data manipulation, and scientific and academic research
CO5. Pave the way for lifelong learning

Mapping of Course Learning Outcomes (COs) with POs
3: Strongly aligned 2: Moderately Aligned 1: Weakly Aligned

	Program Learning Outcomes									
COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1			3							
CO2			3							
CO3					3					
CO4							1		3	
CO5										3

The thesis work can be started from the beginning of MS 1st semester and thesis course registration will be at the beginning of the 3rd Semester.

Dissertation Evaluation

Dissertation of Master's by Mixed Mode program must be evaluated using a prescribed rubric as outlined in Clause B6.4.1. Two examination committees, namely the dissertation evaluation committee (DEC) and the oral examination committee(OEC), will assess the dissertation work. The distribution of marks for both the dissertation evaluation and oral examination is as follows: i) Supervisor : 30% ii) Two (2) Examiners (Dissertation evaluators): 40% (20% + 20%) iii) Oral Examination Committee Members : 30%

III) Master's by Research program

Master's by Research: A Master's by Research program is primarily centered around the development of a thesis or dissertation, with the possibility of including some taught components. However, it is important to note that any taught components within this program are non-credit bearing, and the students' evaluation is solely based on their thesis or dissertation work. Every candidate is required to submit a progress report to the Graduate Studies Committee (GSC) through the Supervisor at the end of each semester which will be evaluated by an examination committee. The research work is supposed to be conducted at SUST. However, it can be carried out outside SUST, subject to consultation with the Supervisor and approved by the Graduate Studies Committee (GSC).(ordinance C6-7 & C6-8)

Program requirement and duration:

Graduates of the Master's by Research program will receive a degree, Master of Philosophy(MPhil) in Chemistry

Eligibility: i) Graduates with a Bachelor's degree in a relevant Discipline from SUST or any other university or equivalent foreign university, with a minimum CGPA of 3.00, are eligible to apply for the Master's by Research program. **ii)** A candidate holding a Master's by Coursework (General) degree in a relevant Discipline from SUST is eligible for admission to the Master's by Research program, provided s/he has achieved a minimum CGPA of 3.25 in his or her Master's by Coursework program iii) A candidate currently enrolled in a Master's by Coursework program at SUST, who has already completed 18 credits of coursework with a CGPA of 3.25 or higher, is eligible to apply for the conversion from his/her current program to this program.

Duration: Minimum duration for the degree is four (4) semesters, two years.

Credit Requirement: To obtain the Master's degree by Research, a student must complete a minimum of forty-eight (48) credit hours through research.

Master's by Research course structure

Semesters	Courses	Credits
Semester 1	**CHE 600A: Progress of research work**	**10**
Semester 2	**CHE 600B: public seminar (Progress of research works)**	**10**
Semester 3	**CHE 600C: (Progress of research work)**	**12**
Semester 4	**CHE 600D: Final Thesis dissertation**	**16**
Any semester	**Two international conference presentations**	**0**
	Total	**48.0**

Note: An examination committee will be formed to conduct the course evaluation in each semester.

Description of the courses:

Theory courses: The students will complete non-credit theory courses if admission committee recommended.

CHE 600 A (Progress of research work), 10 credits :

This course will be included the following parts

(i) Research proposal

In consultation with supervisor, a student will prepare a research proposal. In the proposal, idea and plan of the future research must be given related to his/her MPhil work. Evaluation: Students will be evaluated out of 100 (Supervisor: 30, two examiners: 40, oral: 30). The examiners must provide required observations / suggestions /recommendations to improve the quality of the research work.

(ii) Review of articles

The students will prepare one review article report based on contemporarily published articles. Each time, the students will read at least 15 articles (at least 5 articles must not be older than 2 years) and write a review report following a format of review articles published by the standard journals. The mentor of this course will be supervisor/co-supervisor/ any faculty member of the department. Evaluation: reports will be evaluated out of 100 (mentor: 30, Average of two examiners: 70). The report will be accepted if a student can score at least 50% marks.

CHE 600B: Public seminar (Progress of research works), 10 credits

At the end of 2nd semester , the students will submit their progress report of research works to the examination committee. **Evaluation:** Students will be evaluated out of 100 (Supervisor: 30, two examiners: 40, oral: 30).

Seminar-talk on research progress: This constitutes an obligatory element of this program. At the end of the first year, the registered student is mandated to deliver a public seminar talk, organized by the Graduate Studies Committee (GSC), at the respective discipline or institute. The topic of talk must be aligned to the field of research. A protocol for the seminar must be meticulously maintained, encompassing essential details, such as: (i) the total number of GSC members within the Discipline and the percentage in attendance; (ii) the overall number of participants and their categorization (Professors, Associate Professors, Assistant Professors, Lecturers, PhD/Master students, undergraduate students, experts, and guests); (iii) the presentation's topic; date, time, and duration; as well as noteworthy questions and suggestions raised during the event. The seminar presentation should be accessible to all.

CHE 600C: (Progress of research work), 12 credits

The students will submit their progress report of research works to the examination committee. Evaluation: Students will be evaluated out of 100 (Supervisor: 30, two examiners: 40, oral: 30).

CHE 600D: Final Thesis dissertation, 16 credits

At the end of final semester, the student/s will prepare a thesis dissertation and submit to the department for evaluation. The dissertation will contain all the research works including previous works and have to be presented in CHE 600D.

The GSC of the department will follow the University graduate ordinance to construct examiners' panels (both thesis dissertation and oral presentation), and the evaluation will be made accordingly.

Paper-presentation in conferences: The dissemination of the research work within the scholarly community and relevant stakeholders is an imperative facet of this program. The student is required to present his/her research work at a minimum of two international conferences. The evidence of participation and presentation, including conference proceedings and / or abstract books, must be submitted to the GSC and be incorporated into the respective semester progress report.

Dissertation Evaluation: Dissertation of Master's by Research must be evaluated using a prescribed rubric as outlined in Clause B6.6.1. Two examination committees, namely the dissertation evaluation committee and the oral examination committee, will assess the dissertation work. The distribution of marks for both the dissertation evaluation and oral examination is as follows: iv) Supervisor : 30% v) Two (2) Examiners (Dissertation evaluators): 40% (20% + 20%) vi) Oral Examination Committee Members : 30%

Report Evaluation (Marks: Supervisor 30%, Examiners 40%)			
	Excellent	**Good**	**Poor**
Project Title *Title of the needs to match with the objectives and should reflect the activities and expected outcomes.*	Project Title matches very perfectly and reflect 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

Presentation Quality (Marks:30%)			
	Excellent	**Good**	**Poor**
Content of the Presentation	-The facts are clear, understandable -Students discuss the subject in great details -Student describes in detail about their topic -Students indicate what they have learned	-The facts are clear, understandable -Students discuss the subject with some details -Student outlines their topic -Students show what they have learned	-The facts were not correct -Students discuss the subject with very minimal details -Students do not outline what they have learnt -Students still sound confused on this topic
Presentation and Delivery	-The presentation was very creative -Good posture -Eye contact with the audience most of the time -Appropriate gesture and expression -Deliverance with confidence	-The presentation was somewhat creative -Good posture -Frequent eye contact with the audience -Appropriate gesture and expression	-The presentation was not good. -Poor posture -Seldom eye contact with the audience -Not enough easy during presentation
Answering to the Question making logical Arguments	-Answers All the questions asked properly -Makes logical argument nicely	-Answers some of the questions asked properly -Makes logical argument vey weekly	-No Satisfactory Answer for most of the Questions asked -Unable to make logical argument
Professionalism	Presenter is well prepared, speaks loudly and clearly, maintains eye contact with the audience, and avoids all distracting behaviors (i.e. pacing, saying "um" or "ah", etc.)	Presenter is well prepared, speaks loudly and clearly, generally maintains eye contact, and avoids most distracting behaviors (i .e. pacing, saying "um" or "ah", etc.)	Presenter is not organized, does not speak loudly or clearly, avoids eye contact, or exhibits distracting behaviors (i.e. pacing, saying "um" or "ah", etc.)