Program: Master of Science Program in Chemistry (International Program)
Degree: Master of Science (Chemistry)
Study Plan:

1) Research Program (Scheme A 1)

Year	First Trimester	Cr	Second Trimester	Cr	Third Trimester	Cr
Year 1	102991 Thesis	3	102991 Thesis	10	102981 Seminar I	1
					102991 Thesis	8
	Total	**3**	**Total**	**10**	**Total**	**9**
Year 2	102991 Thesis	10	102982 Seminar II	1	102991 Thesis	6
			102991 Thesis	8		
	Total	**10**	**Total**	**9**	**Total**	**6**

2) Regular Program (Scheme A 2)

Year	First Trimester	Cr	Second Trimester	Cr	Third Trimester	Cr
Year 1	1026XX Major Course	3 or 4	1026XX Major Course	9 or 8	1027XX Elective Course	7 or 6
	1027XX Elective Course	2 or 3			102981 Seminar I	1
	Total	**5 or 7**	**Total**	**9 or 8**	**Total**	**8 or 7**
Year 2	1027XX Elective Course	3	102982 Seminar II	1	102991 Thesis	8
	102991 Thesis	3	102991 Thesis	8		
	Total	**6**	**Total**	**9**	**Total**	**8**

Program: Master of Science Program in Chemistry (International Program)
Degree: Master of Science (Chemistry)
Course Description:

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
Core Course (Inorganic Chemical Course)					
102621	Inorganic Reactions in Aqueous and Non-Aqueous Media	3(3-0-9)	Consent of the School of Chemistry	Definitions of acid and base in aqueous solution, applications of acidity and basicity of inorganic compounds, oxidation and reduction; Nernst equation, disproportionation and comproportionation, diagrams related to redox reaction, application of redox reaction in industries, non-aqueous solvents, and reactions in non-aqueous solvents and the related applications.	1. Students will be able to identify acidity and basicity of substances. 2. Students will be able to apply acid-base properties to explain related chemical reactions. 3. Students will be able to write, balance, and explain redox reactions. 4. Students will be able to describe diagrams related to redox reactions and use them to explain and predict the related chemical reactions. 5. Students will be able to tell the importance of redox reactions and their applications in industries. 6. Students will be able to tell the importance of non-aqueous solvents and their applications. 7. Students will be able to choose the appropriate solvents for the given chemical reactions.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102622	Symmetry and Molecular Orbital Theory	3(3-0-9)	Consent of the School of Chemistry	Introduction to group theory and molecular symmetry, symmetry operations, symmetry elements, point groups, multiplication table, character, applications of group theory and molecular symmetry to determine structural chemistry, molecular vibrations, vibrational spectroscopy, orbital symmetry and bonding, molecular orbital theory, molecular orbital diagram, molecular orbitals of polyatomic molecule, and applications of molecular orbital theory	1. Student will be able to explain group theory and molecular symmetry and identify symmetry elements, symmetry operations, and point groups of various molecules. 2. Student will be able to use molecular symmetry, multiplication table, and character table to describe structural chemistry of molecules. 3. Student will be able to use molecular symmetry and character table to determine molecular vibrations and explain the fundamental of vibrational spectroscopy techniques. 4. Student will be able to use group theory and molecular symmetry to describe symmetry of orbitals and bonding. 5. Student will be able to explain molecular orbital theory and describe an orbital hybridization and bondings in molecules. 6. Student will be able to write molecular orbital diagrams for diatomic molecules and polyatomic molecules. 7. Student will be able to use group theory and molecular orbital theory to determine chemical structures and properties of molecules.

Courses	Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102623 Coordination Chemistry	3(3-0-9)	Consent of the School of Chemistry	Nomenclature of ligands, complexes and isomers, shapes of the compounds, bonding theories including crystal field theory and ligand field theory, syntheses and reaction mechanisms, term symbols, electronic spectra, and magnetic properties of coordination compounds.	1. Students will be able to explain the formation of coordination compounds. 2. Students will be able to correctly name ligands, complexes and isomers. 3. Students will be able to identify the shape and isomers of the coordination compounds. 4. Students will be able to explain crystal field theory and ligand field theory and use them to explain the complexes and their properties. 5. Students will be able to explain each chemical reaction in the synthesis of coordination compounds. 6. Students will be able to explain and predict chemical reactions of coordination compounds. 7. Students will be able to write term symbols of free ions. 8. Students will be able to explain the construction of diagrams related to electronic spectra and use them to explain the electronic spectra of coordination compounds. 9. Students will be able to explain the origin of magnetic properties in coordination compounds and apply the knowledge in predicting magnetic properties of the compounds.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102624	Solid State Chemistry	3(3-0-9)	Consent of the School of Chemistry	Packing of spheres, closed-packed structures, crystal structures of solids, factors that affect crystal structure, ionicity and covalency of crystal structures, characterization of crystal structures and elemental composition of solids, and X-ray diffraction.	1. Students will be able to explain the structure and packing of solids. 2. Students will be able to discuss the factors that affect crystal structure and apply them in predicting the structures. 3. Students will be able to describe solid preparation techniques and choose the appropriate method to prepare the designated solids. 4. Students will be able to explain the x-ray diffraction technique for structural characterization. 5. Students will be able to explain Bragg's law and use it to interpret the x-ray diffraction patterns of solids. 6. Students will be able to describe several characterization techniques for elemental composition and choose them appropriately.
102625	Inorganic Porous Materials	3(3-0-9)	Consent of the School of Chemistry	Structure and composition, synthesis, characterization, and applications of various porous materials including microporous materials such as zeolites, mesoporous materials such as MCM-41, activated carbon, and metal-organic frameworks (MOFs).	1. Students will be able to explain structure and composition of various kinds of porous materials, synthesis of porous materials and relevant reactions, characterization and properties of porous materials by various techniques. 2. Students will be able to read, comprehend, and present to the class recent literature on porous materials. 3. Students will be able to propose research ideas on porous materials.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102626	Physical Methods for Characterization of Inorganic Materials	3(3-0-9)	Consent of the School of Chemistry	Techniques to characterize inorganic compounds including infrared and Raman spectroscopy, ultraviolet-visible spectroscopy, nuclear magnetic resonance spectroscopy, electron paramagnetic resonance spectroscopy, x-ray methods, and other techniques.	1. Students will be able to explain techniques to characterize inorganic compounds including infrared and Raman spectroscopy, ultraviolet-visible spectroscopy, nuclear magnetic resonance spectroscopy, electron paramagnetic resonance spectroscopy, x-ray methods, and other techniques. 2. Students will be able to read, comprehend, and present to the class recent literature on characterization of inorganic materials. 3. Students will be able to propose research ideas on characterization of inorganic materials.
Core Course (Organic Chemical Course)					

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102631	Physical Organic Chemistry	4(4-0-12)	Consent of the School of Chemistry	Molecular orbital theory, configuration and conformation of organic molecules as well as stereoselectivity, energy surfaces and kinetic analyses, experiments related to thermodynamics and kinetics, Brønsted acid-base catalysis, and concepts of pericyclic reactions.	1. Students will be able to use Hückel molecular orbital theory to draw molecular orbitals and construct orbital energy diagrams of planar conjugated hydrocarbon polyenes. 2. Students will be able to use perturbation molecular orbital theory and frontier molecular orbital theories to predict reactivity of organic molecules toward nucleophiles and electrophiles. 3. Students will be able to distinguish different types of stereoisomers. 4. Students will be able to predict the stability and reactivity of organic molecules based on their molecular structures. 5. Students will be able to propose reaction mechanisms using stereochemistry and/or kinetic information. 6. Students will be able to design experiments to investigate organic reaction mechanisms. 7. Students will be able to apply linear free-energy relationships to characterize reaction mechanisms. 8. Students will be able to distinguish between specific catalysis and general catalysis. 9. Students will be able to apply several models developed, such as state correlation diagram model, frontier molecular orbital theory and aromatic transition state theory to treat pericyclic reactions.
102632	Insight into Organic Reaction Mechanisms	3(3-0-9)	Consent of the School of Chemistry	Insight into mechanisms of different types of reactions including nucleophilic substitution, polar addition and elimination reactions, reactions of carbonyl compounds, and aromatic substitution.	1. Students will be able to propose reasonable mechanisms for organic reactions, using the reaction condition and the nature of the starting materials as a basis for the mechanism. 2. Students will be able to use curly arrow reaction mechanisms and a knowledge of the relative stability of intermediates to predict and/or account for the products of reactions.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102633	Spectrometric Identification of Organic Compounds	3(3-0-9)	Consent of the School of Chemistry	Structural elucidation of organic compounds from ultraviolet, mass, infrared and nuclear magnetic resonance spectral data.	1. Students will be able to interpret peaks from ultraviolet, mass, infrared, and nuclear magnetic resonance spectral data. 2. Students will be able to solve structures of organic compounds by using ultraviolet, mass, infrared, and nuclear magnetic resonance spectral data. 3. Students will be able to match the structures of organic compounds with the ultraviolet, mass, infrared, and nuclear magnetic resonance spectral data.
Core Course (Analytical Chemistry Course)					
102641	Analytical Spectroscopy	3(3-0-9)	Consent of the School of Chemistry	Concepts of spectrochemical analysis, instrumental components, noise sources, characteristics of noise, signal-to-noise ratio enhancement techniques, methodology in spectrochemical analysis, atomic and molecular spectrometric techniques.	1. Students will be able to describe the principles and instrumentation of atomic/molecular spectrometry. 2. Students will be able to identify the types of noise present in spectroscopic measurements and be able to apply hardware and software methods to improve the measured signal-to-noise ratio. 3. Students will be able to compare applications of various spectroscopic methods.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102642	Analytical Separation Techniques	3(3-0-9)	Consent of the School of Chemistry	Principles of classical and modern separation techniques based on gas chromatography, liquid chromatography and capillary electrophoresis, principal instrumental components and their functions, method developments, and method for separation performance evaluation.	1. Students will be able to describe principle of classical separation techniques. 2. Students will be able to explain principle of chemical component separation by chromatography and capillary electrophoresis. 3. Students will be able to list critical factors for separation method development in chromatography and capillary electrophoresis. 4. Students will be able to show principal components of the instruments and describe their functions. 5. Students will be able to evaluate the performance of method from the given separation results. 6. Students will be able to compare advantages and disadvantages/limitations of each technique. 7. Students will be able to choose an appropriate separation technique for the application based on physical and chemical properties of the sample and group of the analytes.
102643	Analytical Electrochemistry	3(3-0-9)	Consent of the School of Chemistry	Electrochemical cell, electrode processes, kinetics of electrode reactions, mass transport, electrochemical instrumentation, potentiometry, and voltammetric techniques.	1. Students will be able to explain the basic principles of electrochemistry. 2. Students will be able to describe the basic principles of various electroanalytical techniques. 3. Students will be able to distinguish the structures and functions of different instrument components. 4. Students will be able to compare and choose different electroanalytical techniques for quantitative analysis.
Core Course (Physical Chemistry / Computational Chemistry Course)					

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102651	Quantum Chemistry	4(4-0-12)	Consent of the School of Chemistry	Mathematical review, quantum theory, SCF-MO theory, approximate molecular orbital theories and electron correlations, density functional theory, and examples of applications in chemical problems.	1. Students will be able to define and explain mathematics that are related to quantum theory. 2. Students will be able to analyze and interpret quantum chemical methods. 3. Students will be able to design and construct models to solve chemical problems using quantum chemical methods.
102652	Advanced Chemical Thermodynamics	3(3-0-9)	Consent of the School of Chemistry	Ensembles and partition functions, atomic and molecular degrees of freedom: translation, rotation, vibration, electronic and nuclear spin, chemical equilibrium and thermodynamic properties: entropy, enthalpy, free energy, chemical potential, intermolecular potentials and equations of state, models for materials: Einstein and Debye, metals, semiconductors and polymers, statistical thermodynamics of liquid, and molecular dynamic and Monte Carlo simulation of liquid.	1. Students will be able to explain principles of statistical thermodynamics and the relationship between microscopic properties of molecules with macroscopic thermodynamic observables. 2. Students will be able to explain mathematical tools to calculate thermodynamic properties at the atomic and molecular level. 3. Students will be able to formulate the derivation of statistical thermodynamic model and compare to experimental data. 4. Students will be able to apply simple statistical thermodynamic models for predictive understanding of physical phenomena associated with chemical thermodynamics. 5. Students will be able to evaluate the limitations and uses of statistical thermodynamic models for the solution of applied problems involving chemical thermodynamics.
102653	Advanced Chemical Kinetics	2(2-0-6)	Consent of the School of Chemistry	Advanced theory of chemical reactions, potential energy surfaces, experimental procedure, kinetic analysis of experimental data, and complex reactions in gas phase and solutions.	1. Students will be able to explain basic principles of chemical kinetics for studying chemical reactions. 2. Students will be able to apply chemical kinetics for elucidating mechanisms of chemical reactions.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102654	Quantum Spectroscopy	2(2-0-6)	Consent of the School of Chemistry	Introduction to quantum chemistry, atomic electronic structure and atomic spectroscopy, molecular electronic structure and molecular electronic spectroscopy, particle-in-box models and UV-Vis spectroscopy, rigid-rotor models and microwave spectroscopy, molecular vibrations and Infrared/Raman spectroscopy, magnetic resonance spectroscopy, semi-empirical methods and applications of symmetry, introduction to ab initio calculation and density functional methods.	1. Students will be able to explain the basic principle of quantum chemistry in relation to physical spectroscopy. 2. Students will be able to explain the basic physical chemistry law that governs atomic and molecular spectroscopy. 3. Students will be able to describe basic information on atomic and molecular spectroscopy (Microwave, IR, Raman, UV-VIS, NMR, EPR). 4. Students will be able to calculate both by hand and by computer to predict atomic and molecular spectra. 5. Students will be able to analyze results of measurements using atomic/molecular spectroscopy methods. 6. Students will be able to apply atomic/molecular spectroscopy methods suitable for solving given scientific problems.
102655	Quantum Mechanical Calculations	2(2-0-6)	Consent of the School of Chemistry	Quantum mechanics calculations, determination of molecular properties using ab initio quantum mechanics calculations, advanced ab initio methods and density functional theory, and applications of computational chemistry software in chemical research.	1. Students will be able to explain basic principles of quantum mechanics. 2. Students will be able to use software packages for quantum mechanics calculations. 3. Students will be able to apply quantum mechanics calculations for studying chemical systems.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102656	Quantum Chemistry for Solids	3(3-0-9)	Consent of the School of Chemistry	Fundamental of density functional theory (DFT) and its limitations, method of DFT with plane waves and periodic boundary conditions for solid systems, basic principle of crystallography, periodic model calculations implemented in VASP program package to study properties of materials, examples of solid surface modeling and chemical process analysis using DFT calculations, and workshops related to DFT-based periodic modeling of extended systems.	1. Students will be able to explain basic principle of DFT and its limitations when used for studying solid systems. 2. Students will be able to discuss the importance of various parameters used in periodic DFT calculations. 3. Students will be able to associate systems in real space with their reciprocal space and be able to construct the first Brillouin zone from given lattice points. 4. Students will be able to use DFT with plane waves method to calculate various properties of bulk and surface systems. 5. Students will be able to apply DFT and transition state theory to study various chemical processes occurred on surfaces.
Research Promotion Elective Course					
102711	Scientific Information Access	2(2-0-6)	None	Techniques how to get access into scientific information available both in the university library and on the internet, and basic knowledge with respect to data manipulation and storage.	1. Students will be able to retrieve the scientific information assigned in class. 2. Students will be able to discuss the completeness of the retrieved information. 3. Students will be able to explain, analyze and synthesize the retrieved documents.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102712	Scientific Writing and Presentation	2(2-0-6)	None	Formats and techniques of scientific writing such as a research proposal, a scientific abstract and article, a thesis and a research paper, formats and techniques of scientific presentation, referencing and standard reference formats, design and preparation of presentation media, and presentation in class or in seminar courses.	1. Students will be able to write scientific articles and/or research works and be able to present them in class or in seminar courses. 2. Students will be able to analyze and synthesize information from references and be able to rephrase it. 3. Students will be able to prepare suitable media for presentation in class or in seminar courses.
102713	Advanced Computer Programming for Scientific Research	3(3-0-9)	Consent of the School of Chemistry	Scientific computing and mathematical modeling, review on linear algebra, review on a selected computer programming language such as C, FORTRAN or Pascal, designing of efficient algorithms for vector and parallel computers, examples of scientific problems solved by vector and parallel computers, three-dimensional graphic modeling, and a short project on scientific computation.	1. Students will be able to use a computer programming language to design an algorithm for mathematic and scientific calculations. 2. Students will be able to apply vector and parallel computers to solve scientific problems and be able to design 3-dimensional graphic modeling. 3. Students will be able to use the obtained computational tools to carry out a project on scientific computations.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102714	Chemical and Laboratory Safety	1(1-0-3)	None	Basic concepts of laboratory safety, regulations and laws, concepts of hazard and risk, classification of laboratory hazards, risk reduction strategies, protective equipment, hazardous waste handling, and accident reporting and situation remediation.	1. Students will be able to recognize principles of laboratory safety, regulations and related laws. 2. Students will be able to classify laboratory hazards and be able to tell risk reduction strategies. 3. Students will be able to appropriately handle hazardous waste. 4. Students will be able to explain how to remedy the situation in case of accident in laboratory.
Inorganic Chemical Elective Course					
102721	Organometallic Chemistry of Transition Elements	3(3-0-9)	Consent of the School of Chemistry	Definitions of organometallic chemistry of transition elements and 18-electron rule, type of ligands, structures and bonding between metal and ligands, syntheses, reactions, characterization and applications of organometallic compounds, and parallels to main group organometallic chemistry.	1. Students will be able to explain definitions of organometallic chemistry of transition elements and 18-electron rule, type of ligands, structures and bonding between metal and ligands, syntheses, reactions, characterization and applications of organometallic compounds, and parallels to main group organometallic chemistry. 2. Students will be able to read, comprehend and present to the class current research literature on organometallic chemistry of transition elements. 3. Students will be able to propose a research idea on a topic related to organometallic chemistry of transition elements.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102722	Functional Materials	3(3-0-9)	102624 Solid State Chemistry or Consent of the School of Chemistry	Related energy in solids, bonding in solids, band structure, electronic properties of solids, types of semiconductors, insulators and metallic conductors, manipulating the electronic properties of solids, dielectric properties and magnetic properties of solids.	1. Students will be able to explain related energy in solids and calculate the lattice energy. 2. Students will be able to explain bonding in solids. 3. Students will be able to describe band formation and predict the band structure of given solids. 4. Students will be able to describe electronic properties of solids and predict the properties based on band structures. 5. Students will be able to explain the manipulation of electronic properties. 6. Students will be able to explain dielectric properties and related characterizations and applications. 7. Students will be able to explain magnetic properties and related characterizations and applications.
102723	Heterogeneous Catalysis	3(3-0-9)	Consent of the School of Chemistry	Introduction and basic principles of heterogeneous catalysis, steps in catalysis, rate and kinetics of catalytic reactions, preparation, properties, characterization and deactivation of catalysts, and examples of heterogeneous catalytic process.	1. Students will be able to explain definitions of heterogeneous catalysis, steps in heterogeneous catalysis, preparation of heterogeneous catalysts, physicochemical characterization of heterogeneous catalysts, reactors and catalytic testing procedures, application of kinetics to understand mechanism in heterogeneous catalysis and catalyst deactivation. 2. Students will be able to read, comprehend and present to the class current research literature on heterogeneous catalysis. 3. Students will be able to propose a research idea on a topic related to heterogeneous catalysis.
102724	Selected Topics in Inorganic Chemistry I	3(3-0-9)	Consent of the School of Chemistry	Selected topics of current interests in inorganic chemistry.	1. Students will be able to explain each selected topic of current interest in inorganic chemistry. 2. Students will be able to read, comprehend and present to the class current research literature related to the selected topics in inorganic chemistry. 3. Students will be able to propose a research idea related to the selected topics in inorganic chemistry.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102725	Selected Topics in Inorganic Chemistry II	3(3-0-9)	Consent of the School of Chemistry	Selected topics of current interests in inorganic chemistry.	1. Students will be able to explain each selected topic of current interest in inorganic chemistry. 2. Students will be able to read, comprehend and present to the class current research literature related to the selected topics in inorganic chemistry. 3. Students will be able to propose a research idea related to the selected topics in inorganic chemistry.
102725	Frontiers in Inorganic Chemistry I	3(3-0-9)	Consent of the School of Chemistry	Topics of current interest leading to frontiers in inorganic chemistry of the future.	1. Students will be able to explain the academic and industrial trend related to inorganic chemistry. 2. Students will be able to describe the basic principle of the theory leading to the development of the inorganic chemistry frontier. 3. Students will be able to predict the trend in inorganic chemistry being developed in the future.
102726	Frontiers in Inorganic Chemistry II	3(3-0-9)	Consent of the School of Chemistry		1. Students will be able to explain the academic and industrial trend related to inorganic chemistry. 2. Students will be able to describe the basic principle of the theory leading to the development of the inorganic chemistry frontier. 3. Students will be able to predict the trend in inorganic chemistry being developed in the future.
Organic Chemical Elective Course					
102731	Carbon-Carbon Bond Forming Reactions	3(3-0-9)	Consent of the School of Chemistry	Alkylation of enolates and other carbon nucleophiles, reactions of carbon nucleophiles with carbonyl compounds, pericyclic carbon-carbon bond forming reactions, electrophilic carbon-carbon bond forming reactions, and carbon-carbon bond forming reactions via radicals and carbenes.	1. Students will be able to describe various types of carbon-carbon bond forming reactions and write their mechanisms. 2. Students will be able to apply stereochemical considerations for chiral product formation. 3. Students will be able to formulate multistep syntheses of molecules of moderate complexity. 4. Students will be able to conduct retrosynthetic analysis. 5. Students will be able to develop communication skills in group discussions and oral presentations.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102732	Transformations of Functional Groups	3(3-0-9)	Consent of the School of Chemistry	Functional group interconversion by substitution, electrophilic addition to alkenes, reductions, oxidations, and nucleophilic aromatic substitution.	1. Students will be able to classify the structures and reactivity of organic functional groups. 2. Students will be able to describe a variety of modern synthetic methods for transformation of functional groups. 3. Students will be able to explain synthetic methods from the literature in oral and written form. 4. Students will be able to identify and remedy selectivity issues by choices of appropriate synthetic methods and protective groups. 5. Students will be able to evaluate a proposed synthetic pathway with regard to an access of appropriate starting material selectivity.
102733	Organic Synthesis	3(3-0-9)	Consent of the School of Chemistry	Routine for designing a synthesis by disconnection approach, strategy for choosing a disconnection, strategy of carbonyl disconnections, strategy of ring synthesis, and advanced synthetic strategy for complex chemical structures.	1. Students will be able to design a synthetic route for a target compound by using disconnection approach. 2. Students will be able to formulate multi-step syntheses of molecules of moderate complexity. 3. Students will be able to choose the starting material fragments from commercial available compound. 4. Students will be able to solve problems in class. 5. Students will be able to develop communication skills in group discussions and oral presentations.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102734	Chemistry of Natural Products	3(3-0-9)	Consent of the School of Chemistry	Structures, chemical properties and syntheses of carbohydrates, proteins, nucleic acids, aromatic compounds, alkaloids, terpenoids, steroids, and other natural products of current interest.	1. Students will be able to identify and characterize various classes of natural products by their structures. 2. Students will be able to draw structural and molecular formulas of natural products. 3. Students will be able to describe the chemical properties of carbohydrates, proteins, nucleic acids, aromatic compounds, alkaloids, terpenoids, steroids, and other natural products of current interest. 4. Students will be able to explain the syntheses of carbohydrates, proteins, nucleic acids, aromatic compounds, alkaloids, terpenoids, steroids, and other natural products of current interest. 5. Students will be able to identify and solve organic chemical problems and explore new areas of research. 6. Students will be able to develop communication skills in group discussions and oral presentations.
102735	Heterocyclic Chemistry	3(3-0-9)	Consent of the School of Chemistry	Synthesis and reactivity of simple heteroaromatic compounds including pyridines, quinolines, diazines, pyrylium salts, pyrones, furans, thiophenes, indoles and different five-membered rings with two heteroatoms, nomenclature in heterocyclic chemistry, and some applications of heterocyclic compounds.	1. Students will be able to name both monocyclic and polycyclic heterocyclic compounds. 2. Students will be able to suggest the syntheses of simple heterocyclic compounds. 3. Students will be able to explain the reactivities of heteroaromatic compounds. 4. Students will be able to identify the differences in reactivities of heterocyclic compounds. 5. Students will be able to demonstrate how heterocyclic compounds can be prepared from simple starting materials. 6. Students will be able to solve problems in class. 7. Students will be able to develop communication skills in group discussions and oral presentations.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102736	Natural Products Isolation	3(3-0-9)	Consent of the School of Chemistry	Preparation procedures for extraction, extraction of natural products by various methods, fractionation and purification of natural products, and structural elucidation of natural products.	1. Students will be able to recognize the preparatory processes for the isolation of natural products from biological sources. 2. Students will be able to describe and apply the techniques for extraction of natural products through solvents and supercritical fluids. 3. Students will be able to explain and apply the principles for isolation and purification of compounds from natural extracts. 4. Students will be able to explain and apply the different chemical methods and spectroscopic techniques, important to the correct identification of natural products.
102737	Introduction to Medicinal Chemistry	3(3-0-9)	Consent of the School of Chemistry	Descriptions of structure, dynamics and interactions of drugs and drug targets, different strategies of drug design and development, pharmacodynamics and pharmacokinetics, and current drug delivery systems.	1. Students will be able to explain the concept of molecular target. 2. Students will be able to describe the mechanism of action of drugs through their interactions with molecular targets. 3. Students will be able to recognize basic principles of rational drug design. 4. Students will be able to demonstrate concepts of drug metabolism, bioavailability and pharmacokinetics, and be able to explain the role of medicinal chemistry in improving these parameters. 5. Students will be able to design new drugs and/or targeted biomaterials (e.g. Liposomes, nanoparticles, drug conjugates with peptides/proteins, and drug conjugates with polymeric materials) based on current literatures. 6. Students will be able to describe the current challenges and opportunities in medicinal chemistry in light of contemporary developments in the field of drug discovery.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102738	Polymer Chemistry	3(3-0-9)	Consent of the School of Chemistry	Mechanisms and kinetics of polymerization including condensation polymerization, free radical polymerization, emulsion polymerization, ionic polymerization, copolymerization, coordination polymerization and ring-opening polymerization, and polymerization reactors and processes.	1. Students will be able to explain concept of different methods for chemical synthesis of polymeric molecules. 2. Students will be able to explain mechanisms and kinetics of each type of polymerization method. 3. Students will be able to design experimental methods to synthesize polymer of interest. 4. Students will be able to analyze results of experimental data based on kinetic and mechanism of polymerization. 5. Students will be able to apply concept of different methods for polymerization to real-life polymerization reactors and processes.
102739	Selected Topics in Organic Chemistry I	3(3-0-9)	Consent of the School of Chemistry	Selected topics of current interests in organic chemistry.	1. Students will be able to explain principles of the selected topics of current interest in organic chemistry. 2. Students will be able to apply the selected topics to related research in literature.
102831	Selected Topics in Organic Chemistry II	3(3-0-9)	Consent of the School of Chemistry	Selected topics of current interests in organic chemistry.	1. Students will be able to explain principles of the selected topics of current interest in organic chemistry. 2. Students will be able to apply the selected topics to related research in literature.
102832	Frontiers in Organic Chemistry I	3(3-0-9)	Consent of the School of Chemistry	Topics of current interest leading to frontiers in organic chemistry of the future.	1. Students will be able to explain the academic and industrial trend related to organic chemistry. 2. Students will be able to describe the basic principle of the theory leading to the development of the organic chemistry frontier. 3. Students will be able to predict the trend in organic chemistry being developed in the future.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102833	Frontiers in Organic Chemistry II	3(3-0-9)	Consent of the School of Chemistry	Topics of current interest leading to frontiers in organic chemistry of the future.	1. Students will be able to explain the academic and industrial trend related to organic chemistry. 2. Students will be able to describe the basic principle of the theory leading to the development of the organic chemistry frontier. 3. Students will be able to predict the trend in organic chemistry being developed in the future.
Analytical Chemistry Elective Course					
102741	Sample Preparation Techniques in Analytical Chemistry	3(3-0-9)	Consent of the School of Chemistry	Principles of sample preparation techniques by liquid and solid extraction methods for solid, liquid and gas samples for interference removal and pre-concentration purposes, and on-line extraction methods for common analytical techniques.	1. Students will be able to describe principle of sample preparation techniques by liquid and solid extraction methods. 2. Students will be able to identify critical factors for the sample extraction methods. 3. Students will be able to select a suitable sample preparation method for a particular application. 4. Students will be able to design a sample preparation experiment for a particular application. 5. Students will be able to choose an appropriate on-line coupling method for sample extraction and analytical technique.
102742	Advanced Instrumental Methods of Analysis Laboratory	1(0-3-3)	Consent of the School of Chemistry	Laboratory works involving advanced instrumental techniques in spectrometry, electrochemistry, chromatography and other related techniques.	1. Students will be able to identify the essential components of the instruments for spectrometry, electrochemistry, chromatography and other related techniques. 2. Students will be able to perform experiments for the quantitative and qualitative analysis in real samples with spectrometry, electrochemistry, chromatography and other related techniques. 3. Students will be able to interpret, analyze and evaluate the obtained results and/or data. 4. Students will be able to identify critical sources of possible errors in the experiments.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102743	Polymer Characterization	3(3-0-9)	Consent of the School of Chemistry	Molecular weight determination, spectroscopic determination of chain structure, X-ray techniques of condense phase structure, thermal analysis of solid polymer, viscoelastic and rheological analysis.	1. Students will be able to identify the essential components of the instruments for spectrometry, electrochemistry, chromatography and other related techniques. 2. Students will be able to perform experiments for the quantitative and qualitative analysis in real samples with spectrometry, electrochemistry, chromatography and other related techniques. 3. Students will be able to interpret, analyze and evaluate the obtained results and/or data. 4. Students will be able to identify critical sources of possible errors in the experiments.
102744	Selected Topics in Analytical Chemistry I	3(3-0-9)	Consent of the School of Chemistry	Selected topics of current interests in analytical chemistry.	1. Students will be able to describe principles of the studied topics. 2. Students will be able to identify the contribution of the topics to the field of chemical analysis.
102745	Selected Topics in Analytical Chemistry II	3(3-0-9)	Consent of the School of Chemistry	Selected topics of current interests in analytical chemistry.	1. Students will be able to describe principles of the studied topics. 2. Students will be able to identify the contribution of the topics to the field of chemical analysis.
102746	Frontiers in Analytical Chemistry I	3(3-0-9)	Consent of the School of Chemistry	Topics of current interest leading to frontiers in analytical chemistry of the future.	1. Students will be able to explain the academic and industrial trend related to analytical chemistry. 2. Students will be able to describe the basic principle of the theory leading to the development of the analytical chemistry frontier. 3. Students will be able to predict the trend in analytical chemistry being developed in the future.
102747	Frontiers in Analytical Chemistry II	3(3-0-9)	Consent of the School of Chemistry	Topics of current interest leading to frontiers in analytical chemistry of the future.	1. Students will be able to explain the academic and industrial trend related to analytical chemistry. 2. Students will be able to describe the basic principle of the theory leading to the development of the analytical chemistry frontier. 3. Students will be able to predict the trend in analytical chemistry being developed in the future.
Physical Chemistry / Computational Chemistry Elective Course					

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102751	Surface Chemistry	3(3-0-9)	Consent of the School of Chemistry	Surface and colloid systems, thermodynamics of interfaces, surface tension, wetting and contact angle, surface free energy, adsorption, surfactants and their applications, dispersion systems, and electrokinetic phenomena.	1. Students will be able to incorporate surface specific phenomena into any thermodynamic analysis. 2. Students will be able to use surface energy concepts to explain wetting, contact angle and surfactant action. 3. Students will be able to use the basic models of an interface to determine adsorbate orientation. 4. Students will be able to discuss the principles behind the electron transfer reaction and the related model describing the effect of potential on the rate of electron transfer.
102752	Physical Chemistry of Polymers	3(3-0-9)	Consent of the School of Chemistry	Molecular weights and molecular weight distribution of polymer molecule, Structure of polymer chain, Polymer solutions and blends, Amorphous state of polymers, Polymer viscoelasticity, Crystalline state of polymers, Relaxation and transitions in polymers, Rubber elasticity.	1. Students will be able to explain the principles of physical chemistry and the relationship between structure and properties of polymer molecules and polymeric materials. 2. Students will be able to formulate the derivation of physical chemistry model and compare it to experimental data. 3. Students will be able to apply simple physical chemistry models to predict physicochemical phenomena associated with polymer molecules and polymeric materials. 4. Students will be able to evaluate the limitations and uses of physical chemistry models for the solution of applied problems involving properties of polymer molecules and polymeric materials.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102753	Fundamental and Methodology of Modern Electrochemistry	3(3-0-9)	Consent of the School of Chemistry	Introduction to chemical thermodynamics and electrochemistry, electrolytic conductivity and ionic interaction, electrolytic double layer, types of electrodes and selected electrochemical reaction mechanisms, potential-pH diagrams and their interpretation, methods for the study of electrode/electrolyte interfaces, and electrochemical processes of particular relevance to energy conversion and energy storage.	1. Students will be able to incorporate electrochemistry-related phenomena into thermodynamic analysis. 2. Students will be able to explain concepts and principles of electrochemistry related to electrolytic conductivity and ionic interaction. 3. Students will be able to describe the electrochemical double layer based on common models. 4. Students will be able to describe and interpret any potential-pH diagrams. 5. Students will be able to apply electrochemistry to describe various electrochemical processes occurring in batteries, fuel cells and supercapacitors.
102754	Numerical Methods for Chemists	3(3-0-9)	Consent of the School of Chemistry	Steps in solving scientific problems with computer, computer language, programs with closed-form algorithms, roots of equations, systems of linear equations, regression analysis, numerical integration, differential equations, eigenvalues and eigenvectors, and miscellaneous topics related to modern chemical calculations.	1. Students will be able to define and explain steps in solving scientific problems with computer. 2. Students will be able to explain numerical methods that are connected to mathematics related to chemical calculations. 3. Students will be able to design and construct models to solve chemical problems using numerical methods. 4. Students will be able to analyze and interpret results obtained from the applications of numerical methods on chemical problems.
102755	Computer Programming	3(3-0-9)	Consent of the School of Chemistry	Computer languages, problem analysis and construction of algorithms, and computer programming for solving scientific problems.	1. Students will be able to recognize basic principles of computer languages. 2. Students will be able to analyze scientific problems and to generate appropriate algorithms for solving the problems. 3. Students will be able to write computer programs for solving scientific problems.

Courses	Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102756 Molecular Modelling Techniques	3(3-0-9)	Consent of the School of Chemistry	Reviews of essential mathematics backgrounds, concepts in molecular modelling, introductions to quantum mechanics and molecular mechanics calculations, conformational analysis, optimization techniques based on non-derivative and derivative methods, optimization techniques applied to study structure and energetic details of chemical systems, molecular modelling techniques based on Monte Carlo and molecular dynamics methods.	1. Students will be able to explain essential basic mathematics for studying chemical systems through molecular modeling techniques. 2. Students will be able to use software packages for studying structure and energetic details of chemical systems. 3. Students will be able to apply molecular modelling techniques, namely Monte Carlo and molecular dynamics technique, for studying chemical systems.
102757 Computational Nanotechnology	3(3-0-9)	Consent of the School of Chemistry	Multiscale computation and simulation, electronic structure calculation, atomistic simulation, and mesoscale simulation.	1. Students will be able to explain the concepts of multiscale computation and simulation in relation to nanotechnology in chemistry. 2. Students will be able to explain the basic physicochemical laws that govern the electronic, atomic, molecular and mesoscale structure, and properties of the chemical nanosystems. 3. Students will be able to do calculation by computer to predict physicochemical properties of chemical nanosystem. 4. Students will be able to analyze results of calculation using multiscale computation and simulation of chemical nanosystem. 5. Students will be able to apply multiscale computation and simulation methods suitable for solving the given chemical nanosystem.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102758	Selected Topics in Physical Chemistry/Computational Chemistry I	3(3-0-9)	Consent of the School of Chemistry	Selected topics of current interests in physical chemistry/computational chemistry.	1. Students will be able to explain principles of the selected topics of current interest in organic chemistry. 2. Students will be able to apply the selected topics to related research in literature.
102759	Selected Topics in Physical Chemistry/Computational Chemistry II	3(3-0-9)	Consent of the School of Chemistry	Selected topics of current interests in physical chemistry/computational chemistry.	1. Students will be able to explain principles of the selected topics of current interest in organic chemistry. 2. Students will be able to apply the selected topics to related research in literature.
102851	Frontiers in Physical Chemistry/Computational Chemistry I	3(3-0-9)	Consent of the School of Chemistry	Topics of current interest leading to frontiers in physical chemistry/computational chemistry of the future.	1. Students will be able to explain the academic and industrial trend related to physical chemistry/computational chemistry. 2. Students will be able to describe the basic principle of the theory leading to the development of the physical chemistry/computational chemistry frontier. 3. Students will be able to predict the trend in physical chemistry/computational chemistry being developed in the future.
102852	Frontiers in Physical Chemistry/Computational Chemistry II	3(3-0-9)	Consent of the School of Chemistry	Topics of current interest leading to frontiers in physical chemistry/computational chemistry of the future.	1. Students will be able to explain the academic and industrial trend related to physical chemistry/computational chemistry. 2. Students will be able to describe the basic principle of the theory leading to the development of the physical chemistry/computational chemistry frontier. 3. Students will be able to predict the trend in physical chemistry/computational chemistry being developed in the future.
Applied Chemistry Elective Course					

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102761	Nanoscience and Nanotechnology	3(3-0-9)	Consent of the School of Chemistry	Introduction to nanotechnology, carbon nanotubes, quantum dots, properties of materials as a function of size, self-assembly, nanostructured materials, nanoscale films and composites, devices and applications, molecular engineering, molecular electronics, nanofabrication and bionanotechnology, imaging and manipulating at the atomic scale, and nanotechnology in industry.	1. Students will be able to explain relationship of crystal structure, electronic structure, morphology, and properties of functional nanomaterials. 2. Students will be able to explain basic principles of syntheses and preparations of interested nanomaterials. 3. Students will be able to discuss in principle the strategies to improve efficiencies of interested functional nanomaterials.
102762	Chemical Crystallography	3(3-0-9)	Consent of the School of Chemistry	Basic principles of x-ray diffraction and crystallography, structural chemistry, experimental methods, applications of crystallography to problems of chemical interest, and diffractometric equipment and computer data analysis for actual structure determination.	1. Students will be able to explain basics and theoretical concepts of x-ray diffraction and crystallography. 2. Students will be able to describe the process of crystal structure analysis. 3. Students will be able to outline instrumentation, hardware and technology used in x-ray diffraction. 4. Students will be able to explain the procedure to evaluate crystal, collect single crystal XRD data, analyze diffraction data and analyze single crystal structure, and be able to report the final result.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102763	Polymers and Applications	3(3-0-9)	Consent of the School of Chemistry	Polymer synthesis and kinetics in condensation polymerization, addition polymerization and copolymerization, molecular weight determination, polymer solutions and phase behavior, morphologies, crystallization, melting and glass transition, mechanical and rheological properties, and example of polymer researches for energy, environment and biomedical application.	1. Students will be able to explain the basic principles of polymer science in terms of synthesis, characterization, properties and application. 2. Students will be able to provide the reaction mechanisms and kinetics involved in polymer synthesis. 3. Students will be able to explain the basic concept of polymer characterization and properties with particular emphasis on molecular weight determination, morphologies, and thermal, mechanical and rheological properties. 4. Students will be able to describe the characteristic behavior of polymers in solution, solid and molten state. 5. Students will be able to broaden their perspective from examples of polymer researches in various real-life application.
102764	Selected Topics in Applied Chemistry I	3(3-0-9)	Consent of the School of Chemistry	Selected topics of current interests in applied chemistry.	1. Students will be able to explain principles of the selected topics of current interest in organic chemistry. 2. Students will be able to apply the selected topics to related research in literature.
102765	Selected Topics in Applied Chemistry II	3(3-0-9)	Consent of the School of Chemistry	Selected topics of current interests in applied chemistry.	1. Students will be able to explain principles of the selected topics of current interest in organic chemistry. 2. Students will be able to apply the selected topics to related research in literature.
102766	Frontiers in Applied Chemistry I	3(3-0-9)	Consent of the School of Chemistry	Topics of current interest leading to frontiers in applied chemistry of the future.	1. Students will be able to explain the academic and industrial trend related to applied chemistry. 2. Students will be able to describe the basic principle of the theory leading to the development of the applied chemistry frontier. 3. Students will be able to predict the trend in applied chemistry being developed in the future.

Courses	Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
102767 Frontiers in Applied Chemistry II	3(3-0-9)	Consent of the School of Chemistry	Topics of current interest leading to frontiers in applied chemistry of the future.	1. Students will be able to explain the academic and industrial trend related to applied chemistry. 2. Students will be able to describe the basic principle of the theory leading to the development of the applied chemistry frontier. 3. Students will be able to predict the trend in applied chemistry being developed in the future.
Seminar Course				
102981 Seminar I	1(0-1-9)	102712 Scientific Writing and Presentation or Consent of the School of Chemistry	Students demonstrate an understanding of a chemistry-related topic of interest. Students are encouraged to study at least one chemistry-related paper, write an abstract, deliver a presentation and discuss with instructors and audiences in English.	1. Students will be able to think critically and be able to express their thought. 2. Students will be able to communicate scientifically through discussions, presentations and debates.
102982 Seminar II	1(0-1-9)	102981 Seminar I	Students demonstrate an understanding of their thesis. Students are encouraged to study at least two thesis-related papers, write an abstract, deliver a presentation and discuss with instructors and audiences in English.	1. Students will be able to think critically, evaluate, solve problems and express their thought. 2. Students will be able to communicate scientifically through discussions, presentations and debates.