First Year

First Semester			
Course Code[**]	**Course Title**	**Ct**	**Crt**
CHEM 7x1 or 7x2	Core Course 1 (M.F)	3	3
CHEM 7xx	Elective Course – n1	3	3
CHEM 701	Teaching	1	0
CHEM 702	Ethics[*]	1	0
CHEM 703	Safety in the Laboratory[*]	1	0
CHEM 704	Chemical Literature[*]	1	0
CHEM 790	Research Rotation 1	3	0
		13	6

[*]*For students who have not taken this course in Master Degree*

[**]*x: 1 for Organic, 2 for Inorganic, 3 for Physical, and 4 for Analytical*

n: refers to the other fields except the specialty

Second Semester			
Course Code	**Course Title**	**Ct**	**Crt**
CHEM 7x1 or 7x2	Core Course 2 (M.F)	3	3
CHEM 7xx	Elective Course – n2	3	3
CHEM 701	Teaching	1	0
CHEM 791	Research Rotation 2	3	0
		10	6

Second Year

Third Semester			
Course Code	**Course Title**	**Ct**	**Crt**
CHEM 8xx	Elective 1 (M.F)	3	3
CHEM 8xx	Elective Course - n3	3	3
CHEM 801	Scientific Communication	1	0
CHEM 890	Advanced Pre-Dissertation Research 1	3	0
		10	6

Fourth Semester			
Course Code	**Course Title**	**Ct**	**Crt**
CHEM 8xx	Elective 2 (M.F)	3	3
CHEM 801	Scientific Communication	1	0
CHEM 891	Advanced Pre-Dissertation Research 2	3	0
CHEM 892	Original Research Proposal	1	0
		8	3

Third Year

Fifth Semester			
Course Code	**Course Title**	**Ct**	**Crt**
CHEM 990	Ph.D. Dissertation		21

Sixth Semester			
Course Code	**Course Title**	**Ct**	**Crt**
CHEM 990	Ph.D. Dissertation		-
			21
Total Credits			**42**

V. Courses List

V.1 Core Courses – المقررات الاساسية

Organic	
Chem 711	Physical Organic Chemistry
Chem 712	Spectroscopic Organic Structure Determination
Inorganic	
Chem 721	Advanced Inorganic Chemistry I
Chem 722	Advanced Inorganic Chemistry II
Physical	
Chem 731	Quantum, Structure and Dynamics I
Chem 732	Chemical Thermodynamics
Analytical	
Chem 741	Separation Techniques
Chem 742	Spectroscopic Analytical Techniques

V.2 Elective Courses – المقررات الاختيارية

Organic	
Chem 811	Advanced Organic Chemistry I
Chem 812	Advanced Organic Chemistry II
Chem 813	Advanced Synthetic Chemistry
Chem 814	Selected Topics in Organic Chemistry
Inorganic	
Chem 821	Inorganic Chemistry Synthesis
Chem 822	Radiations and nuclear chemistry
Chem 823	Group theory and their applications
Chem 824	Selected Topics in Inorganic Chemistry
Physical	
Chem 831	Chemical Kinects and Reaction Dynamics
Chem 832	Statistical Thermodynamics
Chem 833	Quantum, Structure and Dynamics II
Chem 834	Selected Topics in Physical Chemistry
Analytical	
Chem 841	Environmental Analytical Chemistry
Chem 842	Electroanalysis Chemistry
Chem 843	Bioanalytical Chemistry
Chem 844	Selected Topics in Analytical Chemistry

V.3 Applied Courses – المقررات التطبيقية

Chem 970	Applied X-Ray structure determination
Chem 971	Applied mass spectroscopy: fundamental, instrumentation and techniques
Chem 972	Applied spectroscopic methods of structure determination
Chem 973	Applied quantitative methods of computational chemistry
Chem 974	Applied physical methods of inorganic chemistry
Chem 975	Applied separations
Chem 976	Applied NMR techniques
Chem 977	Applied statistics and Data analysis
Chem 978	Applied Phys. Meth. Material Chem
Chem 979	Applied scientific presentations
Chem 980	Applied research techniques
Chem 981	Applied mathematics in physical chemistry

VI. Scientific contents of the program courses

VI.1. Core courses

Organic Chemistry Track

Physical Organic Chemistry Chem 711

The goal of this course is to mediate the principles of the relationships between structure and reactivity of organic molecules. These will include a review on structure, energy, and solvation and the influence of substituents on reactivity and activity; steric effects, stereo electronic effects, conformation analysis, orbital symmetry, thermodynamics and kinetics The course is designed to dissect the different forces of molecules to increase the understanding of reactivity. This knowledge will help the organic chemistry student to pick appropriate solvents and reactants for chemical conversion and stimulate new ideas applicable for their research. The student will have the opportunity to present an important topic of physical organic chemistry. Additionally, we will discuss selected chemistry and biochemistry highlights.

Spectroscopic Organic Structure Determination Chem 712

This course covers advanced applications of modern techniques of spectroscopy used in structural elucidation of complicated organic compounds including Near-IR; MS; solid and liquid NMR (1D, 2D and 3D). This course will discuss also diffuse reflectance UV-Vis and advanced applications.

Inorganic Chemistry Track

Advanced Inorganic Chemistry I Chem 721

This course offers students comprehensive studies in advanced inorganic chemistry fields. The course offers an advanced overview for f-block elements and discuss the magnetism and magnetic materials, put many advances in perspective and allow the students to make connection to related fields; advanced physical methods for materials chemistry studies, coordination complexes and coordination kinetics-thermodynamics. The course maintains advanced perspectives in the fields of catalysis and biological inorganic chemistry as well.

Advanced Inorganic Chemistry II Chem 722

This course offers students comprehensive review in advanced chemistry of inorganic materials which serves to put many advances in perspective and allow the students to make connection to related fields, such as, magnetic materials, conductive materials

and nanostructured inorganic materials. The course presents the students the recent developments in inorganic chemistry.

Physical Chemistry Track

Quantum Structure and Dynamics I Chem 731

This is the first of a two-part course in Quantum, Structure and Dynamics. This course focuses on the essential principles, concepts and applications of electronic structures, quantum mechanism and quantum dynamics.
It covers several topics including fundamental concepts, methods of Quantum Mechanics, Quantum theories, Ab initio Methods, Hartree-Fock, Post Hartree-Fock, Moller-Plesset Theory, Coupled Cluster Theory, Density Functional Theory, Semi-empirical methods, group theory, applications of electronic structure theory, time dependent quantum mechanics, and time dependent approach to spectroscopy.

Chemical Thermodynamics Chem 732

This course intends to train the students in the application of the concepts to problems that are commonly encountered by the chemist. The mathematical tools that are necessary for this purpose are considered in more detail than is usual. In addition, solving thermodynamic problems using computer simulations, graphical, numerical, and analytical, are described fully and are used frequently, both in illustrative and in assigned problems.

Analytical Chemistry Track

Separation Techniques Chem 741

- Provides students with a solid grounding in the theory of chromatography, important considerations in its application, and modern instrumentation.
- Highlights the primary variables that students can manipulate, and how those variables influence chromatographic separations.
- Explain the application of chromatographic methods to actual, complex chemical samples.

Spectroscopic Analytical Techniques Chem 742

Instrumental analysis is divided into three branches; spectroscopy, electrochemistry and chromatography. This course is mainly based on spectroscopic instrumentation (Vis/UV, IR, AAS, ICP-OES, and ICP-MS) and analysis. The interaction of electromagnetic radiation with the matter in its state (gas, liquid and solid). The interaction will characterized as absorption, emission, refraction and scattering.

Contents including fundamental theory, application and methods development will be widely covered throughout the course.

VI.2. Elective courses

Organic Chemistry Track

Advanced Organic Chemistry I Chem 811

This course will focus on a deeper understanding of the structure and reactivity of organic molecules with an emphasis on reaction mechanisms. It is a review of aspects of organic chemistry, covering pericyclic reactions, aldol additions and condensation reactions, advanced nucleophilic substitution, photochemistry, as well as introduction about the generation of free radicals.

Advanced Organic Chemistry II Chem 812

The course covers several topics with the focus mainly the following areas: Methods for functional group interconversion by Substitution Including Protection and Deprotection, Generation, properties and alkylation of Enolates and Other Carbon Nucleophiles, Reactions Involving Carbocations, Carbenes, and Radicals as Reactive Intermediates.

Advanced Synthetic Chemistry Chem 813

1.This course covers the advanced principles of retrosynthetic analysis and the chemistry of protecting groups.

2.This course describes the natural products; their classes include (carbohydrates, peptides, proteins, nucleosides, nucleotides, nucleic acids, terpenes, alkaloids) and structures and biosynthesis.

Selected Topics in Organic Chemistry Chem 814

The objective of this course is to explore selected topics about the latest advancements in the field of Organic Chemistry; without obligation that these topics will related to the research area of the dissertation. As proposed topics:

1. Polymer for Advanced Technology

This course will focus on the polymer structure–property relationships that are based on well-known

basic chemistry and physical relationships. Because such relationships build on one another you need to study in an ongoing manner. This course depends on firm foundations in all the core areas of chemistry. Each chapter emphasizes knowledge from one or more of these areas.

2. Biochemistry of Free Radicals and Antioxidants

Generation of free radicals and reactive species, the phenomenon of free radicals toxicity, the mechanisms of oxidative degradation of the biomolecules by free radicalsand the subsequent pathological changes; and the mechanisms of the antioxidant molecules in their elimination

Inorganic Chemistry Track

Inorganic Chemistry Synthesis Chem 821

The course is an up-to-date review of the area of Inorganic Synthesis, providing the detailed foolproof information needed by lab chemists on procedures for the preparation of important and timely inorganic compounds. Inorganic chemistry synthesis, deals with synthesis and preparative chemistry under specific conditions: high temperature, low temperature and cryogenic, hydrothermal and solvothermal, high pressure, Chemical Vapor Deposition (CVD), photochemical and microwave. Synthesis of functional inorganic aggregates is discussed giving special attention to the assembly of nanomaterials.

Radiations and Nuclear Chemistry Chem 822

The course aims at acquiring the PhD students an advanced knowledge of nuclear chemistry and radiation chemistry, and nuclear chemistry and discuss the evidence for shell structure in nuclei. This course maintains the isotopes and the chart of nuclides, in addition, explain the precision mass spectrometry. Describe the radioactive decay and spontaneous nuclear transformation. Understand of the Fermi gas, shell, Nilsson and macroscopic–microscopic model. Describe the short-lived elementary particles in atoms and molecules and explain production of radionuclides, measurement of nuclear radiation, nuclear reactors and accelerators.

Group theory and their Applications Chem 823

The course provides the Ph.D. students advanced knowledge of several topics in symmetry and its role in chemistry. We will discuss point group theory and develop an understanding of the mathematical basis of symmetry and how this can simplify understanding the physical and chemical properties of molecules. We will apply this knowledge to understand the molecular vibrations (IR and Raman) of the molecules and their spectra, followed by several topics so that students can understand the advanced applications to chemical bonding and ligand field theory, and larger systems such as crystals as well as the use of symmetry in Nuclear Magnetic Resonance..

Selected Topics in Inorganic Chemistry Chem 824

The objective of this course is to explore selected topics about the latest advancements in the field of Inorganic Chemistry; without obligation that these topics will related to the research area of the dissertation. As proposed topics:

1.Green chemistry:

This course highlights the potential and scope of green chemistry for clean and sustainable development. The course introduces many applications and benefits and advantages of environmentally friendly chemical practice and application in industry. The ecologically safe products, catalysts and solvents, conditions needed to produce such products, types of chemical processes that are conducive to green chemistry will be introduced.

2.Advanced inorganic materials:

This course includes the preparation of solid-state inorganic materials by chemical processing techniques. It also expands upon new chemical precursors available to materials scientists, the applications of those materials, and existing or emerging topics where materials chemistry plays an important role, such as in microelectronics, surface science, and nanotechnology. The characterization techniques and structure-property relationships, and materials classifications based on type and applications, including electronics, biomaterials, thin films, and coatings will be maintained.

Physical Chemistry Track

Chemical Kinects and Reaction Dynamics Chem 831

It focuses on advanced concepts of Chemical Kinetics. It covers flow techniques, theories of reaction mechanism. It also concentrates on the details of the reaction dynamics (molecular scattering, potential Energy Surface, classical dynamics and molecular energy transfer).

Statistical Thermodynamics Chem 832

This course will cover the subject of statistical thermodynamics. The course will mainly focus on system in equilibria. We explore the general principles, from which emerge an understanding of the microscopic significance of entropy and temperature. We develops methods of quantum statistics and use them to calculate observable properties of systems in thermodynamic equilibrium. Topics treated include the principles of thermodynamics, canonical ensembles for quantum mechanical system, partition functions, chemical equilibrium. We consider a range of applications of quantum statistics. The course will elucidate the relation between thermodynamics and statistical mechanics, which are essential ingredients of many fields of physical chemistry and related science.

Quantum Structure and Dynamics II Chem 833

This is the second of a two-part course in Quantum, Structure and Dynamics. This course focuses on the advanced quantum chemical methods and applications in various fields, as well as group theory applications. It covers Monte Carlo method, Principles of Molecular mechanics, Born-Oppenheimer approximation, Principles of Molecular dynamics, Group theory and molecular electronic states, Molecular orbital theory and its applications, Spectroscopy – interaction of atoms and molecules with light, Applications of quantum dynamics in spectroscopy, Group Theory and its

application to the Quantum Mechanics, Applications of group theory to structure, chemical bonding, molecular systems, and spectroscopy. In addition, it presents usage and application of Quantum Mechanics and Dynamics in biological, materials science, and chemical systems in order to understand the experimental results.

Selected Topics in Physical Chemistry Chem 834

The objective of this course is to explore selected topics about the latest advancements in the field of Physical Chemistry; without obligation that these topics will related to the research area of the dissertation. As proposed topics:

1- Advanced Electrochemistry

The course is divided into three parts. Fundamentals: this covers potential and thermodynamics of electrochemical cells, kinetics of electrode reactions, mass transport, electron transfer and electrical double layer. The electrolyte solutions and transport in solutions will also be covered in this part. Electrochemical Methods: this covers the basic technics in electrochemistry including potentiostatic and galvanostatic methods, cyclic voltammetry and electrochemical impedance spectroscopy. Applications: this covers, and not limited to, one or more of the following applications: electrochemical energy systems (batteries and fuel cells), corrosion phenomena and corrosion prevention, electrochemical device for water treatment.

2- Surface Chemistry and Catalysis

The course describes the physical chemistry of reactions on solid surfaces as they relate to current problems in heterogeneous catalysis. Experimental techniques, methods and data analysis used in modern surface chemistry research. The course links between surface chemistry and methods for the catalysts characterizations. The course covers fundamental and applied aspects of molecular adsorption/desorption, kinetics, surface analysis and instrumentation. Moreover, the course covers up-to-date applications of heterogeneous catalysis, especially green conversions and sustainable energy production.

3- Computational Chemistry

Topics will include platform choice, operation systems, systems requirements and installation of softwares. Additionally, modeling the behavior of chemical systems with emphasis on hands on experiments. Various properties of interests would be calculated by advanced quantum chemical approaches. The focus would be on structure-property relationship, photophysical, electronic, thermodynamical, structural, and charge transfer properties at molecular and bulk scales by density functional theory, time dependent density functional theory, molecular mechanics, molecular dynamics and accessible quantum chemical methods. Problems addressed will include topics in advanced functional materials, solar cells, energy minimization, molecular mechanics, molecular dynamics, spectroscopy prediction, charge transfer, electronic, optical, solid state bulk level, and biological systems.

Analytical Chemistry Track

Environmental Analytical Chemistry Chem 841

This course is aimed to emphasize the concepts essential to the practice of environmental science, technology and chemistry while introducing the newest innovations in the field. The relationship of environmental chemistry to the key concepts of sustainability, industrial ecology and green chemistry is also considered.

Electroanalysis Chemistry Chem 842

Identifying the advanced techniques of Spectrophotometric Analysis Describing the different methods of Electrochemical Analysis Indicating the main components of spectrophotometrs, types of electrodes and cells used for potentiometric, conductometric, voltametric, polarographic, and amperometric analysis Analyzing UV and Visible spectra and chromatograms Solving some of spectrophotometric and electrochemical problems.

Bioanalytical Chemistry Chem 843

The contents of this course includes Quantitative Instrumental Measurements; Spectroscopic Methods for the Quantitation of Classes of Biomolecules; Enzymes and Quantitation of Enzymes and Their Substrates; Biosensors; Design of Macromolecular Reagents; Image-Based Bioanalysis; Electrophoresis; Centrifugation Methods; Chromatography of Biomolecules; Mass Spectrometry of Biomolecules; Micro-TAS, Lab-on-a-Chip, and Microarray Devices and Validation of New Bioanalytical Methods.

Selected Topics in Analytical Chemistry Chem 844

The objective of this course is to explore selected topics about the latest advancements in the field of Analytical Chemistry; without obligation that these topics will related to the research area of the dissertation. As proposed topics:

1.Food Analysis:

The food analysis topic will be applied to illustrate the principles of selection and applying the advanced methods and techniques for chemical analysis to analyze the major, trace and the chemical contaminates residues constituents in the different types of foods, including studying the sample treatment techniques, data validation and analysis. Applying the Quality control and Quality Assurance programs for the applied method of analysis. The course will cover analysis of Fat, Protein, Carbohydrate, Vitamins, Antioxidant, trace metals, Food additives and total phenolic and pesticides contaminates residues. Comparison between the different approved and well-established standard methods of food analysis also will be studied.

2.Drug Analysis and Forensic Chemistry Applications:

In this topic, definition and classification to the different types and categories of drugs (Acidic Drugs, Basic Drugs, Alkaloids and Nonalkaloids) and its chemistry and absorption in the body will be studied. In addition to applying the advanced methods and techniques for qualitative and quantitative analysis of drugs in the different formulations. Applying the Quality control and Quality Assurance programs for the

applied method of analysis. The topic also will be covering the forensic chemistry analysis for drugs, toxic, explosive, Inks and paints materials.

VII. Scientific contents of the required Miscellaneous Courses

Chem 701 Teaching (for two semesters)

This course is associated with the study of the different science teaching methods including the teacher centered, learner centered, content focused and interactive methods. Students enroll for 2 units of Chemistry during the semesters in which they serve as teaching assistants.

Chem 702 Ethics

The course addresses the most important ethical concepts, theories, questions and rules of relevance to chemistry research in all its aspects including normative ethics, research ethics and ethical issues related to risk assessments. The course will convey different concepts to make students familiar with the role of chemistry in society, the ethical problems related with chemistry and the ethical responsibilities of chemists.

Chem 703 Safety in the laboratory

This course is based on basic safety measures and basic standards in laboratory at University level. To enhance the knowledge of students for effective practicing the health and safety's regulations in Chemistry laboratories. In addition, students will develop their skills of the daily practice related to health and safety in laboratory. Moreover, students will be trained on real laboratory's situation and how to react and response to such situation.

Chem 704 Chemical literature

A survey of the tools employed for the effective and efficient search and the retrieval and analysis of chemical information including online databases, chemical abstracts, patents, handbooks, encyclopedias, and comprehensive works. Types of information in technical publications; exercises in finding, assembling, and using such data.

Chem 801 Scientific Communication (2^{nd} year)

First term: The course objective is to teach students how to evaluate and begin to write scientific documents, specifically a journal paper. It covers a wide range of topics such as literature searching using online databases, components of abstracts and construction of hypotheses. The course also prepares graduate students for written part of Research Rotation I.

Second term: This course is a continuation of Scientific Communication I. It specifically concentrates on various aspects of preparing and writing a scientific research proposal and an original research proposal. The course also prepares graduate students for the written and oral portions of Research Rotation II.