

**Doctor of Philosophy in Chemistry**  
**Program code: 042070**

***INTRODUCTION***

The Department of Chemistry (College of Science) offers a Ph.D. program in Chemistry. A graduate successfully completing this program will be expected to have an in-depth knowledge in specific areas of Chemistry. In addition, he/she would be trained to become an independent thinker, planner and executor of specific ideas relevant to Chemistry. A major part of the program is the dissertation, which requires high quality research in a specific area of Chemistry.

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***PROGRAM REQUIREMENTS***

**33 TOTAL COURSE CREDITS**

**9 COMPULSORY (3 credits each)**

- 0420-620 Advanced Topics in Physical Chemistry
- 0420-641 Selected Topics in Advanced Inorganic & Analytical Chemistry
- 0420-651 Advanced Organic Chemistry -II

**6 ELECTIVES\* (3 Credits each)**

- 0420-611 Catalytic Chemistry
- 0420-621 Thermo Chemistry of Solids
- 0420-622 Colloid and Surface Chemistry
- 0420-623 Photo-Electrochemistry & Solar Energy Conversion
- 0420-625 Structure and Bonding
- 0420-626 Molecular Modeling
- 0420-627 Corrosion and Protection of Metallic Materials
- 0420-628 Surfactant Science
- 0420-642 Bio-Inorganic Chemistry
- 0420-643 Advanced Chemistry of Coordination Compounds & Homogeneous Catalysis
- 0420-644 Physical Methods and Data Analysis in Inorganic Chemistry
- 0420-652 Non-Thermal Reactions in Organic Chemistry
- 0420-653 Advances in Organic Synthesis

\* Students may substitute up to 3 credit hours from the (500 level) graduate courses offered by the Master Program of Chemistry and which has not been previously studied by the student with the approval of Program Director.

**18 COMPULSORY COURSES**

- 0420-697 Dissertation (0)
- 0420-698 Dissertation (0)
- 0420-699 Dissertation (18)

## ***COURSE DESCRIPTION***

### **0420-611: CATALYTIC CHEMISTRY CR: 3**

Catalysis in solution: Acid-base catalysis by electron transfer, organometallic catalysis, catalysis by macromolecules, phase transfer catalysis, and catalysis by micelles. Catalysis by enzymes: Composition and structure of enzymes, reactions catalyzed by enzymes, nature of catalytic sites, and supported enzyme catalysts. Catalysis by polymers: The nature of polymers, catalysis by polymer gels, kinetics of polymer-catalyzed reactions, bi-functional and multi-functional catalysis, porous polymers and surface catalysis, and applications of polymer catalysts. Catalysis in molecular-scale cavities: Structure of crystalline solids, structure of zeolites, families of zeolites, adsorption and diffusion in zeolites, the solvent-like nature of zeolite pores, catalysis by zeolites. Catalysis on surfaces: surface structure, adsorption, surface catalysis, industrial catalysis, and catalytic surfaces.

### **0420-620: ADVANCED TOPICS IN PHYSICAL CHEMISTRY CR: 3**

Chemical Kinetics, quantum Chemistry, electrochemistry, colloid and surface chemistry, molecular spectroscopy, macromolecular chemistry, nanoparticles and nanotechnology, and other topics.

### **0420-621: THERMOCHEMISTRY OF SOLIDS CR: 3**

Heterogeneous equilibria: Generalization of equilibrium conditions, thermodynamic properties of substances, energy balance, thermodynamics of phase changes and chemical reactions, and thermodynamics of interfaces. Study of equilibrium states by methods of thermal analysis: Calorimetric measurements, measurements of other thermo-physical properties, direct investigations of equilibria (condensed state, solid-gas equilibria, solid-liquid equilibria), and calculation of standard enthalpy changes of phase transitions from phase diagrams. Theory of kinetics and mechanism of solid state heterogeneous processes: Types of processes, activated state concept, homogeneous-like descriptions of heterogeneous processes, physico-geometrical description of heterogeneous processes, and molecular description of heterogeneous processes. Study of kinetics under non-isothermal conditions: Fundamental problems,

methods of kinetic data evaluation, study cases, kinetic parameters by differential thermal measurements.

### **0420-622: COLLOID AND SURFACE CHEMISTRY CR: 3**

1. The Colloidal State: Classification of colloidal systems, structural characteristics, preparation and purification of colloidal systems.
2. Kinetic properties: Brownian motion, osmotic pressure.
3. Optical Properties: Optical and electron microscope, light scattering.
4. Surfaces and interfaces: General concepts: surface free energy, the molecular nature of interfacial region, the Gibbs surface energy, adsorption, the Gibbs adsorption equation.
5. Liquid-gas and liquid-liquid interfaces: Surface and interfacial tension. orientation at interfaces, surfactant and the reduction of surface tension, micelle formation, spreading, mono-molecular films.
6. Charged interfaces: The electric double layer, electro-kinetic phenomena and electro-kinetic theory.
7. Colloidal stability: DLVO theory, reversible flocculation and secondary minimum, kinetic of coagulation, steric stabilization. depletion flocculation,. solvent effects in steric stabilization.
8. Rheology: Viscosity, non-Newtonian flow viscoelasticity.
9. Emulsions: Formation and stability, surfactants, emulsion type. The Hydrophilic-Lipophilic Balance (HLB),. multiple emulsions, microemulsion.
10. Foams
11. Industrial importance of colloids: Medical and pharmaceutical. applications in food industry, cosmetic emulsion.

### **0420-623: PHOTO-ELECTROCHEMISTRY & SOLAR ENERGY CONVERSION CR: 3**

Introduction: The sun: ultimate origin of most of the energy available, heat energy wind-hydroelectric power. fossil fuels, radioactivity, sun model.

Semiconductors: Origin of semi-conductivity, types of semiconductors, mechanism of excitation, temperature effects. Photo effects, examples and problems.

Photovoltaic effects: The p-n junction, current transport phenomena, forward current, reverse saturation current, the junction photovoltaic, electronic model, mechanism of energy conversion. Schottky barrier solar cells: SIS, SIM cells, SnO solar cells, principle of operation, current transport, improvement of the characteristics for practical applications.

Spectral responsivity of the photocurrent: Maximum theoretical efficiency of a solar cell, solar arrays and systems, examples and problems.

Semiconductor electrochemistry: Semiconductor/electrolyte interface, energy barrier and redox potentials, principle of photoelectrochemical energy conversion.

Photoelectrochemical cells: Different types, applications.

Photoelectrochemical semiconductors: Advantages and disadvantages of photoelectrochemical cells, corrosion of semiconductors, stabilization of semiconductors, applied systems.

**0420-625: STRUCTURE AND BONDING**  
**CR: 3**

Introduction to atomic structure and molecular properties and Valence bond theory; the molecular orbital theory of electronic structures and the spectroscopic properties of diatomic molecule; electronic structures; photoelectronic spectroscopy and frontier molecular orbital theory of reactions of polyatomic molecules; bonding in solids and liquids; correlation diagram; Walsh diagram (triatomic); Polyatomic molecules: Huckel theory, Woodward-Hoffman rules, Bond theory of solids; insulators and semiconductors.

**0420-626: MOLECULAR MODELING**  
**CR: 3**

Building and Visualizing molecules; building small and large molecules and coordination complexes; Molecular geometry and properties; bond length and angles; electron affinity; structure stability relationship; molecular orbitals and bonding; formation of MO; Walsh diagram; Jahn-Teller Effect; conformational analysis; small and large conformation analysis; inversion barrier in ammonia; thermodynamics; heat of formation; combustion; hydrogen bonding; steric effects tautomerism; resonance energy; charge distribution; dipole moment, charge transfer and excited states; spectroscopy, UV, vibrational spectra; solvent effects n spectra; molecular dynamics; stability of carbocations; conformation

searches; stimulated annealing; Langevin dynamics and intramolecular vibration.

**0420-627: CORROSION AND PROTECTION OF METALLIC MATERIALS**  
**CR: 3**

Electrochemical equilibria, free energy calculations, phase diagrams, grain boundaries, inclusion, crystal structure, diffusion in solids, electrical double layer, thermodynamics and kinetics of electrode reactions.

**0420-628: SURFACTANT SCIENCE**  
**CR: 3**

Micellization and surfactants absorption at interfaces; liquid crystals, emulsion and microemulsions; thin films and foams; Rheology of surfactant solutions; Self-assemblies as templates for nanoparticles and porous materials; characterization of self-assemblies systems; Industrial applications; relevant legislation.

**0420-641: SELECTED TOPICS IN ADVANCED INORGANIC AND ANALYTICAL CHEMISTRY**  
**CR: 3**

**Part (I) Inorganic Chemistry**

1. Solid state chemistry
2. Mechanism of inorganic reactions.
3. Chemical crystallography
4. Organometallic Chemistry
5. Advanced inorganic spectroscopy
6. Advanced magnetochemistry

**Part (II) Analytical Chemistry**

1. Analytical spectroscopy
2. Electrochemical methods
3. Separation methods

**0420-642: BIO-INORGANIC CHEMISTRY**  
**CR: 3**

1. The identification of the functions of metal ions and main groups compounds in biological systems. The chemistry of model and isolated biological compounds.
2. Study of metalloproteins and other metal-containing biological molecules.
3. The transition metals in biological redox reactions.
4. Nitrogen fixation.
5. The biochemistry of iron.
6. Metal ions and chelating agents in medicine

**0420-643:    ADVANCED CHEMISTRY OF  
COORDINATION COMPOUNDS  
AND HOMOGENEOUS CATALYSIS  
CR: 3**

**Part (I)**

1. Review of the chemistry of transition and inner transition elements.
2. Theories of bonding.
3. Structure and reactivity
4. Coordination compounds in biological systems.

**Part (II)**

1. Theories
2. Homogeneous and heterogeneous catalysis
3. Recent developments

**0420-644:    PHYSICAL METHODS AND DATA  
ANALYSIS IN INORGANIC  
CHEMISTRY  
CR: 3**

**Part (I)**

1. Physical methods in inorganic chemistry.
2. Nuclear magnetic resonance. Mossbauer effect, optical rotary dispersion and circular dichroism, electron paramagnetic resonance, nuclear quadrupole resonance and photoelectron spectroscopy.
3. Theoretical principles and applications of physical methods relevant to characterization and organometallic compounds.

**Part (II)**

The application of mathematical and statistical techniques to chemical measurements. These applications include the theory of single detection, filtering and smoothing, curve fitting, uni- and multi-component calibration and analysis.

**0420-651:    ADVANCED ORGANIC  
CHEMISTRY - II  
CR: 3**

Specific and general acid and base catalysis. Enzyme mimics and catalysis. Stereoelectronic effects. Treatment of steric effects. T.S. recognition and molecular recognition processes. Physical organic chemistry of macromolecular systems and supermolecular assemblies. Structure/reactivity correlation analysis with emphasis on LFER. Interpretation of isotope effects. Non-catalytic thermal gas-phase free radical and molecular processes. Organic reactions involving carbocations, carbanions, and radical cations and anions; tautomerism; resonance energy; charge; charge distribution.

**0420-652:    NON-THERMAL REACTIONS IN  
ORGANIC CHEMISTRY  
CR: 3**

1. Photochemistry
2. Sonochemistry
3. Biotransformations

**0420-653:    ADVANCES IN ORGANIC  
SYNTHESIS  
CR: 3**

1. Organometallics in Synthesis
2. Free radicals in organic chemistry
3. Asymmetric synthesis
4. Classical and modern natural products total synthesis.
5. Computer assisted routes to organic synthesis

**0420-697: DISSERTATION  
CR: 0**

**0420-698: DISSERTATION  
CR: 0**

**0420-699: DISSERTATION  
CR: 18**