POST GRADUATE COURSES

Chem 6000: Thesis

Ph.D. : 45 Credits

M Phil. : 30 Credits

M.Sc. : 18 Credits

Organic Branch

Chem 6001: Chemistry of Natural Products
3.00 Credit (3 hrs/wk)

Terpenes: Chemistry of important terpenes from various groups, e.g., Humulene, Germacrone etc. Alkaloids: Structure and synthesis of some important alkaloids. Steroids: Synthesis, spectral properties, configuration and reactions of steroids, hormones, growth regulators, biosynthesis of sterols.

Chem 6002: Chemistry of Biomolecules
3.00 Credit (3 hrs/wk)

Amino acids, structure and bio-synthesis of proteins, purines, nucleic acids and nucleoproteins. Fundamental role of nucleic acids in life processes, structures of DNA and RNA and their function, lipids and phospholipids.

Chem 6003: Organic Reagents in Synthesis
3.00 Credit (3 hrs/wk)

Use of some of the more important organic and inorganic reagents in organic synthesis. Exercises in the synthesis of C-C, C-O, C-X, C-N, C-S and C-P bonds. Exercises in the synthesis of complex molecules of nature.

Chem 6004: Carbohydrate Chemistry
3.00 Credit (3 hrs/wk)

Configuration assignments and conformational analysis of mono and disaccharides. Use of optical methods including Hudson's rule of isorotations and Lactone rule. Reactions of sugars including their actions with acids and bases. Esters, ethers and acetals of sugars. Anhydro-sugar, branched chain sugar, unsaturated sugar, deoxy-sugar and polyamine sugar. Polysaccharides: Structural investigation and group analysis, Barry and Smith degradation, molecular weight determination etc. Amylose and amylopectin, cellulose, hemicullulose, glycogen and inulin. Sulphated polysaccharides and marine algal polysaccharides.

Chem 6005: Spectroscopy and Structure of Organic Molecules
3.00 Credit (3 hrs/wk)

UV Spectroscopy: Principle of measurement, electron excitation, simple chromophore groups, conjugated systems and aromatic systems. IR spectroscopy: Vibration spectra, factors affecting IR frequencies and applications. NMR spectroscopy: Introduction, nuclear overhauser effect, shift reagents, dynamic polarization and interpretation of the spectral data. Mass spectrometry: Theory, spectrometer and application to structure determination of organic molecules. Application of all the spectroscopic

methods in following the progress of reactions by diagnostic appearance and disappearance of functional groups in organic compounds and also in characterizing the products. Application of spectroscopy in the elucidation of the structure of organic compounds.

Chem 6006: Advanced Organic Reaction Mechanism
3.00 Credit (3 hrs/wk)

Structure and bonds in organic molecules, localised and nonlocalised bonds in terms of molecular orbital theory. Orbital symmetry and chemical reactions, electrocyclic, cyclo-addition and sigmatropic reaction. Free radical reactions: mechanism of free radical reactions in substitution, addition, rearrangement and oxidation reactions. Photochemical reactions; isomerization and molecular rearrangement.

Chem 6007: Advanced Stereochemistry
3.00 Credit (3 hrs/wk)

(i) Symmetry elements, point groups (ii) Optical activity - its origin, atomic and conformation asymmetry (iii) Variation of optical activity with wave length. Optical rotatory dispersion and circular dichroism curves and their application in determining the configuration and conformation of different compounds (iv) Conformational analysis, reactivity of alicyclic, cyclic, fused and bridged ring systems. Curtin Hammet principle and its application in determining the course of reaction in different compounds (v) Tricovalent carbon (vi) Optical activity due to atoms other than carbon.

Chem 6008: Kinetic and Energetics of Organic Reactions
3.00 Credit (3 hrs/wk)

(i) Thermodynamic considerations and study of energetics of organic reactions, kinetics of organic reactions, consecutive reactions, the steady state approximation, parallel reactions, entropy of activation in conjunction with energy of activation particularly in reactions leading to cyclisation (ii) Variation in kinetics in acid and base catalyzed reactions, microscopic reversibility, correlation of reaction rates and equilibria (iii) Solvent effects (iv) Isotopic effects (v) Linear free energy relationship (vi) Application of the above concepts to substitution, addition and elimination reactions.

Chem 6009: Organo-Metallic Chemistry
3.00 Credit (3 hrs/wk)

Nature of carbon metal bonding systems, structures and reactions of organo-metallic compounds. Organo-metallic reagents in organic synthesis. A general introduction to the types and nature of carbon metal bonding systems. Structures and reactions of:

a. The alkali metal organo-metallic with special reference to organo-lithium.
b. The alkaline earth metal compounds with special reference to organo-magnesium reagents.
c. The main group (IV) organo-metallics with special reference to organosilicon compounds.
d. Organic compounds of transition metals: Reactions, structure, nature and stability etc. of complexes.
e. A brief study of organo-phosphorus, antimony and bismuth compounds.

Chem 6010: Chemistry of Heterocyclic Compounds
3.00 Credit (3 hrs/wk)

Types of hetero-atomic structures, criterion of hetero-aromaticity, concept of

abundancy and deficiency. Reactivity of hetero-atoms, role of hetero-cycles and hetero-atoms as substituent and conductor of electronic effect. Chemistry of three, four and five membered hetero-cycles, condensed five membered hetero-cycles, five-membered ring hetero-cycles with more than one hetero-atom. Pyridine, quinoline and isoquinoline compounds. Addition to the cyano group to form heterocycles, tautomerism in purines, hydroxythiophene and hydroxy furan systems. Synthesis of heterocycles involving cyclo-addition reactions, heterocycles of biological interest.

Chem 6011: Biogenesis and Biosynthesis of Natural Product
3.00 Credit (3 hrs/wk)

Introduction to primary and secondary metabolites, precursors. Methods used in study of biosynthesis, chemical speculation, seasonal variation, organisms with blocked biosynthesis pathways, feeding experiments, measurement of the efficiency of precursors and studies with enzymes, feed back and other regulatory mechanisms.

Acetongenins-construction of acetate hypothesis, biosynthesis of saturated, unsaturated, fatty acids, polyacetylenes and aromatic polyketides. Isoprenoids-biosynthesis of mevallanat, the biological isoprene unit, alkylation of non-isoprenoids, alkylation, polymerization of isoprenoids, tail to tail linkages and cyclization of poly isoprene chains to mono, sesqui, diand triterpenes etc. Modifying reactions of triterpenes and steroids.

Shikimic metabolites (phenyl propanoids), simple cinnamic acid derivatives, flavonoids, coumarins, carotenoid, tropolones, lignins etc. Alkaloids and other amino acid derivatives, alkaloids based on aliphatic amino acids, based on aromatic amino-acids, alkaloids derived from trytophan, other amino acid derivatives and peptide derivatives. Methods precursor incorporation experiments in fungi, biosynthesis in cell free systems and biosynthesis in mutant organism.

Chem 6012: Spectra of Organic Compounds
3.00 Credit (3 hrs/wk)

Introduction to electromagnetic spectrum, ultraviolet spectroscopy, electronic transition, simple chromophoric groups, conjugated systems, aromatic systems, use of UV spectra in structure determinations.

Infra-red spectroscopy, molecular vibrations and their interaction with infrared radiation, interpretation of IR spectra.

Nuclear magnetic resonance spectroscopy, magnetic properties of nuclei, the chemical shift, spin-spin interactions, nuclear magnetic double resonance, interpretation of the spectra of organic molecules. Mass spectroscopy, the production analysis of positive ions, molecular ion, application of isotopic abundance measurements, fragmentation modes of mass spectra of some representative compounds. The effect of stereochemistry on the above spectra will be discussed in each case.

Chem 6013: Organic Synthesis
3.00 Credit (3 hrs/wk)

Formation of carbon-carbon single bond via reactions of enolate anions, enamine reactions, bisthio carbonions 1,4-addition of organo-metallic compound of lithium diakyl- and diaryl-cuprates, carbenes and carbenoids and photocyclisation.

Formation of C=C bonds via elimination, oxidative decomposition reactions. Thermal and photosensitised Diel's Alder reaction, its mechanism and stereochemistry, the "One" synthesis.

Oxidation reaction: Selective oxidation of hydration of hydrocarbons, olefines, alcohols, Baeyer Villigre, photosensitised oxidation of olefines.

Reduction reactions: selective catalytic hydrogenations dissolving metal reductions, hydride-transfer reductions.

Examples: stereospecific synthesis, synthesis of naturally occurring compounds.

Chem 6014: Stereochemistry and Reactivity of Organic Compounds
3.00 Credit (3 hrs/wk)

Structure and symmetry point groups, stereoisomerism, optical isomerism, racemic modification, diastereoisomers, torsional isomerism, allotropisomers, absolute configuration, conformational analysis, conformation and reactivity, stereochemistry of ring systems, fused rings, allenes, macromolecules of tri-covalent carbon. Optical rotatory dispersion, circular dichroism and their application. stereo-specific and stereo-selective synthesis. Stereochemistry and mechanism of reactions.

Chem 6015: Chromatography Principle and Application
3.00 Credit (3 hrs/wk)

Fundamental types of chromatography: Liquid partition chromatography, thin layer and reversed phase partition chromatography. Chemical constitution and R_f value. Adsorption chromatography, gas liquid chromatography, column efficiency and resolution, various types of detectors, preparative, programmed temperature gas chromatography, exclusion chromatography, gel permeation and ion exclusion techniques, ion exchange chromatography. Exchange equilibria plate theory, applications, electrophoresis and electro-chromatography, mechanisation and automation of column chromatography. Solutions of different problems by chromatographic methods.

Chem 6016: Advanced Topics in Chemistry

3.00 Credit (3 hrs/wk)

Chem 6017: Organic Pollutants

3.00 Credit (3 hrs/wk)

Degradation of different components of biosphere by environmental pollutants; a general overview of interconnections among biosphere, atmosphere, antrosphere, hydrosphere and geosphere. Pollution by Hydrocarbons: chemical nature, dispersion, evaporation, photooxidation & microbial transformation to the environment. Petroleum & aquatic organisms, biphenyl & polychlorinated biphenyls (PCBs), physical and chemical properties, environmental distribution and behavior. Polycyclic aromatic hydrocarbon; chemical nature, occurrence and behavior in the environment, carcinogenicity and toxicity of PAHs, effect on human and the natural environment. Pollutants from Industries: their treatment by chemical, physical, thermal and photochemical method with special references to polymers & plastic, soap & detergents, chemical & pharmaceutical and pulp & paper industries. Waste Materials; nature, sources and environmental chemistry of hazardous wastes, hazardous wastes in atmosphere hydrosphere and biosphere, microbial metabolism in waste degradation, appropriate disposal by proper chemical & biological treatment of city waste, domestic & hospital wastes. Fertilizers: nitrogenous, phosphatic fertilizers. Environmental implications of fertilizer, abatement procedure of fertilizer pollution. Organic pollutants in vegetables, fruits and other food materials. Insecticides, fungicides, herbicides, and their effects on environment and human health with reference to DDT, Heptachlor, Endosulfan, Diazinon, Malathion, Parathion, etc. Formulation, mechanism of action and metalbolism of pesticides biological system. Toxicology; introduction to toxicology, dose-response relationship, dose & frequency of use. Maximum Recommended level (MRL) and Acceptable Daily intake. Integrated pest management (IPM): definition, key components of IPM, pest control techniques, reduction of pollution.

Chem 6018: Medicinal Chemistry

3.0 Credit (3 hrs/wk)

Receptors and drug action: role of receptor, receptor families, neurotransmitters, design of agonists and antagonists, and receptor and the biological response. Drugs acting on DNA; antimetabolites, enzyme inhibitors, intercalating agents, alkylating agents, antisense drugs, and chain-cleaving agents. Quantitative structure activity relationship (QSAR); introduction, physiochemical properties, Hanch equation, the Craig plot, bioisosteres, and planning a QSAR study. Combinatorial synthesis for drugs: introduction, basic of combinatorial synthesis, design of combinatorial synthesis, the solid phase synthesis, and combinatorial synthesis in solution. Immunobiologicals: Cells of the immune system, immunity, acquisition of immunity. Allergy: introduction, histamines, types of allergens, antihistamic agents, and inhibition of histamine release. Cancer and cancer chemotherapy: definition, principles, biochemical basis of cancer, cancer therapy, and class of anticancer agents. Medicinal chemistry of herbs: herb, purity and standardization, herb as a drug, types of herbs, and chemistry and pharmacological activity of some herbs. Pharmaceutical Chemistry: introduction, pharmacopoeias, types of analytical methods used for the determination of the purity of pharmaceutical substances, pharmacopoeial assay, example of some pharmacopoeial assays in relation to British Pharmacopoeia - Aspirin, Paracetamol, Ascorbic acid, Ampicillin, Metronidazole.

Chem 6019: Food Chemistry

3.00 Credit (3 hrs/wk)

General introduction to food chemistry, basic food groups. Quality and choice of food, Food safety and security. Milk and dairy products: types of milk, processing of milk. Product of fermented milk; Sour milk, yoghurt, cheese etc. Cereals and cereal products; introduction, origin, chemical composition, celiac diseases. Fruits and Fruits Product: composition, nitrogen containing compounds, carbohydrates, vitamin and mineral in fruits, chemical changes during ripening of fruits, ripening as influenced by chemical agents. Fruit products preparation and preservation; dried fruits, canned fruits, fruit juices, fruit juice beverages, lemonades. Caffeine containing beverages. Protein in foods; fish, meat, and eggs. Lipids; edible

fats, oils and other lipids-their occurrence and composition in foods, their effects on health. Coffee, Tea, Cocoa; coffee and coffee substitutes, tea and tea like products, cocoa and chocolate. Spices, salt and vinegar: composition, occurrence and production. Food additives: vitamins, amino acids, minerals, aromatics substances, flavor enhancer, food colors, antioxidants, thickening agents, gel builders, stabilizers, bleaching agent. Food contamination: toxic trace elements, toxic compounds of microbial origin, pesticides, medicines and feed additives, cleansing agents and disinfectant.

Physical-Inorganic Branch

Chem 6101: Chemistry of Coordination Compounds

3.00 Credit (3 hrs/wk)

Theories of coordination: valence bond theory, crystal field theory, ligand field theory and molecular orbital theory Detailed study of different types of complexes.

Stability constant of complexes: different methods of determination of stability constant, application of stability constants in different fields, e.g., life sciences, medicine, pollution, electrochemistry, analytical chemistry, geochemistry etc.

Chem 6102: Modern Methods of Chemical Analysis
3.00 Credit (3 hrs/wk)

Application of electro-analytical methods in chemical analysis. Application ofUV-visible, IR spectrophotometry, flame photometry, atomic absorption spectroscopy, turbidimetry, nephelelemtry, optical rotatory dispersion/circular dichroism, NMR, Mass spectrometry, DTA and TGA in chemical analysis. Principles of gas chromatography and its applications.

Chem 6103: Corrosion Science
3.00 Credit (3 hrs/wk)

Thermodynamics of corrosion; kinetics of hydrogen evolution and oxygen reduction reaction; hydrogen overvoltage, electrode kinetics, pourbais diagram, theories of homogeneous corrosion and local cell reaction; corrosion in acidic, neutral and alkaline media. Role of inhibitors and alloying elements. Principles governing cathodic protection. Mechanism of atmospheric oxidation of metals and alloys. Study of selected systems of industrial importance.

Chem 6104: Studies on Crystal and Molecular Structure by Diffraction Methods
3.00 Credit (3 hrs/wk)

Classification of crystals, crystal shapes, lattices and unit cells, crystal planes, methods used in crystal structure studies. Principles and application of electron microscopy, electron diffraction, X-ray diffraction and neutron diffraction. Advanced methods of X-ray data collection. Patterson functions, image seeking functions and their use in structure analysis:

Chem 6105: Advanced Electrochemistry
3.00 Credit (3 hrs/wk)

Activity and activity coefficient, activities of electrolytes. The Debye-Huckel theory. Extension of the Debye-Huckel treatment, weak Electrolytes and the Debye-Huckel theory.

Electrolysis and Polarization: Electromotive force and cells, thermodynamic data from cell e.m.f.; polarization, deposition potential, determination of anode and cathode potentials, decomposition voltage of aqueous of solution.

Processes at electrodes. Theories of overvoltage, mechanism of anodic and cathodic age. Rate of growth of overvoltage. The deposition and corrosion of metals. Physical nature of electrodeposition. Separation of metals by electrolysis. Electrochemical passivity and theories of passivity.

Chem 6106: Chemistry of Polymer
3.00 Credit (3 hrs/wk)

Polymers: polymerization reactions, kinetics of polymerization reactions, characterization, solubility chart for identification of polymer, specific chemical tests for various polymers, thermal behaviours of polymers; DTA and TGA studies, mechanical behaviour of polymers, visco-elastic studies, size and shape of macromolecules, internal frictions, swelling phenomenon and crosslink density. Molecular weight determination using viscometry. Osmometry. Light scattering, ultracentrifuge and gel permeation chromatography. Methods to study tacticity, stereoregularity and crystallinity, Electrical resistivity and dielectric behaviour.

Chem 6107: Chemical Kinetics and Solution Thermodynamics
3.00 Credit (3 hrs/wk)

(a) Order of reaction and practical measurement of reaction rate. Kinetics and mechanism of complex reactions. Effect of temperature on reaction rate. (b) Analysis of the different laws of thermodynamics and its application to chemical systems, properties of Gibbs function. Thermodynamics of solution and partial molal quantities. Thermodynamics of mixing.

Chem 6108: Chemistry of Pollution
3.00 Credit (3 hrs/wk)

Chemical equilibrium principles applied to the chemistry of natural and polluted water and to the chemistry of water treatment. Analytical methods applied in the control of water and air pollution. Principles of chemical separations involving adsorption, ion-exchange chromatography, solvent extraction methods. Fundamental concepts of adsorption, ion-exchange chromatography, solvent extraction methods, fundamental concepts of adsorption and emission spectroscopy.

Industrial toxins and their toxicology. Classification and analysis of inorganic and organic toxins. Radiation hazards, air pollution and analysis. Social and economic aspects of pollution.

Chem 6109: Surface Chemistry
3.00 Credit (3 hrs/wk)

Surface growth, the role of defects in the growth of surface, surface composition. Techniques to determine surface composition: high vacuum techniques, electron energy loss spectroscopy, auger electron spectroscopy,

low energy electron diffraction technique, scanning electron microscopy and scanning tunneling microscopy. Adsorption at solid surface: Langmuir and BET isotherms, adsorption kinetics and adsorption processes. Catalytic activity at surfaces: Eley-Ridel mechanism, Langmuir-Hinshelwood mechanism, the significance of volcano curve and catalysis in the industrial processes. Redox processes mediated by surface, conventional and new materials for electrode surface.

Chem 6110: Aquatic Chemistry
3.00 Credit (3 hrs/wk)

Scope of aquatic chemistry in different fields, the solvent water, aspects of chemical thermodynamics, kinetics, acidity and alkalinity. Dissolution of carbon dioxide, atmosphere-water interactions. Metal ions in aqueous solution and ionic equilibrium in aqueous system, aspects of co-ordination chemistry, precipitation and dissolution, redox condition in natural water and microbial radiation. The solid-solution interface: adsorption, dissolution of minerals, nucleation and crystal growth. Trace metals: cycling, regulation and biological role and photochemical process. Particle-particle interaction: colloids, coagulation and filtration, regulation of chemical composition of natural water. Chemical context of water quality.

Chem 6111: Bio-inorganic Chemistry
3.00 Credit (3 hrs/wk)

General principles: Biological functions of inorganic elements. Biological ligands. Nucleotides and Nucleic acids (RNA, DNA) as ligands. Cobalamins including vitamin and co enzyme B12: Reactions of the alkylcobalamines, One electron and reduction and oxidation, activity of coenzyme B12, Metals at the center of photosynthesis: Magnesium and Manganese, Light absorption, Charge separation and electron transport. The oxygen molecule: Oxygen transport and storage through Hemoglobin and Myoglobin,

Alternative oxygen transport in some lower animals: Hemerythin and Hemocyanin. Catalysis through Hemo proteins: Electron transfer oxygen activation and Metabolism of Inorganic Intermediates. Cytochromes, cytochrome P-450: oxygen transfer from O_2 to non-activated substrates. Hemeproteins in the partially reduced nitrogen and sulfur compounds. Iron sulfur and other non heme Iron proteins: Biological relevance of the element combination Iron/sulfur. Rubredoxins, Ferredoxins, Polynuclear Iron sulfur clusters: Model systems for iron-sulfur proteins. Mononuclear nonheme iron enzymes. Transport and storage of an essential elements: The problem of iron mobilization, oxidation states, Iron uptake by plants. Transport and storage of iron, Ferritin, Hemosiderin: Biological function of the early transition metals: Enzymes containing the molybdenum cofactor. Metalo-enzymes in biological nitrogen cycle.

Chem 6112: Colloidal and Nano-chemistry
3.00 Credit (3 hrs/wk)

Methods of preparation, classification and general properties of colloids. Electrokinetic phenomena: Double layer structure, Zeta potential, electrophoresis and electroosmosis. Properties of gels and colloidal electrolytes. Preparation, types, specific properties and stability of emulsions. Micelles formation and critical micelle concentration. Uses of colloids, emulsions, and gels. Fundamental aspects of nanoscience and nanotechnology, fabrication method of nanomaterials: top down and bottom up process, chemical synthesis and modification of nanomaterials. Energy at the nanoscale: surface energy, basic thermodynamics, liquid state, surface energy minimization mechanism. Chemical interactions at the nanoscale: electrostatic interactions, hydrogen bonding, Van der Waals interaction and hydrophobic effect. Tools for nano characterizations: electron microscopy, atomic probe microscopy, X-ray spectroscopy, Raman spectroscopy, and Nanolithography. Advanced materials: fullerenes, carbon nanotubes, and diamondoids. Chemistry of nanoelectronics, nanophotonics, nanofluidics and

nanobiotechnology. Nanotechnology products and applications. Societal implication of nano: ethical implications, legal implications, environmental implications, public perception.

Chem 6113: Textile Chemistry
3.00 Credit (3 hrs/wk)

Chemistry of Dyes and Color: Theories color formation, classification of dyes based on application and chemical constituents, synthesis of some common dyes used in textile industries. Textile fiber chemistry: Natural fiber, man-made fiber, synthetic fiber, chemical structure of cotton, Linen, cellulose, acrylic, wool, silk, nylon, polyester etc, chemical synthesis of synthetic dyes, Characterization of Structure of Fiber Forming Polymers. Finishing of fibers: Use of selective finishing agent/auxiliaries to modify fiber performance including oxidizing, softening and cross- linking agents, fiber aging-effect of heat, chemical and weather conditions on fiber structure and properties, Description and discussion of special finishing processes including water-repellency, easy- care finishing, flame retardancy, oil repellency, softening, anti- microbial finishing, chemical formulation used in these finishing effects, and their effects on fabric performance. Nanotechnology in textile: NanoTechnology in high performance textile, NanoTechnology in textile finishing, some selected application of nanotechnology in Textile. Medical textile: Textile medical products, bio-medical textile materials. Textile waste management: Wastes in textile industries, removal of dyes and pigments from waste water, removal of toxic elements used in textile finishing.

Chem 6114: Chemistry of Materials
3.00 Credit (3 hrs/wk)

Concept and design of organic, inorganic and biomaterials. Types of chemical bonding in solid; ionic solids, metallic solids, covalent network solids, molecular solids. Crystalline state; crystal growth techniques, physical properties of crystal, bonding in crystalline solids. Amorphous state; sol-gel processing, cementitious materials. Properties, synthesis and structure-property relationship of metal, semiconductor, softmaterials and biomaterials. Materials characterization: optical microscopy, electron

microscopy, scanning electron microscopy, scanning probe microscopy, NMR in material chemistry. Chemical approach for the design of fluids.

Chem 6115: Advanced Photochemistry
3.00 Credit (3 hrs/wk)

Photochemistry and radiation chemistry. Mechanism of dark reactions and photochemical reactions. Dosimeters. Basic principle of laser action, various types of lasers. flash photolysis, techniques in laser photochemistry, pico- and femtosecond photolysis, detection of short-lived species. Laser induced breakdown spectroscopy (LIBS), solar energy and solar simulation. Photochemical kinetics, excited species and their fates, photochemical quenching, photochemical processes in atmosphere, Stern-Volmer equation, photolysis. Photoelectrodes, types of photoelectrochemical solar cells, mechanism of energy conversion, energy conversion efficiency. Organic solar cells. Photoelectrochemical production of hydrogen from water. Storage of solar energy. Photocatalysts, Semiconducting metal oxides, Influence of photocatalysts on TOC and BOD of the dye effluents, Degradation of dyes and other organic substances in aqueous system. Roles of mediators, Kinetics of photodegradation of dyes in aqueous solution. Mechanism of advanced oxidation processes (AOP's) in water treatment: The hydrogen peroxide/ultraviolet light (H_2O_2/UV), ozone/ultraviolet light(O_3/UV), hydrogen peroxide/Ozone((H_2O_2 /O_3), hydrogen peroxide/ultraviolet light/ozone (H_2O_2/O_3/UV), TiO_2/UV and TiO_2/UV + H_2O_2 processes.