864. *Plant Biochemistry*

Spring. 4(4-0) BCH 401, BOT 301 or approval of department. Interdepartmental with and administered by the Department of Biochemistry.

Metabolism of nitrogen-compounds, carbohydrates, and lipids unique to plants' cell organelles; photosynthesis; photorespiration; dark respiration; cell walls; lectins; nitrogen cycle including nitrogen fixation; sulfur cycle.

865. *Advanced Growth and Development*

Fall. 3(3-0) BOT 415 or approval of department.

Advanced treatment of the physiological processes of growth and development. The mechanism underlying these processes and the roles played by hormones, light, etc., in controlling them will be analyzed.

871. *Biology of Nematodes*

Spring. 4(2-6) ENT 470 or approval of department. Interdepartmental with and administered by the Department of Entomology.

Ontogeny, taxonomy, morphology, pathology and ecology of nematodes, with special reference to plant-parasitic and phyto-pathogenic species.

878. *Comparative Limnology*

(478.) Summer of odd-numbered years. 6 credits. Approval of department. Given at W. K. Kellogg Biological Station. Interdepartmental with and administered by the Department of Zoology.

Theoretical concepts and methods of analysis of environmental parameters influencing productivity of freshwaters. Comparative field investigations of lakes, streams, and other aquatic habitats.

880. *Plant Virology*

Fall of odd-numbered years. 5(2-6) BOT 405 or approval of department.

External and internal symptomatology, transmission, interactions, purifications, assay and serology of plant viruses.

881. *Pathogenesis and Disease Resistance*

Winter of odd-numbered years. 4(3-2) BOT 405 and BOT 415, or approval of department.

Lectures, readings, and discussions on mechanisms of pathogenicity and infectivity; physiology and biochemistry of disease development; tumorigenesis; metabolic consequences of infection; nature of disease resistance; and parasitism.

882. *Genetics of Host/Parasite Interactions*

Winter of even-numbered years. 3(3-0) ZOL 441, BOT 405.

Inheritance of resistance and susceptibility, virulence and avirulence; types of resistance, aggressiveness in parasites; use of genetics in studies of host/parasite interactions, practical application in disease control.

885. *Plant Diseases in the Field*

Spring. 4 credits. BOT 405 and approval of department.

Diagnosis, distribution, and sequential development of plant diseases in the field. Field trips permit observation of diseases in the natural setting.

890. *Selected Topics in Plant Pathology*

Fall, Winter, Spring. 2 to 5 credits. Approval of department.

Topics will be selected from the following areas: parasitism, plant viruses, ecology, genetics, nematology, fungicidal action, and soil microbiology.

891. *Selected Topics in Botany*

Fall, Winter, Spring. 2 to 5 credits. May reenroll for a maximum of 6 credits if different topics are taken. Approval of department.

Topics may be selected from ecology, systematics, evolution, physiology, cytology, mycology, bryology, phycology, lichenology, anatomy, morphology, genetics, and others.

899. *Master's Thesis Research*

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

Research in anatomy, bryology, cytology, ecology, genetics, lichenology, morphology, mycology, paleobotany, pathology, phycology, physiology, and taxonomy.

918. *Advanced Genetics*

Winter of odd-numbered years. 3(3-0) Approval of department.

Role of the gene in differentiation and development, with special emphasis upon the genetic mechanisms responsible for the control of phenogenesis.

920. *Advanced Plant Taxonomy*

Spring of even-numbered years. 4(4-0) BOT 824, ZOL 441.

Consideration of the recent scientific developments affecting plant classification.

930. *Advanced Plant Ecology*

Winter of odd-numbered years; Summer of even-numbered years. Given at W. K. Kellogg Biological Station summer term. 3(2-4) Approval of department.

Fundamental theories and modern research horizons.

999. *Doctoral Dissertation Research*

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

Research in anatomy, bryology, cytology, ecology, genetics, lichenology, morphology, mycology, paleobotany, pathology, phycology, physiology, and taxonomy.

BUILDING CONSTRUCTION

See Agricultural Engineering.

CHEMICAL ENGINEERING CHE

College of Engineering

300. *Material and Energy Balances*

Fall, Winter. 4(3-2) One year general chemistry, MTH 214 or concurrently, CPS 120 or concurrently.

Chemical engineering calculations. Synthesis of chemical process systems. Analysis of chemical process systems by material and energy balances. Behavior of gases. Enthalpy calculations for changes of termperature, phase changes, chemical reactions.

305. *Transfer Processes and Separations I*

Fall. 4(3-2) MTH 215; CHE 300 or concurrently.

Thermodynamics of fluid flow. Treatment of fluid flow as a momentum transfer process. Laminar and turbulent motion of compressible and incompressible fluids. Heat transfer in solids and flowing fluids.

306. *Transfer Processes and Separations II*

Winter. 4(3-2) CHE 305.

Heat transfer in condensing and boiling systems. Multiple effect evaporation. Radiant heat transfer. Application to engineering equipment. Mass transfer in single-phase systems, transport analogies interphase transfer and contacting of immissible phases.

307. *Transfer Processes and Separations III*

Spring. 4(3-2) CHE 306.

Mass transfer in continuous contacting systems and stagewise processes. Counter-current processes, fractionation, contacting, efficiency, and simultaneous momentum, heat, and mass transfer.

311. *Thermodynamics for Chemical Engineering*

Winter, Spring. 3(3-0) CHE 300 or approval of department.

First and second laws. Energy, enthalpy, entrophy, free energy, the mathematics of property relationships. Energy conversion processes. Thermodynamics of flow.

381. *Chemical Engineering Analysis*

Fall, Spring. 3(3-0) Students may not receive credit in both CHE 381 and MTH 341. MTH 310. Interdepartmental with the Department of Mathematics.

Formulation of ordinary and partial differential equations describing chemical systems. Boundary value problems, numerical methods, matrices, and applications, to chemical engineering systems.

411. *Phase and Chemical Equilibria*

Winter. 3(3-0) CEM 361, CHE 311 or concurrently.

Properties in solutions. Deviations from ideality. Liquid-vapor equilibria. Chemical equilibria in the gas, liquid, and solid states. Electrochemical and irreversible systems.

423. *Chemical Engineering Laboratory*

Fall, Summer. 3(1-6) CHE 307.

Assigned laboratory problems, requiring team effort. Experimental work, involving momentum, heat and mass transfer; separation processes, such as distillation, filtration, and drying; reactor kinetics; automatic process control.

424. *Transport Phenomena and Physical Properties Laboratory*

Winter, Spring. 3(1-6) CHE 306.

Experiments involving the transport processes and measurement of physical, chemical and thermodynamic properties of various materials. Comparison of theoretical and experimental results.

428. *Chemical Reaction Engineering*

Fall. 3(3-0) CEM 361, CHE 306, CHE 311.

Quantitative treatment of mechanisms and rates of chemical reactions. Catalysis. Design and analysis of flow and non-flow reactors. Interpretation of laboratory kinetic data.

442. *Polymer Science and Engineering*

Spring. 3(3-0) One year organic chemistry. CEM 361.

Structure of polymers. Polymerization reaction kinetics. Polymer characterization. Solution rheology. Polymer processing and fabrication. Commercial polymerization processes.

443. *Chemical Engineering of the Solid State*

Winter. 3(3-0) CEM 361.

Structure and properties of inorganic and organic solids. Relation of bond type and steric configuration to mechanical, electrical, thermal, optical properties. Macroscopic structure influence on physical properties. Surface phenomena. Applications.

451. *Process Systems Control*

Winter. 3(3-0) CHE 307, CHE 428.

Foundation of control theory for chemical processes. Integration of present and developing practice with modern theory.

460. *Problems and Reports*

Fall, Winter, Spring. 1 to 9 credits. Seniors, approval of department.

Library and laboratory investigations of problems relating to departmental research.

461. *Process Selection and Optimization*

Winter. 5(5-0) CHE 307, CHE 428.

Application of chemical engineering principles in design calculations. Selection of the optimum design for equipment, functional units, and for the overall process. Influence of design on capital investment, operating cost, product loss, and product quality.

462. *Process Design*

Spring. 3(1-6) CHE 461.

Integrated design of the complete chemical engineering process. Process engineering, project engineering, instrumentation, and layout.

465. *Process Optimization Methods*

Fall. 3(3-0) MTH 310. Interdepartmental with Systems Science.

Methods for determining optimum design and operating policies of systems of varying complexity. Includes classical methods, mathematical programming and modern methods.

470. *Theory of Nuclear Reactors*

Winter. 3(3-0) PHY 289 and MTH 215 or approval of department.

Theory and design of nuclear research and power reactors. Nuclear transformation, fission, and energy conversion. Derivation of chain reaction design criteria, and calculation of flux-power distribution. Analysis of reactor safety, reliability and economics.

481. *Transport Phenomena*

Spring. 3(3-0) CHE 307, CHE 381.

Fundamental treatment of momentum, energy and mass transport. Use of partial differential equations and equations of change for chemical engineering applications. Analogies among the phenomena, dimensional analysis, and boundary layer theory.

801. *Advanced Chemical Engineering Calculations I*

Fall. 3(3-0) CHE 307.

Chemical engineering applications of advanced mathematical methods. Formulation and solution of mathematical equations which describe physical problems. Computer solutions.

802. *Advanced Chemical Engineering Calculations II*

Winter. 3(3-0) CHE 801.

Continuation of CHE 801.

806. *Thermodynamics and Kinetics in Chemical Engineering*

Summer. 5(7-0) B.S. with a major in chemistry, biochemistry, or a closely allied area. Mathematics through calculus. College level physics. General physical, and organic chemistry. Not open to students with B.S. in chemical engineering for graduate credit.

Mass and energy balances in batch continuous and open systems. Process thermodynamics. Cryogenics. Properties of substances and mixtures. Phase equilibria. Chemical reaction equilibrium. Chemical reactor kinetics. Process design orientation.

807. *Transfer and Separation Processes*

Summer. 5(7-0) B.S. with a major in chemistry, biochemistry, or a closely allied area. Mathematics through calculus. College level physics. General physical, and organic chemistry. Not open to students with B.S. in chemical engineering for graduate credit.

Momentum, energy, and mass transfer. Laminar and turbulent flow. Fluid friction. Dimensional analysis. Heat through stationary and flowing materials. Interchangers. Condensation. Boiling. Binary and multicomponent distillation, absorption, extraction.

811. *Advanced Chemical Engineering Thermodynamics I*

Fall. 3(3-0) CHE 311, CHE 411. CEM 361.

Advanced treatment of the laws of thermodynamics. Cryogenic processes. Corresponding state and higher parameters in computing properties of chemical compounds and solutions.

817. *Advanced Chemical Reaction Engineering I*

Spring. 3(3-0) CHE 428.

Treatment of absorption and catalysis and their application to catalytic reactors. Heat, momentum, and mass-transfer in fixed-bed and fluidized-bed reactors. Noncatalytic heterogeneous reactions. Homogeneous chain reactions and free radical mechanisms. Computer applications to solution of complex kinetic problems.

826. *Flow of Heat I*

Spring. 3(3-0) CHE 307.

Steady and unsteady state heat transfer. Conduction and convection in flow and non-flow systems.

831. *Distillation, Absorption, and Extraction–Ideal Stages*

Fall. 3(3-0) CHE 307. May precede or follow CHE 832.

Stagewise calculations in distillation, absorption, and extraction processes. Computer techniques. Liquid-gas and liquid-liquid equilibria. Batch, continuous, binary and multi-component calculations.

832. *Distillation, Absorption and Extraction–Phase Contractors*

Winter. 3(3-0) CHE 307. May precede or follow CHE 831.

Mass transfer in distillation, absorption, and extraction processes. Continuous and stagewise phase contactors. Column hydrodynamics and plate efficiency.

835. *Nonlinear Optimization Models*

Winter, Summer. 4(4-0) Students may not receive credit for both SYS 835 and MGT 835. MTH 215 or MTH 228; MGT 834 or CHE 465. Interdepartmental with Systems Science and the Department of Management. Jointly administered by Systems Science and the Department of Management.

Nonlinear optimization-examples and applications. Khun-Tucker Theory. Saddle point optimality conditions. Algorithms for problems with constraints. Unconstrained optimization; introduction to search methods.

847. *Physical Chemistry of Macromolecules*

Winter of odd-numbered years. 3(3-0) CHE 442.

Thermodynamics—phase equilibria of polymer solutions; configuration and conformation of chain molecules; characterization of polymer molecular weight and distribution; theoretical and experimental results for dilute solution viscosity and diffusivity; polyelectrolytes.

850. *Fluid Flow and Rheology*

Fall. 3(3-0) CHE 481 or approval of department.

Application of fluid dynamics to chemical engineering systems. Balance principles for fluids; Newtonian and non-Newtonian behavior; theory and practice of laminar and turbulent flows; stability.

851. *Mass Transfer*

Winter. 3(3-0) CHE 850.

Formulation of component material balances; Fick's first and second laws; convective mass transfer; multicomponent fluxes; boundary layer theory and interfacial mass transfer for laminar and turbulent flows.

881. *Seminar*

Fall, Winter, Spring, Summer. 1(0-2) May reenroll for a maximum of 3 credits allowed toward M.S. degree and 6 credits toward Ph.D. degree.

Detailed library investigation of one or more specialized aspects of chemical engineering, such as recent theoretical developments in one of the unit operations; presentations of these studies to a seminar group. Participation generally required each term of residence.

886. *Selected Topics in Chemical Engineering*

Fall, Winter, Spring, Summer. 3(3-0) May reenroll for a maximum of 9 credits if a different topic is taken.

A newly developing area of chemical engineering selected by the department for offering each term. Information on the specific topic to be covered should be obtained from the department office before registration.

888. *Research Survey*

Fall, Winter, Spring, Summer. 1 to 3 credits. May reenroll for a maximum of 3 credits.

Literature search, problem analysis, and layout of a complete research program.

893. *Special Problems*

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

899. *Master's Thesis Research*

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

912. Advanced Chemical Engineering Thermodynamics II

Spring of even-numbered years. 3(3-0) Approval of department.

Relation of thermodynamics to quantum theory and statistical mechanics. Computation of chemical engineering thermodynamic data from spectral measurements. Irreversible thermodynamics.

918. Advanced Chemical Reaction Engineering II

Fall of odd-numbered years. 3(3-0) Approval of department.

Quantitative treatment of current literature in chemical kinetics and reaction engineering.

999. Doctoral Dissertation Research

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

CHEMISTRY CEM

College of Natural Science

Credit cannot be earned in more than one course of each of the following groups: 141A and 141B and 151; 143, 241, and 351; 142 and 153; 242 and 352; 243 and 354; 244 and 355; 245 and 353; 361 and 383; 363 and 385; 384 and 461; 394 and 472.

With department approval, students with advanced placement credit in CEM 151 and 161 may enroll in CEM 181H and 184H. Those with advanced placement credit in CEM 152 may enroll in CEM 182H, and those with advanced placement credit in CEM 153 may enroll in CEM 183H. CEM 181-182-183 is a more advanced treatment of material in CEM 151-152-153. CEM 184-185-186 is a more advanced treatment of material in CEM 161-162-163. Students with credit in an honors chemistry course may not enroll in the corresponding nonhonors course.

139. Selected Topics in Introductory Chemistry

Fall, Winter, Spring, Summer. 1 to 3 credits. May reenroll for a maximum of 7 credits. Previous college chemistry, approval of department.

Self-instructional units from CEM 140, CEM 141A, CEM 141B (or equivalent) selected and approved by the department for individual students with special needs.

140. Introductory Chemistry

Fall, Winter, Spring, Summer. 2 credits. Self-scheduled instruction only. MTH 108 or MTH 111 or concurrently.

Chemical symbols, formulas, equations, stoichiometry, structure of atoms, bonding, states of matter, solutions.

141A. Chemical Principles

(141.) Fall, Winter, Spring, Summer. Fall 4(4-0); Winter, Spring, Summer: 4 credits. Self-scheduled instruction only. MTH 108 or MTH 111 or concurrently; CEM 140 or satisfactory chemistry placement test score.

Chemical principles for students in the physical sciences and engineering.

141B. Chemical Principles

Fall, Winter, Spring, Summer. Fall 4(4-0); Winter, Spring, Summer: 4 credits. Self-scheduled instruction only. MTH 108 or MTH 111 or concurrently; CEM 140 or satisfactory chemistry placement test score.

Chemical principles for students in biological, health-related, and agricultural disciplines.

142. Descriptive Inorganic Chemistry

Winter, Spring. 3(3-0) CEM 141A or CEM 141B or CEM 152.

Reactions and behavior of inorganic compounds illustrated in part by industrial and environmental applications.

143. Introductory Organic Chemistry

(132.) Fall, Spring, Summer. 4(3-3) CEM 141A or CEM 141B or CEM 152.

Chemistry of carbon compounds, introducing the aliphatic and aromatic hydrocarbon series. Some typical compounds are prepared and their behavior studied.

151. Principles of Chemistry I

Fall, Winter. 4(4-0) MTH 108 or MTH 111 or concurrently; CEM 140 or satisfactory chemistry placement test score.

First of a 3-term sequence for science majors, chemical engineering students, and others desiring a comprehensive general chemistry sequence. Atomic and molecular structure; stoichiometry; solids, liquids, and gases; solutions.

152. Principles of Chemistry II

Winter, Spring. 3(3-0) MTH 112 or concurrently; CEM 151 or CEM 141A or CEM 141B or CEM 181H.

Continuation of CEM 151. Chemical thermodynamics; kinetics, acids, bases, and aqueous equilibria; electrochemistry.

153. Introductory Inorganic Chemistry

Fall, Spring. 3(3-0) CEM 152 or CEM 182H.

Continuation of CEM 152. Descriptive inorganic chemistry with further discussion of bonding.

161. Introductory Chemistry Laboratory

Fall, Winter, Spring, Summer. 1(0-3) CEM 140 or CEM 141A or CEM 141B or CEM 151 or concurrently.

Laboratory work in chemistry, including quantitative physiochemical or analytical experiments and chemical synthesis.

162. Quantitative Analysis

Fall, Winter, Spring, Summer. 3(1-6) CEM 141A or CEM 141B or CEM 151 or CEM 181H; CEM 161 or CEM 184H.

Laboratory work in quantitative chemistry.

163. Introductory Inorganic Laboratory

Spring. 2(0-6) CEM 142 or CEM 153 or concurrently; CEM 161.

Qualitative analysis and inorganic preparations.

181H. Honors Chemistry I–Principles

Fall. 4(4-0) An A average in high school chemistry, physics and mathematics; MTH 112 or MTH 122 concurrently. Results of examination during orientation; approval of department.

Subatomic, atomic and molecular structure; quantum theory and bonding; experimental methods of structure determination; states of matter; nuclear chemistry.

182H. Honors Chemistry II–Principles

Winter. 4(4-0) CEM 181H with grade of 3.0 or better and/or approval of department. MTH 113 or MTH 123 concurrently.

Kinetic theory of gases, thermodynamics, chemical equilibrium, electrochemistry, chemical kinetics, properties of solutions, macromolecular chemistry.

183H. Honors Chemistry III–Inorganic Chemistry

Spring. 3(3-0) CEM 182H with grade of 3.0 or better and/or approval of department.

Descriptive inorganic chemistry by periodic groups of elements. Nomenclature, bonding, sterochemistry, and reactions of compounds of the representative and transition elements.

184H. Honors Chemistry Laboratory I

Fall. 1(0-3) CEM 181H concurrently; approval of department.

Techniques of measurement; errors and significant figures; experiments related to atomic and molecular structure.

185H. Honors Chemistry Laboratory II

Winter. 2(0-6) CEM 184H; CEM 182H concurrently; approval of department.

Experiments related to gas behavior, thermodynamics, electro-chemistry, chemical kinetics and properties of solutions.

186H. Honors Chemistry Laboratory III

Spring. 2(0-6) Approval of department.

Introductory independent laboratory work in chemistry.

241. Organic Chemistry

Fall, Winter, Summer. 4(4-0) CEM 141A or CEM 141B or CEM 152 or CEM 181H; CEM 161 or CEM 184H.

Common classes of organic compounds with emphasis on nomenclature, structural principles, reactions and reaction mechanisms.

242. Organic Chemistry

Winter, Spring, Summer. 4(4-0) CEM 241.

Continuation of CEM 241 with emphasis on polyfunctional compounds, particularly groups of compounds having biological significance.

243. Organic Chemistry Laboratory

Fall, Winter, Summer. 1(0-2) CEM 241 or concurrently.

Introduction to standard organic laboratory techniques.

244. Organic Chemistry Laboratory

Winter, Spring, Summer. 1(0-3) CEM 241, CEM 243, CEM 242 concurrently.

Organic preparations and qualitative analysis.

245. Organic Chemistry

Fall, Spring. 4(4-0) CEM 242.

Selected topics of organic chemistry, especially compounds of biological interest, discussed with emphasis on mechanisms and stereochemistry. Topics include polymers, amino acids, proteins, sugars, terpenes, steroids, and alkaloids.

333. Instrumental Methods

Spring. 4(2-6) CEM 143 or CEM 241 or CEM 351; CEM 162.

Principles, applications of separation and instrumental analysis. Atomic emission, absorption, fluoresence spectrometry; UV, visible, IR spectrophotometry; molecular fluoresence; gas and other chromotography; electro-analytical chemistry; electrophoresis; radiochemistry.

351. Organic Chemistry

Fall. 3(4-0) CEM 152 or CEM 182H.

A comprehensive introduction to the fundamentals of organic chemistry designed for chemistry majors but open to others who desire a rigorous, modern treatment of the subject.