Expected Learning Outcomes for Courses for the Chemistry Major Programs

Introduction

The department of chemistry presently has over 500 undergraduate majors and a small number of minors. Six programs are offered, B.S. Chemistry Major with an undergraduate degree certified by the American Chemical Society, A.B. Chemistry Major, B.S. Majors in Pharmaceutical Chemistry and Chemical Physics, and B.S. Majors with Designated Emphases in Environmental Chemistry and Forensic Chemistry.

Student Learning Outcomes

The major in chemistry provides training for students planning careers in the chemical sciences and also for those whose interests lie in biology, medicine, earth sciences, secondary education, business, and law. The curriculum of the Department is designed to satisfy the diverse needs of these students. Advanced coursework and educational activities outside the traditional classroom, such as independent research provide students the opportunity to conduct individual research projects or participate as member of a research team.

At graduation, chemistry majors should have a set of fundamental competencies that are *knowledge-based, performance/skills-based,* and *affective*.

Knowledge-Based

1. Graduates will be able to master a broad set of chemical knowledge concerning the fundamentals in the basic areas of the discipline (organic, inorganic, analytical, physical and biological chemistry).
2. Graduates will be able to solve problems competently by identifying the essential parts of a problem and formulating a strategy for solving the problem. They will be able to rationally estimate the solution to a problem, apply appropriate techniques to arrive at a solution, test the correctness of the solution, and interpret their results.
3. Graduates will be able to use computers in data acquisition and processing and use available software as a tool in data analysis.
4. Graduates will be able to use modern library search tools to locate and retrieve scientific information about a topic, chemical, chemical technique, or an issue relating to chemistry.

Performance/Skills-Based

5. Graduates will be able to understand the objective of their chemical experiments, properly carry out the experiments, and appropriately record and analyze the results.
6. Graduates will be able to use standard laboratory equipment, modern instrumentation, and classical techniques to carry out experiments.
7. Graduates will know and follow the proper procedures and regulations for safe handling and use of chemicals.
8. Graduates will be able to communicate the concepts and results of their laboratory experiments through effective writing and oral communication skills.

Affective

9. Graduates will be able to successfully pursue their career objectives in advanced education in professional and/or graduate schools, in a scientific career in government or industry, in a teaching career in the school systems, or in a related career following graduation.

Relationship between the Major's core curriculum and student learning outcomes:

Course	Course (Name)	Learning Outcomes								
		1	2	3	4	5	6	7	8	9
2AH	Honors Gen Chem	✓	✓							
2BH	Honors Gen Chem	✓	✓							
2CH	Honors Gen Chem	✓	✓							
100	Environ Water Chem	✓	✓	✓						
104	Forensic Chem	✓	✓	✓	✓	✓	✓	✓	✓	✓
105	Analytical Chem Lab	✓	✓	✓	✓	✓	✓	✓	✓	✓
110A	P-Chem Quantum	✓	✓							
110B	P-Chem Atoms/Molec	✓	✓							
110C	P-Chem Thermo/Kinet	✓	✓							
115	Instrumental Analysis	✓	✓	✓	✓	✓	✓	✓	✓	✓
121	Molec Spectroscopy	✓	✓							
122	Chem of Nanoparticles	✓	✓							
124A	Inorg Chem	✓	✓							
124B	Inorg Chem Main Gp	✓	✓							
124C	Inorg Chem d/f Block	✓	✓							
124L	Inorg Chem Lab	✓	✓	✓	✓	✓	✓	✓	✓	
125	Advanced P-Chem Lab	✓	✓	✓	✓	✓	✓	✓	✓	✓
128A	O-Chem Majors	✓	✓							✓
128B	O-Chem Majors	✓	✓		✓	✓		✓	✓	✓
128C	O-Chem Majors	✓	✓		✓	✓		✓	✓	✓
129A	O-Chem Majors Lab	✓	✓			✓	✓	✓	✓	
129B	O-Chem Majors Lab	✓	✓		✓	✓	✓	✓	✓	
129C	O-Chem Majors Lab	✓	✓		✓	✓	✓	✓	✓	
130A	Pharm Chem	✓	✓							✓

130B	Pharm Chem	✓	✓	✓	✓	✓			✓	✓
131	Organic Synthesis	✓	✓							✓
135	Pharm Chem Lab	✓	✓	✓	✓	✓	✓	✓	✓	✓
150	Natural Products	✓	✓		✓					✓
194H	Honors Research	✓	✓	✓	✓	✓			✓	✓
199	Undergrad Research	✓	✓	✓	✓	✓			✓	✓

Specific Courses

CHE2AH – Honors General Chemistry –

Learning Goals
The primary goal of 2AH is to help students gain understanding of chemical bonding at three levels: 1) macroscopic or chemical reactions 2) nanoscopic or the structure of chemicals and 3) electronic or quantum mechanics. Labs and practical examples will be employed to facilitate this understanding process. Through these intellectual exercises, students will be able to rationalize the structure of atoms and their relative positions in the Periodic table, structures of molecules, and the chemical properties of molecules. This course will equip students with the necessary knowledge to understand chemistry at the most fundamental level of wavefunction solutions of Schrodinger equation for any chemical system.

CHE2BH – Honors General Chemistry –

Learning Goals
This course introduces students to thermodynamics, acid base chemistry, chemical equilibria, and to the crystal structures of simple inorganic solids. At the end of the class students will be able to calculate the heat released and absorbed during chemical reactions, predict the equilibrium constant of chemical and phase transfer processes (e.g. melting), interpret phase diagrams, calculate the solubility of compounds and the vapor pressure of solutions. They will also be able to relate thermodynamic quantities (e.g. acidity) to molecular properties (e.g. electronegativity), and draw the crystal structures of simple inorganic solids.

CHE2CH – Honors General Chemistry –

Learning Goals
The primary goal of 2CH is to get the honors students well trained in a variety of chemical topics, including electrochemistry, kinetics, nuclear chemistry, transition metal coordination chemistry, and spectroscopy. Labs and practical examples will be employed to facilitate this

understanding process. It is important for the honors students to be exposed to chemistry as a modern exciting discipline, not just stuff that was figured out 100 years ago. To this end a running theme of the course is the fundamental role chemical research plays in the important contemporary topic of energy, from fossil fuels to nuclear to modern chemical approaches to clean renewable energy.

CHE100 – Environmental Water Chemistry –

Learning Goals
The course covers practical aspects of water chemistry including thermodynamic relations, coordination chemistry, solubility calculations, redox reactions and rate laws. Laboratory assignments include determination of solute concentrations in natural waters and computer modeling of the evolution in water chemistry that follows from contact with minerals and gases. Undergraduate students will learn the use of thermodynamics and molecular concepts to solve contemporary problems in water chemistry. Students are expected to demonstrate a working knowledge of the concepts in examinations and to complete a final project that involves a computer simulation of natural water chemistry and knowledgeable interpretation of the results.

CHE104 – Forensic Applications of Analytical Chemistry –

Learning Goals
The course covers practical aspects of the use of analytical procedures and instrumentation to characterize samples commonly found in modern forensic applications. This includes ignitable liquids, explosives, controlled substances, polymer films, fibers, and gunshot residue. The analytical instrumentation used is similar to that found in many government and private forensic laboratories: Gas Chromatography/Mass Spectrometry, Ion Mobility Spectrometry, Attenuated Total Reflection-Fourier Transform Infrared (FTIR) Spectroscopy, FTIR Microscopy, Scanning Electron Microscopy-Energy Dispersive X-ray Spectroscopy. Application of these techniques to standards and unknowns is required.

CHE105 – Analytical and Physical Chemistry Methods –

Learning Goals
Fundamental theory and laboratory techniques in analytical and physical chemistry. Errors and data analysis methods. Basic electrical circuits in instruments. Advanced solution equilibria. Potentiometric analysis. Chromatographic separations. UV-visible spectroscopy. Lasers.

CHE110A – Physical Chemistry: Intro to Quantum Mechanics –

Learning Goals
Introduction to the postulates and general principles of quantum mechanics. Approximations based on variational method and time independent perturbation theory. Application to harmonic oscillator, rigid rotor, one-electron and many-electron atoms, and homo-and hetero-nuclear diatomic molecules.

CHE110B – Physical Chemistry: Properties of Atoms and Molecules –

Learning Goals
Group theory. Application of quantum mechanics to polyatomic molecules and molecular spectroscopy. Intermolecular forces and the gas, liquid and solid states. Distributions, ensembles and partition functions. Transport properties.

CHE110C – Physical Chemistry: Thermodynamics, Equilibria and Kinetics –

Learning Goals
Development and application of the general principles of thermodynamics and statistical thermodynamics. Chemical kinetics, rate laws for chemical reactions and reaction mechanisms.

CHE115 – Instrumental Analysis –

Learning Goals
Intermediate theory and laboratory techniques in analytical and physical chemistry. Advanced data analysis methods and goodness-of-fit criteria. Fourier transform spectroscopic methods and instrumentation. Mass spectrometry. Electrochemistry. Liquid chromatography.

CHE121 – Intro to Molecular Structure and Spectra –

Learning Goals
Modern theoretical and experimental methods used to study problems of molecular structure and bonding; emphasis on spectroscopic techniques.

CHE122 – Chemistry of Nanoparticles –

Learning Goals
CHE122 is an introduction to the chemistry, preparation, structure and physical properties of inorganic nanoparticles. Students will learn about methods to synthesize inorganic nanoparticles, and learn to evaluate particle size and shape distributions. At the end of the class, they will be able to predict the stability of nanoparticles in solution, and to understand the nucleation and growth of nanoparticles. They will know how to analyze the size-dependent physical properties of nanoparticles, and they will know about the different techniques (electron microscopy, X-ray diffraction) to study nanoparticles. Students will also be aware of applications of nanoparticles in science and technology. It is expected that students enrolled in this class have a basic understanding of physical chemistry.

CHE124A – Inorganic Chemistry: Fundamentals –

Learning Goals
CHE124A is the first course in the three-term undergraduate inorganic chemistry sequence that includes CHE124A, CHE124B, CHE124C, and the laboratory class CHE124L (taught concurrently with CHE124C). The course introduces students to the structure, symmetry and bonding of atoms, simple molecules and covalent and ionic solids. Aspects of the reactivity of

compounds (acid/base chemistry, oxidation and reduction) as covered as well, as their spectroscopy. It is expected that students enrolled in this class already have a basic understanding of periodic trends, VSEPR, Lewis dot structures, atomic orbitals, and some familiarity with both valence bond theory and molecular orbital theory.

CHE124B – Inorganic Chemistry: Main Group Elements –

Learning Goals
This second installment in the 124 series covers the production, structure and reactivity of the main group elements and their compounds. Students learn to classify elements into electron poor, electron rich and electron normal, and to rationalize trends in size and electronegativity, and bonding preferences. Structures, electron configurations and preferred oxidation states of the elements are covered, as are syntheses and properties of their compounds, including organometallic ones. Students also learn to balance chemical equations in terms of electrons and stoichiometry, and they are introduced to the concepts of hard and soft acids and bases.

CHE124C – Inorganic Chemistry of the D and F Block Elements–

Learning Goals
CHE 124C deals with the production, chemistry and properties of the transition metals and lanthanides and actinides. Specifically, the class introduces electron configurations for the elements and oxidation state trends for each group, and important concepts, including the 18 VE rule, bonding and isomerism in coordination compounds, crystal field theory, and electronic properties of ligands. Covered also are metal bonding in clusters, the HSAB concept, chelate effect, and complex stability. Reactions of complexes are analyzed, and the role of transition metal compounds in catalysis is described with examples.

CHE124L – Laboratory Methods in Inorganic Chemistry –

Learning Goals
CHE 124L introduces students to practical aspects of the preparation, characterization, and application of main group and transition metal compounds. In seven different sections students learn techniques to prepare and purify compounds, and to characterize them using optical, nuclear magnetic resonance, and infrared spectroscopy, a magnetic balance, and a gas chromatograph. In addition students learn about safety procedures in the laboratory, and how to use chemical databases to locate chemical information. The emphasis of the class is on planning experiments, working in teams, improving experimental skills to maximize yield and purity of products, and document work in accurate and detailed laboratory reports.

CHE125 – Advanced Methods in Physical Chemistry –

Learning Goals
Advanced theory and laboratory techniques in analytical and physical chemistry. Advanced spectroscopic methods. Thermodynamics. Kinetics. Chemical literature. Digital electronics and computer interfacing. Laboratory measurements and vacuum techniques.

CHE128A – Organic Chemistry –

Learning Goals
CHE128A is the first course in the three-term undergraduate organic chemistry lecture sequence that includes CHE128A, CHE128B, CHE128C. Students will learn the basic principles that govern the structure of molecules. Two different bonding theories, valence bond and molecular orbital theories, will be introduced. The appropriate application of these theories will be covered on-and-off by example for the duration of the course. The structures and properties of alkanes will be presented, and their industrial importance discussed. The concept of stereoisomerism will be introduced in the context of organic chemistry (i.e., tetrahedral carbon). Recognition and assignment of configuration will be taught. Students will learn about the separation and analysis of stereoisomers. The concepts of acids and bases in the context of organic chemistry will be reviewed. The molecular properties that determine acidity will be analyzed. Alkenes, unsaturated hydrocarbons, will be introduced and their reactions will be covered in depth. Students will learn about oxidations and reductions of alkenes, and this serves also to introduce them to concepts of organic synthesis. Discussion of alkynes, hydrocarbons with triple bonds, will follow alkenes and the similarities and differences between their properties and reactions will be highlighted. Halogenated alkanes and their reactions are the last subject of this section of CHE128. Their properties and reactions, both nucleophilic substitution and β-elimination, are covered in depth. The properties of the nucleophile/base, the haloalkane, and the leaving group that drive reaction toward one extreme or the other are discussed and used as a model for understanding organic reactivity in terms of structure.

CHE128B – Organic Chemistry –

Learning Goals
CHE 128B is a continuation of the full-year organic chemistry lecture sequence for Chemistry majors. Continuation of course 128A with emphasis on aromatic and aliphatic substitution reactions, elimination reactions, and the chemistry of carbonyl compounds; application of spectroscopic methods to organic chemistry. Students will transition from memorization to understanding by programmed exposure to integrated problems involving mechanism, multi-step synthetic planning, and organic spectroscopy.

CHE128C – Organic Chemistry –

Learning Goals
CHE128C is the third and the last course in the three-term undergraduate organic chemistry lecture sequence that includes CHE128A, CHE128B, CHE128C. It is a continuation of course 128B and emphasizes on the chemistry of benzene and its derivatives, amines, carbon-carbon bond formation, carbohydrates, and selected biologically important compounds. It provides a bridge between basic and more advanced organic chemistry knowledge. It also makes connection from chemical principles to the structures and functions of biological molecules.

CHE129A – Organic Chemistry Laboratory –

Learning Goals
CHE 129A is the first of a sequence of three practical laboratory courses for Chemistry majors. Students attend two lectures and one 3-hour laboratory session per week. The lectures cover laboratory safety, keeping an organic laboratory notebook, basic laboratory operation, and the separation and purification of organic compounds (simple and fractional distillation, precipitation and crystallization, sublimation, solid-liquid and liquid-liquid extraction, and chromatography). Laboratory exercises in simple distillation, fractional distillation, melting point determination, recrystallization, extraction, paper chromatography, thin-layer chromatography, and rudimentary organic synthesis and analysis are performed.

CHE129B – Organic Chemistry Laboratory –

Learning Goals
CHE 129B is a continuation of the full-year organic chemistry laboratory sequence for Chemistry majors. Students will carry out reactions representative of the processes typically employed in synthetic organic chemistry including but not limited to nucleophilic substitution, hydroboration, Grignard reaction, alcohol oxidation, aldol condensation, and at least one multi-step synthesis. Students will utilize techniques that include carrying out of reactions under anhydrous conditions, under a specific gaseous atmosphere, and at room temperature as well as reflux. Students will gain experience in work-up techniques that include extraction, water removal, chromatography, distillation, and crystallization. An analytical experimental component will include the determination of kinetic order of a reaction and/or compound identification by a variety of means including spectroscopy.

CHE129C – Organic Chemistry Laboratory –

Learning Goals
CHE 129C is the third course in a series of three organic chemistry laboratory course sequence offered for Chemistry majors. Students carry out reactions representative of the processes typically employed in synthetic organic chemistry including epoxidation of alkenes, synthesis of various polymers, Claisen condensation, bimolecular substitution reactions, Synthesis of porphyrin derivatives, Diels-Alder Reaction, preparation of acid halides and their conversion to amides, saponification of oil and biodiesel production, preparation of dyes such as methyl

orange, Isolation of lactose from milk and acetylation of lactose, and solid phase peptide synthesis. Some of these experiments involve multi-step syntheses. Students will utilize techniques that include carrying out of reactions under anhydrous conditions, and at room temperature as well as reflux. Students will gain experience in work-up techniques that include extraction, water removal, chromatography, distillation, and crystallization. Analytical experimental components include determination of physical properties of compounds and structure determination using spectroscopic methods.

CHE130A – Pharmaceutical Chemistry –

Learning Goals
This class provides an introduction to the chemical principles behind the design and production of pharmaceutical agents. Focus is on explaining and predicting how small organic molecules bind to biological receptors, inhibit enzymes and get metabolized. This course draws on and expands upon material covered in introductory organic chemistry such as proposing reasonable arrow-pushing mechanisms for organic reactions and predicting the reactivity of organic molecules with particular reagents.

CHE130B – Pharmaceutical Chemistry –

Learning Goals
CHE130B is the second course in a two-term upper division undergraduate sequence on Pharmaceutical Chemistry. Through lectures from outside speakers with careers in the Pharmaceutical/Biotech industry, this course demonstrates real-life applications of the fundamental principles taught in 130A. Broader societal issues such as ethical aspects of scientific research that has clear implications to public health will be explored. Through molecular modeling laboratory experiments, students learn the process of rational drug design.

CHE131 – Modern Methods of Organic Synthesis –

Learning Goals
CHE131 provides an introduction to the synthesis of complex organic molecules. Trans-formations for C-X and C-C bond-formation, functional group reactivity, chemoselectivity, regioselectivity, and the strategy of multistep synthesis will be the core topics that are covered. Concepts include strategy/retrosynthesis, advanced aromatic chemistry, protecting groups, stereochemistry, enolates and other carbonyl chemistry, alkene synthesis, reduction/oxidation (introductory), heterocycles, cross-coupling reactions and other modern methods of synthesis. CHE128C is a prerequisite and students who have completed 118C may be enrolled at the discretion of the instructor. A central theme of this course is the ability to recognize retrosynthetic simplification of target molecules and be able to provide forward synthetic proposals. Although the logic for this type of analysis evolved around natural products, this course emphasizes parallel strategies as they are applied to complex drugs. Given the recent increase in the structural complexity of drug molecules required to achieve specificity and potency while eschewing metabolic liabilities, knowledge of synthetic strategy is increasingly important in the pharmaceutical industry.

CHE135 – Advanced Bio-organic Laboratory/Pharmaceutical Chemistry Laboratory –

Learning Goals

CHE135 is an advanced laboratory course taken by junior and senior chemistry majors that is part of the required courses for the Pharmaceutical chemistry major. The course provides a "hands-on" laboratory-based reinforcement of concepts covered in CHE130A and CHE 130B. The course allows students to develop qualitative and quantitative skills used in the identification and chemical analysis of various medicinal agents by utilizing analytical instruments and synthetic techniques. Specifically, in this course, each student makes a different derivative of a known organic drug using amide bond chemistry. Subsequent to purification using flash chromatography, the student performs rigorous characterization of their compound using 1- and 2-dimensional NMR techniques (^{1}H and ^{13}C), mass spectrometry, infrared spectroscopy and polarimetry. The students then turn to analysis of the compound as a potential pharmaceutical by measuring the lipophilicity (logP) using liquid chromatography/mass spectrometry, binding to human serum albumin using fluorescence and circular dichroism spectroscopy, and toxicity using a brine shrimp assay. Though-out the course the students are grouped in a "team" that has related compounds and are asked to compare and contrast their data from these various experiments to enhance data analysis skills required for professional chemists. There is a weekly lecture component to provide the background for each element of the laboratory course and expand upon concepts presented in CHE130A and 130B.

CHE150 – Natural Products Chemistry –

Learning Goals

CHE150 is a course that provides a survey of natural products chemistry including biogenesis by enzyme-mediated pathways, structure determination, medicinal and biochemical significance and synthesis. Given the breadth of the material, one or more topic areas may be emphasized to a greater or lesser extent based on the expertise of the instructor. CHE128C is a prerequisite and students who have completed 118C may be enrolled at the discretion of the instructor. A central theme of this course is to recognize the chemical building blocks in nature that enable student to link structures to biosynthetic hypotheses. The four major biosynthetic pathways (fatty acid/poly propionate synthesis, shikimate pathway, isoprenoids and alkaloid biosynthesis) are consistently discussed in detail. Additional topics can include biosynthetic origins of carbohydrates and non-ribosomal peptides (NRPs), structure determination by multiple spectroscopic methods (MS and NMR), and the chemical synthesis of natural products and their derivatives.