

CHEMISTRY MAJOR PANEL

Course Approval Criteria – Updated Spring ‘17

5/17/17

An institutionally-approved representative syllabus in electronic format from a recent offering is required for the panel to review. Course submission materials and any representative syllabus must indicate:

- Prefix/number and title, number of credit hours
- Catalog/course description including any prerequisites
- Course objectives
- Course outcomes
- A detailed topical outline and weekly schedule. **This should go beyond chapter numbers and titles.**
- Method(s) of evaluating/assessing student learning
- Grading criteria and scale
- Laboratory contact hours, (equating to 2 hours and 40 minutes of physical lab time) if the course is to be designated as a lab course
- Required text(s), learning resources, and reading lists, and supplemental materials if applicable
- If an “in-house” laboratory manual is used, 3 examples must be submitted
- Date of preparation of the syllabus and any supporting materials
- Delivery mode (traditional or non-traditional)

All materials submitted for panel review must be recent and representative. Syllabus Checklist follows on separate page.

General Coding Practice

- A course can only be assigned to one code/description. However, multiple courses from the same institution may be assigned the same code/description.
- A student may “count” only one course per code in fulfilling major requirements.

Laboratory Course Submission

- Laboratory experiences should develop an understanding of the methods of scientific inquiry, including the development of the skills and disposition necessary to become independent inquirers about the natural world.

Laboratory students will be expected to

- formulate or evaluate questions (hypotheses),
- plan and conduct experiments (test hypotheses),
- make systematic observations and measurements,
- interpret and analyze data,
- draw conclusions, and communicate the results (orally and/or in writing)

A concise description of each laboratory experience is required (not simply a title), including equipment/instrumentation used. In addition, the panel requests an indication if any non “hands-on” lab experiences or instructional methodologies are used (e.g. web, videotape). If a published lab manual is used, it must be identified (with full bibliographic reference) in

the syllabus. If an “in-house” lab manual is used then 3 sample lab exercises should be submitted. The syllabus should contain a weekly outline of the labs and indicate how these experiences relate to contemporary content.

Computer Simulations as Lab Experiences

In 1999, the Panel conducted a survey of IAI participating institutions regarding the use of computer simulations for lab experiences. After reviewing the results, members agreed to the following: “Computer simulations may be used to augment instruction but are not generally considered suitable replacements for hands-on experiments. This perspective appears to be in line with positions taken by professional associations of science teachers, as well. Courses will not be approved by the panel in which computer simulations comprise 100% of the laboratory experiences.”

Common Reasons Courses Are Not Approved

- Course does not match description for IAI designation
- Course has inappropriate prerequisites
- Course has insufficient attention to writing or speaking
- Topical outline does not have enough detail.
- Syllabi for both courses of a sequence are not submitted.
- Lab content is not described in sufficient detail.
- 3 examples from “in-house” laboratory manual were not submitted
- Laboratory contact hours do not meet the IAI panel’s requirements.
- Lab content is inadequate

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Course Syllabus Checklist

☐ **Course Description**

- A complete description for this course is required; a catalog description may be substituted if it is sufficiently informative. The course description should compare favorably to the description given on the iTransfer website.

☐ **Prerequisites**

- The committee must review both courses in the sequence in order to accept the first course as a prerequisite.

☐ **Course Objectives**

- The course goals and an outline of the course content are expected.

☐ **Student Outcomes**

- Student outcomes must be included to provide additional evidence that the course focus is aligned with the IAI description and should be stated in such a manner that it is clear how one would assess them.

☐ **Detailed Topical Outline (Daily/Weekly Schedule)**

- The Chemistry Major Advisory Committee will review the schedule for evidence of the content of the course for a full semester or equivalent. Provide detailed outlines of all topics, assignments and activities.
- Do not list simply, 'Chapter 1, Chapter 2' etc. Listing the chapter titles from the published text is not sufficient either. More detail is required.
- A lab weekly lab schedule including a concise description of each laboratory experience is required including equipment/instrumentation used. In addition, the panel requests an indication if any non "hands-on" lab experiences or instructional methodologies are used (e.g. web, videotape)

☐ **Methods of Evaluation**

- Specific assignments are required. In particular, the lab assignments must include a brief description.
- Include a grading scheme.

☐ **Grading Criteria and Scale**

- The points or percentages attached to course work are required. Indicate how grades are determined.

☐ **Laboratory Contact Hours**

- A minimum of 2 hours and 40 minutes (clock time) of lab time per week of lab instruction is required for each semester of General Chemistry and Organic Chemistry.

☐ **Textbooks/Learning Resources**

- The choice of text is required and may provide evidence of course content and focus. The author and date of publication of text is required.
- If there are supplemental texts that will be used, these should also be listed.
- As institutions pursue the opportunity to expand into online/open resource electronic text material, the panel has sought to provide some necessary guidance on citing these resources in submitted syllabi and documents. If any online reading or learning resource materials are used, a complete working url or bibliographic citation (embedded hyperlinks are acceptable) must be provided. This site/resource must be active, working, and viewable by the panel.

☐ **Date of Preparation of the Syllabus**

- The submitted syllabus must have date of preparation and the semester for which it was written.
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☐ **Delivery Modes**

- Specify the delivery mode, whether traditional, online, blended, etc.

CHEMISTRY MAJOR PANEL

General Chemistry Description, Topics and Student Outcomes

Since topic selection varies between institution and/or instructor, the topics and student outcomes are written for the full year course with the typical semester break noted. The committee must review both courses in the sequence in order to accept the first course as a prerequisite.

General Chemistry I

(4-5 semester credits)

Course Description:

Topics include the periodic table of the elements, atomic structure, basic concepts of quantum theory, bonding, stoichiometry of compounds and reactions, thermochemistry, the gaseous state, basic concepts of the liquid and solid states, solutions, acid and bases, equilibrium, acid-base equilibria, solubility equilibria, kinetics, thermodynamics, electrochemistry, coordination compounds, nuclear chemistry and descriptive topics in inorganic chemistry. Laboratory required. Prerequisite: One year of high school chemistry or the equivalent. Students should complete CHM 911 and 912 at the same school before transfer, since topics are covered in different order by different schools.

General Chemistry II

(4-5 semester credits)

Course Description:

Topics include the periodic table of the elements, atomic structure, basic concepts of quantum theory, bonding, stoichiometry of compounds and reactions, thermochemistry, the gaseous state, basic concepts of the liquid and solid states, solutions, acid and bases, equilibrium, acid-base equilibria, solubility equilibria, kinetics, thermodynamics, electrochemistry, coordination compounds, nuclear chemistry and descriptive topics in inorganic chemistry. Laboratory required. Prerequisite: General Chemistry I. Students should complete CHM 911 and 912 at the same school before transfer, since topics are covered in different order by different schools.

Course Topics:

Students successfully completing the General Chemistry I and II courses will be able to understand and apply the concepts and principles associated with the topics and subtopics listed below. It is understood that not all programs will cover all of the subtopics listed to the same depth. Some programs will include topics and subtopics not included on the list below. Distribution of topics between General Chemistry I and II varies.

1. Measurements in Chemistry

- a) Units of measurement common to the sciences (S. I. Units).
- b) Conventions for stated precision of measured numbers.
- c) Unit conversions and manipulation.

2. Components of matter

- a) The structure of the atom and atomic isotopes.
- b) How atoms combine to form ionic and molecular compounds.
- c) Inorganic nomenclature.
- d) States of matter (solid, liquid, gas).

3. Stoichiometry

- a) Balancing chemical equations.
- b) The mole concept.

- c) Empirical and molecular formulas.
- d) Mass/mole calculations from chemical formulas and equations.

4. Reactions in aqueous solution

- a) Precipitation reactions and solubility rules.
- b) Acid/base definitions and reactions.
- c) Oxidation states and oxidation/reduction reactions.
- d) Molarity calculations.

5. Thermochemistry

- a) Reaction enthalpies and Hess's Law.
- b) Calorimetry.
- c) Heat capacity.

6. Electronic structure of atoms

- a) Atomic transitions and line spectra.
- b) Atomic orbitals, electron spin, and quantum numbers.
- c) Electron configurations for atoms and ions.
- d) Periodicity and atomic electron configurations.

7. Periodic properties of atoms

- a) Trends in atomic and ionic radii.
- b) Trends in ionization energy, electron affinity, and electronegativity.
- c) Similarities in chemical properties within groups of the periodic table.

8. Chemical bonding

- a) Ionic bonds
- b) Covalent bonds.
- c) Lewis structures of atoms, ions, and molecules.
- d) Resonance structures.
- e) Average bond enthalpies.

9. Molecular geometries

- a) VSEPR.
- b) Hybridization of atomic orbitals.
- c) Introduction to molecular orbital theory.

10. Properties of gases

- a) Laws describing ideal gas behavior.
- b) Pressure, volume, and temperature calculations for ideal gases.
- c) Mixtures of gases.
- d) Kinetic molecular theory of gases.
- e) How real gases differ from ideal gases.

11. Intermolecular forces and states of matter

- a) Phase changes.

- b) Vapor pressure.
- c) Different types of inter-particle forces.

12. Solutions and their properties

- a) Impact of molecular/ionic properties on solubility.
- b) Concentration units and their interconversion.
- c) Colligative properties.

Typical semester break

13. Chemical Kinetics

- a) Differential rate laws.
- b) Integrated rate laws (first and second order reactions).
- c) Temperature effects and the Arrhenius equation.
- d) Collision theory.
- e) Reaction mechanisms.
- f) Catalysis.

14. Chemical equilibrium

- a) Equilibrium constant expressions and calculations.
- b) LeChatelier's principle
- c) Solubility equilibria.

15. Acid-base equilibria

- a) Acid/base definitions
- b) Strong acids/bases.
- c) Conjugate acids/bases.
- d) Weak acid/base equilibria
- e) The pH scale and calculations of pH.
- f) Buffer solutions.
- g) The common ion effect.
- h) Polyprotic acids.
- i) pH calculations during titrations.

16. Chemical thermodynamics

- a) Spontaneity, entropy, and Gibbs free energy.
- b) The first, second, and third laws of thermodynamics
- c) Relationships between equilibrium constants and ΔG .

17. Electrochemistry

- a) Balancing Redox reactions.
- b) Voltaic and electrolytic cells.
- c) The Nernst equation; relationship between concentration and voltage.
- d) Relationship between emf and ΔG .
- e) Applications of electrochemistry.

18. *Nuclear chemistry

- a) Types of radioactivity.
- b) Balancing nuclear reactions.
- c) Half-lives and decay rates.
- d) Fission and fusion.

19. *Descriptive chemistry

- a) Nonmetals.
- b) Metals.
- c) Metalloids.

20. *Coordination compounds

- a) Nomenclature.
- b) Isomers.
- c) Valence bond theory.

Topics 18-20 are annotated with a star (“*”); this means that the topic is important, but may not be covered by all programs. Those topics and subtopics not annotated with a star are considered to be an essential part of a majors-level 2-semester general chemistry course sequence.

Student Outcomes:

Upon completion of two semesters in General Chemistry, students will be able to:

1. demonstrate appropriate safety techniques and proper use of protective equipment; demonstrate skills in measuring and in recording data; and communicate results and data in clear and understandable forms.
2. use names and formulas to relate the observable properties and characteristics of elements, compounds, and mixtures to the concept of atoms and molecules.
3. use the mole concept and molarity to perform calculations involving gases, solutions, compounds and chemical reactions.
4. describe chemical reactions in terms of bond rearrangement of the atoms, the law of conservation of mass, balanced chemical equations, and energy changes.
5. describe the development of the model of the atom including the sub-atomic structures of atoms, ions, and isotopes
6. utilize the modern periodic table to describe the chemical and physical properties of elements, and demonstrate knowledge of chemical bonding to create formulae and Lewis structures.
7. predict the relative solubility of a solute in a solvent, and relate ion formation to electrical conductivity in aqueous solutions
8. demonstrate knowledge of the various ways that carbon and hydrogen can combine to form a wide range of compounds and differentiate the various types of bonding between carbon atoms

Typical semester break

9. apply collision theory to explain how reaction rates can be changed, describe the use of a catalyst, and represent graphically the energy changes associated with catalyzed and uncatalyzed reactions
10. explain the concept of chemical equilibrium, apply Le Châtelier’s principle to the shifting of equilibrium,

and evaluate the changes in the value of K_{eq} and in concentrations of substances within an equilibrium system

11. determine the solubility and concentration of ions from a compound in aqueous solution and perform calculations involving solubility equilibrium concepts
12. classify an acid or base in solution as either weak or strong, with reference to its electrical conductivity and analyze the equilibria that exist in weak acid or weak base systems
13. perform calculations relating pH, pOH, $[H_3O^+]$, and $[OH^-]$, explain the significance of the K_a and K_b equilibrium expressions, and describe buffers as equilibrium systems
14. describe oxidation and reduction processes and balance equations for redox reactions
15. analyze electrochemical and electrolytic cells in terms of its components and their functions, and describe how electrochemical and electrolytic concepts can be used in various practical applications

Substitution or addition of student outcomes of equal rigor may be acceptable.

General Chemistry Laboratory Outcomes

This section is intended as a guide for the laboratory instructor in General Chemistry I and II. The objective is to provide an overview of expected student outcomes for the first year of general chemistry laboratory. The student will be exposed to the scientific method as foundation of chemistry in the laboratory. As a result, the student will design and conduct experiments, collect and organize data and interpret results as practical examples of course content.

In particular, students should have exposure to laboratory techniques and equipment. By the end of the course, students will be able to:

1. apply proper lab safety and proper procedures for handling and disposal of chemicals.
2. demonstrate proper manipulation of common equipment including, but not limited to:
 - a. balances - general wet chemistry equipment for investigation of chemical reactions and chemical separation techniques.
 - b. volumetric glassware for quantitative solution chemistry.
3. use and understand selected instrumentation such as NMR, IR, and UV/Visible spectrometers, chromatographs, electrochemical instruments and lab computers.

The laboratory section of the syllabus should include the following items:

- the number of total student laboratory hours per semester
- bibliographic information for the laboratory textbook, if one is used
- topical outline including a list of experiments and short statement of the objective of each experiment and a listing of any specialized equipment from the list given above.

CHEMISTRY MAJOR PANEL
Organic Chemistry Description, Topics and Student Outcomes

Since topic selection varies between institution and/or instructor, the topics and student outcomes are written for the full year course with the typical semester break noted. The committee must review both courses in the sequence in order to accept the first course as a prerequisite.

Organic Chemistry I

(4-5 semester credits)

Course Description:

Topics include structure, bonding, molecular properties, reactivity and nomenclature of alkanes, cycloalkanes, alkenes and alkynes; stereochemistry, alkyl halides, reaction mechanisms, nucleophilic substitution and elimination, conjugated dienes, mass spectrometry; IR, NMR, and UV spectroscopy, benzene, aromaticity and electrophilic aromatic substitution, organometallic compounds, alcohols, phenols and ethers, aldehydes and ketones, carboxylic acids and derivatives, dicarbonyl compounds, carbohydrates, amines, amino acids and proteins, heterocyclic compounds, and nucleic acids. Laboratory required. Prerequisite: General Chemistry I or II as determined by the receiving institution. Students should complete CHM 913 and 914 at the same school before transfer, since topics are covered in different order by different schools.

Organic Chemistry II

(4-5 semester credits)

Course Description:

Topics include structure, bonding, molecular properties, reactivity and nomenclature of alkanes, cycloalkanes, alkenes and alkynes; stereochemistry, alkyl halides, reaction mechanisms, nucleophilic substitution and elimination, conjugated dienes, mass spectrometry; IR, NMR, and UV spectroscopy, benzene, aromaticity and electrophilic aromatic substitution, organometallic compounds, alcohols, phenols and ethers, aldehydes and ketones, carboxylic acids and derivatives, dicarbonyl compounds, carbohydrates, amines, amino acids and proteins, heterocyclic compounds, and nucleic acids. Laboratory required. Prerequisite: Organic Chemistry I. Students should complete CHM 913 and 914 at the same school before transfer, since topics are covered in different order by different schools.

Course Topics:

Students successfully completing the Organic Chemistry I and II courses will be able to understand and apply the concepts and principles associated with the topics and subtopics listed below. It is understood that not all programs will cover all of the subtopics listed to the same depth. Some programs will include topics and subtopics not included on the list below. Distribution of topics between Organic Chemistry I and II varies.

1. Fundamentals of Molecular Structure and Chemical Reactivity
 - a) Bonds
 - b) Hybridization
 - c) Resonance
 - d) Polarity
2. The Alkanes and Cycloalkanes
 - a) Structure, Nomenclature & Physical Properties
 - b) Isomers
 - c) Acyclic Conformations
 - d) Cyclic Conformations
3. Stereochemistry
 - a) Optical Activity - Optical Purity
 - b) R & S Enantiomers, Diastereomers, Meso

4. The Alkenes and Alkadienes
 - a) Structure & Physical Properties
 - b) Nomenclature - cis-trans and E/Z isomers
 - c) Alkene Synthesis
 - d) Electrophilic Addition Reactions - Mechanisms
 - e) Oxidation Reactions - Mechanisms
5. Alkynes
 - a) Structure, Nomenclature & Physical Properties
 - b) Alkyne Synthesis - Mechanisms
 - c) Addition Reactions - Mechanisms
 - d) Oxidation Reactions - Mechanisms
6. Alkyl Halides
 - a) Structure, Nomenclature & Physical Properties
 - b) Substitution Reactions - Mechanisms
 - c) Elimination Reactions - Mechanisms
7. Alcohols, and Ethers and Epoxides
 - a) Structure, Nomenclature & Physical Properties
 - b) Synthesis of Alcohols and Ethers - Mechanisms
 - c) Reactions of Alcohols - Mechanisms
 - d) Reactions of Ethers and Epoxides
8. Spectroscopic Methods of Structure Determination
 - a) Visible and ultraviolet spectroscopies
 - b) Proton Nuclear Magnetic Resonance spectroscopy
 - c) Carbon-13 NMR spectroscopy
 - d) Infrared spectroscopy
 - e) Mass spectrometry

Typical semester break

9. Conjugated Unsaturated Systems - Allylic & Benzylic
 - a) Structure
 - b) Addition Reactions - Mechanisms
 - c) Diels Alder Reaction - Mechanism
10. Aromatic Compounds
 - a) Aromatic Character
 - b) Structure, Nomenclature & Physical Properties
 - c) Electrophilic Aromatic Substitution Reactions - Mechanisms
 - d) Substituent Activating/Deactivating Ability
 - e) Substituent Directing Ability
 - f) Phenols - Reactions
 - g) Aryl Halides: Nucleophilic Aromatic Substitution Reactions - Mechanisms
11. Organometallic Compounds: Organic Oxidation-Reduction Reactions
 - a) Synthesis
 - b) Reactions
12. Aldehydes and Ketones
 - a) Structure, Nomenclature & Physical Properties
 - b) Synthesis of Aldehydes and Ketones

- c) Nucleophilic Addition to the Carbonyl Group - Mechanisms
- d) Reactions at the Alpha Carbon - Mechanisms

13. Carboxylic Acids and Their Derivatives

- a) Structure, Nomenclature and Physical Properties
- b) Synthesis of Carboxylic Acids - Mechanisms
- c) Synthesis of Carboxylic Acid Derivatives - Mechanisms
- d) Reactions of Carboxylic Acids and Derivatives - Mechanisms

14. Amines

- a) Structure, Nomenclature and Physical Properties
- b) Synthesis - Mechanisms
- c) Reactions of Amines - Mechanisms

15. Carbohydrates*

16. Proteins and Nucleic Acids*

Topics 15-16 are annotated with a star (“*”); this means that the topic is important, but may not be covered by all programs. Those topics and subtopics not annotated with a star are considered to be an essential part of a majors-level 2-semester organic chemistry course sequence.

Student Outcomes:

Upon completion of two semesters in Organic Chemistry, students will be able to:

1. use the IUPAC system to name organic molecules (up to 10 carbons). This should include recognizing the major functional groups, including hydrocarbons, alcohols, alkyl halides, aldehydes, ketones, amines, carboxylic acids and their derivatives.
2. demonstrate an understanding of the chemical reactions, their mechanisms, and be able to use them in syntheses. The key reactions should include Diels Alder, S_N1 , S_N2 , E1, and E2, nucleophilic addition to carbonyl compounds, and electrophilic aromatic substitutions, nucleophilic aromatic substitutions, radical reactions, electrophilic additions to alkenes and alkynes, oxidations and reductions (and oxidative cleavage reactions). Aromatic substitutions should include an understanding directing groups and activating/deactivating groups. Students should have an understanding of enolate reactions, including but not limited to aldol condensations and Claisen condensations.
3. demonstrate an understanding of organometallic reagents, including Grignard reagents, organolithiums, and organocuprates.
4. demonstrate an understanding of ultraviolet/visible spectroscopy, infrared spectroscopy, and nuclear magnetic spectroscopy (proton and carbon-13), and mass spectrometry. They should be able to use the information provided by these techniques to determine the structure of an organic molecule. Students should also have an understanding of the effect of conjugation on the absorption wavelength. When using NMR, they should be able to determine the number of signals, have an understanding of coupling, and be able to determine the multiplicity of a particular signal.
5. recognize chiral compounds, determine configuration of the stereocenter, and classify pairs of compounds as enantiomers, diastereomers, or a different class of isomer. Students should also be able to draw chiral compounds by perspective drawings and Fisher projections. Students should also be able to relate the stereochemistry of a product to the reaction mechanism.
6. determine the relative stability of reaction intermediates, such as carbocations, radicals, and carbanions. They should be able to determine if a carbocation will rearrange and what rearrangement will take place.

7. demonstrate an understanding of molecular geometry using hybridization and VSEPR theory. Based on the molecular structure, they should be able to draw conclusions about a molecule's physical properties, such as (but not limited to) dipole moment, relative acid/base strength, formal charges, solubility, and melting/boiling points. Students should be able to apply the basic ideas of molecular orbital theory.
 8. draw conformations, using prospective drawing and Newman projections. They should be able to determine the relative energies of the conformational isomers of simple alkanes, substituted alkanes, and cyclohexanes.
 9. classify compounds as aromatic, nonaromatic, or antiaromatic. They should also be able to classify alcohols, alkyl halides, amines, and amides as primary, secondary, or tertiary. Students should be able to classify individual carbons as primary, secondary, tertiary, or quaternary.
- | 10. be familiar with proteins, nucleic acids, and carbohydrates.

Organic Chemistry Laboratory Outcomes

This section is intended as a guide for the laboratory instructor in Organic Chemistry I and II. The objective is to provide an overview of expected student outcomes for the first year of organic chemistry laboratory.

Upon completion of two semesters in Organic Chemistry, students will be able to:

1. Employ appropriate and safe laboratory techniques to perform experiments, collaborating with partners.
2. Interpret the results of spectroscopic and chromatographic instruments to analyze reactions and products.
3. Employ laboratory skills and content knowledge to determine the identity of unknown compounds.
4. Report the results of the laboratory experiments in a laboratory notebook, performing quantitative calculations, and interpreting the results.