FIRST-YEAR CHEMISTRY for science and engineering majors

Typical range 4-5 semester hours each term, 2 semesters in a sequence

In the first-year chemistry course for science and engineering majors, students should:

- develop scientific thinking skills,
- apply precise, logical reasoning, correct mathematical manipulations, and clear communication to problem solving,
- learn vocabulary, theories and techniques that are fundamental to the field of chemistry, and
- gain fundamental skills in the chemical laboratory.

The first-year chemistry course sequence for science and engineering majors will virtually always be the prerequisite for Organic Chemistry. The course sequence will also be intended to serve as the year of "inorganic" chemistry required by most medical and other professional schools. There is often an alternative first-year course sequence intended for nursing, allied health and engineering technology majors. While this sequence covers many of the same topics, it does not require the same level of problem solving as the sequence for science and engineering majors.

To qualify for statewide transfer equivalency, a first-year chemistry sequence must cover the 13 essential learning outcomes listed below with an asterisk. A first-year sequence may also include some of the listed nonessential learning outcomes. These optional topics should be included only if there is adequate course time to do so beyond giving primary course attention to the essential learning outcomes. At least 80% of the classroom instructional time has to be spent on the essential learning outcomes. The optional learning outcomes are learning experiences that enhance, reinforce, enrich or are further applications of the essential learning outcomes. If review of prerequisite course content is necessary, only a minimal amount of time should be devoted to such review.

The Sample tasks are provided to illustrate the level and type of activity related to specific skills or competencies that students should be able to demonstrate during class and/or on assessments such as course exams. Individual departments offering this course sequence are not required to cover every Sample task or to cover them in the semester indicated. Outcomes labeled (F) are typically taught mostly in the first semester course; outcomes labeled (S) are typically taught mostly in the second semester course, and outcomes labeled (F/S) are typically taught in either or both semesters.

1. *(F)Solve chemistry problems using mathematical techniques of dimensional analysis, algebraic manipulation of scientific equations (including logarithms and exponentials), and extraction of scientific information from slope and intercept parameters and graphical data.
    a. Sample tasks:
        i. Convert between units, including temperature scales.
        ii. Use scientific notation and significant figures correctly.
        iii. Interconvert between volume, mass and moles.
        iv. Interconvert between energy, wavelength and frequency.

v. Apply Beer's Law to relate concentration and absorbance.
vi. Solve gas law problems.
vii. Use algebra to convert between K_w, K_a, K_b, pH, pOH, pK, $[H^+]$ and $[OH^-]$.
viii. Connect a scientific equation to a curve-fit equation for data and extract information from slope and intercept values.

2. *(F)Name inorganic chemical compounds and write formulas from names.
   a. Sample compounds:
      i. binary ionic and molecular (covalent) compounds
      ii. compounds that include polyatomic ions and variable oxidation state metals
      iii. acids and bases
      iv. gases (monatomic and homonuclear diatomic)
3. *(F)Solve chemistry problems involving stoichiometry (molar mass, mass, mass percent, density, molarity, gas laws, limiting reagent, percent yield, empirical and molecular formulas, balancing chemical reaction equations).
   a. Sample tasks:
      i. Interconvert between mass and moles.
      ii. Determine a molecular formula from given data, such as percent composition or results from combustion analysis.
      iii. Balance chemical equations.
      iv. Solve stoichiometry problems involving masses of products and reactants.
      v. Include limiting reagent and percent yield in stoichiometry calculations.
      vi. Solve multi-step stoichiometry problems.
      vii. Use molarity in stoichiometry calculations.
      viii. Solve stoichiometry problems involving gases under varying temperature, pressure and volume conditions.
4. *(F/S)Identify and find the relative and absolute abundances of all species present in a given aqueous solution (strong and weak acids and bases, neutral salts, sparingly soluble salts, weakly acidic and weakly basic salts.)
   a. Sample tasks
      i. Identify- strong acids and bases and their conjugates.
      ii. Calculate pH for soluble strong acid/strong base solutions, including diprotic acids and bases.
      iii. Write appropriate chemical equations, identify conjugate pairs, and convert between a solution recipe and the molecular representation for strong acid, strong base, weak acid, weak base, non-acidic/non-basic salt, non-acidic/non-basic molecules, weakly acidic salt and weakly basic salt solutions.
      iv. Use ICE tables, K_a and K_b tables to calculate pH for monoprotic weak acid and base solutions.
      v. Use qualitative trends to predict relative pH of solutions with different recipes.
      vi. Solve problems involving pH, K_a/pK_a, K_b/pK_b, K_w/pK_w, etc.

    vii. Solve problems involving colligative properties and their relationship to solution concentration (e.g., freezing point depression and boiling point elevation, osmotic pressure, vapor pressure lowering).

5. *(S)Predict products of acid/base reactions and use titrations appropriately for chemical analysis and insight.
    a. Sample tasks
        i. Use molecular representations to demonstrate principles of acid/base reactions.
        ii. Predict the products of any acid/base reactions that occur between recipe species.
        iii. Write net ionic equations.
        iv. Predict amounts and identities of species present and qualitative pH after an acid-base reaction.
        v. Use qualitative trends to predict relative pH of solutions with different recipes.
        vi. Answer questions related to buffers.
        vii. Apply the Henderson-Hasselbalch equation to solve problems.
        viii. Use chemical arguments to predict best buffer and higher buffer capacity from recipes.
        ix. Calculate the concentration of an analyte from pertinent titration data.
6. *(S)Balance redox reactions, draw and interpret electrochemical cell diagrams, calculate cell potentials, and connect cell potential to Gibbs free energy to predict reaction spontaneity.
    a. Sample tasks
        i. Determine oxidation numbers.
        ii. Balance redox reactions.
        iii. Draw and interpret cell diagrams, including electron flow and anode/cathode.
        iv. Use tables of E^o to calculate cell potentials and predict whether a chemical reaction will produce a galvanic or electrolytic cell.
        v. Write fully balanced chemical equations and calculate cell potentials and/or Gibb's free energy changes for chemical reactions
        vi. Use Gibb's free energies and/or K values to predict the outcome of chemical reactions (single and coupled).
        vii. Calculate and answer questions about membrane potentials, concentration gradients, and free energy changes associated with concentration cells and/or movement of ions and other solutes across membranes.
7. *(F/S)Solve thermodynamics problems involving heat transfer, enthalpy, Hess's law, enthalpies of formation, heat capacity, calorimetry, entropy, and Gibbs free energy.
    a. Sample tasks
        i. Calculate heat added to or removed from a system using $q=mc\Delta T$.
        ii. Apply Hess's law.
        iii. Calculate enthalpies, entropies and Gibbs free energies of reaction from enthalpies of formation, absolute entropies and Gibbs free energies of formation.
        iv. Use Gibb's free energies and/or K values to predict the outcome of chemical processes.
8. *(S)Apply Le Chatelier's principle and make predictions and calculations involving chemical equilibria.

a. Sample tasks

i. Use Le Chatelier's principle to predict effects of changes on an equilibrium system.

ii. Use ICE (initial/change/equilibrium) tables to calculate concentrations of species present at equilibrium, given K, K_{sp}, K_a, K_b or K_w.

9. *(F/S)) Interpret molecular representations, draw Lewis structures for ionic and covalent compounds, identify molecular shapes using VSEPR theory, and use shape and electronegativity to predict intermolecular forces between and among molecules.

a. Sample tasks

i. Connect chemical formulas and states of matter with molecular pictures of compounds and solutions containing ions.

ii. Connect chemical reactions and equations with molecular pictures.

iii. Draw Lewis structures for straightforward molecular and ionic species.

iv. Draw single Lewis structures for common expanded-octet molecular and ionic species. Use formal charges and resonance.

v. Predict shapes, including bond angles and resonance, using VSEPR.

vi. Use electronegativity to predict bond polarity.

vii. Predict possible intermolecular forces for small molecules or portions of a larger molecule.

viii. Predict the interaction of molecules based on their intermolecular forces (e.g., solubility properties).

ix. Use kinetic molecular theory to explain the physical basis of the gas laws.

10. *(F)Write out electron configurations and energy diagrams for atoms and simple diatomic molecules; use bonding theories to explain how atoms form bonds in molecules and to make predictions about atomic and molecular properties.

a. Sample tasks

i. Explain models of the atom, including isotopes.

ii. Write electron configurations and orbital energy diagrams for atoms and ions.

iii. Use periodic table to rank atoms and ions by radii/size, ionization energy, electron affinity.

iv. Use molecular orbital theory to write electron configurations and energy diagrams for simple diatomic molecules.

v. Predict magnetic properties, relative bond length and relative bond strength for simple diatomic molecules.

vi. Use valence bond and molecular orbital theories to explain how atoms form bonds and molecules.

11. *(F)Use principles of spectroscopy and the electromagnetic spectrum to predict and understand the behavior of matter.

a. Sample tasks

i. Interconvert between energy, wavelength and frequency.

ii. Given a spectrum (e.g., UV-visible or IR) calculate the excited state energy and create a diagram representing a specified transition.

iii. Apply Beer's Law to relate concentration and absorbance.

iv. Choose an appropriate wavelength for a spectroscopic analysis.

v. Answer questions related to the historical development of models of the atom.

12. *(S)Solve problems involving chemical kinetics, rate laws, rate constants, reaction order, differential and integrated rate laws, and chemical mechanisms.

a. Sample tasks

i. Perform calculations related to first order radioactive decay.
ii. Apply standard kinetics techniques (method of isolation, method of initial rates, integrated rate law plots) to determine rate laws. (reaction order and rate constants).
iii. Use the Arrhenius equation to analyze temperature dependence of reaction rates.
iv. Explain the influence of catalysts on reaction rates.

13. *(F/S) Attain mastery of fundamental laboratory techniques

a. REQUIRED tasks

i. Find and interpret safety information about chemicals.
ii. Follow laboratory safety guidelines.
iii. Follow chemical hygiene and waste disposal guidelines.
iv. Use a balance.
v. Read a buret.
vi. Use volumetric glassware.
vii. Choose glassware appropriately.
viii. Use a hot plate and magnetic stirrer.
ix. Make temperature, conductivity, pH and spectroscopic measurements.
x. Make appropriate choices about the level of precision obtained in measurements.

Non-Essential First-Year Chemistry learning outcomes:

1. Predict properties of coordination compounds.
2. Make connections between structure and properties in transition metal complexes.
3. Balance nuclear reaction equations.
4. Apply qualitative analysis.
5. Identify functional groups and classes of organic compounds.
6. Use line structure for organic compounds.
7. Identify the major classes of biological macromolecules based on structure, and identify major biological functions of these classes of macromolecules.
8. Memorize the 20 amino acids (structure, name and 1- and 3-letter codes) and rank by polarity.
9. Interconvert between amino acid sequence and primary protein structure; use N-terminus and C-terminus conventions correctly.
10. Answer questions about enzyme kinetics and inhibition.

Template for Course Inventory

Please fill out the following table and submit attachment(s). Approved courses must be resubmitted every 5 years.

Please attach the following materials:

- Current working syllabus and lab syllabus that contains instructional goals and/or objectives and the final exam.

<table>
<tr><td>Course #</td><td colspan="4"></td></tr>
<tr><td>Course Title</td><td colspan="4"></td></tr>
<tr><td rowspan="2">Beginning Term (when is/was it first offered?)</td><td colspan="4">If more than five years, check box ☐</td></tr>
<tr><td>If less than five years, enter date:</td><td colspan="3"></td></tr>
<tr><td rowspan="2">Credit Hours (including the entire course, lecture/lab)</td><td>Course:</td><td colspan="3"></td></tr>
<tr><td>Lab:</td><td colspan="3"></td></tr>
<tr><td rowspan="3">Co-/Pre-requisite (test scores for placement)</td><td colspan="2"></td><td>Test</td><td>Score</td></tr>
<tr><td colspan="2">Pre-req:</td><td></td><td></td></tr>
<tr><td colspan="2">Co-req:</td><td></td><td></td></tr>
<tr><td>Successor Course:</td><td colspan="4"></td></tr>
<tr><td>Catalog Description</td><td colspan="4"></td></tr>
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All Textbook(s)/Lab Manual	ISBN: Title: Publisher: Author: Edition: Copyright Year: Additional Notes:	ISBN: Title: Publisher: Author: Edition: Copyright Year: Additional Notes:

Indicate if covered in the first or second semester course and the typical percentage of time spent on each learning outcome/topic	**Learning Objective**	**% Time**	**F/S**
	1. Solve chemistry problems using mathematical techniques of dimensional analysis, algebraic manipulation of scientific equations (including logarithms and exponentials), and extraction of scientific information from slope and intercept parameters and graphical data.		
	2. Name inorganic chemical compounds and write formulas from names.		
	3. Solve chemistry problems involving stoichiometry (molar mass, mass, mass percent, density, molarity, gas laws, limiting reagent, percent yield, empirical and molecular formulas, balancing chemical reaction equations).		
	4. Identify and find the relative and absolute abundances of all species present in a given aqueous solution (strong and weak acids and bases, neutral salts, sparingly soluble salts, weakly acidic and weakly basic salts.)		
	5. Predict products of acid/base reactions and use titrations appropriately for chemical analysis and insight.		
	6. Balance redox reactions, draw and interpret electrochemical cell diagrams, calculate cell potentials, and connect cell potential to Gibbs free energy to predict reaction spontaneity.		
	7. Solve thermodynamics problems involving heat transfer, enthalpy, Hess's law, enthalpies of formation, heat capacity, calorimetry, entropy, and Gibbs free energy.		
	8. Apply Le Chatelier's principle and make predictions and calculations involving chemical equilibria.		

	9. Interpret molecular representations, draw Lewis structures for ionic and covalent compounds, identify molecular shapes using VSEPR theory, and use shape and electronegativity to predict intermolecular forces between and among molecules.		
	10. Write out electron configurations and energy diagrams for atoms and simple diatomic molecules; use bonding theories to explain how atoms form bonds in molecules and to make predictions about atomic and molecular properties.		
	11. Use principles of spectroscopy and the electromagnetic spectrum to predict and understand the behavior of matter.		
	12. Solve problems involving chemical kinetics, rate laws, rate constants, reaction order, differential and integrated rate laws, and chemical mechanisms.		
	13. Attain mastery of fundamental laboratory techniques.		
Non-essential topics (may not be covered at all)	14. Predict properties of coordination compounds.		
	15. Make connections between structure and properties in transition metal complexes.		
	16. Balance nuclear reaction equations.		
	17. Apply qualitative analysis.		
	18. Identify functional groups and classes of organic compounds.		
	19. Use line structure for organic compounds.		
	20. Identify the major classes of biological macromolecules based on structure, and identify major biological functions of these classes of macromolecules.		
	21. Memorize the 20 amino acids (structure, name and 1- and 3-letter codes) and rank by polarity.		
	22. Interconvert between amino acid sequence and primary protein structure; use N-terminus and C-terminus conventions correctly.		
	23. Answer questions about enzyme kinetics and inhibition.		

Name of individual submitting the form:____

Email address:____