

CHEM 250 (4 credits): Reactions of Nucleophiles and Electrophiles (Reactivity 1):

Description: This course investigates fundamental carbonyl reactivity (addition and substitution) in understanding organic, inorganic and biochemical processes. Some emphasis is placed on enthalpy, entropy and free energy as a basis of understanding reactivity. An understanding of chemical reactivity is based on principles of Lewis acidity and basicity. The formation, stability and reactivity of coordination complexes are included. Together, these topics lead to an understanding of biochemical pathways such as glycolysis. Enzyme regulation and inhibition is discussed in the context of thermodynamics and mechanisms. Various applications of modern multi-disciplinary research will be explored. Prerequisite: CHEM 125.

Course Goals and Objectives:

1. Students will gain a qualitative understanding of thermodynamics.

- A. Students will develop a qualitative understanding of enthalpy and entropy.
- B. Students will predict the sign of an entropy change for chemical or physical processes.
- C. Students will understand entropy effects such as the chelate effect on chemical reactions.
- D. Students will use bond enthalpies or pK_a s to determine the enthalpy change for a reaction.
- E. Students will draw or interpret a reaction progress diagram.
- F. Students will apply the Principle of Microscopic Reversibility to understand reaction mechanisms.
- G. Students will use Gibbs free energy to relate enthalpy and entropy changes.
- H. Students will develop a qualitative understanding of progress toward equilibrium under physiological conditions (the difference between ΔG and ΔG° .)
- I. Students will understand coupled reactions and how this can be used to drive a non-spontaneous reaction toward products.
- J. Students will apply LeChatelier's Principle to affect the position of an equilibrium by adding or removing reactants or products.
- K. Students will understand the relative ranking of leaving groups and their effect on reaction reversibility in the carbonyl electrophile "ski slope".
- L. Students will understand the relationship between structure and glass transition temperature in a polymer.

2. Students will be able to propose mechanisms or predict products for reactions involving carbonyl addition and substitution reactions.

- A. Students will use curved arrows to show Lewis acid/base reactions, metal-ligand complex formation, etc.
- B. Students will provide a reasonable mechanism for reactions using electron arrows.

- C. Students will begin to recognize the effects of 3D structure on regiochemistry and stereochemistry in organic, metallic and biological systems.
- D. Students will recognize and name carbonyl derivatives such as aldehydes ketones, carboxylic acids, amides and esters, as well as alcohols and amines . Students should also be able to draw a structure given the name.
- E. Students will be able to propose mechanisms or predict products involving carbonyl addition and substitution reactions.
- F. Students will be able to predict the products in the formation of a condensation polymer.
- G. Students will also demonstrate an understanding of bulk properties and structural motifs in polymer chemistry such as cross-linking and branching.
- H. Students will understand relative ranking of leaving groups and their effect on reaction reversibility.
- I. Students will be able to draw tautomers.
- J. Students will be able to know and recognize common ligands and their binding motifs such as hapticity and denticity.
- K. Students will determine formal metal oxidation state and d electron count for a metal in a complex and total number of electrons (d electrons plus ligand electrons) around a metal in a complex.
- L. Students will be able be able to draw complexes, given the formula, and vice versa.
- M. Students will be able to use HSAB (Hard and Soft Acid-Base Theory) to interpret chemical phenomena
- N. Students will be able to name coordination complexes or provide a formula given a name.

3. Students will have a basic understanding of theories such as molecular orbital and ligand field theory to understand properties and reactivity.

- A. Students will use ligand field theory as a way of explaining transition metal properties.
 - i. Students will be able to identify a ligand as being a sigma only ligand, or a pi donor or a pi acceptor.
 - ii. Students will understand what the spectrochemical series is, have a good idea the ordering of ligands, and how the ordering of ligands is related to the type of bonding it is capable of.
 - iii. Students will be able to place a new ligand in the spectrochemical series based on its structure or spectral data.
 - iv. Students will understand what Ligand Field Stabilization energy is and be able to calculate it.
 - v. Students will be able to predict whether a four-coordinated complex will be square planar or tetrahedral.

- vi. Students will demonstrate an understanding of the effect of metal, charge and ligand on Δ .
 - vii. Students will be able to predict whether a complex is high or low spin
- B. Students will use frontier MO theory to predict carbonyl reactivity.
- C. Students will understand the role of conjugation and aromaticity as driving forces in chemical reactions.

4. Students will develop a basic understanding of thermodynamic and mechanistic strategies in catalyzed reactions.

- A. Students will understand how a catalyst affects a reaction progress diagram.
- B. Students will understand how enthalpy and entropy contribute to catalysis.
- C. Students will understand how a Lewis acid can activate a carbonyl or how an Lewis base can activate a nucleophile.
- D. Students will recognize a charge relay system in an enzyme.
- E. Students will recognize the catalytic strategies used in an enzyme (distortion, intermolecular forces, stabilization of intermediates in the transition state).

5. Students will develop a basic understanding of metabolic pathways and regulation.

- A. Students will gain an understanding of enzyme regulation.
 - i. Students will know where a metabolic process occurs (mitochondria vs. cytosol) and the logic behind locating opposing processes in different locations.
 - ii. Students will recognize which amino acids can undergo phosphorylation, acetylation and prenylation and the effect of these modifications on the 3D structure of an enzyme.
 - iii. Students will understand competitive inhibition and transition state analogues.
 - iv. Students will understand allosteric activation and inhibition.

- B. Students will understand which steps in a metabolic pathway would be points of regulation.

- C. Students will understand key aspects of metabolic processes, including glycolysis, the citric acid cycle, fatty acid synthesis, beta oxidation, ketolysis and ketogenesis.
 - i. Students will know the reactants and products in each process.
 - ii. Students will know key intermediates and their role in regulation.
 - iii. Students will understand interconnections and chemical species shared between these processes.
 - iv. Students will understand the storage or production of energy in these processes.

6. Students will earn problem-solving skills through modern applications of chemistry

- A. Students will recognize similar reactivity in new molecules.
- B. Student will apply techniques learned in the analysis of small molecules to more complex systems.
- C. Students will predict reactivity in molecules that have multiple or new functional groups.
- D. Students will recall and draw on knowledge from earlier courses to gain a more complete understanding of a new chemical situation.