CHEM 255 (4 credits): Fundamentals of Macroscopic Chemical Analysis

Description: This course explores thermodynamic approaches to chemical equilibrium. Emphasis on free energy as the driving force for chemical reactions will be developed through the quantitative analysis of chemical equilibria in simple as well as complex systems. Statistical methods will be developed for the assessment of data. Chemical systems in equilibrium as well as in dynamic situations will be studied. Prerequisite CHEM 125

<u>Goals and Objectives for CHEM 255:</u>

1. Develop and understand the thermodynamic basis of chemical equilibrium for simple systems
    a. Laws of thermodynamics
        - Understand the concepts of systems, surroundings, work, heat
        - Identify open, closed and isolated systems
        - Calculate the amount of work done (expansion/ compression)
        - Understand the origin of internal energy and enthalpy
        - Calculate the enthalpies of physical changes
        - Calculate the enthalpies of chemical changes (combustion and formation)
        - Determine the effect of temperature on enthalpy
        - How to use Hess's law
        - Entropy and the second law
        - Determine the entropy changes for the system and surroundings
        - Determine conditions for spontaneous and nonspontaneous changes
        - Understand the Gibbs free energy of reaction
        - Determine the effects of temperature and pressure on Gibb's free energy
        - Develop the concept of chemical potential
    b. Physical equilibrium
        - Understand the relationship between vapor pressure and intermolecular forces
        - Determine the dependence of vapor pressure on temperature
        - The enthalpy and Gibbs free energy of solution
        - Understand the phase boundaries, phase diagrams and the phase rule
        - Understand the vapor pressure of a binary liquid mixture

2. Qualitatively and quantitatively evaluate chemical systems involving equilibria
    a. Chemical equilibrium
        - Understand the equilibrium constant
        - Use the equilibrium constant to determine system composition
        - Predict equilibrium shifts based on Le Chatelier's principle
    b. Activity and the systematic treatment of chemical equilibrium

- Understand the significance of activity coefficients
- Integrate a systematic treatment for evaluation of systems in equilibria

c. Monoprotic acid-base equilibria
  - Calculate the pH of a strong acid and strong base equilibria
  - Calculate the pH of weak acid and weak base systems
  - Determine the fraction of dissociation for weak acids and bases
  - Understand how buffer systems and buffer capacity
  - Calculate changes in pH of a buffer system due to addition of acid or base

d. Polyprotic acid-base equilibria
  - Calculate concentrations for all the species in a polyprotic acid base equilibrium system
  - Qualitatively determine the principle species
  - Learn how to make a diprotic buffer

e. Acid-base Titration
  - Calculate pH along the titration plot for strong acid-strong base titration
  - Calculate pH along the titration plot for strong acid-weak base titration
  - Calculate pH along the titration plot for weak acid-strong base titration
  - Determine the end point of a titration with visual indicators and electrodes
  - Predict the shape of titration plots
  - Determine the effect of acid/base strength and concentration of the shape of titration plot
  - Titration of diprotic acids and bases

f. Electrochemistry
  - Learn to balance half reactions under acidic and basic conditions
  - Understand the construction and operation of Galvanic cells
  - Calculate standard cell potential
  - Apply Nernst equation for cell potential calculation under nonstandard conditions
  - Develop the concept of different kinds of reference electrodes
  - Understand how ion selective electrodes work
  - Calculate concentrations of select analytes using ion selective electrodes

g. Redox titrations
  - Calculate electrode potential along a redox titration
  - Determine the shape of redox titrations
  - How to select indicators for redox titrations
  - Methods involving iodine

3. Understand and develop confidence in both process and results through repetition and exploration of model behavior
   a. The properties of gases
      - Derive the idea gas laws
      - Understand the deviations for real gases

   b. The properties of dilute solutions
      - Learn the properties of ideal solutions
      - Qualitative and quantitative understanding of colligative properties

4. Recognize, treat and report experimental errors and their propagation using statistical tools
   a. Experimental errors
      - Understand the types and sources of experimental errors
      - Recognize experimental errors and suggest ways to minimize errors
      - Calculate the propagation of uncertainty from systematic and random errors
   b. Statistics
      - Understand the Gaussian distribution of data
      - Use confidence interval to report analytical data
      - Use t-test and F-test for comparison of data sets
      - Learn how to identify the bad datum (Q test)
      - When to use one or two tailed t-tests
   c. Calibration methods and quality assurance
      - Learn different types of calibration methods
      - How to select a suitable calibration method
      - Understand the analytical figures of merit: accuracy, precision, limits of detection, linear dynamic range, specificity
      - Basic quality assurance method

5. Learn problem-solving skills through applications of chemical principles
   a. Isothermal and differential scanning Calorimetry
      - Characterize binding interactions (binding constant, stoichiometry, enthalpy change)
      - Predict binding strength as a function of structural features
   b. CO_2 equilibrium in sea water
      - Understand the buffering mechanism of sea water
      - Effect of increasing atmospheric CO_2 concentration on the pH of sea water
   c. EDTA titration for monitoring water quality
      - Understand EDTA as a chelating agent
      - Application of EDTA titration to determine metal ions concentrations in drinking water