New York City College of Technology
Department of Chemistry

Course Code: CHEM 3222
Title: Physical Chemistry: Thermodynamics and Kinetics
Number of hours, credits: (4 credits, 3 hours lecture, 3 hours lab)

Course Description:
Introduces the foundational ideas in thermodynamics and kinetics. Thermodynamics topics include First, Second and Third Laws of Thermodynamics, states of matter and phase transformations, equilibrium, Gibbs free energy and prediction of spontaneous reactions. Kinetics topics include reaction rates, rate laws and transition states. Thermodynamics and kinetics topics will be presented with emphasis on applications to industrial chemistry.

Pre-requisites: CHEM 1210, PHYS 1442, MAT 1575 or higher
Course Attributes: Writing Intensive

Required Texts:
1. McQuarrie, D. A., and Simon, J. D. *Physical Chemistry: A Molecular Approach*; University Science Books, Sausalito, 1997.
2. Spencer, J. N., Moog, R. S., Farrell, J. J. *Physical Chemistry: A Guided Inquiry-Thermodynamics*; Houghton Mifflin, Boston, 2004.

Required instructional materials or supplies: safety goggles, lab coat, laboratory notebook

Course Specific Student Learning Outcomes.

Learning outcome	**Assessment**
Upon completion of the course, students should be able to predict reaction spontaneity using relevant thermodynamic parameters.	In class problem solving sessions, homework problem sets, exams
Upon completion of the course, students should be able to explain the thermodynamic interpretation of phase equilibria.	In class problem solving sessions, homework problem sets, exams
Upon completion of the course, students should be able to model simple and complex reactions using reaction rates and integrated rate laws.	In class problem solving sessions, homework problem sets, exams
Upon completion of the course, students should be able to explain reaction rates in terms of transition state theory.	In class problem solving sessions, homework problem sets, exams
Upon completion of the course, students should be able to calculate rate constants and activation energies based on laboratory data.	Laboratory reports

General Education Learning Outcomes.

Learning outcomes	**Assessment**
Upon completion of the course, students should be able to conduct targeted searches of scholarly literature.	Final project: laboratory report in which students present their own data and compare and contrast their findings with relevant findings from the chemical literature
Upon completion of the course, students should be able to present laboratory findings in a clear, concise laboratory report.	Laboratory reports

Evaluation Methods and Criteria:
The lecture will account for 75% of a student's grade and the laboratory will account for 25% of a student's grade. The grades in lecture and lab will be computed as described below.

Lecture: The activities and assignments comprising the lecture grade will be:

Exam 1:	15 %
Exam 2:	15 %
Cumulative final exam:	25 %
Problem sets:	30 %
Guided inquiry activities:	15 %

Laboratory: The activities and assignments comprising the laboratory grade will be:

Written lab reports:	30%
Laboratory participation:	50%
Final laboratory project:	20%

Course Outline for Lecture and Laboratory:

Week	Topics
1	**Lecture: Introduction to thermodynamics:** ideal gases, equations of state for gases, liquids, and solids Lab: Check-in safety orientation
2	**Lecture: First law of thermodynamics:** work, heat, First Law Lab: Heat engines and the first law of thermodynamics
3	**Lecture: First law of thermodynamics:** Adiabatic processes, molecular interpretation of work and heat, enthalpy, enthalpies of reaction, heat capacity Lab: Heat engines and the first law of thermodynamics
4	**Lecture: Second law of thermodynamics:** Entropy, entropy changes, Second Law of thermodynamics, statistical interpretation of entropy Lab: Determining entropy using calorimetry
5	**Lecture: Third law of thermodynamics:** Entropy as a function of T, third law, implications for phase transitions, heat capacities Lab: Determining entropy using spectroscopy
6	**Lecture: Helmholtz and Gibbs energies:** Spontaneous processes, Maxwell relations, Gibb's-Helmholtz equation, fugacity; **EXAM 1 (WEEKS 1 – 5)** Lab: Measurement of diffusion coefficients of CO_2-Ar and CO_2-He
7	**Lecture: Phase equilibria:** Phase diagrams, relationship between Gibbs Free energy and phase diagram, chemical potential Lab: Binary solid/liquid phase diagrams (naphthalene-diphenylamine)
8	**Lecture: Liquid-Liquid solutions:** partial molar quantities, Gibbs-Duhem equation, Raoult's law Lab: Binary liquid/vapor phase diagrams (distillation of cyclohexanone and tetrachloroethane)
9	**Lecture: Liquid-Liquid solutions:** Non-ideal solutions, activities, Gibbs energy of mixing in terms of activity coefficient Lab: Data processing- in lab analysis of phase diagrams
10	**Lecture: Chemical equilibrium**: Definition of chemical equilibrium in terms of Gibbs free energy, equilibrium constant and temperature dependence (Van't Hoff Equation), relationship between equilibrium constant and direction of reaction Lab: Construction of a gas thermometer
11	**Lecture: Chemical kinetics- Kinetic theory of gases:** Relationship between temperature and molecular speed, Maxwell-Boltzmann distribution of molecular speeds, Frequency of Collision, mean free path, gas phase reaction rate and molecular speed, **EXAM 2 (WEEKS 6 – 10)** Lab: Construction of a gas thermometer
12	**Lecture: Chemical kinetics- Rate laws:** Rate laws, time dependent rate laws, transition state theory Lab: **Library class:** searching and evaluating the chemical literature
13	**Lecture: Chemical kinetics- Reaction mechanisms:** elementary steps, detailed balance, steady state approximations Lab: Critical reading of chemical literature
14	**Lecture: Chemical kinetics- gas phase reaction dynamics:** collision theory, reaction cross section, impact parameter, orientation of collision, distribution of internal energy Lab: Moderate temperature decomposition of tert-butyl peroxide
15	**Lecture: Chemical kinetics-** Case studies of kinetics in industrially important processes; **CUMULATIVE FINAL EXAM** Lab: Final lab report- compare and contrast student results with chemical literature

Academic Integrity Policy Statement
Students and all others who work with information, ideas, texts, images, music, inventions, and other intellectual property owe their audience and sources accuracy and honesty in using, crediting, and citing sources. As a community of intellectual and professional workers, the College recognizes its responsibility for providing instruction in information literacy and academic integrity, offering models of good practice, and responding vigilantly and appropriately to infractions of academic integrity. Accordingly, academic dishonesty is prohibited in The City University of New York and at New York City College of Technology and is punishable by penalties, including failing grades, suspension, and expulsion. The complete text of the College policy on Academic Integrity may be found in the catalog.

Technology Statement
Before entering the course, students must be familiar with MS Word, MS Excel (simple spreadsheet calculations and graphing), and power point. During this course, students will learn how to convert between different data file types and how to import text file data into graphing software. Students will also learn how to perform simple computational chemistry calculations using commercially available software.

Date of most recent revision of this document: (2015 JDeiner, 3/2017 DSamaroo)