**Chemistry 320 Course Objectives**

**Chemistry of Macromolecules**

**Chapter 01 – Introduction**

1. Describe the definition of polymer
2. Describe what are the general properties of polymeric materials and the difference between polymers and small molecular compounds
3. A brief history of polymer science

**Chapter 02 – Microstructures**

1. Learn how to calculate the number average molecular weight and weight average molecular weight
2. Understand molecular weight distribution
3. Understand the difference between linear and branched chains and how this affects their ability to align regularly and hence crystallize
4. Describe the ways network structures are formed in polymers
5. Understand the different isomeric forms found in macromolecular chains (sequence, stereo, and structural isomerism)
6. Explain the difference between the arrangement of units in “random”, block, alternating and graft copolymers
7. Have a broad “feel” for how microstructure affects the ability to crystallize and hence affects properties like strength, toughness, and stiffness

**Chapter 03 – Polymerization: I. Methods**

1. Understand the nature of step-growth polymerization and its dependence on the number and type of functional groups present in the monomers
2. Describe the five types of chain-growth polymerizations (free radical, anionic, cationic, coordination and ring opening)
3. Describe examples of commercial polymer products produced by each type of polymerization method
4. Describe the main features of these polymerizations (initiation, propagation, termination and chain transfer)
5. Understanding the unique features that distinguish living polymerizations from the ordinary addition or chain polymerizations
6. Have a broad feel for the main types of polymerization processes (bulk, solution, suspension, emulsion, etc.)

**Chapter 04 – Polymerization: II. Kinetics**

1. Derive equations describing the kinetics of step-growth polymerizations using polyesterifications as an example
2. Understand that step-growth polymerizations are generally slow and high molecular weight polymer is only obtained at high degrees of conversion
3. Describe how polyethylene terephthalate and nylon are produced in industry
4. Describe the kinetics of the main features of free radical polymerization (initiation, propagation, termination and chain transfer)
5. Show how the use of steady-state assumption allows the derivation of equations describing the rate of polymerization, conversion, the kinetic chain length and the effect of chain transfer
6. Describe how the equation for the rate of polymerization provides an understanding of things like the Tromsdorff effect and why ethylene can only be polymerized free radically at high pressure and elevated temperature.
7. Show how these equations are modified to describe aspects of ionic polymerizations, such as chain transfer to solvent and living polymerizations

**Chapter 05 – Polymerization: III. Probability and Statistics**

1. Understand simple aspects of probability theory and be able to formulate equations for the probability of an event
2. Apply this theory to linear step-growth polymerization and obtain equations for the number and weight average molecular weights and molecular weight distributions
3. Account for the effect of a non-stoichiometric amount of monomers and the effect of monofunctional groups or “chain stoppers”
4. Show how this approach can be applied to chain polymerizations, but are less useful apart from the special case of “living” polymerizations
5. Understand how the polymerization of multifunctional monomers leads to network formation or hyperbranched polymers
6. Apply probability theory to a description of gelation and the incipient gel point

**Chapter 06 – Polymerization: IV. Copolymerization**

1. Understand the kinetics of free radical copolymerization and the derivation of the copolymer equation
2. Be familiar with the concept of reactivity ratios and the types of copolymers formed under certain limiting conditions
3. Be familiar with the various methods used to determine reactivity ratios
4. Understand the use of conditional probabilities to describe copolymer sequence distributions
5. Describe number fraction, run fraction and the parameter χ using probability theory.
6. Understand the nature of composition drift
7. Understand the difference between the terminal and penultimate model and how to test if data is consistent with one or the other of these models

**Chapter 07 – Polymerization: V. Macromolecular Engineering**

1. Be familiar with “living” polymerization methods, e.g., “living” radical polymerization, “living” cationic polymerization, “living” coordination polymerization
2. An understanding of how block copolymers can phase-separate and self-assemble to form ordered structures
3. Describe the concept of polymeric material design at a molecular level and example of polymers with advanced molecular architectures
4. Discuss examples of advanced functional materials based on molecular design

**Chapter 08 – Microstructure Characterization**

1. Be familiar with the fundamentals of spectroscopy, including simple harmonic motion, resonance and the nature of molecular transitions
2. Understand the nature of the transitions involved in infrared and NMR spectroscopy
3. Describe how these methods differ in their ability to perform quantitative analysis
4. Understand the nature and effect of spin-spin coupling in NMR
5. Be familiar with the application of IR and NMR to the characterization of polymer microstructure (branching, sequence isomerism, structural isomerism, tacticity in vinyl polymers, copolymer composition, and copolymer sequence distributions)
6. Understand some of the limitations and difficulties involved in the characterization of polymer microstructure by IR and NMR methods
7. A knowledge of the four principal methods (osmotic pressure, light scattering, viscosity and size exclusion chromatography) used to determine the molecular weight of polymers

**Chapter 09 – Morphology and Properties: I. Single Chain and Solution**

1. Understand the conformations of an ideal chain and the conformations of a real chain
2. An understanding of the random walk statistics, the root mean square end-to-end distance
3. A knowledge of the steric factors that control chain conformations and how this depends on microstructure
4. Understand regular solution theory and how to obtain simple expressions for the entropy and enthalpy of mixing
5. Know the Flory-Huggins equation and the relationship between the χ parameter and solubility parameters
6. Be able to describe qualitatively the excluded volume effect in dilute solutions
7. Be able to derive the conditions for obtaining a single-phase system and how to obtain expressions for the binodal and spinodal from the Flory-Huggins equation

**Chapter 10 – Morphology and Properties: II. Condensed State**

1. A broad knowledge of the states of matter in which polymers can exist
2. An understanding of the types of interactions that can occur between segments of a polymer chain and a feel for their relative strengths
3. A familiarity with the principle morphologies found in semicrystalline polymers
4. Understand the nature of crystallization, melting and the glass transition and how these transitions are accompanied by changes in properties such as specific volume
5. Realize that although crystallization is a kinetic phenomenon, thermodynamic arguments provide important insight and show that extended chain crystals have the lowest free energy
6. Recall the general features of crystallization kinetics and understand that both the rate of primary nucleation and the fold period depend upon the degree of undercooling, so that only folded chain crystals can form in finite time periods
7. Understand how primary crystallization also depends on undercooling and the factors that result in an inverted U-shaped dependence of the rate of crystallization on undercooling
8. Be familiar with the fact that polymers melt over a range of temperatures, understand why, and also understand the factors that affect the melting temperature
9. Understand the nature of the glass transition and the factors that affect the Tg

**Chapter 11 – Mechanical and Rheological Properties**

1. Understand the concepts of stress, strain, modulus, and viscosity and have a broad feel for the strength, stiffness and toughness of polymers relative to other materials
2. Sketch the form of the stress-strain plots obtained from various general classes of polymers (elastomers, glassy polymers, etc.)
3. Understand yielding phenomena in polymers
4. Describe the theory of rubber elasticity and know the limitations imposed by the assumption that the chains display Gaussian behavior
5. Describe the basic properties of polymer melts, the concept of reptation and the dependence of melt viscosity on molecular weight and phenomena like jet swelling and melt fracture
6. Understand the nature of viscoelasticity, particularly creep and stress relaxation and how these properties can be described using simple mechanical models
7. Describe the time-temperature superposition principle and the WLF equation

**Chapter 12 – Processing**

1. Understand how the process of extrusion works and how single screw and twin screw extrusion differ in operation and application
2. Describe the nature and origin of phenomena like jet swelling, melt fracture and die drool
3. Have a broad knowledge of the types of products produced by extrusion (e.g., blown film, pipes) and its use as the “front-end” of other processing methods
4. Describe the main features of injection molding equipment and the types of products it is used to form
5. Have a broad knowledge of how the injection molding process can be varied for different applications
6. Understand the main features of blow molding and how it can be used to make plastic bottles
7. Describe the main features of thermoforming and other molding processes