General Chemistry II, in broad strokes…

I. Intermolecular forces and changes in chemical state or phase

II. Solutions, solubility, and colligative properties

III. Chemical Kinetics -- the study of rates of reaction

IV. Dynamic chemical equilibria
- A. General equilibria and equilibrium constants
- B. Acid/base equilibria
- C. Solubility equilibria
- D. Complex equilibria

V. Chemical Thermodynamics -- the study of energy in chemical reactions
- A. Enthalpy
- B. Entropy
- C. Free energy
- D. Relating equilibrium concepts and thermodynamics

VI. Electrochemistry -- redox revisited

VII. Nuclear chemistry

Intermolecular forces and changes in chemical state or phase

Intermolecular forces

- types (ionic, dipole, hydrogen bond, dispersion (London, or Van der Waals))
- predicting types of forces present between molecules based on their structure
- relative strength of different intermolecular forces
- how these relate to properties of substances such as state changes, viscosity, surface tension, etc.
- be able to predict trends in boiling or melting points based on structures of molecules and thus on intermolecular forces
- be able to explain which forces are most important, given structures and values for boiling or melting points
- be able to predict general trends in solubility based on structures of molecules and thus on intermolecular forces

Energy consumption or release that accompanies change in state (breaking intermolecular interactions *consumes* energy; forming them *releases* it)

Does the temperature of a substance change *while* it is changing state?

The concept of <u>*critical temperature*</u> and <u>*pressure*</u>

<u>*Vapor pressure*</u>

- what it is
- how it is established at the molecular level
- how it relates to:
    - temperature
    - <u>*boiling point*</u>
    - atmospheric pressure
    - <u>*volatility*</u>

General familiarity with <u>*phase diagrams*</u>, ability to extract data from them or build one from data

Solutions and their properties

The concept of <u>*solution*</u>

The meaning of: <u>*solubility, solvation, solute, solvent, saturation, supersaturation, concentration, molarity, molality, mass percent, parts per million, colligative*</u> (you should be able to interconvert between the various measures of concentration)

The breaking and making of intermolecular interactions in the process of solvation

Dependence of solubility on

- temperature
- pressure

Colligative properties (because we did not get as far into this today as I had hoped, I will decrease the point value associated with it on the test, and will drop osmotic pressure altogether)

- the concept
- effect of solute on vapor pressure of solvent
    - concept and computation via <u>*Raoult's law*</u> (formula will be given)
    - calculating <u>*mole fractions*</u>
- effect of solute on boiling point of solvent
    - concept and computation (formula and constant will be given)
- effect of solute on freezing point of solvent
    - concept and computation (formula and constant will be given)

Chemical Kinetics -- the study of rates of reaction

The concept of *rate*

The definition of rate -- change in concentration with time

The relationship between rates of (dis)appearance for different components from the balanced equation of a reaction

Determining average rates from data on concentration of reagents at different time points (either graphical or tabular)

Rate laws

- what they are
- determining *reaction order*
  - from an *elementary reaction*
  - from data on concentrations at different time points (equations for integrated rate laws will be provided)
  - from a series of experiments that utilize varying starting concentrations of the reactants
- determining the magnitude and units of *rate constants*
- predicting the concentrations of reagents based on a starting concentration and integrated rate law
- what they tell you about
  - the *molecularity* of an *elementary reaction*
  - the validity of candidate *reaction mechanisms*
    - terms to know: *reaction intermediate*, *rate-determining step*

The concept of *half-life* (I expect you to have only a general conceptual understanding of this)

Factors that govern rates

- as summarized in the *Arrhenius equation* (which I will provide to you)
- temperature (both conceptually and computationally)
- *orientation* and frequency of productive *molecular collisions*
- energies of reactants, products, and *activation* ; *energy profile diagrams*

  Let me clarify what I mean here: you should be comfortable with energy profile diagrams and be able to identify the points on the curve that represent the energies of the reactants, intermediates, transition states, and products. From this sort of diagram you should be able to tell me the energy of activation, and you should also be able to comment on the relative energies of the reactants and products -- that is, does the reaction give off energy or consume it?
- *catalysis* (the effects of catalysts and how they work, in general terms)

(items that are *italicized and underlined* are important terms that I expect you to understand)

Dynamic equilibrium

The concept of dynamic chemical ***equilibrium***

The ***equilibrium constant***

- how to write and calculate it
- what it means in terms of
  - concentration
  - rates of reaction
  - energies of reactants and products

General equilibria

- inter-relationships between rate, energy, and equilibrium (using energy profile diagrams)
- finding K_{eq} when adding reactions, reversing reactions and multiplying reactions through by a constant
- K_c vs K_p
- equilibrium constant expressions for reactions involving heterogeneous phases
- the ***reaction quotient***, Q, vs K_{eq}
- ***Le Chatelier's principle***
- quantitative and qualitative analysis of chemical systems attaining equilibrium
- interpreting the magnitude of K_{eq}

Acid/base equilibria

- definitions of acids and bases by Arrhenius, Brønsted/Lowry, (and Lewis) theories
- ***dissociation*** of acids and bases, reactions with water
- ***conjugate acid/base pairs***
- K_a and K_b (be sure that you can write K_a and K_b equations for ***any*** conjugate acid/base pair)
- ***autoionization*** of water and K_w
- $[H^+]$, $[OH^-]$, pH, and pOH
- ***weak and strong acids and bases***
- mono vs. ***polyprotic acids***, ***amphoteric*** substances (and dealing with multiple K_a's)
- calculations involving the reactions of acids and bases with water
- acid/base behavior of ***salt solutions*** (qualitative and quantitative analysis)
- structural factors affecting acid and base strength
- ***neutralization*** reactions, both qualitatively and quantitatively
- ***titrations*** (as done in lab)
- ***buffers***
  - what makes a buffer buffer?
  - creation and properties of buffers
  - addition of strong acids or bases to buffers
  - addition of common ions to buffers

Solubility equilibria

- K_{sp}
- effects on solubility of common ions, pH, and complex ion formation
- qualitative analysis (as in lab)

(items that are ***italicized and underlined*** are important terms that I expect you to understand)

Chemical Thermodynamics -- the study of energy in chemical reactions

The first, second, and third laws of thermodynamics

- what the definitions are, and what they mean for chemical processes

The language of ***thermodynamics*** (you should understand these terms and what they imply)

- *Entropy*
- *Enthalpy*
- *Free Energy*
- *Heat*
- *Work*
- *State function*
- *Spontaneity*

Enthalpy

- calculation from Hess's law
  - from ΔH^o of formation
  - from *calorimetry* (at constant P, at constant V)
    in this context, you should understand *Heat Capacity*

Entropy

- understand the concept, how it relates to spontaneity, to *degrees of freedom*
- predicting the relative magnitudes of entropies of different substances
- predicting the sign of entropy changes accompanying reactions
- calculation from standard S^o
- calculation for reversible processes (at equilibrium) at constant T, such as phase transition

Free energy

- why is it "free"?
- its role in coupled reactions
- meaning of the sign of free energy change associated with a chemical process
- predicting the sign of ΔG given other thermodynamic information
- the impact of T on ΔG^o
- the relationship between K_{eq}, Q, and ΔG^o
- the impact on ΔG of stressing a system at equilibrium
- calculation from
  - ΔH^o and ΔS^o
  - standard values ($\Delta G^o{}_f$)
  - K_{eq} values

(items that are *italicized and underlined* are important terms that I expect you to understand)

Electrochemistry

Oxidation/reduction reactions

- oxidation numbers (be able to assign them)
- redox reactions (be able to balance them in acidic or basic solution)

Electrochemical cells

- electrochemical cells and electrical flow
    - construction and interpretation of cell diagrams (e.g., direction of ion and/or electron flow)
- *cell potential/EMF*
    - calculation of cell EMF from *half-cell (reduction) potentials*
    - be able to interconvert freely between EMF, K_{eq}, ΔG, ΔH and ΔS
    - relative spontaneity of reactions based on the EMFs of their component half-reactions
    - use of the *Nernst equation* to predict cell voltage under non-standard conditions
- deposition/depletion of chemical species with the passage of current (be able to write half reactions for *electrolysis* or electroplating reactions, and be able to determine the correlation between cell current and change in the concentration or mass of cell components)

Nuclear Chemistry

Radiochemical *decay*

- know the different kinds of decay and how they change nuclear composition
- trends in stability/radioactivity
    - be able to predict decays
- be able to write *radiochemical equations* describing decays
- *half-life* and radiochemical dating (you should be able to determine the amount of a radioisotope remaining after the passage of some amount of time)

[If time allows: economic, political, and biological applications of radiochemistry]

(items that are *italicized and underlined* are important terms that I expect you to understand)