General Chemistry, in broad strokes….

I. Introduction to chemistry, matter, measurements, and naming
-- The Language of Chemistry

II. Stoichiometry
-- The Numerical Logic of Chemistry

III. A survey of chemical reactions
-- Trends in Reactivity

IV. A closer look at atomic and molecular structure
-- Relating Reactivity to Structure

V. Gases, liquids, solids, and intermolecular forces
-- Relating Bulk Behavior of Matter to Structure

VI. Chemical Kinetics
-- Studying rates of reactions

VII. Dynamic chemical equilibria
-- Reactions in balance

VIII. Chemical Thermodynamics
-- Energy and Entropy in chemical reactions

IX. Nuclear Chemistry

Observing matter (Chapter One)

Matter

- what is it? What is it made of?
- How do we describe the *physical states of matter*?
- Mixtures
    - *homogeneous* (*solutions*) vs. *heterogeneous*
- The building blocks: *elements* vs. *compounds*
- You should be comfortable with all the terms in sections 1.1~1.4 of the text

Measurements

- conveying information about what is being measured, with
    - units
        - *SI units* (be familiar with the units for length, time, mass, and temperature)
        - metric prefixes (mega, kilo, deci, centi, milli, micro, nano, pico)
        - *density* (what it is and how it's measured)
    - scientific notation
    - indicators of uncertainty
        - *significant figures* (think of the use of sig. fig. as a form of communicating confidence)
          (we always report all the digits we're sure of, plus one in which there is uncertainty. Always.)
        - *accuracy* vs. *precision*
        - preserving the correct number of significant figures in calculations
        - *confidence intervals* (what they are, how to derive them, how to use them)
- converting between different types of measurements -- Dimensional Analysis

Learning to speak the Language (Chapters 2 and 3)

The building blocks of matter -- *atoms*

- atomic structure
  - the basic form of an atom: *electrons*, *protons*, and *neutrons* (where is most of the mass of an atom? where is most of the volume?)
  - *atomic number*
  - *mass number*
  - what changes between atoms of different elements?
  - what changes between *isotopic forms* of the same element?
  - what changes between atomic and ionic forms of the same element?

Periodic trends

- *metals* vs. *non-metals* vs. metalloids
- common charges on *ions*
- which elements form *diatomic* (elemental) molecules?
- which elements form *ionic* vs. *molecular (covalent) compounds*?

The language of Chemistry

- types of *formulas* (*molecular*, *empirical*, *structural*)
- naming *anions* and *cations* (see Tables 2.4 and 2.5, and the handout)
- naming molecular covalent compounds (be sure to know the prefixes listed in Table 2.6)
- chemical equations (Sections 3.1 and 3.2)
  - reactants and products
  - physical states
  - subscripts vs. coefficients
  - balancing them

(test #1 is to here...)

Stoichiometry (mass-mole-number relationships)

- For elements and compounds
  - what is a *mole* and how is it used to relate macroscopic quantities to microscopic quantities?
  - what is Avogadro's number?
  - determining the *molar mass* of a substance by looking at its chemical formula
  - relating masses of substances to the number of particles they contain
  - interconverting between *mass percent* and molar mass via *empirical formula mass*
- For chemical equations
  - inferring molar ratios from the coefficients of a balanced chemical equation
  - interconverting between numbers of particles, moles, and masses for all substances in a balanced chemical equation ("grams --> moles --> moles --> grams")
  - using stoichiometric relationships to determine the *limiting reagent* in a chemical reaction
  - calculating the *theoretical yield* and *percent yield* of a chemical reaction
  - swimming moles -- using *molarity* to perform stoichiometric analysis of reactions in solution

Aqueous solution chemistry (chapter 4)

Thinking about aqueous solutions at the molecular level
- be able to predict whether a substance will *dissolve* in water (know how to use a table of solubility rules)
- be able to predict whether a substance will *dissociate* in water
    - ionic compounds dissociate; covalent/molecular compounds do not, with the exception of acids/bases
        - covalent polyatomic ions do NOT dissociate
    - *strong* vs. *weak* *acids* and *bases*
- be able to predict whether a mixture will conduct electricity (i.e., is it an *electrolyte*?)
    - only substances that produce *ions in solution* (they both dissolve and dissociate) will conduct electricity
- be able to describe the state of substances in solution by writing *complete ionic* and *net ionic equations*
    - what is a *spectator ion*?

Precipitation (or solubilization) reactions
- typically involve formation of an insoluble solid by double-displacement (*metathesis*)

Acid/base reactions
- in the cases we are concerned with, acid/base reactions involve transfer of *hydrogen ions*
- be able to identify acids and bases based on what they do in reactions
- be able to identify *conjugate acid/base pairs* by examining acid/base reaction equations
- be familiar with the strong acids and strong bases listed in the nomenclature handout
- what is an acid/base *indicator*?
- what is a *neutralization* reaction?
- why do some acid/base reactions liberate gas?

Oxidation-reduction reactions
- be able to assign *oxidation numbers*
- be able to identify what is being oxidized or reduced in a reaction on the basis of oxidation numbers of products and reactants
- be able to predict the reactivity of metals in redox reactions given an activity series chart or table (like Table 4.5)

For pairs of reacting species, you should be able to predict
- whether a reaction will occur, and
- what kind of reaction it would be.

What does this really mean? In more detailed steps,

1. Predict the molecular species that would result if a reaction took place (typically by single or double displacement)
- decide whether each species is soluble or not
- decide which species can dissociate
- write dissociable species as ions
- cancel the ions that are the same on both sides
- that should give you a net ionic equation

2. Decide which kind of reaction it is (e.g., precipitation, acid/base, or redox)
- precipitation reactions involve the creation (or disappearance) of an insoluble ionic substance from soluble ionic reactants
- acid/base reactions involve the transfer of a proton from one species to another; the net ionic equation of an acid/base reaction will highlight this proton transfer
- redox reactions involve the transfer of electrons from one species to another; a sure sign of redox reaction is the presence of a substance in elemental form on one side of the equation and in ionic form on the other; more generally, the oxidation numbers of at least two species will change in the course of a redox reaction

3. Decide whether this reaction is likely to occur (that is, whether it is favorable).
- For precipitation reactions, this will happen if all the reactants and all the products are soluble

- For redox reactions, it will happen if an element with a lower oxidation potential would be required to reduce an element with a higher oxidation potential
- For acid-base reactions, it will happen if a weak acid and weak base combine to form a stronger acid and base.

Light and atoms (chapters 6 and 7)

General properties of electromagnetic radiation
- know the relationship between the wavelength, energy, and frequency of different colors of light
  (in other words, know the following equations and when to use them)
  $c = \nu/\lambda$
  $E = h\nu$
- have a casual understanding of the dual nature of light -- both particle-like and wave-like. Understand the meaning of the *de Broglie relationship* (see p. 213; you don't need to know this mathematical relationship, only the concept).
- have a casual understanding of the *Heisenberg uncertainty principle*

Line spectra
- what they are, where the lines come from, what determines their position
- *emission* vs *absorption* of energy in the form of light

The modern model of the atom
- be able to describe differences between the *Bohr model of the atom* and the *quantum mechanical model of the atom*
- *quantum numbers*, *orbital diagrams*, and electron configurations
  - be able to designate the position of electrons in atoms by their quantum numbers, by their positions in an orbital diagram ("boxes"), or by their electron configuration notation (e.g., $1s^2 2s^2 2p^4$)
  - be able to comment on the relative energies of electrons based on their quantum numbers, their positions in an orbital diagram, or their electron configuration notation
  - be able to sketch and recognize the shapes of s, p, and d electron "orbitals" (more properly, electron probability clouds)
  - be able to write a ground-state electron configuration and orbital diagram for any element or ion in the periodic table up through Xenon, embodying the *Pauli Exclusion Principle*, the *Aufbau Principle*, and *Hund's Rule* (for large atoms, use condensed electron configurations with a noble gas core)
  - understand how the arrangement of the periodic table reflects shared chemical properties and shared valence electron configurations
  - understand how the arrangement of the periodic table reflects the arrangement of *orbitals* and *sub-orbitals* in the quantum-mechanical model of the atom

Using electron configurations to predict properties of atoms and ions (Sections 7.1 to 7.5)
Be able to understand and predict the periodic trends in:
  - *atomic size*
  - *effective nuclear charge*
  - *ionization energy*
  - *electron affinity*
  - *ionic size*

Molecular Bonding (Chapter 8)

Ionic vs. *polar covalent* vs. "pure" *covalent* bonding
- how are they different?
- be able to predict what kind of bonding will occur between atoms based on *electronegativity* differences
- be able to estimate *relative* electronegativities from position of elements on the periodic table
- understand the general relationship between *bond order* and *bond length* (and strength)

Lewis structures, electronegativity, and bond polarity
- be able to construct *Lewis-dot structures* for atoms and ions
- understand the principle of (and underlying reason for) formation of *octets* of electrons
- be able to indicate bond formation with Lewis structures
- be able to indicate bond *polarity* with Lewis structures
- understand the relationship between electronegativity, *formal charge*s, and oxidation numbers
- understand the meaning of *resonance* structures (this is also an issue with regards to molecular geometry!)
- don't be confused by atoms with '*expanded octets*'

<u>Molecular Geometry and Bonding</u> (Chapter 9)

VSEPR (sections 9.1 and 9.2)

- you should understand the principle of electron-pair repulsion that underlies this model of molecular structure
- you should be able to identify the number of electron domains around an atom on the basis of Lewis structure
- you should be able to determine electron domain geometry from the number of electron domains
- you should be able to determine molecular (i.e., bond) geometry from the electron domain geometry and the number of bonding/non-bonding pairs of electrons

Polarity of bonds and molecules (based on electronegativity differences; section 9.3)

- molecules are polar only if two conditions are met:
  - the molecule contains polar bonds
  - the molecule is asymmetrical
- you should be able to predict the polarity of almost any bond and any molecule based on molecular geometry and periodic trends in electronegativity

Valence bond theory (sections 9.4 - 9.6)

- bonds occur as the result of overlap between molecular bonding orbitals
- *<u>hybridization</u>* of atomic electron orbitals generates 'hybrid' bonding orbitals that explain molecular shape
- you should be able to identify which hybrid orbitals correspond to which electron-domain geometries
- you should be familiar with the differences between sigma and pi bonding
- you should be able to use valence bond theory to explain the relative energies of rotation around a single, double, or triple bond
- you should understand the concept of *<u>delocalization</u>* of electrons in pi bonding

Correlations between Electronic structure, molecular shape, and orbital hybridization

Number of e^- domains	**e^- domain geometry**	***Approximate* angles between e^- domains (degrees)**	**Corresponding hybrid orbitals**
2	linear	180	sp (2 orbitals)
3	trigonal planar	120	sp^2 (3 orbitals
4	tetrahedral	110	sp^3 (4 orbitals)
5	trigonal bipyramidal ("trig bipy")	90 or 120, depending on the pair of domains	sp^3d (5 orbitals)
6	octahedral	all 90	sp^3d^2 (6 orbitals)

You should be comfortable assigning shapes to molecules based on variations to this basic pattern due to mixtures of bonding and non-bonding electron pairs

<u>Molecular Orbital</u> theory (sections 9.7 and 9.8)

- you should be able to create MO diagrams for simple diatomic molecules (involving only s and p atomic orbitals)
- given a set of MO diagrams, you should be able to use them to talk about magnetic properties, bond order, and probability that a molecule will exist
- you should be able to relate the relative differences in energy between the *<u>HOMO</u>* and *<u>LUMO</u>* for a set of molecules to their absorbance properties

<u>The behavior of Gases</u> (Chapter 10)
What are gases? (section 10.1)
What is gas pressure? How is it measured?

The kinetic-molecular theory (section 10.7)
- you should have a good mental image of the molecular events that lead to the macroscopic properties of gases as described by the ideal gas law
- you should understand the relationships between particle mass, speed, and temperature
- you should understand how the kinetic molecular theory explains phenomena of *<u>diffusion</u>* and *<u>effusion</u>*

The ideal gas law and its corollaries (sections 10.3 and 10.4)
- what is STP?
- you should KNOW the ideal gas law and what it means
- you should be able to deduce patterns of behavior such as Boyle's and Charles' Laws from the ideal gas law
- you should be able to interconvert between units of pressure, volume, and temperature
- you should be able to quantitatively determine changes in other gas properties that result from changing P, V, n, or T
- you should be able to determine gas properties based on reaction stoichiometry

Applications of the ideal gas law (sections 10.5 and 10.6)
- relationship of gas properties to density and molar mass
- meaning and applications of partial pressure (and how this relates to *<u>mole fraction</u>*)
- gas volumes and gas-phase reaction stoichiometry