**Learning Goals**

**Atomic Structure:**

* Remember the subatomic particles and their characteristics
* Understand how spectroscopy suggests that the energies of electrons in atoms are quantized
* Explain the wave-particle duality and the Heisenberg Uncertainty Principle
* Hydrogenic orbitals:
  + Understand what information is contained in the Schrodinger equation
  + Describe the location of an electron using quantum numbers
  + Interpret radial wave function and radial probability graphs
  + Predict the number of nodes from quantum numbers and sketch atomic orbital boundary surfaces
  + Sketch boundary surfaces of atomic orbitals (for *s*, *p*, and *d*)
* Multi-electron atoms:
  + Explain the meaning of *Z*\*in terms of shielding and use Slater’s rules to calculate *Z\*.*
  + Understand how *Z*\* affects the relative energies of atomic orbitals.
  + Write ground state electronic electron configurations and explain them in terms of the Pauli Exclusion Principle, the Aufbau principle and Hund’s rule (c and e)
  + Remember the definitions of atomic properties. Predict trends in properties of elements based on their atomic structure and explain these predictions.

**Simple Bonding Theories:**

* Draw Lewis structures of molecules and ions and predict their shapes using VSEPR.
* Predict distortions from ideal geometry, based on electronegativity and atom size.
* Predict molecular polarity based on molecular shape and electronegativities of bonded atoms.

**Symmetry and Group Theory:**

* Remember the types of symmetry operations and elements.
* Identify which symmetry elements are possessed by a molecule or other object and use this information to assign a point group.
* Understand the information contained in a character table.
* Use group theory to determine whether a molecule is chiral.
* Use group theory to predict the vibrational spectrum of a molecule.
  + Write a reducible representation based on the transformation of a molecule under its point group and reduce this representation.
  + Predict the number of IR active vibrational modes in a molecule.

**Molecular Orbital Theory:**

***Formation of Molecular Orbitals***

* Analyze and sketch atomic orbital interactions based on symmetry and overlap to determine if formation of a molecular orbital is possible.
* Understand the origin of the stabilization of bonding molecular orbitals and destabilization of antibonding molecular orbitals relative to the component atomic orbitals.
* Label overlaps between atomic orbitals and resulting molecular orbitals as either , , or .

***Molecular Orbitals for Diatomic Molecules***

* Derive molecular orbitals and energy diagrams for homonuclear and heteronuclear diatomic molecules, taking into account atomic orbital overlap and mixing of molecular orbitals.
* Correlate bond lengths and stabilities of molecules with bond order.
* Understand that a molecule is predicted to form if the total electron energies in the molecule are less than the electron energies in the free atoms.

***Molecular Orbitals for Larger Molecules***

* Draw group orbitals/ SALCs (Symmetry Adapted Linear Combinations) and assign symmetries by writing a representation based on the transformation of the orbitals under the point group of the molecule and reducing this representation.
* Form molecular orbitals from SALCs and the atomic orbitals of the central atom by matching symmetries.
* Derive molecular orbital energy diagrams.

**Acids and Bases:**

* Identify frontier orbitals in MO energy level diagrams.
* Understand the influence of frontier orbital energies and symmetries on the products of reactions between Lewis acids and bases.
* Explain relative Lewis acid-base strength in terms of inductive and steric effects.
* Understand hard-soft acid-base (HSAB) classifications and use them to explain physical and chemical properties.

**Crystalline Solids:**

* Given a unit cell structure, determine the number of ions or atoms present and their coordination numbers.
* Understand the types of close-packed structures (hexagonal close packing and cubic close packing) and identify tetrahedral and octahedral holes.
* Use the Born-Mayer equation to calculate lattice enthalpy.
* Use the Born-Haber cycle to calculate thermodynamic quantities.
* Understand how band structure arises and relate it to conductors, semiconductors, and insulators.

**Coordination Chemistry:**

* Remember the rules for naming coordination compounds. Be able to name and draw common ligands.
* Identify common geometries and coordination numbers and the factors by which they are determined.
* Learn the types of isomers in the two classes below and be able to draw structures that illustrate the different isomers.
* Predict splitting of *d*-orbitals in ligand fields with different geometries.
* Understand the difference between low and high spin complexes and the factors that determine the spin state.
* Predict the magnetic properties of a complex based on its *d*-electron configuration and predict *d*-electron configurations based on magnetic properties.
* Rationalize properties of complexes based on the spectrochemical series.
* Predict the geometry of a complex based on the metal’s *d*-electron count.
* Understand the different types of ligands and how they bond to transition metals.
* Rationalize the spectrochemical series based on ligand field theory.
* Understand the difference between kinetically labile and inert metal ions. Kinetically inert metal ions are those that have large LFSE, which leads to a low energy ground state and high activation energy for ligand substitution.
* Predict outcomes of ligand substitution reactions of square planar complexes, based on the trans effect.
* Understand the difference between an inner and outer sphere redox reactions.

**Organometallic Chemistry:**

* Determine the *d*electon counts, oxidation states, and overall electron count for most organometallic complexes.
* Explain the rationale behind the counting schemes and to articulate the pros and cons of each method.
* Use the MO diagram, specifically frontier orbitals, of a ligand to predict the bonding (sigma, pi, donation, acceptance) interactions in organometallic complexes, including those that contain metal-metal bonds.
* Describe and draw the molecular orbital interactions of a terminal CO ligand and a symmetric μ2-CO ligand with a metal.
* Describe and explain the σ-donating and π-accepting nature of the CO ligand.
* Understand and apply the terms *backbonding* and *backdonation*.
* Articulate the relationship between the M-C and C-O bond strengths in a carbonyl complex.
* Relate the CO stretching frequencies of two or more carbonyl complexes to the strength of the metal-ligand interaction and to the electron density on the metal fragment.
* Remember the different types of reactions and be able to classify reactions, based on the changes in coordination number, oxidation state, and total electron count.
* Write balanced chemical reactions from mechanisms of catalytic reactions.