**Detailed Learning Objectives for Foundational Inorganic Chemistry**

# **Atomic structure (quantum mechanics, periodic trends, and nuclear chemistry)**

## Electronic structure and periodicity

1. Describe differences and similarities between atomic subshells within a given shell and in different shells in terms of quantum numbers, shapes, spatial orientations, and nodes (radial and angular).
2. Rationalize periodic trends in atomic radii, ionization energies, and electron affinities using the concepts of effective nuclear charge, electron shielding, electron penetration, relativistic effects, and the lanthanide contraction.

## Nuclear chemistry

1. Write nuclear equations involving alpha decay, beta decay, positron emission, and electron capture.
2. Rank alpha decay, beta decay, and gamma ray emission in terms of ionizing power and penetrating power.
3. Predict the type of radioactivity that will most likely occur for a given isotope.
4. Given the expression, ln(N/No) = -kt, determine the amount of radioactive sample remaining after time t or determine the date of a specimen.
5. Differentiate between nuclear fusion and nuclear fission.

# **Bonding (covalent, coordinate covalent, metallic, and ionic)**

## Covalent bonding and physical properties of molecular compounds

1. Describe the basic tenets of molecular orbital theory.
2. Define the following terms: linear combination of atomic orbitals, bonding orbital, and antibonding orbital.
3. Explain why the energy of a bonding MO is lower than the energies of the contributing AOs; the energy of an antibonding MO is higher than the energy of a bonding MO; and the energy of an anti-bonding MO is higher than the energies of the contributing AOs.
4. Predict the bond orders for period 1 and period 2 homonuclear diatomic molecules and ions.
5. Recognize that the molecular orbital diagram for a heteronuclear diatomic molecule is more complex than the molecular orbital diagram for homonuclear since the energies of the contributing AOs differ.
6. Know the classification of MOs according to the type of orbital interaction (σ, π, and δ).
7. Predict the strength of different bonds (σ, π, and δ) according to orbital overlap.
8. Predict a reasonable Lewis structure, shape and polarity of a molecule composed of non-metal elements with up to six areas of electron density on the central atom.

## Coordinate covalent bonding and physical properties of coordination compounds

1. Identify monodentate, bidentate, tridentate, polydentate, chelating, and ambidentate ligands.
2. Predict the shapes for four-, five-, and six-coordinate complexes where the central atom is a non-main group metal.
3. Define the following terms: complex, ligand, coordination compound, primary coordination sphere, coordination number, chelate effect, pairing energy, and Jahn-Teller effect.
4. Name coordination compounds including those that contain complexes that can exist as geometric isomers.
5. Describe the difference between weak field and strong field ligands and between high spin and low spin complexes.
6. Use crystal field theory to predict the d-orbital splitting pattern in octahedral, tetrahedral, square planar, trigonal bipyramidal, trigonal planar and linear complexes.
7. Explain how the magnitude of the d-orbital splitting will influence the magnetic and absorption properties of a coordination complex.
8. Describe the difference between crystal field theory and ligand field theory.
9. Use ligand field theory to explain how the following ligands affect the magnitude of o: sigma only, pi donor, pi acceptor.
10. Given the identity of the metal, the oxidation state of the metal, and the identity of the ligand, predict whether the corresponding octahedral complex is high spin or low spin.
11. Define the following terms: selection rule, allowed transition, and forbidden transition.
12. Predict whether an electronic transition will be spin-allowed or spin-forbidden.
13. Relate the intensity of an absorption to the selection rules.

## Metallic bonding and physical properties of metals

1. Define valence and conduction bands, doping, p-type and n-type semiconductor.
2. Use the tenets of band theory to describe the conductivity differences between a metallic conductor, semiconductor and insulator.
3. Describe primitive cubic, body‐centered cubic, hexagonal closed‐packed, and cubic closed packed (or face‐centered cubic) lattices.
4. Determine the atoms per unit cell, coordination number per atom, the length of an edge in terms of the radius of an atom, and the packing efficiencies of primitive cubic, body‐centered cubic, and face centered cubic lattices.
5. Determine the metallic radius given the lattice type and density of a metal.

## Ionic bonding and physical properties of ionic compounds

1. Use Coulomb’s law to rationalize and predict which ionic compound will possess the greatest lattice enthalpy.
2. Given the Born-Mayer equation, ionic radii, and the Madelung constant, calculate the theoretical lattice energy of an ionic compound.
3. Describe the following common ionic structural motifs: cesium chloride, sodium chloride, sphalerite, wurtzite, fluorite, and anti-fluorite.
4. Determine the radius of an ion given the crystal lattice type, density data, and radius of the counterion.
5. Define interstitial site and “rank” them according to size (tetrahedral → octahedral → cubic)
6. Given the description of which holes are filled in a close packed structure, determine the stoichiometry of an ionic solid.
7. Use the radius ratio of ions to predict lattice type for an ionic solid.
8. Given appropriate thermodynamic data, use a Born-Haber cycle to calculate experimental lattice energy of an ionic compound.

# **Reactivity (thermodynamics, acid-base chemistry, and electrochemistry)**

## Thermodynamics

1. State the second and third law of thermodynamics.
2. Define entropy. Given a chemical reaction involving gases, predict the sign of Ssys.
3. Describe how we can calculate the Suniv if we know Ssys and Hsys.
4. Predict the effect of T on G given the signs of H and S.
5. Define standard free energy of formation, Go, and calculate given enthalpies and entropies of formations.

## Acid-base chemistry

1. Explain the trends in relative acidity of binary acids, oxoacids, and metal cations.
2. Using your knowledge of relative Bronsted-Lowry acidity, predict whether reactants or products will be favored in an acid/base reaction.
3. Classify a binary hydride or binary oxide as acidic or basic. Write reactions describing their behavior in water.
4. Define Lewis acid-base theory and identify an ion or compound as a Lewis acid or Lewis base.
5. Describe the basic tenets of Hard-Soft Acid-Base theory, HSAB.
6. Using your knowledge of HSAB, predict whether reactants or products will be favored at equilibrium.

## Redox chemistry

1. Write balanced oxidation-reduction equations in acid or base.
2. Sketch an electrochemical cell and identify the anode, cathode, oxidation half-cell, reduction half-cell, salt bridge, flow of electrons, and flow of ions.
3. Calculate Eocell for a reaction given standard potential data and relate Eocell to the spontaneity of the redox reaction and to K.
4. Use the Nernst equation to calculate Ecell under non-standard conditions.
5. Rank a group of metals into an activity series based on Pauling electronegativities.
6. Predict which metals will react with water, which will react with acid, and which need a stronger oxidizing agent to dissolve.
7. Know the general periodic trends in oxidizing and reducing strengths of the non-metal elements and their anions.
8. Know the general periodic trends in the stability of oxo anions where the central atom is in its highest oxidation state.
9. Write balanced chemical equations involving the oxidation or reduction of water. Define disproportionation and comproportionation.
10. Interpret a Latimer diagram. Use a Latimer diagram to predict which form of an element is susceptible to disproportionation. Write a balanced equation for the disproportionation reaction and calculate Eocell for the disproportionation reaction.
11. Use a Latimer diagram to determine the standard potential for nonadjacent species.