**Chem 20A: Suggested Syllabus**

Suggested readings, labeled informally as “Oxtoby”, refer to “Principles of Modern Chemistry 8th edition, by David W. Oxtoby, H. Pat Gillis and Laurie J. Butler; published by Cengage Learnings.

A star (\*) symbol corresponds to more advanced topics.

**Lecture 1: Introduction to course and to the scientific method**

**Learning outcomes/goals:** Scientific method. SI units and scientific notation. Dimensional analysis. Significant figures. Volume density calculations.

**Lecture 2: Atomic Theory**

**Suggested Readings (Oxtoby):** Chapter 1.1 - 1.6

**Learning Outcomes/Goals**: Conservation of charge, mass and energy laws and consequences. Atomic theory. Make-up of atoms and differences between different elements. Isotopes. Ions. Relative atomic masses, relative molecular masses (molar masses) and moles and corresponding calculations. \*Mass spectrometry and how a simple mass spectrometer works.

**Lecture 3: Stoichiometry**

**Suggested Readings (Oxtoby):** Chapter 2.1-2.5

**Learning Outcomes/Goals:** Law of definite proportions. Solve empirical and molecular formula problems. \*Combustion analysis. Balance chemical equations. Solve stoichiometry problems to determine mass/moles of products/reactants. Solve stoichiometry problems involving limiting reagents and percent yield.

**Lecture 4: Extra Review Day**

**Learning outcomes/goals:** \*More stoichiometry problems. \*Extra time on other materials that students need.

Quantum Mechanics

**Lecture 5: Introduction to waves & failings of classical physics**

**Suggested Readings (Oxtoby):** Chapter 4.1-4.2.1

**Learning outcomes/goals:** Light described as electromagnetic waves. Wave speed/frequency/wavelength calculations. Electromagnetic spectrum. Wave interference and how (two-slit) diffraction patterns arise (basic math of wavelength overlap). \*Recover atomic spacing using basic x-ray diffraction problems. Qualitatively understand the failing of the classical description of blackbody radiation compared to experiment and Planck's solution. Qualitatively understand the failing of the classical description of radiation to describe photoelectron emission from metals. Use Einstein's photoelectric equation to solve problems.

**Lecture 6 and 7: Intro to quantum mechanics**

**Suggested Readings (Oxtoby):** Chapter 4.2.2-4.4

**Learning outcomes/goals:** Understand atomic emission spectra and using Rydberg's equation. Use Bohr's model of the atom to explain atomic emission. Understand existence of wave-particle duality and calculations including the De Broglie relation. \*Use simple electron diffraction to recover crystallographic information (wave diffraction for matter). Heisenberg's Uncertainty Principle and its implications (and solve basic problems using it).

**Lecture 8 and 9: The Schrodinger Equation**

**Suggested Readings (Oxtoby):** Chapter 4.5-4.7

**Learning outcomes/goals:** The time independent Schrodinger equation. What the wavefunction is and what its amplitude tells you. The particle in a box from Schrodinger's equation (compare to free particle solution and how boundary conditions impose quantization). Use particle in the box energy equation to calculation energy level differences (\*optical transitions), how box size changes energy spacing. Be able to relate nodes to energy level (excited states). Understand meaning of degeneracy and relate to dimensionality of problem.

**Lecture 10,11, and 12: Intro to the hydrogen atom**

**Suggested Readings (Oxtoby):** Chapter3.3 (some) & 5.1

**Learning outcomes/goals:** Review conservation of total energy, definition of kinetic energy, attractive/repulsive nuclear/electron electrostatic potentials (including plots). Schrodinger's hydrogen atom setup and energy level equation and how it relates to Rydberg and differs from Bohr's model. Understand the principle quantum number, angular quantum number and magnetic quantum number and degeneracies. Relate quantum numbers to the s, p, d and f orbitals and familiar with orbital shape. Understand how the quantum numbers relate to nodes and nodal planes. Understand the radial wavefunction and radial nodes. Electron spin quantum number. \*Electrons as Fermions.

**Lecture 13: Electronic configurations and periodic trends**

**Suggested Readings (Oxtoby):** 5.2-5.5 & 3.2-3.5

**Learning outcomes/goals:** Understand the Hartree approximations for many electron atoms and effective nuclear potential and shielding and idea of shells. Atom's/ion's electronic configuration (Aufbau, Hund rules, Pauli excluision principle) up to d-block. Understand when an atom is diamagnetic or paramagnetic. Understand how what ionization/electron affinity energies definitions and ionization/electron affinity chemical equations. Relate electronic structure to periodic trends (ionization energy, electronic affinity, atomic/ionic radii), including spin correlation effects. \*Interpret atomic photoelectron spectra. \*Know that 0 potential is arbitrarily defined at vacuum (refer to photoelectric effect).

**Lecture 14 and 15: Classical bonding I (Review)**

**Suggested Readings (Oxtoby):** 3.1, 3.6-3.10

**Learning outcomes/goals:** Understand what a bond is in terms of forces and energy. Understand what the bond dissociation is. Be able to draw and interpret a bonding potential curve (Morse potential). Understand what electronegativity is and how it results in polar bonds. Understand ionic bonding and be able to calculate relevant electrostatic quantities from Coulomb's law. Qualitatively understand that covalent bonds cannot be described classically and can be thought of overlapping atomic wavefunctions (sharing electron density). Understand polar bonds (in terms of electronegativity) and nature of bonds being on a spectrum between ionic and polar. Able to draw simple Lewis dot structure for covalent compounds. Determine bond order. Know roughly the length of an average bond (the Angstrom unit). Calculate dipole moments and percent ionic character.

**Lecture 16: Classical bonding II (Review): VSPER**

**Suggested Readings (Oxtoby):** 3.9-3.13

**Learning outcomes/goals:** Be able to draw simple resonance structures. \*Be able to draw expanded octet Lewis structures. Understand and use VSEPR to predict the shape of molecules - know the names the geometries and roughly the bond angles in the geometries. Know the effects of lone pairs on geometries. Understand when a molecule is polar and the direction of its dipole moment. Be able to calculate formal charge. Be able to calculate oxidation number. Compound ions. Use and read IUPAC inorganic naming system.

**Lecture 17 and 18: Intro to quantum mechanical bonding**

**Suggested Readings (Oxtoby):** 6.1-6.5

**Learning outcomes/goals:** Understand the difficulty in multibody solutions and methods to get around this. Understand implications of Born-Oppenheimer approximation. Understand how LCAO lets us approximate molecular orbitals. Identify MO nodes and nodal planes. Use MO theory on homo-nuclear diatomic molecules. Predict bond order with MO theory and compare to Lewis structures. Realize that more nodes correspond to higher energy (excited) states.

**Lecture 19: Molecular orbital theory: Continued**

**Suggested Readings (Oxtoby):** 6.6-6.7

**Learning outcomes/goals:** Identify diamagnetic or paramagnetic properties of diatomic gases. Use MO theory on hetero-nuclear diatomics. Understand non-bonding orbitals. Understand polar nature of bonds from MO theory. \*Interpret basic molecular photo emission spectra.

**Lecture 20: Valence bond theory and hybridization**

**Suggested Readings (Oxtoby):** 6.8-6.12

**Learning outcomes/goals:** Understand valence bond theory. Construct and draw hybrid orbitals (including wavefunctions formulation). Relate hybrid orbitals to Lewis structures. \*Use MO theory with hybrid orbitals on hetero-nuclear basic polyatomics. \*Relate π-conjugation and particle in box.

**Lecture 21: \*Spectroscopy Topics 1 (Special Topic 1)**

**Learning outcomes/goals:** NMR & EPR spectroscopy (Zeeman effect). Microwave (rotational spectroscopy) (Moment of Inertia).

**Lecture 22: \*Spectroscopy Topics 2 (Special Topic 2)**

**Learning outcomes/goals:** IR (Vibrational spectroscopy) (zero point energy). UV-Vis (Absorption and photoluminescence), vibrational splitting, particle in box and conjugation and quantum dots, Beer's law.

**Lecture 23: Intro to transition metal complexes**

**Suggested Readings (Oxtoby):** 8.1

**Learning outcomes/goals:** Review of oxidation states. Definition of ligand. Definition of Lewis acid and base. Understand coordination (dative) bonds. Identify ligand substitution reactions.

**Lecture 24: Coordination geometries and crystal field theory**

**Suggested Readings (Oxtoby):** 8.2-8.4

**Learning outcomes/goals:** Identify coordination complex geometries. Understand basic crystal field theory and how it gives rise to d-orbital splits and color compounds (absorption). Understand high spin/low spin and how it relates to magnetic properties. Know a few key ligands on the spectrochemical series and it relates to weak field and strong field. Realize that that absorption corresponds to the complementary color seen (e.g. something absorbing at ~700 nm, i.e., absorbing red, would look green).

**Lecture 25: Ligand field theory**

**Suggested Readings (Oxtoby):** 8.6

**Learning outcomes/goals:** \*Qualitative understand of Jahn-Teller distortion and effects on the d-split. Basic ligand field theory. \*Sigma acceptor ligands, pi-donor ligands and backbonding.