CHEMISTRY 305

Descriptive Inorganic Chemistry

Syllabus
Spring 2012
Problems with solutions for various topics are posted
on Blackboard under Assignments

WHAT IS SCIENCE

PART I. Biological Evolution, Big Bang, and Other Myths of Science (Lecture notes only)

Part II. The Nature of Science

Facets of the doing of science
- Subject field
- Method of procedure
- Practitioners
- Knowledge
- Motivations

Definition of science
Facts
The scientific method
Representing the facts - descriptive observations
- Symbolization
- Classification
- Association
- Ordering
- Measurement

Are sociology and psychology sciences?

We will arrive at a consensus definition and understanding of science which we will then use to understand and interpret the remaining topics of the course as appropriate.

No problems.

I. ELECTRONIC STRUCTURE OF ATOMS (Fay and HS)

The Bohr Atom (HS 1.4: Z 7:4)
deBroglie's Wave/Matter Concept (HS 1.5; Fay 3.2, 4)
- l = h/p
- Rationalization of Bohr's second postulate

The Schrodinger Equation for Hydrogen-like Atoms (HS 1.5, 6)
- *Reminiscences of the Early Days of Quantum Mechanics by Felix Bloch in Physics Today*
- Partial derivation
- Solutions to the Schrodinger equation
  - Energy
  - Wave functions - orbitals

Aufbau Principles (HS 1.9; Fay 3.9, 10, 11, 12)
- Paul exclusion principle
- Orbital filling order
- Hund's rule

Interpretation of ψ (HS 1.6: Fay 3.6, 7)
- Probability
- Radial portions
- Angular portions
- Contour diagrams

Periodic Trends in the Properties of Elements (HS 1.10: Fay 3.14; 4.3, 4, 5, 6)

- Ionization enthalpy
- Atomic radii
- Electron attachment enthalpy
- Electronegativity

The Composition and Temperature of Stars - Phillip Morrison in The Ring of Truth.

- *The Bohr atom and stars*
- *The contributions of Cecelia Payne, first woman full professor at Harvard University*

Problem Set: Electrons in Atoms on Blackboard

Assignment: How does the discovery of the Schrodinger equation fit into our understanding of science? (50 points)

II. MORE CHEMICAL EQUILIBRIUM (HS 7 and Fay 14, 15)

Acids and Bases (HS 7.1,2,4; Fay14.1-10)

- Arrhenius
- Bronsted-Lowry
- Lewis
- Strong and weak acids and bases
- Conjugate acids and bases
- Self-dissociation of water
- pH

Polyprotic Acids and Bases (Fay 14.11)
Hydrolysis of Anions & Cations or Acid-Base Properties of Salts (Fay 14.14)
Titration Curves (Fay 15.6, 7, 8, 9)

- Strong acid with a strong base
- Weak acid with a strong base
- Other titration systems

Chemical Indicators (DWT notes only)
Buffers (HS 7.10; Fay 15.3)
Amphoteric oxides and hydroxides (HS 7:8)
Stability constants of coordination compounds (HS 7.12)

Problem Set: Acids, Bases, Ions in Aqueous Solution on Blackboard

III. REVIEW OF FREE ENERGY (Fay 16)

Enthalpy (Fay 16.2)
Entropy (Fay 16.2)
Free Energy (Fay 16.7, 8, 9)
Free Energy in Chemical Reactions (Fay 16. 10)

- Standard free energy changes
- Spontaneity

Free Energy and Equilibrium (Fay 16. 11)

Problem Set: Free Energy on Blackboard

IV. REVIEW OF ELECTROCHEMISTRY (HS 8.1,2; Fay 17)

Background (HS 8.1)
Galvanic Cells (HS 8.1; Fay 17.1, 2)
Standard Reduction Potentials (HS 8.1; Fay 17.4,5)
Free Energy, Equilibrium, and Cell Potentials (HS 8.2; Fay 17.3)
Dependence of Cell Potential on Concentration (HS 8.1; Fay 17.6)
Fuel cells (HS 10.Box 10.2)
Solar cells (DWT notes only)

Problem Set: Electrochemistry

V. NUCLEAR CHEMISTRY (HS 3:1, 2,3,4,5,8,9,10,11 and DWT notes)

Nuclear and Chemical Properties of Matter (DWT notes only)
Nuclear Stability and Radioactive Decay (HS 3.3)
- Stability zone (DWT notes only)
- Natural radioactivity (DWT notes only)
- Induced radioactivity (DWT notes only)
- Nuclear reactions (DWT notes only)

Rate of Radioactive Decay (HS 3.3)
Radiocarbon Dating (HS 3.9)
Thermodynamic Stability of the Nucleus
- Atomic mass units (HS 1.3)
- Binding energy (HS 3.2)
- Einstein equation (HS 3.2)
- Binding energy per nucleon curve (HS 3.2)
- Fission & fusion (HS 3.5, 8)

Multi-Nuclear NMR (HS 3.11)
Problem Set: Nuclear Chemistry on Blackboard

The 100th Anniversary of the Discovery of Radioactivity by Henri Becquerel - Physics Today: The Limitations of Science Fat Man and Little Boy A film portrayal of the development of the bomb.

Problem Set: Nuclear Chemistry

VI. ELECTRONIC STRUCTURE OF MOLECULES (Z 8.13; Z 9.2, 3; HS 2.8, 9,, 17)

Review of Lewis Diagrams and VSEPR Concept (HS 2.1; Fay 5.6, 7, 8, 9)
Hybridization (Useful in organic and simple inorganic molecule chemistry.)
Molecular Orbital Theory (HS 2.1, 2, 3, 7,; Fay 5.14, 15, 16)
- LCAO Approach
- Hydrogen and Helium
- Overlap of Orbitals
  - Positive - bonding
  - Negative - anti-bonding
  - Zero - non-bonding
- Homonuclear diatomic molecules
- Heteronuclear diatomic molecules

Problem Set: Electrons in Molecules on Blackboard

VII. SYMMETRY (HS 4.1-4; DWT notes)

Symmetry Elements and Operations (HS 4.2)
- Proper rotation axis
- Inversion center
- Symmetry plane
- Improper rotation axis

Symmetry Point Groups (HS 4.3, 4)
- Multiplication tables
- Groups derived from a single element
- Groups derived from two elements
- Groups derived from three elements
- Special Groups
- Assigning molecules to point groups

Applications
- Dipole Moments (HS 2.6)
- Optical activity/chiral molecules (HS 4.8)
- Chemical equivalence (DWT notes only)

Problem Set: Symmetry on Blackboard

VIII. COORDINATION CHEMISTRY (HS 7, 20, 21, 22; Fay 20)

- Definitions (HS 7.11)
- Apologetic (HS 29.1; DWT notes)
- Historical Perspective (HS 22.10 and Box 22.9)
  - Multiple salts
  - Cobalt-ammine complexes
  - Werner's coordination theory
  - Geometric structure of six-coordinate complexes
- Ligands (HS 7.11, 13; Fay 20.6)
- Nomenclature (HS 7.13, Fay 20.7)
- Coordination Numbers and Geometries (HS 20.7)
- Isomerism (HS 20.8; Fay 20.8)
  - Optical
  - Geometric
  - Linkage
- Bonding and Electronic Properties (HS 21.1, 3, 4, 5; Fay 20.11,12)
  - Effective Atomic Number Rule (HS 24.3)
  - Ligand or Crystal Field Theory for Octahedral Complexes (HS 21.3,9, 10; Fay 20.12)
    - Orbital splittings
    - Spectrochemical series
    - Magnetic properties
    - Other physical properties affected by orbital splitting
      - Heats of hydration (HS 21.10)
      - Ionic radii (DWT notes only)
      - Jahn Teller effect
- Crystal field Splittings for Other Geometries (HS 21.3)
  - Square planar
  - Tetrahedral

Problem Set: Coordination Chemistry on Blackboard

IX. HYDROGEN, OXYGEN AND WATER (HS 2, 7, 10, 15)

- Hydrogen (HS 10.1,2)
  - Position in periodic table (HS 10.1,2)
  - Isotopes of hydrogen (HS 10.3)
  - Preparation of hydrogen (HS 10.4)
  - Bonding of hydrogen
    - H^+ formation (HS 10.2)
    - Hydride formation (HS 10.2)
    - Formation of electron pair covalent bonds (HS 10.5)
    - Hydrogen bonding (HS 10.6)
- Water (HS 7.2,9)
  - Structure (HS 7.2)
  - Solvent (HS 7.2)
  - Solubility of ionic solids (HS 7.9)
- Oxygen (HS 2.3; 7,8;1.4,5)
  - Allotropes (HS 16.4)
  - Major property - oxidizing agents (HS 16.4)
  - Bonding of oxygen (HS 2.3)
  - Compounds of oxygen
    - Hydrogen peroxide (HS 15.5,13)
    - Superoxides (HS 16.4; 2.3)
    - Dioxygenyl cation (HS 16.4; 2.3)
    - Oxides - acidic, basic, amphoteric (HS 16.8)

No problems!

X. ALKALI AND ALKALINE EARTH METALS (HS 11)

Some General Properties (HS 11.3)
The Formation of Ionic Compounds (HS 6.13; Fay 4.8,9)
- Sodium Chloride
- Lattice energy calculations
- Why don't Group II metals for MX salts?

Solubilities on Ionic Salts (HS 7.9)
The Anomalous E° Value for Lithium (DWT notes only)

No problems!

XI. METAL CARBONYLS (HS 24)

Historical Perspective (DWT notes only)
CO as a ligand (HS 24.2)
- Metal Oxidation states
- Basicity
- Dipole moment
- Orbital structure

Bonding Model for Metal-Carbonyl Complexes (HS 24.2)
Binary Metal carbonyls (HS 24.4)
- Mononuclear
- Polynuclear

EAN rule applied to metal carbonyls (HS 24.3)
Preparation of Metal Carbonyls (24.4)
- Direct reaction
- Reductive carbonylation

Carbonylate Anions and Hydrides (24.9)
Other CO-Like Ligands (HS 24.4)
- Phosphine
- Ethylene

Catalytic Reactions of Transition Metal Carbonyls and Organometallic Compounds
- Hydroformylation reaction (HS 27.5)
- Basic reaction principles (HS 24:7; 27.1)
  - Coordination unsaturation
  - Electron unsaturation
  - Oxidative addition - reductive elimination
  - Insertion reactions
    - CO
    - Olefin
  - β-Hydrogen elimination
- Monsanto acetic acid synthesis (HS 27.5)
- Olefin metathesis – The Nobel Prize (2005) work of Grubbs and Schrock (HS 27.3)
- Alkene polymerization: Ziegler-Natta catalysis (HS 27.8)

Problem Set: Metal Carbonyl and Organometallic Chemistry

XII. MISCELLANEOUS TOPICS in MAIN GROUP CHEMISTRY