AP® Chemistry

Syllabus 1

Text

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Goals of the course

- Students are prepared to be critical and independent thinkers who are able to function effectively in a scientific and technological society.
- Students will be able to analyze scientific and societal issues using scientific problem solving.
- Students will emerge from this program with an appreciation for the natural world.
- Students will be able to make an acceptable score on the AP Chemistry Examination in May.
- In each laboratory experiment, students will physically manipulate equipment and materials in order to make relevant observations and collect data; use the collected data to form conclusions and verify hypotheses; and communicate and compare results and procedures (informally to other experimenters, and also in a formal, written report to the teacher). **[C5]**

C5—Laboratory (Physical manipulations; Processes and procedures; Observations and data manipulation; Communication, group collaboration, and the laboratory report)

Fall Semester

Introductory and review concepts (1 ½ weeks)

Chapters 1-3 Primarily completed during the summer

I. Measurement topics
II. Atomic theory
III. Symbols and formulas
IV. Periodic table
V. Ionic and covalent bonds
VI. Nomenclature
VII. Reactions
VIII. Stoichiometry
  A. Percent composition
  B. Empirical formulas
  C. Solutions

D. Mole relationships

1. percent (%) yield
2. Limiting reagents

E. Titrations and other analyses

The student will:

1. Define terms such as matter, energy, element, compound, mixture, solution. Learn the meaning of the following thermodynamic terms: enthalpy, ΔH, exothermic, endothermic, system, surroundings, universe, heat of formation, heat of reaction, calorimetry, heat, calorie, joule, standard molar enthalpy of formation, molar heat of combustion.
2. Work comfortably with the metric system. Work problems using dimensional analysis. **[C6]**
3. Understand and work with the proper number of significant figures.
4. Apply knowledge of significant figures to laboratory work.
5. Correctly use an analytical balance, a vacuum flask, and Buchner funnel.
6. Know the name and application of the common laboratory equipment used in this course.
7. Work problems involving calories and specific heat. **[C6]**
8. Name the polyatomic ions, given the formula, and vice versa.
9. Name inorganic compounds, including acids, using the Stock system.
10. Write formulas for the names of inorganic compounds.
11. Work problems involving mole concepts, molarity, percent composition, empirical formulas, and molecular formulas. **[C6]**
12. Balance equations given both reactants and products
13. Solve stoichiometric problems involving percent yield, and limiting reagents. **[C6]**

C6—The course emphasizes chemical calculations and the mathematical formulation of principles.

Apply these concepts to the laboratory setting.

Laboratory

- The System
- Recycling in the Chemistry Classroom
- Clean and White—An Inquiry Lab **[C5]**

C5—Laboratory (Physical manipulations; Processes and procedures; Observations and data manipulation; Communication, group collaboration, and the laboratory report)

Types of Chemical Reactions and Solution Stoichiometry (2 weeks)

Chapter 4

I. Reaction types
   A. Acid base reactions
      1. Concepts of
         a) Arrhenius
         b) Lowry-Brønsted
         c) Lewis
   B. Precipitation reactions
   C. Oxidation reduction reactions
      1. Oxidation number
      2. Electron transport
      3. Electrochemistry
II. Stoichiometry
III. Net ionic equations
IV. Balancing equations including redox
V. Mass-volume relationships with emphasis on the mole

The student will:

1. Apply the periodic law to chemical reactivity in predicting reaction products.
2. Discuss the activity series of the elements.
3. Distinguish between metals and nonmetals. **[C4]**
4. Classify compounds as to acids, bases, acid anhydrides, basic anhydrides, salts, and covalent molecules.
5. Use the properties of metals and nonmetals to predict reaction products. **[C4]**
6. Write chemical equations for synthesis, decomposition, single replacement, metathetical, redox, combustion, and acid-base reactions. **[C3]**
7. Use the Periodic Table to predict common oxidation states.
8. Use the Activity series of elements to predict single replacement reactions. **[C4]**
9. Know the major components of the atmosphere.
10. List the major air pollutants.
11. Discuss some solutions to the air pollution problem

C4—Descriptive Chemistry (Relationships in the Periodic Table)

C3—Reactions (Reaction Types, Stoichiometry, Equilibrium, Kinetics, Thermodynamics)

12. Know the major water pollutants.

13. Understand which ions make water “hard” and know methods of softening water.

Laboratory

- Solutions and Reactions
- Percent composition of Epsom Salts
- Laboratory Practical Exam [C5]

C5—Laboratory (Physical manipulations; Processes and procedures; Observations and data manipulation; Communication, group collaboration, and the laboratory report)

The Kinetic-Molecular Theory and States of Matter (2 weeks) [C2]

C2—States of Matter (Gases, Liquids, and Solids, Solutions)

Chapters 5, 10

I. Gases Laws
   A. Ideal gases
   B. Boyle’s law
   C. Charles’ law
   D. Dalton’s law of partial pressure
   E. Graham’s law
   F. Henry’s law
   G. Van der Waal’s equation of state
II. Kinetic-Molecular theory
   A. Avogadro’s hypothesis and the mole concept
   B. Kinetic energy of molecules
   C. Deviations from ideality
III. Liquids and solids
   A. Liquids and solids from the K-M viewpoint
   B. Phase diagrams of one-component systems
   C. Changes of state
   D. Structure of solids including lattice energies

The student will:

1. State and discuss the major tenants of the kinetic-molecular theory.

2. Apply the kinetic-molecular theory to liquids and solids, as well as gases.

3. Discuss intermolecular forces and relate them to physical properties such as boiling point.

4. Discuss the methods and units for measuring pressure; convert between units.

5. Work problems using: Charles's law, Boyle's law, Gay-Lussac's law, Avogadro's Law, Dalton's law. Maxwell-Boltzmann distribution law, the ideal gas law, and Van der Waal's equation. [C6]

6. Interpret heating curves as to melting point, boiling point, and specific heat.

7. Interpret phase diagrams and correctly define terms such as triple point, critical temperature, and critical pressure.

8. Discuss the phenomena of boiling, and be able to relate it to pressure.

9. Carry out a distillation to separate substances with differing boiling points.

10. Distinguish between crystalline and amorphous solids.

11. Use the unit cell information for calculation of ionic radii.

12. Use X-ray diffraction data to calculate unit cells.

C6—The course emphasizes chemical calculations and the mathematical formulation of principles.

Laboratory

- Flick your Bic [C5]
- Triple Point of Dry Ice

C5—Laboratory (Physical manipulations; Processes and procedures; Observations and data manipulation; Communication, group collaboration, and the laboratory report)

Thermochemistry (2 weeks)

Chapter 6

I. Thermal energy, heat, and temperature
II. Calorimetry
III. Enthalpy changes
IV. Hess's Law

The student will:

1. Learn the meaning of the following thermodynamic terms: enthalpy, ΔH, exothermic, endothermic, system, surroundings, universe, heat of formation, heat of reaction, calorimetry, heat, calorie, joule, standard molar enthalpy of formation, molar heat of combustion.

2. Solve calorimetry problems involving $q = mc\Delta T$.

3. Use Hess's Law to solve for heat of reaction.

4. Use stoichiometric principles to solve heat problems. [C6]

Laboratory

- Heats of Reaction

Atomic and nuclear structure (3 weeks) [C1]

> **C1**—Structure of Matter (Atomic Theory and Atomic Structure, Chemical Bonding)

Chapters 7 and 21

I. Electronic Structure
   A. Evidence for the atomic theory
   B. Atomic masses
   C. Atomic number and mass number
   D. Electron energy levels: atomic spectra, quantum numbers, atomic orbitals
   E. Periodic relationships

II. Nuclear structure
   A. Nuclear equations
   B. Half-lives
   C. Radioactivity
   D. Chemical application

The student will:

1. Name the major subatomic particles in an atom.
2. List the types of radioactive emissions.
3. Discuss the Bohr model of the atom, and compare it to the quantum mechanical model of the atom.
4. Discuss the major differences in the classical mechanical model and the quantum mechanical model.
5. Work problems involving quantum numbers and energies of electron transitions. [C6]

> **C6**—The course emphasizes chemical calculations and the mathematical formulation of principles.

6. Define and discuss the following terms or concepts: Heisenberg uncertainty principle, Pauli exclusion principle, wave-particle duality of matter, Wave function of electrons (Y), radial probability density, orbitals, aufbau process, and Hund's rule.
7. Draw and name the s, p, and d orbitals.
8. Understand the basis for the periodic law, and apply it to periodic trends such as atomic radii, ionization energy, electron affinity, density, melting point, oxidation states, and electronegativity.
9. Work problems involving nuclear binding energy.
10. Predict nuclear stability and mode of decay using N/Z ratio.
11. Work problems involving half-life.
12. Balance nuclear equations.

Laboratory

- Atomic Spectrum of Hydrogen
- Radioactivity vs. Distance [C5]

C5—Laboratory (Physical manipulations; Processes and procedures; Observations and data manipulation; Communication, group collaboration, and the laboratory report)

1st quarter Organic Review (Structures) Organic chemistry is covered using a self-paced computer program. One unit is due each of the first three quarters Production of ChemDraw.

Bonding and Molecular Structure (3 weeks) [C1]

C1—Structure of Matter (Atomic Theory and Atomic Structure, Chemical Bonding)

Chapters 8 and 9

I. Binding forces
   A. ionic
   B. covalent
   C. metallic
   D. hydrogen bonding
   E. Van der Waals
II. Relationships to states, structure, and properties of matter
III. Polarity of bonds, Electronegativities
IV. Molecular models
   A. Lewis structures
   B. Valence bond: Hybridization of orbitals, resonance, sigma and pi bonds
V. VSEPR
   A. Geometry of molecules and ions
   B. Structural, geometric, optical, and conformational isomerism of:
      1. Organic molecules
      2. Coordination complexes
VI. Polarity of molecules
VII. Relation of molecular structure to physical properties

The student will:

1. Draw Lewis structures for the common atoms, ions, and molecules.
2. Use periodic trends of electronegativity to predict bond type.
3. Distinguish between polar and nonpolar molecules.
4. Use electronegativity values and bonding concepts to determine oxidation states on atoms.
5. Draw resonance structures. Assign formal charges.
6. Pass a quiz over polyatomic ions with a 95 percent.

7. Name compounds and write chemical formulas.

8. Compare and contrast VB theory with MO theory.

9. Name and draw the molecular orbitals resulting from both positive and negative overlap of s and p atomic orbitals.

10. Draw molecular orbital energy level diagrams for all 1st and 2nd period homonuclear diatomic molecules and use it to predict stability, bond order, bond length, and magnetic properties.

11. Draw molecular orbital energy level diagrams for selected heteronuclear diatomic molecules.

12. Use the VSEPR model to predict molecular geometry.

13. Relate VSEPR to hybridization.

Laboratory

- The Covalent Bond
- Gravimetric Analysis of Nickel
- Determination of Vitamin C

C5—Laboratory (Physical manipulations; Processes and procedures; Observations and data manipulation; Communication, group collaboration, and the laboratory report)

Laboratory Semester Final: Analysis of Iron in Iron Pyrite [C5]

2nd Quarter Organic Review: (Nomenclature) Production of ChemDraw document

Solutions and Colloids (2 ½ weeks) [C2]

C2—States of Matter (Gases, Liquids, and Solids, Solutions)

Chapter 11

I. Types of solutions
II. Factors affecting solubility
III. Concentration issues
IV. Raoult's law and colligative properties
V. Nonideality

The student will:

1. Define solution vocabulary.

2. Discuss the effect that physical conditions have on solubility.

3. Discuss what is meant by an azeotrope.

4. Use the concepts of intermolecular forces in discussing the dissolving process.

5. Separate compounds into electrolytes and nonelectrolytes; separate electrolytes into ionic salts, acids, bases, acid anhydrides, and basic anhydrides.

6. Pass a quiz over the solubility rules; apply the solubility rules when predicting reaction products.

7. Solve problems involving molarity, molality, percent composition, mole fraction, and normality; to be able to convert between concentration designations. [C6]

> **C6**—The course emphasizes chemical calculations and the mathematical formulation of principles.

8. List the colligative properties and solve problems involving depression of freezing point, elevation of boiling point, lowering of vapor pressure, and increasing of osmotic pressure.

9. Distinguish between an ideal and a nonideal solution; discuss the Debye-Huckel theory to explain ion activity.

10. Know the names of the various colloidal systems.

11. Explain Brownian movement.

12. Discuss the cleansing action of soaps and detergents.

Laboratory

- Determining Molecular Weight by Freezing Point Depression [C5]

> **C5**—Laboratory (Physical manipulations; Processes and procedures; Observations and data manipulation; Communication, group collaboration, and the laboratory report)

Spectroscopy and Chromatography (3 weeks)

Supplemental Chapter

I. Spectroscopy
   A. Regions of Electromagnetic interest
      1. Radio-nuclear magnetic resonance
      2. Microwave-esr
      3. IR-molecular vibrations
      4. UV/visible
      5. X-ray
      6. Mass spectrometry

II. Separation techniques
   A. Distillation
   B. Recrystallization
   C. Chromatography
   D. Ion Exchange columns

The student will:

1. Correlate the various regions of the electromagnetic spectrum with its effect on matter.

2. Identify characteristic absorption bands in an IR spectrum.

3. Use visible spectroscopy to determine a point of maximum absorption (lmax).

4. Correctly use Beer's law to determine concentration of a solution.

5. Know the meaning of absorption, percent transmittance, _max, absorptivity.

6. Understand how a Spectronic-20 works.

7. Understand the concept of hydrogens in different chemical environments.

8. Correctly derive the structure of simple organic molecules from nmr data.

9. Understand the concepts of chemical shift and spin-spin coupling.

10. Explain several other areas of spectroscopy such as esp and X-ray.

11. Understand the concept of chromatography as a separation technique.

12. Use column, paper, and thin layer chromatography in the laboratory to separate mixtures.

13. Explain the difference between normal phase and reverse phase chromatography.

Vocabulary for Instrumentation unit:				
chromatography	**spectroscopy**	**characterization**	**derivatives**	**spectrometry**
GC	TLC	HPLC	adsorption	electromagnetic spectrum
reverse phase	Beer's law	deshielding	λmax	conjugated bonds
absorbance	% transmittance	normal phase	IR	spin-spin coupling
NMR	frequency	wavelength	wave number	electronic transitions
lambda max	shielding	chemical shift	shifted upfield	shifted downfield
GCMS	mass spectra	integration curve	step function	molar absorptivity
UV	splitting	MRI	esr/epr	molar extinction coefficient
m/e ratio				equivalent protons

Laboratory

- The Absorption Spectrum of Cobalt(II) Chloride
- Identifying an Unknown from Physical Properties

- Separation of F, D, & C Dyes **[C5]**

Chemical Kinetics (2 weeks) [C3]

Chapter 12

I. Rate of reaction
II. Order of the reaction
III. Factors that change the rate of the reaction
   A. Temperature
   B. Concentration
   C. Nature of substance
   D. Catalysts
IV. Relationship between the rate-determining step and the reaction mechanism

The student will:

1. List the factors that influence the rate of a chemical reaction.
2. Use experimental data to determine the rate law, determine the order of the reaction, and to define proper units for the constant.
3. Compare and contrast zero, first, and second order reactions in terms of the plot needed to give a straight line, the relationship of the rate constant to the slope of the straight line, and the half-life of the reaction.
4. Use experimental data to postulate a reaction mechanism.
5. Interpret how changing the conditions of the reaction (i.e., temperature, pressure, concentration, and addition of a catalyst) affects both the rate and the rate constant of the reaction.
6. Discuss the role of a catalyst in the rate and mechanism of a reaction; distinguish between a homogeneous and a heterogeneous catalyst.
7. Interpret data from a first order reaction to determine its half-life.
8. Solve problems involving activation energy and the Arrhenius equation. **[C6]**
9. Interpret the Boltzmann distribution law in light of reaction rates. Laboratory: Determination of the half-life of a 1st order reaction.

Laboratory

- Kinetics of Crystal Violet
- Determination of a first order reaction.
- Kinetic study of thiosulfate in acid.
- Determination of a rate law. **[C5]**

C5—Laboratory (Physical manipulations; Processes and procedures; Observations and data manipulation; Communication, group collaboration, and the laboratory report)

C3—Reactions (Reaction Types, Stoichiometry, Equilibrium, Kinetics, Thermodynamics)

C6—The course emphasizes chemical calculations and the mathematical formulation of principles.

Equilibrium (2 weeks) [C3]

C3—Reactions (Reaction Types, Stoichiometry, Equilibrium, Kinetics, Thermodynamics)

Chapter 13

I. Concept of dynamic equilibrium including Le Chatelier's principle
II. Equilibrium constants and the law of mass action

The student will:

1. Describe the meaning of physical and chemical equilibrium, and give real life examples of each.

2. Write the law of mass action for any system at equilibrium.

3. Understand the meaning of equilibrium constant and reaction quotient (Q).

4. Interpret the position of equilibrium from the size of the equilibrium constant.

5. Use Le Chatelier's principle to predict the direction a system in equilibrium will shift in order to re-establish equilibrium.

6. Know that temperature, pressure, and concentration will shift the position of equilibrium.

7. Understand that a catalyst will not have an effect of the equilibrium constant. Laboratory: Determination of equilibrium constant.

Laboratory practical exam [C5]

C5—Laboratory (Physical manipulations; Processes and procedures; Observations and data manipulation; Communication, group collaboration, and the laboratory report)

- 3rd quarter organic review (reactions) Production of ChemDraw document

Acids and Bases (1½ weeks)

Chapter 14

I. Arrhenius theory
   A. Properties of acids and bases
   B. Acid base neutralization
II. Lowry-Brønsted theory
   A. Amphiprotic species
   B. Relative strengths of acids and bases
   C. Polyprotic acids
III. Lewis acids and bases. Comparison of all three definitions.

The student will:

1. Distinguish between the various modern theories of acids and bases.

2. Name and write formulas for normal salts, hydrogen salts, hydroxy salts, oxysalts, and acids.

3. Write balanced equations involving acids, bases, and salts.
4. Perform a titration and solve for the appropriate concentration.
5. Use the concept of conjugate acid-base pairs to predict reaction products.
6. Define and give examples of amphiprotic species.
7. List the six strong acids.
8. Recognize Lewis acid-base reactions.

Laboratory

- Determination of an Ionization Constant, Ka **[C5]**

C5—Laboratory (Physical manipulations; Processes and procedures; Observations and data manipulation; Communication, group collaboration, and the laboratory report)

Weak Ionic Equilibrium (2 ½ weeks)

Chapter 15

I. Weak acids and bases
   A. pH
   B. pOH
   C. Buffer systems
   D. Hydrolysis
II. Solubility Product
   A. Factors involving dissolution
   B. Molar solubility

The student will:

1. Identify weak electrolytes.
2. Write a law of mass action for any reaction in equilibrium.
3. Know and use the water constant, Kw.
4. Define pH, pOH, pK, Ka, Kb, ionization constant, percent ionization, Ksp.
5. Convert from {H3O+} or {OH-} to pH or pOH. **[C6]**
6. Use a pH meter to determine a titration curve and an ionization constant.
7. Pick a suitable indicator for a titration.
8. Recognize salts that undergo hydrolysis and write a reaction for the ion with water.

C6—The course emphasizes chemical calculations and the mathematical formulation of principles.

9. Given the concentration and amount of weak acids or bases and an appropriate titrant, calculate data to produce a titration curve. **[C6]**

10. Write solubility product expressions for slightly soluble compounds.

11. Solve problems involving: (a) solubility product constants from solubility; (b) molar solubility from Ksp; (c) concentrations of substances necessary to produce a precipitate; (d) concentrations of ions involved in simultaneous equilibrium. **[C6]**

C6—The course emphasizes chemical calculations and the mathematical formulation of principles.

Laboratory

- Solubility Product Constant (Ksp) for Calcium Sulfate

Chemical Thermodynamics (2 weeks) [C3]

C3—Reactions (Reaction Types, Stoichiometry, Equilibrium, Kinetics, Thermodynamics)

Chapter 16

I. State functions
II. Laws of thermodynamics
III. Relationship of change of free energy to equilibrium constants

The student will:

1. List and define the meanings and common units for the common thermodynamic symbols.

2. Distinguish between a state function and a path function.

3. Define internal energy, PV work, enthalpy, entropy, and free energy.

4. Use Hess's law to solve problems of energy, entropy, and free energy. **[C6]**

5. Define the terms exothermic, endothermic, exergonic, and endergonic.

6. Determine the spontaneity of a reaction.

7. Discuss the laws of thermodynamics (in order).

8. Understand the relationship between free energy change and equilibrium constants.

Laboratory

- Vapor Pressure and enthalpy of the vaporization of water. **[C5]**

Analysis of nmr data to determine equilibrium constants, ΔG, ΔH, and ΔS of a reaction.

C5—Laboratory (Physical manipulations; Processes and procedures; Observations and data manipulation; Communication, group collaboration, and the laboratory report)

Electrochemistry (1½ weeks)

Chapter 17

I. Galvanic cells and cell potentials
II. Electrolytic cells
III. Redox equations

The student will:

1. Use the half-reaction method to balance redox equations.
2. Define electrochemical terms: redox, anode, anion, cathode, cation, oxidizing agent, reducing agent, emf, electrode, etc.
3. Distinguish between an electrolytic cell and a voltaic cell in terms of function and *G.
4. Solve problems using Faraday's law.
5. Predict reaction products for both electrolytic and voltaic cells.
6. Discuss the importance of and draw a diagram of a standard hydrogen electrode.
7. Use a table of Standard Reduction Potentials to compute cell voltages.
8. Solve problems using the Nernst's equation.
9. Diagram voltaic cells using proper notation.
10. Establish the relationship between the free energy change, the cell potential, and the equilibrium constant.
11. Discuss and give examples of primary cells, secondary cells, and fuel cells.
    Exam: multiple choice, reaction prediction, essays, problem solving.

Laboratory

- Electrochemical cells.

Transition Metals and Coordination chemistry (1½ week)

Chapter 20

I. Names and structures of complexions
II. Bonding in coordination systems
III. Formation of complex ions (reactions).
IV. Practical applications

The student will:

1. Define the following: central ion or atom, coordination sphere, coordination number, polydentate ligand, ligand, chelating agent, cis and trans isomers, t2g and e.g. orbitals, ligand field splitting, 10 Dq, LFSE, low spin complex, high spin complex, paramagnetic, diamagnetic, % transmittance, Absorbance, Beer's law, spectrometer.

2. Name coordination complexes.

3. Draw geometric and optical isomers of various complexes.

4. Use crystal field theory to predict colors and magnetic properties of complexes.

5. Use crystal field theory to predict high spin and low spin complexes.

6. Write net ionic equations involving complex ions. Laboratory: (Final) Synthesis and analysis of a nickel(II) ammine complex.

Laboratory Final

- Synthesis and analysis of a nickel ammine complex (1 week) **[C5]**

C5—Laboratory (Physical manipulations; Processes and procedures; Observations and data manipulation; Communication, group collaboration, and the laboratory report)

Requirements

Students are expected to be in class on time with the required materials. The AP Chemistry class meets for 45 minutes two days each week and for 95 minutes three days each week. A minimum of 45 minutes per day outside of class is expected.

Each week, at least one of the 95-minute periods will be devoted to laboratory work. Students keep a formal laboratory notebook. This notebook is graded with each lab. Laboratory work counts 30 percent of the total class grade. The notebook goes with the student to the university to evaluate their placement in a college laboratory program. **[C7]**

Students in AP Chemistry are expected to take the AP Chemistry Exam in May.

C7—The course includes a laboratory component comparable to college-level chemistry laboratories. A minimum of one double-period per week or its equivalent is spent engaged in laboratory work. A hands-on laboratory component is required. Each student should complete a lab notebook or portfolio of lab reports. **Note:** Online course providers utilizing virtual labs (simulations rather than hands-on) should submit their laboratory materials for the audit. If these lab materials are determined to develop the skills and learning objectives of hands-on labs, then courses that use these labs may receive authorization to use the "AP" designation. Online science courses authorized to use the "AP" designation will be posted on the AP Central® Web site. (For information on the requirements for an AP Chemistry laboratory program, the Guide for the Recommended Laboratory Program is included in the Course Description.)*