Syllabus for AP Chemistry

Textbook: Kotz, John C., Paul M. Treichel, Gabriela C. Weaver. *Chemistry & Chemical Reactivity, 4th Ed.*. Pacific Grove, CA: Brooks/Cole Thomson Learning

Classes are organized according to the ideas outlined in Understanding by Design (Wiggins & McTighe). Instead of topics and concepts, chapters and units are organized according to "essential questions" that address WHY we are learning the knowledge and skills associated with each chapter. For each **AP content area**, the applicable chapters are listed. For each **chapter**, the **essential questions**, the **calculations** taught, and the **laboratory activities** students perform are listed.

Students in AP chemistry do not take a first year chemistry course. AP chemistry begins with an intensive summer school class. Students continue their studies through the regular school year. AP chemistry is a three-semester course of study rather than a second year course. During the school year, students meet for 100 minutes every other day averaging 250 minutes/week as well as an additional 120 minutes on most weekends. Class and extra time is used for lecture, discussion, laboratory activities, skill building, and assessments.

Laboratory:
Many laboratory activities are performed during the summer school portion of this course. Some time during the school year is spent doing laboratory work. Class time after the AP exam is used exclusively for laboratory work. Including prelab assignments and discussions, collecting data and making observations, and postlab work, students spend an average of 100 minutes per week on laboratory work.

Student laboratory groups rotate responsibility for the post-lab discussion to the class.
Laboratory Notebooks are required and formed from graded lab reports.
Formal Lab Reports are written for selected labs throughout the year.
Informal lab reports are required for each laboratory investigation.

Curricular Requirements:
The course is taught in chapter order. For the purposes of the AP Audit, chapters are listed according to the four AP Content Areas: Structure of Matter, States of Matter, Reactions, and Descriptive Chemistry.

STRUCTURE OF MATTER (Atomic theory and atomic structure, Chemical bonding)
Chapter 1 – Matter and Measurement (5 days, 500 minutes)
Essential Questions:

- How do chemists classify the world around them into matter and energy?
- What do chemists see when they look at matter?
- How do chemists link the macroscopic, microscopic, and particulate worlds of chemistry?
- How can you separate mixtures of pure substances?
- How do chemists use symbols to communicate about matter?
- What are some physical and chemical properties of matter that help chemists differentiate between types of matter?
- What properties of matter can we measure?
- How are units and uncertainty communicated in measurements?

Calculations:

- Calculating density of regular and irregular objects
- Dealing with uncertainty in measurements and calculations involving measurements
- Communicating accuracy and precision in measurements
- Converting between temperature scales

Laboratory:

- Separating Mixtures using Chromatography Lab
- Handboiler Distillation Lab
- Determining the Density of Different Objects Lab

Demos:

- Nitric Acid Acts on Copper
- Eye Safety
- Density of Sodas
- Galileo Thermometer

Chapter 2 – Atoms and Elements (4 days, 400 minutes)

Essential Questions:

- What do atoms look like?
- How did chemists develop the atomic theory?
- What particles make up an atom?
- How do changes in particles change the atom?
- How can the elements be organized?
- What are family resemblances of the elements?

Calculations:

- Perform calculations to support the laws of conservation of mass, definite proportion, and simple multiple proportions
- Calculate the number of subatomic particles in any atom, isotope, or ion
- Calculate the atomic mass from isotopic abundance data
- Calculate the isotopic abundance from the atomic mass

Laboratory:

- Paper Clip Isotopes—Measuring Atomic Masses
- Mendeleev's Periodic Table
- Family Resemblances—The Reactivity of Metals

Demos:

- Gas Discharge Tube
- Beam of Electrons

Chapter 3 – Molecules and Compounds (4 days, 400 minutes)

Essential Questions:

- How do chemists communicate the composition of molecules and compounds?
- How can some compounds be made of ions while some consist of molecules?
- How does the mole bridge the chemicals we measure and the atoms we think about?
- What can we calculate about molecules and ionic compounds?

Calculations:

- Calculate the molar mass of an element or compound
- Convert between moles, mass, volume, and number of particles for a chemical
- Calculate percentage composition from a chemical formula
- Calculate the empirical formula from the mass percent
- Determine the formula of a hydrated compound from experimental data

Labs:

- Percent Composition Lab
- Formulas of Chemical Samples Lab
- Formula of a Hydrate

Demos:

- Coulomb's Law,
- Decomposition of Mercuric Oxide

Chapter 7 – Atomic Structure (5 days, 500 minutes)

Essential Questions:

- What are waves and standing waves?
- What does the hydrogen spectrum tell us about atoms?
- How can electrons be both particles and waves?

Calculations:

- Convert among wavelengths, frequencies, and energies of waves
- Convert among Hz, MHz, meters, nanometers, and picometers
- Calculate the energy of any level, n, in the hydrogen atom
- Calculate the energy of the photon emitted from any transition in the hydrogen atom
- Convert between kJ/mol and the energy of a single photon
- Calculate the wavelength of any moving particle

Labs:

- Flame Test Lab
- Balloon Shapes
- Viewing and Measuring the Hydrogen Spectrum
- Waves and Standing Waves

Demos:

- Flatman and the 3rd Dimension
- The Bloogle and Quantized Energy Levels
- The Photoelectric Effect

Chapter 9 – Bonding and Molecular Structure: Fundamental Concepts (4 days, 400 minutes)

Essential Questions:

- Why are the outer electrons the most important for bonding?
- Why do atoms form ionic bonds or covalent bonds or metallic bonds?
- What changes take place as an ionic bond if formed?
- How are the valence electrons arranged in a molecule or polyatomic ion?
- How does electron arrangement determine the shape of a molecule or polyatomic ion?
- What is the octet rule and when is it violated?
- Do all covalent bonds have the same length, strength, and vibrational frequency?
- How can we tell which of several electron arrangements is the actual arrangement?
- What are limitation of the Lewis structure for showing bonding in molecules?

Calculations:

- Determine average electronegativity and electronegativity difference for a pair of atoms
- Use Hess's law to determine lattice energy during ionic bond formation
- Determine the steric number for any atom from its electron configuration
- Calculate reaction enthalpies from bond dissociation energies
- Determine the bond order for simple molecules and those displaying resonance

Labs:

- Bending Water Lab
- Soap and Polarity
- Like Dissolves Like
- Cleaving a Salt Crystal

Chapter 10 – Bonding and Molecular Structure: Orbital Hybridization & Molecular Orbitals (2 days, 200 minutes)

Essential Questions:

- How do we modify and expand the orbital model to account for observed phenomena?
- How can orbitals blend into hybrid orbitals?
- What are orbitals doing in a double and triple bond?
- What really happens to orbitals in molecules that exhibit resonance?
- Do all orbitals hold atoms together? (bonding, anti-bonding, and non-bonding orbitals)

Calculations:

- Determine the bond angle for any molecule

Labs:

- Conductivity of Metals and graphite
- Paramagnetism of Ionic Salts

Demo:

- Paramagnetism of Liquid Oxygen

Chapter 11 – Bonding and Molecular Structure: Carbon—More Than Just Another Element (4 days, 400 minutes)

Essential Questions:

- Why is carbon such a special element?
- What classes of molecules are based on carbon and hydrogen?
- How are the huge variety of hydrocarbons systematically named?
- How do properties of hydrocarbons change as their size increases?
- What classes of molecules are formed when oxygen is added to the mix?
- What are polymers?
- What are fats and why are foods with 0 trans fats healthier?

Calculations:

- Determine the number of hydrogens in an alkane, alkene, and alkyne
- From the chemical formula, determine the type of hydrocarbon

Labs:

- Molecular Models of Organic Molecules
- Slime and Silly Putty Lab

Demos:

- Polyurethane, Nylon and other Polymers

Chapter 24 – Nuclear Chemistry (3 days, 300 minutes)

Essential Questions:

- Who discovered radioactivity?
- What is radioactive decay?
- What happens to the nucleus during alpha, beta, and positron decay?
- How can we quantify radioactive decay?
- What are the dangers and uses of radioactivity?
- Where does the energy in nuclear processes come from?

Calculations:

- Determine the atomic number and mass number of daughter products in decay equations
- Do half-life problems for whole numbers of half-lives
- Do half-life problems that utilize the first order integrated rate law equation
- Determine the energy released during nuclear changes when mass is converted to energy

Labs:

- Shielding Radioactivity
- Building and Viewing Radioactive Particles in Cloud Chambers
- Penny Decay

STATES OF MATTER (Gases, Liquids and solids, Solutions)

Chapter 12 – Gases and Their Properties (3 days, 300 minutes)

Essential Questions:

- How is pressure measured?
- How do graphical representation of proportional and inversely proportional relationships look?
- What is the relationship between pressure, volume, temperature and moles in a gas?
- Why does the temperature scale used make a difference?
- How can we explain the observed gas laws—what are the particles doing?
- How do "real gases" differ from "ideal gases"?
- Why do all gases have the same power to cause pressure?
- How can we deal with mixtures of gases?

Calculations:

- Convert among various pressure units
- Convert data that gives a straight line into a mathematical statement
- Solve gas law problems
- Use the ideal gas law to solve for gas density and molar mass
- Do stoichiometry problems that involve gases
- Do partial pressure problems and apply this to gases collected over water
- Calculate the root mean square velocity of gas particles
- Use the van der Waal's equation to quantify real gases

Labs:

- PV Lab
- Boyle's Law Lab
- Natural History of Airs Lab
- Measuring the Molar Volume of Hydrogen

Chapter 13 – Bonding and Molecular Structure: Intermolecular Forces, Liquids, & Solids (3 days, 300 minutes)

Essential Questions:

- Why is a liquid different than a gas?
- What kinds of intermolecular forces of attractions hold molecules together?
- How can we recognize and categorize all types of solids?
- What properties of matter depend on the intermolecular forces?
- What happens when a liquid boils?
- How are phase changes affected by pressure (phase diagrams)?
- How is energy involved (and quantified) during phase changes?

Calculations:

- Calculate energy changes during phase changes
- Determine the boiling point of a liquid at different pressures

Labs:

- Rates of Evaporation of Liquids
- Phase Diagrams and Liquid Dry Ice

Chapter 14 – Solutions and Their Behavior (4 days, 400 minutes)

Essential Questions:

- How can the concentration of solutions be quantified?
- What properties of solutions depend on the concentration of the solution?
- How do we explain differences in boiling point, melting point, vapor pressure, and osmotic pressure on the molecular level of a solution?
- How differently do different solutes act (van't Hoff factor)?
- What are some useful applications of solutions (petroleum distillation, cooking, salt on streets)?

Calculations:

- Determine the concentration of a solution
- Convert between concentration units using density of the solution
- Calculate the freezing point depression and boiling point elevation of a solution
- Use colligative properties to determine molar mass of an unknown solute
- Use Raoult's Law to determine the vapor pressure above a solution

Labs:

- Colligative Properties Lab

Chapter 19 – Principles of Reactivity: Precipitation Reactions (2 days, 200 minutes)

Essential Questions:

- How can we predict the result of mixing two solutions?
- How do we explain (and quantify) solubility in terms of equilibrium?
- What factors (pH, common ions) affect the solubility of a substance and why?

Calculations:

- Calculate the solubility of substances from their formula & K_{sp} value
- Use K_{sp} to determine the pH of slightly soluble bases
- Calculate the Q_{sp} to determine whether precipitation will occur

Labs:

- Determining the K_{sp} of $Ca(OH_2)$ Lab

<u>REACTIONS (Reaction types, Stoichiometry, Equilibrium, Kinetics, Thermodynamics)</u>

[Note: Ch 5—Reactions in Aqueous Solutions is listed in both the Reactions and Descriptive Chemistry sections]

Chapter 4 – Chemical Equations and Stoichiometry (4 days, 400 minutes)

Essential Questions:

- How do chemists communicate chemical reactions?
- How does the balanced chemical equation allow chemists to quantify chemical reactions?
- What happens when one chemical runs out during a reaction?
- How can chemists turn chemical measurements into chemical formulas?

Calculations:

- Determine molecular formulas from molar mass and empirical formulas
- Perform stoichiometric calculations from a balanced chemical equation
- Perform limiting reactant problems

- Solve percent yield problems

Labs:

- Finding Ratio of Moles of Reactant,
- Lab in a Baggie ($CaCl_2$ + $NaHCO_3$),
- Limiting Reactant Lab (acid and sodium bicarbonate)

Demos:

- Silver nitrate and copper metal form silver metal and cupric or cuprous nitrate?
- Limiting reactants

Chapter 5 – Reactions in Aqueous Solutions (5 days, 500 minutes)

Essential Questions:

- What are some measurable properties of aqueous solutions?
- Why are different solutions good, poor, and non-electrolytes?
- What drives a double replacement reaction to form new compounds?
- What makes acids and bases act like acids and bases?
- Are all chemical reactions acid-base reactions?
- What happens during an oxidation-reduction reaction?
- How can we quantify solution concentrations?
- What can volumetric analyses tell us about solutions?

Calculations:

- Determine the oxidation numbers of elements in compounds
- Determine the molarity of solutions in terms of compounds and their constituent ions from mass and volume data
- Calculate amounts of solute and solvent needed to make a specified solution
- Perform dilution problems
- Perform titration calculations for acid-base and oxidation-reduction titrations

Labs:

- Testing Household Products with Cabbage Juice
- Precipitate Lab
- $Ca(OH)_2$ + NH_4NO_3 in your hand
- Introduction to Oxidation Reduction – $CuCl_2$ + Al
- Gas Formation Reactions in Baggies
- Testing solutions concentrations
- Testing the Conductivity of Solutions
- The Six-Solution Problem

Demos:

- Nitrogen Triodide Decomposition
- Polymer formation – A Synthesis Reaction

Chapter 6 – Principles of Reactivity: Energy and Chemical Reactions (5 days, 500 minutes)

Essential Questions:

- What factors drive a reaction toward completion? (Enthalpy & Entropy)
- Where does the energy come from in an exothermic reaction?
- How do we measure the heat gained or lost by a system?
- Does all energy show up as work?
- How can a chemical system do work?
- What is a state function and a path function?

- How can Hess's Law be used to calculate difficult-to-measure energy changes?
- What energy changes are involved during phase changes?

Calculations:

- ΔH's are based on final – initial values so the sign of the energy change is important
- Convert between energy units
- Use calorimetry to calculate heat changes during temperature changes
- Calculate internal energy changes based on heat changes and work done by a system
- Relate physical work (w=Fxd) and chemical work (w=PΔV)
- Calculate PΔV work done by expanding gases
- Use Hess's Law to calculate heat changes during chemical or physical changes
- Use heats of vaporization and fusion to calculate heat changes during phase changes

Labs:

- Thermochemistry Lab with hot and cold water
- Measuring the Heat of Fusion of Ice
- Hess's Law and Acid-Base Neutralization

Demos:

- Temperature vs. Heat
- Hot packs and cold packs

Chapter 11 – Bonding and Molecular Structure: Carbon—More Than Just Another Element (4 days, 400 minutes)

Essential Questions:

- What reactions are characteristic of double bonds and functional groups?

Labs:

- Testing for Double Bonds
- Esterification Lab

Chapter 15 – Principles of Reactivity: Chemical Kinetics (4 days, 400 minutes)

Essential Questions:

- How can we observe and quantify the speed of a reaction?
- How can the rate of a reaction be graphically communicated?
- What factors affect the rate of a reaction?
- How do we explain why only some chemicals react at any one time in a slow reaction?
- How do kinetic energy and potential energy play a role in explaining reaction rates?
- Do reactions occur in one step or several steps?
- Do changes in concentration affect rate equally for all reactants (Rate Laws & Order of Reaction)?
- How can we use initial rates to determine the order of reaction for a chemical?
- How can we use graphs of concentration to determine the order of reaction for a chemical?
- How do catalysts speed up a reaction?

Calculations:

- Calculate the average and instantaneous rate of reaction from graphical data
- Convert rate information about one chemical to rate information about any other chemical
- Use initial rates to determine the order of reaction for reactants
- Set up a generalized rate law and determine the value of the rate constant, k
- Use the integrated rate laws to determine the concentration of reactants at different times
- Convert between half-life and the specific rate constant, k

- Determine the order of a reaction by graphing manipulated forms of concentration vs. time

Labs:

- Measuring Rates
- Glow Sticks and Reaction Kinetics
- Crystal Violet and Reaction Order
- Iodine Clock Reaction Lab
- Catalytic Decomposition of Hydrogen Peroxide

Chapter 16 – Principles of Reactivity: Chemical Equilibria (4 days, 400 minutes)

Essential Questions:

- What is equal in equilibrium?
- How do we quantify an equilibrium (the equilibrium constant)?
- What does the equilibrium constant tell us about the reaction?
- How can we tell where we are with respect to the equilibrium?
- How can we use algebra to determine equilibrium amounts of reactants and products?

Calculations:

- Convert Kc to Kp in a gaseous equilibrium
- Calculate Kc (or Kp) when the equilibrium equation is manipulated
- Calculate Q to determine where you are with respect to equilibrium
- Solve simple "ICE box" problems
- Use the quadratic formula to solve equilibrium problems
- Apply simplifications to avoid using the quadratic formula

Labs:

- Le Chatelier's Lab
- Measuring the Equilibrium Constant of the $Fe^{3+} + SCN^{-} \leftrightarrows FeSCN^{2+}$ equilibrium

Demos:

- Cobalt chloride equilibrium

Chapter 17 – Principles of Reactivity: The Chemistry of Acids and Bases (3 days, 300 minutes)

Essential Questions:

- How have different people defined acids and bases (Arrhenius and Bronsted-Lowry)?
- How can water be both an acid and a base?
- How do we explain the differences in strengths of acids?
- How do conjugate acids and bases affect the pH of solutions?
- What kind of chemicals can be acids?
- Where did the pH scale come from?
- How do we explain why weak acids are weak in terms of equilibrium?
- How can different salts make a solution acidic, basic, or leave it neutral?
- What are some special considerations when dealing with diprotic acids?

Calculations:

- Calculate the pH, pOH, $[H^+]$, and $[OH^-]$ of a solution given any one value
- Solve equilibrium calculations dealing with acid-base equilibria
- Determine the K_b of the conjugate base of a weak acid of known K_a (and vice versa)
- Calculate the pH of a salt solution
- Solve equilibrium calculations involving diprotic acids

Labs:

- Indicators, pH meters and Serial Dilutions
- Hydrolysis of Salts Lab

Chapter 18 – Principles of Reactivity: Reactions Between Acids and Bases (4 days, 400 minutes)

Essential Questions:

- What is a buffer and why does it work?
- How does pH change during the titration of a strong acid by a strong base?
- How does pH change during the titration of a weak acid by a strong base?
- Is the pH of a neutralized acid always neutral?
- Where in a titration is the solution a buffer?
- Where in a titration is the solution a salt solution?

Calculations:

- Calculate the pH of a simple buffer solution
- Derive the Henderson-Hesselbach equation
- Determine the pH of a buffer solution given concentrations of the acid and its conjugate base (or base and its conjugate acid)
- Calculate the pH at various points in an acid-base titration (initial solution, equivalence point, buffer region, and after the equivalence point)

Labs:

- Titration Lab
- Measuring the pH during a titration
- Alka Seltzer Buffer Lab
- Serial Dilutions and Acid-Base Indicators
- Measuring the K_a of a Weak Acid

Demos:

- M.O.M. to the Rescue (Milk of Magnesia, HCl and universal indicator)
- Electric Titration (barium hydroxide and sulfuric acid)

Chapter 20 – Principles of Reactivity: Entropy and Free Energy (2 days, 200 minutes)

Essential Questions:

- What are the two big driving forces for a reaction?
- How do we recognize changes in entropy?
- How do we quantify changes in entropy?
- Under what conditions of entropy and enthalpy will a reaction be product-favored?
- How did Gibbs quantify the effect of entropy and enthalpy?
- How is ΔG related to E° (electrochemistry) and K_c (equilibrium) indicating whether a reaction will be product-favored?

Calculations:

- Use Hess's Law to calculate ΔH, ΔS, and ΔG
- Use $\Delta G = \Delta H - T\Delta S$ to calculate the free energy of a reaction

Labs:

- Thermodynamics of a Rubber Band

Chapter 22 – The Chemistry of the Main Group Elements (independent study)
[Note: specific ideas from this chapter are included throughout the course, but students are encouraged to read this chapter over the Spring Break with a "scavenger hunt" assignment.]
Essential Questions:

- What are some important pieces of "chemical trivia"?
- What are some important industrial processes based on the main group elements?

Calculations:

- No calculations are involved in this chapter.

Labs:

- Properties of Selected Elements (this lab is part of the AP review)

Chapter 23 – The Transition Elements (1 day, 100 minutes)
Essential Questions:

- What are complex ions?
- How do electrons in the d-orbitals change the properties of an element?

Calculations:

- No mathematical manipulations, but students do need to determine the

Labs:

- Complex Ion Lab

DESCRIPTIVE CHEMISTRY (Relationships in the periodic table)
Chapter 5 – Reactions in Aqueous Solutions (5 days, 500 minutes)
Essential Questions:

- What are some measurable properties of aqueous solutions?
- Why are different solutions good, poor, and non-electrolytes?
- What drives a double replacement reaction to form new compounds?
- What makes acids and bases act like acids and bases?
- Are all chemical reactions acid-base reactions?
- What happens during an oxidation-reduction reaction?
- How can we quantify solution concentrations?
- What can volumetric analyses tell us about solutions?

Calculations:

- Determine the oxidation numbers of elements in compounds
- Determine the molarity of solutions in terms of compounds and their constituent ions from mass and volume data
- Calculate amounts of solute and solvent needed to make a specified solution
- Perform dilution problems
- Perform titration calculations for acid-base and oxidation-reduction titrations

Labs:

- Testing Household Products with Cabbage Juice
- Precipitate Lab
- $Ca(OH)_2 + NH_4NO_3$ in your hand
- Introduction to Oxidation Reduction – $CuCl_2 + Al$
- Gas Formation Reactions in Baggies
- Testing solutions concentrations
- Testing the Conductivity of Solutions
- The Six-Solution Problem

Demos:

- Nitrogen Triodide Decomposition
- Polymer formation – A Synthesis Reaction

Chapter 8 – Atomic Electron Configurations and Chemical Periodicity (4 days, 400 minutes)

Essential Questions:

- What are the wave patterns of electrons (atomic orbitals)?
- How are electron orbitals filled in each atom (The Aufbau Hotel)?
- Is there a shorthand notation for electron arrangement?
- How does electron configuration relate to the periodic table?
- How do we explain the trends in atomic size and ionization energy on periodic table?

Calculations:

- There are no mathematical manipulations in this chapter, however, students do deal with quantum numbers, ionization energies, electron affinities, and atomic radii.

Labs:

- Trends in Halogen Reactivity

Chapter 21 – Principles of Reactivity: Electron Transfer Reactions (5 days, 500 minutes)

Essential Questions:

- How do you recognize oxidation-reduction reactions?
- How does electricity cause chemical change (electrolysis)?
- How do we quantify electrolysis?
- What occurs at the electrodes during electrolysis?
- In a mixture, how do we predict which chemical will be changed?
- How does chemical change cause electricity (electrochemical cells)?
- What occurs at the electrodes in electrochemical cells?
- What is a salt bridge and why is it necessary?
- Do all spontaneous oxidation-reduction reactions cause electricity?
- How do we quantify electrochemical cells?
- How do changes in concentration affect electrochemical cell voltages?
- How do we explain why electrochemical cells “die”?

Calculations:

- Relate charge, current, and moles of electrons using the Faraday constant
- Calculate the mass of chemical change during a specific electrolysis experiment
- Determine the expected voltage of a standard electrochemical cell
- Use the Nernst equation to determine the voltage of a non-standard cell
- Use cell voltage to determine the concentrations in a non-standard cell

Labs:

- Electrolysis Lab
- Electrochemical Cells
- Golden Penny Lab