Curricular Requirements	Page(s)
CR 1 Students and teachers use a recently published (within the last 10 years) college-level chemistry textbook.	2
CR 2 The course is structured around the enduring understandings within the big ideas as described in the AP® Chemistry Curriculum Framework.	2,4
CR3a The course provides students with opportunities outside of the laboratory investigations to meet the learning objectives within Big Idea 1: Structure of matter.	5-8
CR3b The course provides students with opportunities outside of the laboratory investigations to meet the learning objectives within Big Idea 2: Properties of matter-characteristics, states, and forces of attraction.	5-10
CR3c The course provides students with opportunities outside the laboratory environment to meet the learning objectives within Big Idea 3: Chemical reactions.	4, 6-8
CR3d The course provides students with opportunities outside the laboratory environment to meet the learning objectives within Big Idea 4: Rates of chemical reactions.	10-11
CR3e The course provides students with opportunities outside the laboratory environment to meet the learning objectives within Big Idea 5: Thermodynamics.	11-13
CR3f The course provides students with opportunities outside the laboratory environment to meet the learning objectives within Big Idea 6: Equilibrium.	11
CR4 The course provides students with the opportunity to connect their knowledge of chemistry and science to major societal or technological components (e.g., concerns, technological advances, innovations) to help them become scientifically literate citizens.	3, 4, 11
CR5a Students are provided the opportunity to engage in investigative laboratory work integrated throughout the course for a minimum of 25 percent of instructional time.	2
CR5b Students are provided the opportunity to engage in a minimum of 16 hands-on laboratory experiments integrated throughout the course while using basic laboratory equipment to support the learning objectives listed within the AP Chemistry Curriculum Framework.	2, 3
CR6 The laboratory investigations used throughout the course allow students to apply the seven science practices defined in the AP Chemistry Curriculum Framework. At minimum, six of the required 16 labs are conducted in a guided-inquiry format.	2, 6-14
CR7 The course provides opportunities for students to develop, record, and maintain evidence of their verbal, written, and graphic communication skills through laboratory reports, summaries of literature or scientific investigations, and oral, written, and graphic presentations.	3

Course Overview

This course introduces the concepts of modern chemistry, aligned to six fundamental themes of the nature of matter and its chemical interactions called the Big Ideas, as shown in parentheses below **[CR2]**:

- Big Idea #1: Elements at the building blocks of matter, understood as arrangements of atoms.
- Big Idea #2: Chemical and physical properties are explained by the arrangements of atoms, ions, or molecules, and the forces between them.
- Big Idea #3: Changes in matter involve the rearrangement and reorganization of atoms and/or the transfer of electrons.
- Big Idea #4: Rates of chemical reactions are determined by the details of molecular collisions.
- Big Idea #5: Laws of thermodynamics describe the essential role of energy and predict the direction of change.
- Big Idea #6: Bonds of attraction can be formed or broken. These processes are in constant competition and sensitive to initial conditions and external forces of change.

Topics include atomic particles and structure (1), types of chemical reactions (2, 3); stoichiometry and the use of quantitative methods to investigate reaction events (3); the release and absorption of energy as part of the reaction equation (5), electron orbitals and the geometry of molecular formation (3); competing explanations of bonds (valence bond theory and molecular orbital theory) (3, 4, 5); the behavior of ideal and real gases, intermolecular forces in liquids, formation of crystal lattices in solids (2, 6); an analysis of reactions in solutions that includes studies of reaction rates and chemical equilibrium (3, 4), acid-base reactions and buffers (3), and electron transfer reactions and their application in electrochemical cells (3). Students also investigate basic concepts of organic chemistry and entropy (2, 5).

Instructional Resources

Students are required to obtain the following texts **[CR1]**:

- *Chemistry and Chemical Reactivity,* 9th edition published 2014, John Kotz, Paul Treichel, John Townsend, David Treichel. Softcover version includes online resources and 24 months access to OWLv2, which includes quizzes, simulations, and interactive exercises.
- A*P Guided Inquiry Experiments: Applying the Science Practices Student Manual* (February, 2013, CollegeBoard). This is referenced as AP Guided Inquiry Experiment in the Lab Assignments.
- *Illustrated Guide to Home Chemistry Experiments*, Robert Bruce Thompson (DIY Science, 2008) This text includes 17 experiments aligned to 2009 AP Chemistry expectations, as well as other experiments in organic chemistry and forensics, and is designed for individual students working in a home environment. Either this text or the following must be purchased in addition to the AP Guided Inquiry Experiments Student Manual, since these texts contain important safety and procedures information for students performing experiments at home.
- ALTERNATE LAB TEXT: *The Home Scientist Chemistry Kit Manual* (Jan 2013) is an alternate version of the I*llustrated Guide to Home Chemistry Experiments* which is available online and accompanies the kit described below. (http://www.thehomescientist.com/manuals/ck01-manual.pdf). This is referenced as HSCKM in the Lab Assignments.
- Students must purchase sufficient chemical equipment and chemicals to perform 18 experiments for lab credit. While no specific chemistry set is required, labs for the course can be completed using the Home Scientist Chemistry CK101 set described here: http://makezine.com/2011/06/22/bob-thompsons-homeschooler-chemistry-set/)

Instructional Context

Class normally meets two times a week for 38 weeks in online live chat sessions of 90 minutes each. Two sessions are used to discuss assigned text readings and web-hosted lecture materials. Sessions make extensive use of internet resources including simulations, pictures, diagrams and animations, short videos, and current events, as well as the textbook publisher's companion site. Chat logs are available as soon as chat ends for students who missed class or need to review discussions.

A third weekly hour-long session is used to analyze posted lab results, improve student lab techniques, data analysis and presentation skills. These quasi-tutorial sessions provide materials that bridge the high school-to-college gaps in student backgrounds and cover selected topics in greater depth than the text, and include review of representative questions from previous AP courses.

Investigative Laboratory Component

Students are required to perform 18 labs (allowing 2-3 chat sessions per lab), spending three to five hours for each on lab setup, execution, and reporting, for a total commitment of 25% of their course time [**CR5a]**. Students must complete the safety introductions and three Lab Skills exercises prior to formal lab work to ensure their safety.[**CR5b, CR6**]. These initial exercises require students to build their own equipment, helping them develop an understanding of the relationship between the measuring device and the quantity measured, as well as challenging their creative skills.

All of the formal lab exercises are presented as Guided Inquiry investigations. Students review the lab purpose and techniques in chat, identifying the science skills and learning objectives for each lab. They then investigate options for achieving these goals, using as references the *The Home Scientist Chemistry Kit Manual* (Robert Bruce Thomson, 2013) , *Illustrated Guide to Home Chemistry Experiments* (Robert Bruce Thomson, O'Reilly 2008), *AP Chemistry Lab Manual* (College Board, 2009), and *AP Chemistry Guided Inquiry Experiments* (College Board, 2013), and jointly identify an appropriate experimental approach, materials, equipment, and required safety practices. Once their proposed experiment has been reviewed by the teacher to ensure that the methods are safe and will achieve the learning objectives, the students carry out their experiments, presenting their individual results and defending their analysis in chat.

Each student must complete and upload a formal laboratory report to a common bulletin board for teacher and peer review, and maintain a laboratory notebook as evidence of their work. Reports must include the title, an abstract (under 200 words), a list of materials and equipment used, and a description of the procedure followed. These must be in sufficient detail that another student can repeat the experiment. The rest of the report includes data tables, sample calculations demonstrating the data reduction methods used, including statistical error analysis, all derived or calculated organized appropriately in list or tabular format, graphical displays or analysis, and clearly identified conclusions. Students may also be required to answer specific questions and upload further evidence (photos or videos) to prove they conducted the lab as designed. **[CR7]**.

Live-chat and asynchronous bulletin-board discussions of lab exercise processes, questions posed in the Guided Inquiry instructions, individual adaptations, and data analysis techniques allow students to develop skill in precisely communicating lab experiences, and to work together to identify successful strategies for current and subsequent laboratory work. Students gain additional experience in data analysis possibilities and statistical error analysis by using spreadsheets such as Excel for data manipulation and presentation.

Teaching Strategies

All our school courses are designed to take advantage of our asynchronous environment. This course uses live chat sessions, a Chemistry content site developed by the teacher, and the Moodle course content delivery system, to support asynchronous access to course materials, including web-based lecture notes, course calendars and lecture schedule, quizzes, forums, and wikis. Materials presented through teacher lectures at brick-and-mortar schools are presented instead as teacher-written websites, read at the student's own convenience, employing multimedia resources to demonstrate processes. Both static website materials and chat sessions make extensive use of the textbook's companion website animations and videos, as well as other publicly available online resources (such as videos of chemical reactions at YouTube). The forums and wikis allow students to enter materials at their own convenience and share their homework assignments and study notes with each other, supporting a cooperative learning environment. The course site also includes general study aids, homework assignment pages for each chat session, study notes for reading assignments, and instructions for the lab associated with that unit.

Students are expected to demonstrate a high level of self-discipline and self-motivation in preparing for our limited discussion time. All preparation work (reading text and web lectures, completing assignments at the text publisher's companion site, posting assigned problems) must be completed prior to chat sessions. Live chat time is devoted to addressing students' questions, reviewing assignments posted to the class online forum, presenting supplementary materials (especially graphics, including web-based animations and simulations) or raising discussion topics suggested by the text, current events, or ongoing student concerns. **[CR 4, CR 7]**

Students upload their homework, lab data, and lab reports to the Moodle forum. They are also encouraged to contribute definitions of terms and concepts or historical notes to the Moodle wiki pages. Chat logs, solved homework problems, lab reports, and wiki entries become part of the course content, accessible to all class participants, supporting a student-centered, cooperative learning environment.

The flexibility of the Moodle environment, real-time online chat, ten years of previous chat records, and access to the Internet allow the teacher to respond quickly to specific interests or learning needs of the student, tailoring the presentation of material to compensate for differences in background and to challenge gifted students with additional material by creating alternate presentations on the fly, or (where a traditional classroom teacher might use a blackboard or slides), leading students on "Web tours" to sites that contain descriptions of research, animations, and simulations of the topic raised by the student.

Students are encouraged to view science as a complex human endeavor, and examine the benefits and limitations of current scientific methodologies. Supplemental historical, philosophical, and religious materials from books, articles, and current events are used to help students understand the interaction of scientific theories with human societies, especially where theories involve ethical and religious issues, such as appropriate use of natural resources and possibilities of environmental damage **[CR4]**.

AP Chemistry Syllabus with reference to Learning Objectives and Science Practices

Text/ Session Topic	Text/Lecture/Discussion Topic	Opportunities to achieve specific Learning Objectives (LO) using textbook assignments (TB), class discussion (CD), homework assignments (HW), website lectures (WL), or selected AP Free Exercise questions (AP).	CR met by Big Idea, EK, EU topics covered in session	Coordinated Lab Exercises emphasizing Science Practices (SP) Illustrated Guide to Home Chemistry Experiments (IGHCE) The Home Scientist Chemistry Kit Manual (HSCKM) AP Guided Inquiry Experiments: Applying the Science Practices 2013 (APGIE) AP Chemistry Lab Manual 2009 (AP2009)
Intro and Review of Basics	**Experimental methodology, scientific notation, basic matter and energy concepts**	**Opportunity or Activity achieving specific Learning Objectives**	**CR met by LO**	**Lab Methods and Safety**
1: 1-7	**Introduction to Course** • Course expectations • Online resources (Moodle forum use, posting homework, quizzes, email) • Textbook, online textbook site •**Basic concepts** • Scientific Methods, Hypothesis, Natural Law •Classification of Matter •Atoms, molecules, compounds •Physical and chemical changes	Sample Quiz, Essay, Homework entry into Courseware. CD: Discussion of classification of matter, difference between chemical and physical change LO 3.10, 5.10	**CR2: Big Ideas 1-6** EK 3C1 EK 5D2	**Introduction to Chemistry Home Lab Work** Students review scientific method, lab notebook options, and reporting procedures, and establish requirements for lab accuracy and reports. [**CR 7**] References: •*IGHCE Preface and Ch. 1: Introduction* •*HSCKM Chapter 2*
1: Review of Tools	**Tools of Quantitative Science** •Units of Measurement •Precision, Accuracy, Experimental Error, Standard Deviation •Scientific Notation •Graphing	**CD:** Students review scientific method, experimental, survey ways of gathering data, construction of hypothesis. **HW:** Unit conversions, error estimates, scientific notation, graphical representation of data. SP 1-7	Overview of **Science Practices 1-7**	**Lab Methods: Safety** Students read MSDS sheets, learn how to identify and follow proper storage and disposal procedures, and report on the effects of improper disposal methods for specific chemicals **[CR 4]**. SP 4 References: •*IGHCE: Ch. 2 -Lab Safety (all) and Ch. 4 (pp. 48-58)* •*HSCKM Chapter 1.*
UNIT 1 **Big Ideas 1, 2, 3, 5**	**Chemical bonds, types of reactions, stoichiometry**	**Opportunity or Activity achieving specific Learning Objectives**	**CR met by LO**	**Basic Lab Techniques, Precipitation reactions and Calorimetry.**
2: 1-4	**Atoms** • Atomic Structure • Atomic Number and Mass • Isotopes • Atomic Weight	**CD:** Students discuss evidence for isotopes using average atomic mass and confirmation by mass spectrometry **HW:** Students describe elements by atomic structure, number, mass; and identify isotopes. LO 1.4, 1.14	**CR3a** is met in this session by activities achieving learning objectives for Big Idea 1 Essential Knowledge areas EK 1A1 EK 1D2.	**Overview of Required Equipment and Chemicals** **HW**: Students generate personalized list of equipment and supplies for selected experiments, along with sources, and identify items requiring special safety procedures. SP 4, 5 References •*HSCKM Chapter 1* •*IGHCE: Ch. 3 and Ch. 4 (45-47, 58-67)* •*APGIE Individual Lab Materials lists.*

2: 5	**Elements** • The Periodic Table	**CD:** Students practice representation of scientific data in table form, review historical development of periodic table notation. **HW**: Students predict properties of elements based on group and period location and identify exceptions. LO 1.9	**CR3a:** EK 1C1	**LAB SKILLS A - Mastering Basic Lab Skills: Equipment Calibration** *Teacher-written Lab: REQUIRED but does not count for Lab Credit)* Students build an equal-arm balance, calibrate it, and use it along with different methods of determining volume to calculate the density of multiple objects. Students then use standard deviation analysis to determine the accuracy of their measurements. LO 1.1 SP 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.2
2. 6-11	**Molecules and Ions** • Formulas and Molecular Models • Ionic Compounds and Naming Conventions • Molecular Compounds and Naming Conventions • The Mole • Percent Composition, Empirical and Molecular Formulas • Hydrated Compounds	**CD:** Students show they can identify formula from names, names from formula. **HW**: Students use mass and atomic weight to determine percent composition and empirical formula from experimental data. LO 1.1, 1.2, 1.3, 1.4, 3.5, 3.6	**CR3a, 2c:** EK 1A1 EK 1A2 EK 1A3 EK 3B1	**LAB SKILLS B - Mastering Basic Lab Techniques: Distillation and Recrystallization** *Teacher-written Lab (REQUIRED but does not count for Lab Credit)* Students select extraction target, justify choice of method, and demonstrate basic lab skills in performing experiment, including safety check. LO 3.10 SP 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.2 References: •*IGHCE 6.1/HSCKM I-4: Differential Solubility: Separate Sugar and Sand* •*IGHCE 6.2 Distillation: Purify Ethanol* •*IGHCE 6.3/HSCKM I-1: Recrystallization: Purify Copper Sulfate* •*IGHCE 6.4/HSCKM I-3: Solvent Extraction: Isolate iodine present in Lugol's solution*
3: 1-3	**Chemical Reactions** • Balancing Chemical Equations	**WL,CD**: Students examine and describe rearrangement of atoms from one set of molecules to another using interactive diagrams. **HW**: students balance chemical reaction equations using conservation of mass, atoms, and charge. LO 1.17, 1.18, 3.2	**CR3a:** EK 1E1 EK 1E2 EK 3A1	**LAB SKILLS C - Solution Preparation** Since students are responsible for their own lab equipment and materials, creating solutions of specific molarity / molality is necessary for later experiments. Students select up to three solutions, calculate mass or volume of solvent and solute required for each, then demonstrate safety practices in solution preparation and storage. LO 1.19 SP 2, 3, 4, 5 References: •*IGHCE Lab 7.1-2 Make up a molar / molal solution of a solid chemical* •*IGHCE Lab 7.3 Make up a molar solution of a liquid chemical* •*IGHCE Lab 7.4 Make up a mass-to-volume percentage solution*

<table>
<tr><td>3: 4-5</td><td>• Chemical Equilibrium
• Reactions in Aqueous Solutions
• Precipitation Reactions</td><td>HW: Students identify which reactions will be precipitation reactions using data from solubility chart.
LO 3.1, 3.2</td><td>CR3c:
EK 3A1</td><td rowspan="3">LAB #1 GUIDED INQUIRY — Determination of water in copper sulfate pentahydrate and sodium hydrogen carbonate:
What is the Amount of Water in Common Hydrates?

Students devise an appropriate dehydration method to determine the amount of water in a common hydrated salt (copper sulfate pentahydrate), and justify formula predictions. They use the method to dehydrate a common household chemical and determine its formula by conservation of mass. They then decompose sodium hydrogen carbonate in a modified Solway process, calculating percent yield and percent atom economy.
LO 3.5
SP 1.1, 1.2, 2, 4..1, 4.2, 4.3, 6, 7

Reference:
•IGHCE Lab 6.6: Determine the Formula of a Hydrate
• APGIE Investigation 7: Stoichiometry: Using the Principle That Each Substance Has Unique Properties to Purify a Mixture
•AP2009 #1 - Determine the formula of a compound (using decomposition)
•IGHCE Lab 9.1 and HSCKM III-1 Observe a Composition Reaction
•IGHCE Lab 9.2 and HSCKM III-2 Observe a Decomposition Reaction</td></tr>
<tr><td>3: 6-7</td><td>• Acids and Bases
• Gas-Producing Reactions</td><td>HW: Students classify acid-base reactions, gas-producing reactions; predict products, including net ionic reactants and products, based on interactions between particles.
LO 2.1, 2.2</td><td>CR3b:
EK 2A1</td></tr>
<tr><td>3: 8-9</td><td>• Oxidation-Reduction Reactions
• Classifying Reactions</td><td>HW: Students determine and use oxidation numbers to identify oxidized/reduced species in reaction.
LO 3.8, 3.10</td><td>CR3c:
EK 3B3
EK 3C1</td></tr>
<tr><td>4: 1-3</td><td>Stoichiometry
• Mass Relationships
• Limited Reactants
• Percent Yield</td><td>HW: Students calculate limiting reactants and percent yield based on mass amounts of reactants and products for specific reactions.
LO 1.17, 3.3, 3.4</td><td>CR3a, 2c:
EK 1E1
EK 3A2</td><td rowspan="2">LAB #2 GUIDED INQUIRY — Qualitative methods of analysis using flame tests and separation of cations and anions:
How do we determine the nature of a chemical reaction?

Students observe and classify several processes as physical change, chemical change, and ambiguous change based on macroscopic observations using flame tests and qualitative analysis techniques to detect the presence of specific</td></tr>
<tr><td>4: 4-5</td><td>• Chemical Analysis and molarity</td><td>HW: Students determine molarity; identify formula from molar measurements.

LO 1.2, 2.9, 3.5, 3.6</td><td>CR3a, 2c:
EK 1A1
EK 2A3
EK 3B1</td></tr>
</table>

4: 6-8	• The pH Concentration Scale for Acids and Bases • Titrations • Spectrophotometry	**TB/CD:** Students learn and discuss methods of spectrophotometry as a means of chemical analysis **HW**: Students use experimental data from titrations to calculate pH and solution concentrations. LO 1.15, 1.16, 1.20	**CR3a:** EK 1D3 EK 1E2	chemicals in known samples, then apply these techniques to identify the anions and cations present in an unknown sample. LO 1.5, 1.6, 3.10 SP 1.4, 3, 4, 6, 7 *References:* •*AP2009 14 Separation and qualitative analysis of cations and anions* •*APGIE Investigation 9 Physical and Chemical Changes: Can the Individual Components of Quick Ache Relief Be Used to Resolve Consumer Complaints?* •*IGHCE Lab 19.1-2 Use Flame Tests and Borax Beads to Discriminate Metal Ions* *IGHCE Lab 19.3 Qualitative Analysis of Inorganic Anions, Cations, and Bone (Forensics applications CR4)*
5: 1-3	**Energy and Chemical Reactions** • Temperature, Heat, and Thermal Equilibrium • Conservation of Energy and Energy Units • Specific Heat Capacity • Changes of State	**HW**: Students perform unit conversions with heat and temperature units, create graphical representations of changes of state, and predict whether reactions will be exothermic and endothermic. LO 3.11, 5.2	**CR3c, 2e:** EK 3C2 EK 5A1	**LAB #3** GUIDED INQUIRY — **Measuring the enthalpy of an exothermic acid-base reaction with a calorimeter:** *How can the characteristics of heat absorption be used to measure enthalpy of reaction?* Students design use calorimeters to determine basic physical properties (specific heat, melting point, boiling point) of materials. They must determine the heat characteristics of their calorimeters, then measure the heat capacity of a sample to identify its metal composition. Students then revise their calorimetry design to measure the heat of enthalpy of an exothermic acid-base reaction. LO 5.2, 5.4, 5.5 SP 2.1, 2.3, 2.4, 4.1, 4.3, 5.1, 5.3 References:: •*IGHCE Lab 15.1-2 OR HSCKM IX-1-2- Determine the Heat of Solution and Heat of Fusion* •*IGHCE Lab 15.3 OR HSCKM IX-3 Determine the Specific Heat of a Metal* •*IGHCE Lab 15.4 OR HSCKM IX-4 Determine the Enthalpy Change of a Reaction* •*AP2009 #13 - Determination of Enthalpy Change Associated with a Reaction* •*APGIE Investigation 12: The Hand Warmer Challenge: Where does the Heat Come From?*
5: 4-5	• The First Law of Thermodynamics • Enthalpy and Enthalpy Changes in Chemical Reactions	**CD/HW**: Students calculate enthalpy changes in chemical reactions using stoichiometric data and temperature change and present justifications for their analysis. LO 5.4, 5.5	**CR3e:** EK 5B1 EK 5B2	
5: 6-8	• Calorimetry • Enthalpy Calculations and Hess's Law • Product vs. Reactant - favored Reactions	**CD:** Presentation of coupled reactions and application to biological systems. **HW**: Students calculate heat generation, temperature change, or specific heat for a material from sample calorimetry data. LO 5.6, 5.7, 5.8, 5.15	**CR3e:** EK 5B3 EK 5B4 EK 5C2 EK 5E4	

UNIT 2 Big Ideas 1, 2, 3, 5	**Atomic Structure, Electron Orbitals and the nature of chemical bonds**	**Opportunity or Activity achieving specific Learning Objectives**	**CR met by LO in session/ Lab**	**Coordinated Lab Exercises**
6: 1-3	**The Structure of Atoms** • Electromagnetic Radiation • Quantization of Energy: Photons • Atomic Spectra and the Bohr Atom	**HW**: Students calculate energy required for energy level changes using the Rydberg formula. LO 1.5, 1.6	**CR3a:** EK 1B1	**LAB #4** GUIDED INQUIRY — **Measuring the reaction rate for photo-sensitive oxalate-iodine reactions:** *How does light affect the rate of a reaction?*
6: 4-5	• Particle- Wave Duality • Modern Electron Structure	**CD**: Students report on experiments supporting quantum mechanic concepts and wave-particle duality. 1..7, 1.12	**CR3a:** EK 1B2 EK 1C2	Students prepare a set of standard concentrations of iodine to act as a reference, then use it to measure the change in concentrations during timed reactions of oxalate and iodine conducted under different amounts of light. LO 1.16, 3.4 SP 4.2, 2.2, 5.1, 6.4
6: 6-7	• Atomic Orbital Shapes • Electron Spin, Diamagnetism and Paramagnetism	**HW**: Students determine diamagnetic and paramagnetic characteristics from electron orbitals LO 1.13	**CR3a:** EK 1B2 EK 1D1	References: • *APGIE Investigation 2: How Can Color Be Used to Determine the Mass Percent of Copper in Brass?* • *IGHCE Lab 17.1 Photochemical Reaction of Iodine and Oxalate* • *HSCMK IX-1: Photochemical Reaction of Iodine and Oxalate*]
7: 1-3	**Periodic Trends** • Pauli Exclusion Principle • Sub-shell Energies and Effective Nuclear Charge • Electron Configuration, Groups and Periods	**CD:** Students use periodic tables to determine trends in atomic weight, atomic radii, electron configuration, ionization energy, and electron affinity. **HW**: Students determine quantum numbers, electron configurations for atoms and ions. LO 1.9, 1.10, 1.11	**CR3a:** EK 1C1	**LAB #5** GUIDED INQUIRY — **Using two-phase chromatography separation of mixtures:** *How can we separate molecules when they are attracted to one another?* Students design an experiment using chromatography techniques to separate dyes in common household substances, then interpret their data terms of the relative strength of interactions among and between the components
7: 4	• Electron Configurations of Ions	**CD:** Students evaluate PES data to identify electron configuration LO 1.11	**CR3a:** EK 1C1	LO 2.10, 2.13 SP 1.4, 4.2, 5.1, 6.4 References:
7: 5-6	• Ionization Energy • Electron Affinity • Trends in neutral atoms and ion sizes	**HW**: Students compare ionization energies for alkali metals, halogens. CR3a: LO 1.7, 1.8, 1.13, 2.17	**CR3a, 2b:** EK 1B2 EK 1C2 EU 2C	• *AP2009 18 Separation by Chromatography* • *APGIE Investigation 5 Sticky Question: How Do You Separate Molecules that Are Attracted to One Another?* • *IGHCE Lab 6.5 Chromatography: Two-Phase Separation of Mixtures* • *HSCKM I-2 Chromatography*
8: 1-3	**Molecular Structure and Bonding** • Covalent Bond Formation • Lewis Structures in Covalent Bonds • Atom Formal Charges	**WL/TB/CD/HW**: Students create Lewis structure diagrams for non-resonant molecules, and determine formal charge based on electron distributions. LO 2.21	**CR3c:** EK 3C3	**LAB #6** GUIDED INQUIRY — **Using qualitative methods to differentiate covalent and ionic bonds.** *How are these atoms bonded together?* Students observe solid compounds and predict bond types for components, then

8: 4-6	• Resonance • Exceptions to the Octet Rule • Molecular Shapes	**HW**: Students create and justify Lewis structures for resonance structures, then use their diagrams to identify molecular shapes. LO 2.21	**CR3c:** EK 3C3	identify appropriate qualitative and quantitative tests, building on techniques developed in Lab #4, and use these to collect any further data needed to deduce the type of bonding in a sample of a solid.
8: 7-10	• Bond and Molecular Polarity • Bond Order, Length, and Energy • Case Study: DNA	**CD:** Students evaluate variation in bond strength based on polarity, bond length, and energy. **HW**: Students determine bond order, length, and energy based on experimental data. LO 2.18, 5.1	**CR3b, 2e:** EK 2C1 EK 5A1 EK 5C1	LO 2.22, 2.24, 2.28, 2.32 SP 1.1, 6.2, 7.1 Reference: *APGIE Investigation 6: Bonding in Solids: What's in that Bottle?* *IGHCE Lab 19.3-4 Qualitative Analysis of Inorganic Cations and Anions*
9: 1-2	**Orbital Hybridization and Molecular Orbitals** Valence Bond Theory	**CD**: Students discuss and classify molecules by hybridization bonds and valence bonds. LO 2.21	**CR3b:** EK 2C4	**LAB #7** GUIDED INQUIRY — **Conservation of energy effects of disturbing chemical equilibrium** *How does a small change to an equilibrium state affect a reaction?*
9: 3	Molecular Bond Theory	**HW**: Students explain the advantages and disadvantages of valence and molecular bond theory for specific molecules, and determine the sigma and pi bond configurations for diatomic gases and other simple molecules. LO2.21	**CR3b:** EK 2C4	Students observe Le Chatelier's principle by modifying the concentration, volume, temperature, pressure, pH, products, or reactants of a solution at equilibrium, then suggest ways optimize the results of a reaction and increase product yield. LO 6.9 SP 4.2 References: •*APGIE Investigation 13 Equilibrium: Can We Make the Colors of the Rainbow?* •*IGHCE Lab 13.1 Observe Le Chatelier's Principle in Action*

UNIT 3 Big Ideas 2, 5	**Properties of Gases, Liquids, and Solids**	**Opportunity or Activity achieving specific Learning Objectives**	**CR met by LO in session/ Lab**	**Coordinated Lab Exercises**
10: 1-3	**Gases and their Properties** • Gas Pressure • Experimental basis of the General Gas Law • The Ideal Gas Law	**HW**: Students calculate gas conditions for pressure and temperature changes using ideal gas law. LO 2.5, 2.6	**CR3b:** EK 2A2	**LAB #8** GUIDED INQUIRY — **Measuring the deviation of real gases from the ideal gas law:** *How do pressure and temperature affect gas volumes?*
10: 4-8	• Gas Laws and Chemical Reactions (determining Molar Mass) • Partial Pressure • Kinetic-Molecular Theory of Gases • Diffusion and Effusion • Applications of the Ideal Gas Law and Real Gases	**CD:** Students are directed to use interactive simulation of KMT gases and discuss their experience. **HW**: Students determine molar mass, diffusion rates, deviation from ideal gas law for real gases. LO 2.4, 2.5, 2.12, 2.16, 5.3	**CR3b, 2e:** EK 2A2 EK 2B2 EK 5A2	Students devise a way to determine how the volume of a gas changes when pressure or temperature changes, while the other factors (including amount of gas) are held constant. They then use their data to predict pressure outcomes when both volume and temperature change, and determine pressure and volume when temperature approaches absolute zero.

11: 1-3	**Liquids and Intermolecular Forces** • States of Matter • Ions and Molecules with Permanent Dipoles • Hydrogen Bonding	**HW**: Students analyze electrical force dependency on distance between atoms, including dipole characteristics, and determine the strength of hydrogen bonds, discussing applications to DNA. LO 2.3, 2.13, 2.14, 5.9, 5.11	**CR3b, 2e:** EK 2A1 EK 2B2 EK 5D1 EK 5D3	LO 1.0, 2.5, 2.6 SP 2.1, 2.2, 4.1, 5.1, 5.2, 5.3 References: •*IGHCE Lab 14.1 OR HSCKM VIII-1: Volume-Pressure relationships (Boyle's Law)* •*IGHCE Lab 14.2 OR HSCKM VIII-2: Volume-Temperature relationships (Charles' Law)* •*IGHCE Lab 14.3 Pressure-Temperature relationship (Gay-Lussac's Law)*
11: 4-6	• Non-Polar Intermolecular Forces • Vapor Pressure • Critical Temperature and Pressure • Surface Tension and Capillary Action	**HW**: Students determine vapor pressure from temperature and pressure constraints, and generate graphical representations of triple point data. LO 2.11, 2.17, 2.30, 5.1, 5.11	**CR3b, 2E:** EK 2B1 EK 2C Big Idea 5 EK 5D2	**LAB #9** GUIDED INQUIRY — **Measuring the dependence of reaction rates on temperature, surface area, concentration, and catalysts** *What factors most affect reaction rates?* Students must devise ways to vary temperature, surface area, concentration, and introduce catalysts into reactions, and determine how changing each factor affects the reaction rate. LO 4.1, 4.2 SP 4.2, 5.1, 6.4 References: •*AP2009 12 Determination of the Rate of a reaction and its order* •*APGIE Investigation 10 Kinetics: Rate of Reaction: How Long Will that Marble Statue Last?* •*IGHCE Lab 12.1-4 Determination of the effect of Temperature, Surface Area, and Catalysts on Reaction Rates* •*IGHCE Lab 12.2 Determination of the effect of Surface Area on Reaction Rate*
12: 1-3	**The Chemistry of Solids** • Crystal Lattices and Unit Cells • Ionic Solid Formulas	**HW**: Students identify unit cell structures from lattice formula, and calculate atomic radii from cell structure and density measurements. LO 2.19, 2.23, 2.24	**CR3b:** EK 2C2 EK 2D1	
12: 4-7	• Lattice Energy • Solid State Materials • Phase Changes and Phase Diagrams	**HW**: Students analyze data to determine bonding characteristics for covalent solids, describe metal properties based on the electronic sea model, and calculate solid state properties for metals. LO 2.20, 2.22, 2.25-2.32	**CR3b:** EK 2C3 EK 2D EK 2D2 EK 2D3 EK 2D4	
UNIT 4 Big Ideas 2, 3, 4, 5, 6	**Solutions and Rates of Reactions**	**Opportunity or Activity achieving specific Learning Objectives**	**CR met by LO in session/ Lab**	**Coordinated Lab Exercises**
13: 1-2	**Solutions and their Behavior** • Units of Concentration • Solution Processes	**CD/WL:** Students discuss properties of solutions (concentration, density, scale used for macroscopic distinctions) and methods of separation (distillation, chromatography) used for analysis. **HW**: Students determine correct processes for generating solutions with specific concentrations. LO 2.7, 2.8, 2.9, 2.10	**CR3b:** EK 2A3	**LAB #10** GUIDED INQUIRY — **Determination of solution concentration of copper sulfate solutions using visual colorimetry.** *How does concentration affect transmission of light through a solution?* **Preparation:** Students use Java Applets to simulate spectroscope operation and identify the appropriate spectroscopy required to analyze vibrational or electronic motions.

13: 3-6	• Solubility Factors: Pressure, Temperature • Le Chatelier's Principle • Colligative Properties • Colloids	**CD**: Students examine solubility of ionic solids using available interactive website simulations, and use Le Chatelier's principle to predict responses to change. **HW**. Students calculate concentrations from experimental data with pressure and temperature factored in. LO 2.14, 2.15, 5.16 6.21	**CR3b:** EK 2B2 EK 2B3	**LAB**: Students determine how to create a reference set of standard solutions of copper sulfate, then use visual colorimetry methods to determine the relationship between transmittance, absorbance, and concentration of calibrated solutions. They finally determine the concentration of an unknown solution using the reference set and methods they propose. LO 1.15, 1.16 SP 4.1, 4.2, 5.1
14: 1-2	**Rates of Chemical Reactions** • Reaction conditions	**HW**: Students identify and calculate effects of factors (concentration, temperature) affecting rates of reaction LO 4.1	**CR3d:** EK 4A1	References •*APGIE 1: What is the Relationship Between the Concentration of a Solution and the Amount of Transmitted Light Through the Solution* •*IGHCE Lab 7.5 Determine the Concentration of a Copper Sulfate Pentahydrate Solution through Visual Colorimetry* •*HSCMK XIII-1: Determine Boron Concentration with Curcumin using Visual Colorimetry*
14: 3-4	• Effect of Concentration on Reaction Rates • Integrate Rate Laws	**CD:** Students discuss factors other than concentration (temperature, presence of catalysts, pollutants) affecting reaction rates. **HW**: Application of zeroth, 1st, 2nd order rate laws; graphical representation. LO 4.2, 4.3, 4.9	**CR3d:** EK 4A2 EK 4A3 EK 4D1	**LAB #11** GUIDED INQUIRY — **Using titration methods to determine the concentration of an unknown solution.** *How can we determine concentrations of solutes and solvents in common household solutions?* Students create and calibrate pH indicators, then analyze data from redox titrations to determine solution concentrations in household solutions. LO 1.20, 3.3, 3.9 SP 2.2, 4.2, 5.1, 6.4
14: 5-6	• Microscopic View of Reaction Rates • Reaction Mechanisms	**HW**: Students determine rate mechanisms from observed data and justify conclusions based on energy considerations and microscopic description of conditions required for effective collisions. LO 4.4, 4.5, 4.6, 4.7, 4.8, 5.3	**CR3d, 2e:** EK 4B1, 4B2, 4B3 EK 4C (all) EK 5A2	•*AP2009 11 Determination of appropriate indicators for various acid-base titrations pH determination* •*APGIE Investigation 8 Redox Titrations: How Can We Determine the Actual Percentage of H_2O_2 in a Drugstore Bottle of Hydrogen Peroxide?*
15: 1-2	**Chemical** Equilibria • The Equilibrium Constant and Reaction Quotient	**HW**: Students identify the equilibrium constant and reaction quotient for different scenarios. LO 6.1, 6.2	**CR3f:** EK 6A1 EK 6A2	•*HSCKM V-1 Determine the Effect of Concentration on pH and the pH Range of Indicators* •*HCSKM V-2 Determine the Molarity of Vinegar by Titration* •*IGHCE Lab 11.1 Concentration effects on pH* •*IGHCE Lab 11.2 pH in salt solutions*

15: 3-4	• Determining the Equilibrium Constant and Using it in Calculations	**HW**: Students use equilibrium constant and reaction quotient, Le Chatelier's principle and stoichiometric relationships to predict the direction, rate, and products of reactions from initial conditions. LO 6.2, 6.3, 6.4, 6.5, 6.6	**CR3e:** EK 5A2 EK 5A3	**LAB #12** GUIDED INQUIRY — **Determination of rate law from changing concentration data over time.** ***How does the rate of a reaction change over time?*** Students identify a reaction and use one of the methods developed in Lab #11 to determine the concentration of its reactants and products at periodic intervals, then collect and analyze concentration vs. time data to determine the rate law for their selected reaction. LO 4.1, 4.2 SP 4.2, 5.1, 6.4 References: •*IGHCE Lab 12.3 Determination of the effect of Concentration on Reaction Rate* •*HSCKM VI-3 Determining a Reaction Order* •*APGIE Investigation 11: What Is the Rate Law of the Fading of Crystal Violet Using Beer's Law*
15: 5-6	• Balancing Equations and Equilibrium Constants • Disturbing Chemical Equilibrium	**HW**: Students use equilibrium constant and reaction quotient data to predict reaction behavior in single and coupled reactions. LO 5.16, 5.17, 6.7, 6.8, 6.9, 6.10	**CR3e:** EK 5E4 EK 5A4 EK 5B1 EK 5B2	
16: 1-4	**Acids and Bases** • Bronsted-Lowry Definition of Acids and Bases • The pH Scale • Acid-Base Equilibrium Constants	**HW**: Use of pH values and acid-base equilibrium constant to determine reaction behavior. LO 3.7, 6.11	**CR3e, 3f:** EK 3B2 EK 6C1	
16: 5-8	• Types of Acid-Base Reactions • Using the Acid-Base Equilibrium Constant • Polyprotic Acids and Bases	**CD:** Students acid-base interactions in biological systems (e.g., blood CO2 concentrations) as an introduction to buffers. **HW**: Students predict outcomes of weak/strong and polyprotic acid/base reaction combinations. LO 3.7, 6.11, 6.12, 6.13, 6.14	**CR3c, 2e:** EK 3B2 EK 5C1	**LAB #13** GUIDED INQUIRY — **Determining the properties of a buffer solution** *How can we determine how well common buffer solutions work?* Students predict and verify outcomes when adding acids and/or bases to buffer solutions of known concentration and composition. LO 1.20, 6.20 SP 4.2, 5.1, 6.4 References: •*AP2009 19 - Preparation and Properties of Buffer Solutions* •*APGIE Investigation 15 Buffering Activity: To What Extent Do Common Household Products Have Buffering Activity?* •*IGHCE Lab 11.3 OR HSCKM VII-3 Observe the Characteristics of a Buffer Solution*
16: 9-10	• Lewis Acids and Bases • Molecular Structure, Bonding, and Acid-Base Reactions	**HW**: Students describe electron transfer in Lewis acids, bases and estimate or calculate pH and concentrations for reaction combinations (weak acid/strong base, etc.) LO 3.8, 6.15, 6.16, 6.17	**CR3c, 2e:** EK 3B3 EK 5C1	
17: 1-3	**Aqueous Equilibria** • The Common Ion Effect • Buffers and pH Control • Acid-Base Titrations	**HW**: Students identify components and concentrations for buffer solutions required for pH control of assigned systems, and analyze titration data to determine concentrations and acid/base equilibrium constants. LO 3.8, 3.9 LO 6.12, 6.13, 6.18 6.19, 6.20	**CR3c, 2e:** EK 3B2 EK 5C2	**LAB #14** GUIDED INQUIRY — **Creating an effective buffer solution to maintain pH within a limited range:** *How can we create a more effective buffer?* Students design a buffer solution with a target pH and buffer capacity by selecting appropriate conjugate-acid base pairs. LO 1.4, 6.18 SP 2.3, 4.2, 6.4, 7.1

17: 4	• Solubility of Salts	**HW**: Students predict and rank the solubility and solution parameters of common salts. LO 6.21, 6.22	**CR3e:** EK 5C3	References*:* •*APGIE Investigation 16 Buffer Design: The Preparation and Testing of an Effective Buffer: How Do Components influence a Buffer's pH and Capacity?* •*IGHCE Lab 13.2 Quantify the common ion effect*
17: 5-7	• Precipitation Reactions • Equilibria for Complex Ions	**HW**: Students predict salt precipitation, enthalpy change and entropy change from acid/base reaction data. LO 6.22, 6.23, 6.24	**CR3e:** EK 5C3	
UNIT 5 Big Ideas 3, 5	**Energy Transfer and Electrochemical Potentials**	**Opportunity or Activity achieving specific Learning Objectives**	**CR met by LO in session/ Lab**	**Orbital Hybridization and Molecular Orbitals** **Valence Bond Theory**
18: 1-3	**Entropy and Free Energy** • Spontaneity and Energy Transfer	**HW**: Students must determine whether reactions are spontaneous or not based on enthalpy data. LO 3.10, 3.11, 5.3	**CR3c,2e:** EK 3C1 EK 3C2 EK 5A2 EK 5E1	**LAB #15** GUIDED INQUIRY — **Creating standardized solution by titration methods:** *How does the initial concentration of an acid-base solution affect the pH during a titration?* Students interpret results of acid-base titrations of acids by a base to determine the concentration and pK for the base or acid and generate a standardized solution. LO 1.18, 1.20, 6.11, 6.12, 6.13 SP 1.1, 1.4, 2.3, 5.1, 6.3, 6.4 References*:* •*AP2009 #6 Standardization of of solution using primary standards* •*APGIE Investigation 14 Acid-Base Titration: How Do the Structure and the Initial Concentration of an Acid and a Base Influence the pH of the Result Solution During a Titration?* •*IGHCE Lab 11.4 Standardize a Hydrochloric Acid Solution by Titration*
18: 4-6	• Entropy (a microscopic explanation) • Entropy Measurement	**CD:** Students analyze entropy increase or decrease based on micro state determinations for simple systems, then generalize their results for chemical reactions. **HW**: Students calculate entropy changes using the laws of thermodynamics. LO 5.12, 5.13	**CR3e:** EK 5E1 EK 5E2	
18: 7	• Gibbs Free Energy • Identifying kinetic constraints	**HW**: Students calculate entropy, enthalpy, Gibbs free energy from reaction data. Using STP tabular values, they predict reaction direction. LO 5.14, 5.15, 5.18, 6.25	**CR3e:** EK 5E3 EK 5E4 EK 5E5 EK 5D1	
19: 1-3	**Electron Transfer Reactions** • Oxidation-Reduction Reactions • Voltaic Cells	**HW**: Students must identify oxidation half-reactions for a set of typical electrolytic solutions. LO 3.12, 3.13	**CR3c:** EK 3C3	**LAB #16** GUIDED INQUIRY — **Create an electrochemical cell and measure the effects of electrolysis on common substances.** *How do solutions generate electric current?* Students identify target battery cell criteria, design and build chemical (wet) battery cells, and calibrate their output. Students then use their batteries (or commercial batteries) to observe the
19: 4-5	• Standard Electrochemical Potentials • Nonstandard Conditions	**HW**: Students calculate electrochemical potentials for standard and non-standard conditions, given cell components. LO 3.12, 3.13	**CR3c:** EK 3C3	

19: 6-8	• Electrochemistry and Thermodynamics • Electrolysis and Counting Electrons	**HW**: Students use electrolysis information to determine current, molar amounts and molecular formula. LO 3.12, 3.13	**CR3c:** EK 3C3	results of electrolysis on common molecules and rank results. LO 3.12, 3.13 SP 3, 4, 5, 6 References •*AP2009 20 Determination of Electrochemical Series* •*AP2009 21 Measurements using electrochemical cells and electroplating* •*IGHCE Lab 16.1 OR HSCKM X-1 Produce Hydrogen and Oxygen by Electrolysis of Water* •*IGHCE Lab 16.2 OR HSCKM X-2 Observe the Electrochemical Oxidation of Iron* •*IGHCE Lab 16.3 OR HSCKM X-3 Measure Electrode Potentials* •*IGHCE Lab 16.4 Observe Energy Transformation* •*IGHCE Lab 6.5 OR HSCKM X-4 Build a Voltaic Cell* •*IGHCE Lab 16.6 Build a Battery*
UNIT 6	**Practical application of Chemical Concepts to Environment, Industry, and Biology [Chapter 20 is always taught; one or more of chapters 21-25 may be presented based on current events, student interest, and available time]**	**Opportunity or Activity achieving key Curriculum Requirement #4**	**CR 4 -- Connection to societal and technological components.**	**Coordinated Lab Exercises**
20: All	**Environmental Chemistry** • Atmosphere: nitrogen, oxygen, ozone, CO2, methane • Water resources: water pollution • Energy supply and demand, fossil fuels, alternate energy sources • "Green Chemistry"	**Student Reports**: Students propose an experimental research project to collect and assess information critical to current or recent ballot initiatives affecting the environment. Students must identify the data to be collected, collection methods, data reduction methods, provide sample calculations, and explain the implications of a range of results. **CR 4: LO will depend on topic selected by student.**	Students relate chemical analysis and principles to emerging issues.	**LAB #17** GUIDED INQUIRY — **Determine the level of impurities in water samples using gravimetric analysis:** *How pure is our water?* Students identify the situations that submit well to gravimetric analysis, then use this method to determine concentrations of components in a solution by analyzing freshwater and seawater samples. LO 1.19, 2.10, 3.2, 3.3 SP 1.5, 2.2, 4.2, 5.1, 6.4, 7.1 •*AP2009 16 Analytical Gravimetric Determination* •*APGIE Investigation 3: What Makes Hard Water Hard?* •*IGHCE Lab 20.3 Quantitative Analysis of SeaWater*
21: All	**Main Group Elements** • Hydrogen • Alkali Metals and Alkaline Earth Elements • Boron, Silicon, Nitrogen, Oxygen, and Halogen Groups	**CD**: Students discuss the environmental impact and costs of element extraction, and the advantages and disadvantages (e.g., energy cost) of preparation of significant compounds for medicine, industrial and agricultural use. **CR 4**	Practical industrial application and careers in chemistry	

22: All	**Transition Elements** • Properties of Metals • Coordination Compounds	**CD**: Students discuss the environmental impact of element extraction, and the advantages and disadvantages (e.g., energy cost) of preparation of significant compounds; impact on industry, society, technology (electronics). **CR 4**	Practical industrial applications and career considerations	**LAB #18** GUIDED INQUIRY — **Use titration acid-base or redox methods to measure pH change and determine acidity of an unknown substance.** *How much acid is in common household solutions?* Students refine their titration skills by choosing an appropriate method to measure the expected pH range, and performing analysis of the acidity of common household items using titration acid-base or redox methods. LO 1.20, 3.3, 6.11, 6.12, 6.18, 6.19, 6.20 SP 2.1, 2.2, 2.3, 4.1, 4.2, 4.3, 4.4, 5.1, 6.4 References*:* •*AP2009 7 Determination of Concentration by acid-base titration* •*APGIE Investigation 4: How much acid is in Fruit Juices and Soft Drinks* •*IGHCE Lab 20.1 Quantitative Analysis of Vitamin C* •*AP2009 8 Determination of Concentration by oxidation-reduction reactions*
23 and 24: All	**Carbon and Organic Chemistry** • Carbon bonding • Hydrocarbons • Alcohols, Esters, Amines • Carbonyl Groups • Polymers	**CD**: Students identify properties of carbon which make it the center of organic compounds, and identify key biological compounds by their functional groups. **CR 4**	Intersection of biology and chemistry	
25: All	**Nuclear Chemistry** • Radioactive Decay and Nuclear Stability • Decay Rates • Fission and Fusion • Radiation Safety • Applications of Nuclear Chemistry	**CD**: Students determine the decay products of radioactive materials, along with their decay rates, half-lives. **CR 4**	Intersection of chemistry and physics	