AP Chemistry II
Science Curriculum

Francis Howell School District

HOME SCHOOL COMMUNITY

LEARNING TOGETHER

Board Approved: June 19, 2014

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Francis Howell School District

Mission Statement

Francis Howell School District is a learning community where all students reach their full potential.

Vision Statement

Francis Howell School District is an educational leader that builds excellence through a collaborative culture that values students, parents, employees, and the community as partners in learning.

Values

Francis Howell School District is committed to:

- Providing a consistent and comprehensive education that fosters high levels of academic achievement for all
- Operating safe and well-maintained schools
- Promoting parent, community, student, and business involvement in support of the school district
- Ensuring fiscal responsibility
- Developing character and leadership

Francis Howell School District Graduate Goals

Upon completion of their academic study in the Francis Howell School District, students will be able to:
1. Gather, analyze and apply information and ideas.
2. Communicate effectively within and beyond the classroom.
3. Recognize and solve problems.
4. Make decisions and act as responsible members of society.

Science Graduate Goals

The students in the Francis Howell School District will graduate with the knowledge, skills, and attitudes essential to leading a productive, meaningful life.

Graduates will:

- Understand and apply principles of scientific investigation.
- Utilize the key concepts and principles of life, earth, and physical science to solve problems.
- Recognize that science is an ongoing human endeavor that helps us understand our world.
- Realize that science, mathematics, and technology are interdependent, each with strengths and limitations that impact the environment and society.
- Use scientific knowledge and scientific ways of thinking for individual and social purposes.

Course Rationale

Science education develops science literacy. Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. A sound grounding in science strengthens many of the skills that people use every day, like solving problems creatively, thinking critically, working cooperatively in teams, using technology effectively, and valuing life-long learning. Scientific literacy has become a necessity for everyone.

To accomplish this literacy, science courses will reflect the following:

- Develop scientific reasoning and critical thinking skills.
- Extend problem-solving skills using scientific methods.
- Include lab-based experiences.
- Strengthen positive attitudes about science.
- Incorporate the use of new technologies.
- Provide relevant connections to personal and societal issues and events.

Course Description for AP Chemistry II

1312551 Semester 1	**AP CHEMISTRY II – NCAA-approved**	**1 Unit**
1312552 Semester 2	Prerequisite: Completion of Chemistry I Pre-AP and Algebra II, with a grade of B or better. Chemistry I may be substituted for Chemistry I Pre-AP with approval of the AP Chemistry instructor.	

This course is designed for the advanced and committed chemistry student. Topics include: solutions, physical behaviors of gases, thermochemistry, electrochemistry, Kinetic Theory, and chemical equilibria. Lab experiences are an integral part of course. This course will emphasize critical thinking as well as advance reading, writing, and problem-solving skills. This is an Advanced Placement course that prepares the student to take the AP Chemistry exam. Advanced credit, when available. This course requires a high degree of independent initiative.

Francis Howell School District
AP Chemistry Curriculum Map

First Semester:

Unit 1: Stoichiometry/Reactions	**Unit 2: Gas Laws and Gaseous Equilibria**	**Unit 3: Solutions and Solution Equilibria**	**Unit 4: Acid/Base Equilibria**	**Unit 5: Electronic Structure & Periodic Trends**
• classification of compounds • indications of chemical reactions • sample purity • Law of Conservation of Mass • Reaction types, including redox, molecular ,ionic and net ionic • stoichiometric analysis • Gravimetric analysis • Physical change, chemical change, or ambiguous change based on macroscopic observations. • Catalyst	• ideal gases • Charles' Gas Law • Graham's Law of effusion • Dalton's Law of partial pressure • Mole fraction • Van der Waal Equation • Equilibrium constants Kp,Kc,Keq • Kinetic molecular theory with a qualitative use of Maxwell-Boltzmann distribution • Deviations from ideal gas law • ICE tables	• solution equilibria • equilibrium constants Kp • Le Chatelier's principle • Spectroscopy, chromatography, distillation • Solute-solvent interaction and intermolecular forces • Coulomb's law • K vs Q	• types of Acids such as Bronsted-Lowry • ICE table • Species present at equilibrium based on value of the equilibrium constant • K_c, K_a, K_b and K_w • Le Chatelier's principle • weak and strong acids and polyprotic systems • pH • buffer solutions • titrations • buffer systems with addition of strong acid or base to the buffer • pH buffering in reference to blood,	• periodicity • atomic models • Describe electron structure using electron structure , PES data, ionization energy data, Coulomb's law • Mass spectroscopy • Use spec-20 data to determine concentration • Energy, wavelength, frequency, change in energy

1.A.1 1.A.2 1.A.3 1.E.1 1.E.2 3.A.1 3.A.2 3.B.1 3.B.3 3.C.1 LO 1.1 LO 1.2 LO 1.3 LO 1.4 LO 1.17 LO 1.18 LO 1.19 LO 1.20 LO 3.1 LO 3.2 LO 3.3 LO 3.4 LO 3.5 LO 3.6 LO 3.8 LO 3.9 LO 3.10 RST.1 RST.2 RST.3 RST.4 RST.6 RST.7 RST.9 RST.10 WHST.1 WHST.2 WHST.3 WHST.4 WHST.6	• Reaction quotient Q and use to determine is reaction is favored in the forward or reverse • LeChatelier's principle • Stresses on an equilibrium shift such as adding or removing a species or changing the temperature 2.A.2 5.A.1 6.A.1 6.A.2 6.A.3 6.A.4 6.B.1 6.B.2 LO 2.4 LO 2.6 LO 2.12 LO 5.2 LO 6.1 LO 6.2 LO 6.3 LO 6.4 LO 6.5 LO 6.6 LO 6.7 LO 6.8 LO 6.9 LO 6.10 RST.1 RST.2 RST.3 RST.4 RST.8 WHST.1 WHST.3 WHST.4	2.A.3 6.A.1 6.A.2 6.A.3 6.A.4 6.B.1 6.B.2 LO 2.7 LO 2.8 LO 2.9 LO 2.10 LO 2.14 LO 2.15 LO 5.16 LO 5.17 LO 6.1 LO 6.2 LO 6.3 LO 6.4 LO 6.5 LO 6.6 LO 6.7 LO 6.8 LO 6.9 LO 6.10 WHST.2 WHST.3 WHST.4	proteins and amino acids • classify salts as acidic, basic or neutral • predict salt solubility based on Ksp • Common ion effect • All sodium, potassium, ammonium and nitrates salts are soluble. 3.B.2 6.A.1 6.A.2 6.A.3 6.A.4 6.B.1 6.B.2 6.C.1 6.C.2 6.C.3 LO 3.7 LO 6.1 LO 6.2 LO 6.3 LO 6.4 LO 6.5 LO 6.6 LO 6.7 LO 6.8 LO 6.9 LO 6.10 LO 6.11 LO 6.12 LO 6.13 LO 6.14 LO 6.15 LO 6.16 LO 6.17 LO 6.18 LO 6.19 LO 6.20 LO 6.21 LO 6.22 LO 6.23 LO 6.24 WHST.1 WHST.4	1.B.2 1.C.1 1.C.2 1.D.1 1.D.2 1.D.3 LO 1.5 LO 1.6 LO 1.7 LO 1.8 LO 1.9 LO 1.10 LO 1.11 LO 1.12 LO 1.13 LO 1.14 LO 1.15 LO 1.16 WHST.1 WHST.3
3 weeks	3 weeks	3 weeks	3 weeks	3 weeks

Second Semester:

Unit 6:
Chemical Bonding; Condensed States of Matter

- shape, polarity and macroscopic properties
- properties of solids
- valence bond theory
- Lewis diagrams and VSEPR
- Electron sea model
- Metallic soslids
- Intermolecular forces vs intramolecular forces
- organic chemistry
  organic nomenclature

1.B.1
2.A.1
2.B.1
2.B.2
2.B.3
2.C.1
2.C.2
2.C.3
2.C.4
2.D.1
2.D.2
2.D.3
2.D.4
5.C.1
5.D.1
5.D.2
5.D.3

LO 2.1
LO 2.2
LO 2.3
LO 2.11
LO 2.16
LO 2.17
LO 2.18
LO 2.19
LO 2.20
LO 2.21
LO 2.22
LO 2.23
LO 2.24
LO 2.25
LO 2.26
LO 2.27
LO 2.28

LO 2.29
LO 2.30
LO 2.31
LO2.32
LO 5.9
LO5.10
LO 5.11

3 weeks

Unit 7:
Thermochemistry

- entropy
- enthalpy
- energy transfer
- deltaG,delta S, delta H calculations
- heat and work
- calorimetry
- enthalpy of making and breaking bonds
- First and Second Law of thermodynamics

3.C.2
5.A.2
5.B.1
5.B.2
5.B.3
5.B.4
5.C.2
5.E.1
5.E.2
5.E.3
5.E.4

LO 3.11
LO 5.1
LO 5.3
LO 5.4
LO 5.5
LO 5.6
LO 5.7
LO 5.8
LO 5.12
LO 5.13
LO 5.14
LO 5.15

WHST.4

3 weeks

Unit 8:
Electrochemistry

- galvanic and electrolytic cell
- electrical current
- redox reactions
- LeChatelier's principle
- Delta G calculations
- Faraday's Law

3.C.3

LO 3.12
LO 3.13

WHST.4

3 weeks

Unit 9:
Chemical Kinetics

- Zero,first and second orders
- Rate laws
- Reaction intermediates
- Rate mechanisms
- Catalysts, surface catalysis
- Kinetic theory
- Activation energy
- Maxwell-Boltzmann distribution

4.A.1
4.A.2
4.A.3
4.B.1
4.B.2
4.B.3
4.C.1
4.C.2
4.C.3
4.D.1
4.D.2
4.D.3

LO 4.1
LO 4.2
LO 4.3
LO 4.4
LO 4.5
LO 4.6
LO 4.7
LO 4.8
LO 4.9
LO 5.18

RST.1
RST.2
RST.3
RST.4
RST.7
WHST.1
WHST.2
WHST.3
WHST.4
WHST.6

3 weeks

Content Area: Science	Course: AP Chemistry II	Unit 1: Stoichiometry/Reactions
Unit Description: The chemical elements are fundamental building materials of matter, and all matter can be understood in terms of arrangements of atoms. These atoms retain their identity in chemical reactions. Changes in matter involve the rearrangement and/or reorganization of atoms and/or the transfer of electrons.		**Unit Timeline:** Approximately 3 weeks

DESIRED RESULTS

Transfer Goal - *Students will be able to independently use their learning to…*
Develop advanced inquiry and reasoning skills, such as designing a plan for collecting data, analyzing data, applying mathematical routines in order to connect concepts in and across domains.

Understandings – *Students will understand that… (Big Ideas)*

1. All matter is made of atoms. There are a limited number and types of atoms; these are elements.
2. Atoms are conserved in physical and chemical processes.
3. Chemical changes are represented by a balanced chemical equation that identifies the ratios with which reactants react and products form.
4. Chemical reactions can be classified by considering what the reactants are, what the products are, or how they changed from one into the other. Classes of chemical reactions include synthesis, decomposition, acid-base, and oxidation-reduction reactions.
5. The seven basic science practices (see Appendix 0.A) are intrinsic to any science field.

Essential Questions: *Students will keep considering…*
1. How are different types of compounds classified?
2. What are the indications that a chemical reaction has taken place?
3. How do we know if a sample is actually pure, and how can we test a solution through chemical reactions to determine the amount of a material present in a mixture?

4. Why don't all chemical reactions occur? 5. How is the Law of Conservation of Mass illustrated in a chemical reaction?

Students Will Know…	Standard	Students Will Be Able to …	Standard

Molecules are composed of specific combinations of atoms; different molecules are composed of combinations of different elements and of combinations of the same elements in differing amounts and proportions. a. The average mass of any large number of atoms of a given element is always the same for a given element. b. A pure sample contains particles (or units) of one specific atom or molecule; a mixture contains particles (or units) of more than one specific atom or molecule. c. Because the molecules of a particular compound are always composed of the identical combination of atoms in a specific ratio, the ratio of the masses of the constituent elements in any pure sample of that compound is always the same. d. Pairs of elements that form more than one type of molecule are nonetheless limited by their atomic nature to combine in whole number ratios. This discrete nature can be confirmed by calculating the difference in mass percent ratios between such types of molecules.	1.A.1	Science Practices for AP Chemistry (see Appendix 0.A)	
		The student can justify the observation that the ratio of the masses of the constituent elements in any pure sample of that compound is always identical on the basis of the atomic molecular theory. [See SP 6.1]	LO 1.1
		The student is able to select and apply mathematical routines to mass data to identify or infer the composition of pure substances and/or mixtures. [See SP 2.2]	LO 1.2
		The student is able to select and apply mathematical relationships to mass data in order to justify a claim regarding the identity and/or estimated purity of a substance. [See SP 2.2, 6.1]	LO 1.3
		The student is able to connect the number of particles, moles, mass, and volume of substances to one another, both qualitatively and quantitatively. [See SP 7.1]	LO 1.4
		The student is able to express the law of conservation of mass quantitatively and qualitatively using symbolic representations and particulate drawings. [See SP 1.5]	LO 1.17
Chemical analysis provides a method for determining the relative number of atoms in a substance, which can be used to identify the substance or determine its purity. a. Because compounds are composed of atoms with known masses, there is a correspondence between the mass percent of the elements in a compound and the relative number of atoms of each element. b. An empirical formula is the lowest whole number ratio of atoms in a compound. Two molecules of the same elements with identical mass percent of their constituent atoms will have identical empirical formulas.	1.A.2	The student is able to apply conservation of atoms to the rearrangement of atoms in various processes. [See SP 1.4]	LO 1.18
		The student can design, and/or interpret data from, an experiment that uses gravimetric analysis to determine the concentration of an analyte in a solution. [See SP 4.2, 5.1, 6.4]	LO 1.19
		The student can design, and/or interpret data from, an experiment that uses titration to determine the concentration of an analyte in a solution. [See SP 4.2, 5.1, 6.4]	LO 1.20
			LO 3.1

c. Because pure compounds have a specific mass percent of each element, experimental measurements of mass percent can be used to verify the purity of compounds. The mole is the fundamental unit for counting numbers of particles on the macroscopic level and allows quantitative connections to be drawn between laboratory experiments, which occur at the macroscopic level, and chemical processes, which occur at the atomic level. a. Atoms and molecules interact with one another on the atomic level. Balanced chemical equations give the number of particles that react and the number of particles produced. Because of this, expressing the amount of a substance in terms of the number of particles, or moles of particles, is essential to understanding chemical processes. b. Expressing the mass of an individual atom or molecule in atomic mass unit (amu) is useful because the average mass in amu of one particle (atom or molecule) of a substance will always be numerically equal to the molar mass of that substance in grams. c. Avogadro's number provides the connection between the number of moles in a pure sample of a substance and the number of constituent particles (or units) of that substance. d. Thus, for any sample of a pure substance, there is a specific numerical relationship between the molar mass of the substance, the mass of the sample, and the number of particles (or units) present. Physical and chemical processes can be depicted symbolically; when this is done, the illustration must conserve all atoms of all types.	1.A.3 1.E.1	Students can translate among macroscopic observations of change, chemical equations, and particle views. [See SP 1.5, 7.1] Note: This learning objective applies to essential knowledge components of 3A–3C. The student can translate an observed chemical change into a balanced chemical equation and justify the choice of equation type (molecular, ionic, or net ionic) in terms of utility for the given circumstances. [See SP 1.5, 7.1] The student is able to use stoichiometric calculations to predict the results of performing a reaction in the laboratory and/or to analyze deviations from the expected results. [See SP 2.2, 5.1] The student is able to relate quantities (measured mass of substances, volumes of solutions, or volumes and pressures of gases) to identify stoichiometric relationships for a reaction, including situations involving limiting reactants and situations in which the reaction has not gone to completion. [See SP 2.2, 5.1, 6.4] The student is able to design a plan in order to collect data on the synthesis or decomposition of a compound to confirm the conservation of matter and the law of definite proportions. [See SP 2.1, 4.2, 6.4] The student is able to use data from synthesis or decomposition of a compound to confirm the conservation of matter and the law of definite proportions. [See SP 2.2, 6.1] The student is able to identify redox reactions and justify the identification in terms of electron transfer. [See SP 6.1] The student is able to design and/or interpret the results of an experiment involving a redox titration. [See SP 4.2, 5.1]	LO 3.2 LO 3.3 LO 3.4 LO 3.5 LO 3.6 LO 3.8 LO 3.9 LO 3.10

a. Various types of representations can be used to show that matter is conserved during chemical and physical processes. 1. Symbolic representations 2. Particulate drawings b. Because atoms must be conserved during a chemical process, it is possible to calculate product masses given known reactant masses, or to calculate reactant masses given product masses. c. The concept of conservation of atoms plays an important role in the interpretation and analysis of many chemical processes on the macroscopic scale. Conservation of atoms should be related to how nonradioactive atoms are neither lost nor gained as they cycle among land, water, atmosphere, and living organisms. Conservation of atoms makes it possible to compute the masses of substances involved in physical and chemical processes. Chemical processes result in the formation of new substances, and the amount of these depends on the number and the types and masses of elements in the reactants, as well as the efficiency of the transformation. a. The number of atoms, molecules, or formula units in a given mass of substance can be calculated. b. The subscripts in a chemical formula represent the number of atoms of each type in a molecule. c. The coefficients in a balanced chemical equation represent the relative numbers of particles that are consumed and created when the process occurs. d. The concept of conservation of atoms plays an important role in the interpretation and analysis of many chemical processes on the macroscopic scale. e. In gravimetric analysis, a substance is added to a solution that reacts specifically with a dissolved analyte (the chemical species that is the target of the	1.E.2	The student is able to evaluate the classification of a process as a physical change, chemical change, or ambiguous change based on both macroscopic observations and the distinction between rearrangement of covalent interactions and non-covalent interactions. [See SP 1.4, 6.1, connects to 5.D.2] <u>Common Core Reading Standards for Grades 11-12</u> Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11–12 texts and topics*. Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, identifying important issues that remain unresolved. Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.	RST.1 RST.2 RST.3 RST.4 RST.6 RST.7 RST.9

analysis) to form a solid. The mass of solid formed can be used to infer the concentration of the analyte in the initial sample. f. Titrations may be used to determine the concentration of an analyte in a solution. The titrant has a known concentration of a species that reacts specifically with the analyte. The equivalence of the titration occurs when the analyte is totally consumed by the reacting species in the titrant. The equivalence point is often indicated by a change in a property (such as color) that occurs when the equivalence point is reached. This observable event is called the end point of the titration.	3.A.1	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. By the end of grade 12, read and comprehend science/technical texts in the grades 11–CCR text complexity band independently and proficiently.	RST.10
A chemical change may be represented by a molecular, ionic, or net ionic equation. a. Chemical equations represent chemical changes, and therefore must contain equal numbers of atoms of every element on each side to be “balanced.” b. Depending on the context in which it is used, there are different forms of the balanced chemical equations that are used by chemists. It is important not only to write a balanced molecular, ionic, or net ionic reaction equation, but also to have an understanding of the circumstances under which any of them might be the most useful form. c. The balanced chemical equation for a reaction is capable of representing chemistry at any level, and thus it is important that it can be translated into a symbolic depiction at the particulate level, where much of the reasoning of chemistry occurs. d. Because chemistry is ultimately an experimental science, it is important that students be able to describe chemical reactions observed in a variety of laboratory contexts.	3.A.2	<u>Common Core Writing Standards for Grades 11-12</u> Write arguments focused on *discipline-specific content*. a. Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence. b. Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience’s knowledge level, concerns, values, and possible biases. c. Use words, phrases, and clauses as well as varied syntax to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims. d. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.	WHST.1

Quantitative information can be derived from stoichiometric calculations that utilize the mole ratios from the balanced chemical equations. The role of stoichiometry in real-world applications is important to note, so that it does not seem to be simply an exercise done only by chemists. a. Coefficients of balanced chemical equations contain information regarding the proportionality of the amounts of substances involved in the reaction. These values can be used in chemical calculations that apply the mole concept; the most important place for this type of quantitative exercise is the laboratory. 1. Calculate amount of product expected to be produced in a laboratory experiment. 2. Identify limiting and excess reactant; calculate percent and theoretical yield for a given laboratory experiment.		e. Provide a concluding statement or section that follows from or supports the argument presented. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. a. Introduce a topic and organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension. b. Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic. c. Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts.	WHST.2
b. The use of stoichiometry with gases also has the potential for laboratory experimentation, particularly with respect to the experimental determination of molar mass of a gas.	3.B.1	d. Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers.	
c. Solution chemistry provides an additional avenue for laboratory calculations of stoichiometry, including titrations. Synthesis reactions are those in which atoms and/or molecules combine to form a new compound. Decomposition is the reverse of synthesis, a process whereby molecules are decomposed, often by the use of heat.		e. Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic).	WHST.3
a. Synthesis or decomposition reactions can be used for acquisition of basic lab techniques and observations that help students deal with the abstractions of atoms and stoichiometric calculations.	3.B.3	Students' narrative skills continue to grow in these grades. The Standards require that students be ab le to incorporate the narrative elements effectively into arguments and information/explanatory texts. In science, students must be able to write precise descriptions of the step-by-step procedures they	

In oxidation-reduction (redox) reactions, there is a net transfer of electrons. The species that loses electrons is oxidized, and the species that gains electrons is reduced. a. In a redox reaction, electrons are transferred from the species that is oxidized to the species that is reduced. b. Oxidation numbers may be assigned to each of the atoms in the reactant and products; this is often an effective way to identify the oxidized and reduced species in a redox reaction. c. Balanced chemical equations for redox reactions can be constructed from tabulated half-reactions. d. Recognizing that a reaction is a redox reaction is an important skill; an apt application of this type of reaction is a laboratory exercise where students perform redox titrations. e. There are a number of important redox reactions in energy production processes (combustion of hydrocarbons and metabolism of sugars, fats, and proteins). Production of heat or light, formation of a gas, and formation of a precipitate and/or a color change are possible evidences that a chemical change has occurred. a. Laboratory observations are made at the macroscopic level, so students must be able to characterize changes in matter using visual clues and then make representations or written descriptions. b. Distinguishing the difference between chemical and physical changes at the macroscopic level is a challenge; therefore, the ability to investigate chemical properties is important. c. In order to develop the ability to distinguish experimentally between chemical and physical changes, students must make observations and collect	3.C.1	use in their investigations that others can replicate them and (possibly) reach the same results. Produce writing in which the organization, development, substance, and style are appropriate to task, purpose, and audience. Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.	WHST.4 WHST.6

data from a variety of reactions and physical changes within the laboratory setting. d. Classification of reactions provides important organizational clarity for chemistry; therefore, students need to identify precipitation, acid-base, and redox reactions.			
EVIDENCE of LEARNING			
Understanding #2, #3, #4	Standards LO 3.3 LO 3.5 WHST.1 WHST.2	**Unit Performance Assessment**: **Description of Assessment Performance Task(s):** *Lab Investigation #7: Using the Principle That Each Substance Has Unique Properties to Purify a Mixture: An Experiment Applying Green Chemistry to Purification* See AP Chemistry Guided-Inquiry Experiments Investigation #7 (Student Manual). In this laboratory activity, the student will participate in the peer-review process by an editor of a journal on green chemistry that has received three different manuscripts (lab write-ups) that report on the same process of separating two substances. First, students will design their own procedure to do the experiment of separating two substances using green chemistry principles. Second, the students will receive one of the manuscripts submitted to the aforementioned journal. The students will assess the quality of the lab report and write a review of it to submit to the editor. **Teacher will assess:** 1. As part of the peer-review process, students attempt to verify the experiment that has been conducted and submitted as a manuscript (lab report) to a journal. 2. As part of the verification activity, students must check the calculations done by the author of the lab report, and must also apply stoichiometry calculations with their own data.	**R/R Quadrant** **D**

		3. Students must determine the percent mass of sodium bicarbonate in the sample in order to verify or refute the findings of the lab report they are reviewing. 4. Students calculate a version of percent yield, called atom economy (this is a theoretical construct), and then interpret it through the lens of environmental consciousness to determine how green the chemical reaction is. 5. As part of the review process, students realize the value of the usual sections of a lab report, which mimics the structure of research papers that are published in journals. In their reviews, they have to provide feedback to the author on how to improve the lab report. Students defend the need for specific information in lab reports when explaining an investigation and presenting results. 6. Students use stoichiometry to determine the weight percentage of each pure substance in a mixture of unknown composition. 7. Students judge the quality of a reported procedure with flaws, and improve upon that procedure by trying it and discovering how to do it better. **Performance:** **Mastery:** Students will show that they really understand when they… 1. Achieve a Level 3, Level 4, or Level 5 **Scoring Guide:** See Appendix 1.A	

SAMPLE LEARNING PLAN				
Pre-assessment: *Please see Appendix 0.C: AP Chemistry Pre-Assessment.*				
Understanding	**Standards**	**Major Learning Activities:**	**Instructional Strategy:**	**R/R Quadrant:**
#3	1.A.3	1. Activity: Learning Module on Chemical Reactions and Stoichiometry		**C**

	ISTE-S.4	http://mw2.concord.org/public/part2/chemreact/index.cml ● Objective: This module walks students through the process of chemical reactions using manipulatives and providing a concrete model of the processes involved in stoichiometric calculations. *The module is Java supported and not accessible to ipad/iphone technology.* ● Appendix Documents: Appendix 1.B – Screen Shots of Module for Chemical Reactions and Stoichiometry	Technology based homework and practice.	
#4	3.A.2 RST.6 RST.10	2. Activity: Frontloading Anticipatory Set for Sugar, The Unusual Explosive ● Objective: This non-fiction reading activity provides real life application of chemical reactions. Students will fill out an anticipatory set before reading the text and to facilitate engagement, they will answer reflective questions. As a follow up, there are think-aloud prompts to extend student thinking. ● Appendix Documents: Appendix 1.C – Sugar, an Unusual Explosive Guided Reading Appendix 1.D – Sugar, an Unusual Explosive Anticipatory Set with Think Aloud	Frontloading, anticipatory set, and think aloud	**D**
#2	3.A.1	*3.* Activity: Cooperative Learning Sweet Sixteen Ion Tournament ● Objective: Using pre-learned solubility rules, students will work in cooperative learning groups to determine the ultimate winner of a tournament based on chemical reactions. ● Appendix Documents: Appendix 1.E – Sweet Sixteen Ion Tournament	Cooperative Learning - numbered heads together structure or other as teacher desired	**D**
UNIT RESOURCES				

Teacher Resources:

- Brown Lemay 12th Edition AP Chemistry, The Central Science, Teac

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her Manual

- AP Chemistry Guided-Inquiry Experiments, Teacher Manual

Links

- "Chemistry Tutorial: Redox." AUS-e-TUTE. Accessed July 29, 2012. http://www.auset ute.com.au/redoxtitr.html

References

- Rees, Thomas. “The Stability of Potas

sium Permanganate Solutions.” *Journal of Chemical Edu*

cation 64, no. 12 (1987):1058. • Young, J.A. "Potassium P

	ermanganate *Journal of Chemical Education* 80, no. 8 (2

003): 873.
Student Resources: • Brown Lemay 12th Edition AP Chemistry, The Central Science, Stu

dent Version • AP Chemistry Guided-Inquiry Experiments, Student Manual • Online learning platform

provided by textbook Company
Vocabulary: ● Atom: the smallest representative particle of

an element.

- AMU: Atomic mass unit. It is a unit based on the value of exactly

12 amu for the mass of the isotope of carbon that has 6 protons and 6 neut

rons in the nucleus. • Acid: a substance that is able to donate a H^+ and hence, incr

eases the concentration of $H^+(aq)$ when it dissolves in water. • Activity series: a

list metals in order of decreasing oxidation number.

- Aqueous solution: a solutio

n in which water is the solvent.

- Atomic number: the number of protons in th e nucleus of an atom of an element.

- Avogadro’s number: $6.022x10^{23}$ represen

tative particles • Base: a substance that is an H^+ acceptor, a produces and excess of

OH^- ions when it dissolves in water.

- Catalyst: a substance that changes the

speed of a chemical reaction without itself undergoing a permanent chemica

l change in the processes.

- Chemical bond: a strong attractive force that exists be tween atoms in a molecule.

- Chemical change: process in which one or mor

e substances are converted into other substances, also called a chemical reac

tion. • Chemical formula: a notation that uses chemical symbols with numerica

l subscripts to convey the relative proportions of atoms other different elem

ents in a substance.

- Chemical reactions: processes in which one or more substa nces are converted into other substances, also called chemical changes.

- Combi

nation reaction: a chemical reaction in which two or more substances combine

to form a single product.

- Combustion reaction: a chemical reaction that proc

eeds with evolution of heat and usually also flame; most combustion involves reactio

n with oxygen, as in the burning of the match.

- Complete ionic equation: a

chemical equation in which dissolved strong electrolytes (such as dissolved

ionic compounds) are written as separate ions.

- Compound: a substance com

posed of two or more elements united chemically in definite proportions.

- Con

version factor: a ration relating the same quantity in two systems of units that

is used to convert units of measurement. • Displacement reaction: a reaction in whi

ch an element reacts with a compound, displacing an element from it. • Elem

ent: a substance consisting atoms of the same atomic number. • Empirical

formula: a chemical formula that shows the kinds of atoms and their

relative numbers in a substance in the smallest possible whole number ratios.

• Endothermic processes: a process in which a system absorbs heat from its su

rroundings.

- Exothermic processes: a processes in which a system releases heat to its surroundings.

- Formula weight: the mass of the collection of atoms re presented by a chemical formula.

- Neutralization reaction: a reaction in which an acid and base react in stoichiometrically equivalent amounts.

- Precipitate re

	action: a reaction that occurs between substances in solution in which one of the

products is insoluble.

- Product: a substance produced in a chemical reaction.

- Reactant: a starting substance in a chemical reaction.
- Stoichiometry: the rel

ationships among the quantities of reactants and products involved in chemi

cal reactions.

Content Area: Science	**Course: AP Chemistry II**	**Unit 2: Gas Laws and Gaseous Equilibria**

Unit Description: This unit will contain the ideal gas law and its applications, assumptions about an ideal gas, and limitations to the ideal gas law. Gaseous equilibria will be included. The use of ICE tables as well as LeChatelier's Principle will be applied to systems at equilibrium subjected to a stress.	**Unit Timeline:** Approximately 3 weeks.

DESIRED RESULTS
Transfer Goal - *Students will be able to independently use their learning to…* Develop advanced inquiry and reasoning skills, such as designing a plan for collecting data, analyzing data, applying mathematical routines in order to connect concepts in and across domains.

Understandings – *Students will understand that… (Big Ideas)*

1. Ideal gases behave predictably according to the Ideal Gas Law.
2. Chemical equilibrium is a dynamic, reversible state in which rates of opposing processes are equal.
3. Systems at equilibrium are responsive to external perturbations, with the response leading to a change in the composition of the system.
4. The seven basic science practices (see Appendix 0.A) are intrinsic to any science field.

Essential Questions: *Students will keep considering…*

1. What assumptions are made about an ideal gas? Under what conditions does a gas behave most ideal?
2. What equations are most useful in describing the behavior of gases under varying conditions of pressure, temperature, volume, and moles of gas?
3. What does a large K_{eq} imply about a reaction? What does a small value of K_{eq} imply?
4. How are equilibrium constants determined?
5. How can the value of an equilibrium constant be changed?
6. How can equilibrium constants be used to calculate the pressure of a mixture of gases at equilibrium?

Students Will Know…	Standard	Students Will Be Able to …	Standard
The gaseous state can be effectively modeled with a mathematical equation relating various macroscopic properties. A gas has neither a definite volume nor a definite shape; because the effects of attractive forces are minimal, we usually assume that the particles move independently. a. Ideal gases exhibit specific mathematical relationships among the number of particles present, the temperature, the pressure, and the volume. b. In a mixture of ideal gases, the pressure exerted by each component (the partial pressure) is independent of the other components. Therefore, the total pressure is the sum of the partial pressures. c. Graphical representations of the relationships between P, V, and T are useful to describe gas behavior. d. Kinetic molecular theory combined with a qualitative use of the Maxwell- Boltzmann distribution provides a robust model for qualitative explanations of these mathematical relationships. e. Some real gases exhibit ideal or near-ideal behavior under typical laboratory conditions. Laboratory data can be used to generate or investigate the relationships in 2.A.2.a and to estimate absolute zero on the Celsius scale. f. All real gases are observed to deviate from ideal behavior, particularly under conditions that are close to those resulting in condensation. Except at extremely high pressures that are not typically seen in the laboratory, deviations from ideal behavior are the result of intermolecular attractions among gas molecules. These forces are strongly distance-dependent, so they are most significant during collisions. g. Observed deviations from ideal gas behavior can be explained through an understanding of the structure of	2.A.2	Science Practices for AP Chemistry (see Appendix 0.A) The student is able to use KMT and concepts of intermolecular forces to make predictions about the macroscopic properties of gases, including both ideal and nonideal behaviors. [See SP 1.4, 6.4] The student can apply mathematical relationships or estimation to determine macroscopic variables for ideal gases. [*See* SP 2.2, 2.3] The student can qualitatively analyze data regarding real gases to identify deviations from ideal behavior and relate these to molecular interactions. [See SP 5.1, 6.5, connects to 2.A.2] The student is able to relate temperature to the motions of particles, either via particulate representations, such as drawings of particles with arrows indicating velocities, and/or via representations of average kinetic energy and distribution of kinetic energies of the particles, such as plots of the Maxwell-Boltzmann distribution. [See SP 1.1, 1.4, 7.1] The student is able to, given a set of experimental observations regarding physical, chemical, biological, or environmental processes that are reversible, construct an explanation that connects the observations to the reversibility of the underlying chemical reactions or processes. [See SP 6.2] The student can, given a manipulation of a chemical reaction or set of reactions (e.g., reversal of reaction or addition of two reactions), determine the effects of that manipulation on Q or K. [See SP 2.2]	LO 2.4 LO 2.6 LO 2.12 LO 5.2 LO 6.1 LO 6.2 LO 6.3

atoms and molecules and their intermolecular interactions.		The student can connect kinetics to equilibrium by using reasoning about equilibrium, such as Le Chatelier's principle, to infer the relative rates of the forward and reverse reactions. [See SP 7.2]	
Temperature is a measure of the average kinetic energy of atoms and molecules. a. All of the molecules in a sample are in motion. b. The Kelvin temperature of a sample of matter is proportional to the average kinetic energy of the particles in the sample. When the average kinetic energy of the particles in the sample doubles, the Kelvin temperature is doubled. As the temperature approaches 0 K (zero Kelvin), the average kinetic energy of a system approaches a minimum near zero. c. The Maxwell-Boltzmann distribution shows that the distribution of kinetic energies becomes greater (more disperse) as temperature increases.	5.A.1		LO 6.4
		The student can, given a set of initial conditions (concentrations or partial pressures) and the equilibrium constant, K, use the tendency of Q to approach K to predict and justify the prediction as to whether the reaction will proceed toward products or reactants as equilibrium is approached. [See SP 2.2, 6.4]	LO 6.5
		The student can, given data (tabular, graphical, etc.) from which the state of a system at equilibrium can be obtained, calculate the equilibrium constant, K. [See SP 2.2]	LO 6.6
In many classes of reactions, it is important to consider both the forward and reverse reaction. a. Many readily observable processes are reversible. Examples include evaporating and condensing water, absorption of a gas, or dissolving and precipitating a salt. Relevant and interesting contexts include biological examples (binding of oxygen to hemoglobin and the attachment of molecules to receptor sites in the nose) and environmental examples (transfer of carbon between atmosphere and biosphere and transfer of dissolved substances between atmosphere and hydrosphere). b. Dissolution of a solid, transfer of protons in acid-base reactions, and transfer of electrons in redox reactions are important examples of reversible reactions.	6.A.1	The student can, given a set of initial conditions (concentrations or partial pressures) and the equilibrium constant, K, use stoichiometric relationships and the law of mass action (Q equals K at equilibrium) to determine qualitatively and/or quantitatively the conditions at equilibrium for a system involving a single reversible reaction. [See SP 2.2, 6.4]	LO 6.7
		The student is able, for a reversible reaction that has a large or small K, to determine which chemical species will have very large versus very small concentrations at equilibrium. [See SP 2.2, 2.3]	LO 6.8
		The student is able to use Le Chatelier's principle to predict the direction of the shift resulting from various possible stresses on a system at chemical equilibrium. [See SP 1.4, 6.4]	LO 6.9
	6.A.2	The student is able to use Le Chatelier's principle to design a set of conditions that will optimize a desired outcome, such as product yield. [See SP 4.2]	LO 6.10

The current state of a system undergoing a reversible reaction can be characterized by the extent to which reactants have been converted to products. The relative quantities of reaction components are quantitatively described by the reaction quotient, Q. a. Given an initial set of reactant and product concentrations, only those sets of concentrations that are consistent with the reaction stoichiometry can be attained. ICE (initial, change, equilibrium) tables are useful for determining which sets of concentration values are possible. b. The reaction quotient, Q, provides a convenient measure of the current progress of a reaction. Q does not include substances whose concentrations are independent of the amount of substance, such as for a solid in contact with a liquid solution or with a gas, or for a pure solid or liquid in contact with a gas. c. The value of Q (and so also K) changes when a reaction is reversed. When reactions are added together through the presence of a common intermediate, Q (and so also K) of the resulting reaction is a product of the values of Q (or K) for the original reactions. When a system is at equilibrium, all macroscopic variables, such as concentrations, partial pressures, and temperature, do not change over time. Equilibrium results from an equality between the rates of the forward and reverse reactions, at which point Q = K. a. When equilibrium is reached, no observable changes occur in the system. 1. Reactant and product molecules are present. 2. Concentration of all species remains constant. b. If the rate of the forward reaction is greater than the reverse reaction, there is a net conversion of reactants to products. If the rate of the reverse reaction is	6.A.3	The student is able to connect Le Chatelier's principle to the comparison of Q to K by explaining the effects of the stress on Q and K. [See SP 1.4, 7.2] <u>Common Core Reading Standards for Grades 11-12</u> Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11–12 texts and topics*. Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.	RST.1 RST.2 RST.3 RST.4 RST.8 WHST.1

greater than the forward reaction, there is a net conversion of products to reactants. An equilibrium state is reached when these rates balance, at which point the progress of reaction, Q, becomes equal to the equilibrium constant, K. c. Comparing Q to K allows the determination of whether the reaction is at equilibrium, or will proceed toward products or reactants to reach equilibrium. d. Equilibrium constants can be determined from experimental measurements of the concentrations of the reactants and products at equilibrium. e. Given a single reaction, initial concentrations, and K, the concentrations at equilibrium may be predicted. f. Graphs of concentration over time for simple chemical reactions can be used to understand the establishment of chemical equilibrium. The magnitude of the equilibrium constant, K, can be used to determine whether the equilibrium lies toward the reactant side or product side. a. For many aqueous reactions, K is either very large or very small, and this may be used to reason qualitatively about equilibrium systems. b. Particulate representations can be used to describe the relationship between the numbers of reactant and product particles present at equilibrium, and the value of the equilibrium constant. Systems at equilibrium respond to disturbances by partially countering the effect of the disturbance (Le Chatelier's principle). a. Le Chatelier's principle can be used to predict the response of a system to the following stresses: addition or removal of a chemical species, change in temperature, change in volume/pressure of a gas phase	6.A.4 6.B.1	<u>Common Core Writing Standards for Grades 11-12</u> Write arguments focused on *discipline-specific content*. a. Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence. b. Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience's knowledge level, concerns, values, and possible biases. c. Use words, phrases, and clauses as well as varied syntax to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims. d. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing. e. Provide a concluding statement or section that follows from or supports the argument presented. Students' narrative skills continue to grow in these grades. The Standards require that students be ab le to incorporate the narrative elements effectively into arguments and information/explanatory texts. In science, students must be able to write precise descriptions of the step-by-step procedures they use in their investigations that others can replicate them and (possibly) reach the same results.	WHST.3 WHST.4

system, and dilution of a reaction system with water or other solvent. b. Le Chatelier's principle can be used to reason about the effects a stress will have on experimentally measurable properties, such as pH, temperature, and color of a solution. A disturbance to a system at equilibrium causes Q to differ from K, thereby taking the system out of the original equilibrium state. The system responds by bringing Q back into agreement with K, thereby establishing a new equilibrium state. a. Le Chatelier's principle involves qualitative reasoning that is closely connected to the quantitative approach of 6.A.3. b. Some stresses, such as changes in concentration, cause a change in Q. A change in temperature causes a change in K. In either case, the reaction shifts to bring Q and K back into equality.	6.B.2	Produce writing in which the organization, development, substance, and style are appropriate to task, purpose, and audience. ISTE Technology Standards Critical Thinking, Problem Solving, and Decision Making: Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources. a. Identify and define authentic problems and significant questions for investigation b. Plan and manage activities to develop a solution or complete a project c. Collect and analyze data to identify solutions and/or make informed decisions d. Use multiple processes and diverse perspectives to explore alternative solutions	ISTE-S.4

EVIDENCE of LEARNING

Understanding	Standards	Unit Performance Assessment:	R/R Quadrant
#2, #3, #5	2.A.2 WHST.2 ISTE-S.4	**Description of Assessment Performance Task(s):** *Lab Investigation #10: How long will that marble statue last?* See AP Chemistry Guided-Inquiry Experiments Investigation #10 (Student Manual). In this laboratory activity, students develop an experimental procedure that is used to monitor the reaction between hydrochloric acid and calcium carbonate. Students will first develop the experimental procedure, which is then approved (or not approved) by the instructor. Once the students' initial experimental designs have been carried out and data collected, students should consider improvements to their procedures and perform the investigations once more. **Teacher will assess:** 1. As each group proposes a potential experiment, the instructor will check for the validity of the procedure and grant approval based upon this validation. 2. Instructor will monitor the collection of data to ensure that proper laboratory safety is followed. 3. Students use the ideal gas law, along with stoichiometry, to determine that mass of calcium carbonate that has dissolved based upon the amount of carbon dioxide gas generated. Teacher will assess the accuracy of these calculations. 4. Students analyze the quality of their experiment and find areas of improvement. Students then conduct their refined experimental procedures. 5. Instructor will assess the quality of the refined procedure and will assess the accuracy of the performed calculations. **Performance:** **Mastery:** Students will show that they really understand when they… 1. Achieve a Level 3, Level 4, or Level 5 **Scoring Guide:** See Appendix 2.A	**D**

SAMPLE LEARNING PLAN

Pre-assessment: *Please see Appendix 0.C: AP Chemistry Pre-Assessment.*

Understanding	**Standards**	**Major Learning Activities:**	**Instructional Strategy:**	**R/R Quadrant:**
#1	2.A.2 WHST.4 ISTE-S.3	1. Activity: Frontloading Activity: Gases Video *www.bozemanscience.com/ap-chemistry* ● Objective: Students are introduced to Ideal Gases and the Ideal Gas Equation by going to *www.bozemanscience.com/ap-chemistry* and viewing video #14 on Gases. Students will complete Cornell-style notes on this short video. ● Appendix Documents: Appendix 0.D – Cornell Notes Template Blank Appendix 0.E – Cornell Notes Grading Rubric	Technology Based Anticipatory Set	**A**
#1, #4	2.A.2 WHST.4 ISTE-S.4	2. Activity: Lab: How pure is that mixture? ● Objective: To apply Dalton's Law of partial pressures and the ideal gas law to determine the percent purity of a sodium hydrogen carbonate mixture. ● Appendix Documents: Appendix 2.B – Lab: How Pure is That Mixture?	Inquiry Based Laboratory	**D**
#2, #3, #4	6.A.1 6.A.2 6.B.1 WHST.1	3. Activity: Think Aloud Activity on the Behavior of Human Hemoglobin ● Objective: Students use LeChatelier's Principle to explain why hemoglobin binds oxygen in the lungs and releases oxygen in the tissues. Students also explain why the synthesis of additional hemoglobin molecules (when the partial pressure of oxygen is lowered) will increase the amount of oxygen that is delivered to the tissues. ● Appendix Documents: Appendix 2.C –Think Aloud Activity for Gaseous Equilibrium	This is a collaborative, scaffolded, multistep process that can take a number of directions based on student input.	**D**

UNIT RESOURCES
Teacher Resources: ● Brown Lemay 12^{th} Edition AP Chemistry, The Central Science, Teacher Manual ● AP Chemistry Guided-Inquiry Experiments, Teacher Manual
Student Resources: ● Brown Lemay 12^{th} Edition AP Chemistry, The Central Science, Student Version ● AP Chemistry Guided-Inquiry Experiments, Student Manual ● Online learning platform provided by textbook Company ● Bozemanscience.com/ap-chemistry
Vocabulary: ● Vapor – Gaseous state of any substance that normally exists as a liquid or solid ● Pressure – A measure of the force exerted on a unit area ● Pascal – The SI unit of pressure describing 1 Newton per square meter of surface area, 1 Pa = N/m^2. ● Atmosphere – A unit of pressure equal to 760 torr and abbreviated atm. ● Standard atmospheric pressure-Defined as 760 torr, or, in SI units, 101.325 kPa. ● Torr- A unit of pressure where 1 torr = 1 mmHg. ● Boyle's Law-A law stating that at constant temperature, the product of the volume and pressure of a given amount of gas is constant. ● Avogadro's Law- A statement that the volume of a gas maintained at constant temperature and pressure is directly proportional to the number of moles of the gas. ● Ideal Gas Equation – An equation of state for gases that embodies Boyle's Law, Charles's Law, and Avogadro's hypothesis in the form PV = nRT. ● Gas constant – The constant of proportionality in the ideal gas equation, symbolized by R. ● STP – Standard Temperature and Pressure, 0°C, 1.00 atm. ● Partial Pressure – The pressure exerted by a particular gas in a mixture. ● Dalton's Law of Partial Pressures – A law stating that the total pressure of a mixture of gases is the sum of the pressures that each gas would exert if it were present alone. ● Mole Fraction – The ratio of the number of moles of one component of a mixture to the total moles of all components ● Kinetic-Molecular Theory of Gases – A set of assumptions about the nature of gases. ● Maxwell Boltzman Distribution – A graph showing the relationship between the relative number of molecules at any speed for a given temperature.

- Root-Mean-Square Speed – The square root of the average squared speeds of the gas molecules in a gas sample.
- Effusion – The escape of a gas through an orifice or hole.
- Diffusion – The spreading of one substance through a space occupied by one or more other substances
- Graham's Law of Effusion – A law stating that the rate of effusion of a gas is inversely proportional to the square root of its molecular weight.
- Van Der Waals Equation – An equation of state for nonideal gases that is based on adding corrections to the ideal gas equation
- Chemical Equilibrium – A state of dynamic balance in which the rate of formation of the products of a reaction equals the rate of formation of the reactants.
- K_P – The ratio of the partial pressures of the products to the partial pressure of the reactants (expressed in units of atm) for a gaseous system at equilibrium.
- Homogeneous Equilibria – The equilibrium established between reactant and product substances that are all in the same phase.
- Heterogeneous Equilibria – The equilibrium established between substances in two or more different phases.
- Reaction Quotient – The value that is obtained when concentrations of reactants and products are inserted into the equilibrium expression.
- Le Chatelier's Principle – A principle stating that when we disturb a system at chemical equilibrium, the relative concentrations of reactants and products shift so as to partially undo the effects of the disturbance.
- ICE Table – A table created to list or determine the initial pressure, change in pressure, and equilibrium partial pressure of a system at equilibrium.

Content Area: Science	Course: AP Chemistry II	Unit 3: Solutions and Solution Equilibria
Unit Description: This unit will focus on solutions. Appropriate units of concentration will be used in solution stoichiometry. Solution equilibria will be included. The use of ICE tables as well as LeChatelier's Principle will be applied to systems at equilibrium subjected to a stress.		**Unit Timeline:** Approximately 3 weeks.

DESIRED RESULTS
Transfer Goal - ***Students will be able to independently use their learning to…*** Develop advanced inquiry and reasoning skills, such as designing a plan for collecting data, analyzing data, applying mathematical routines in order to connect concepts in and across domains.

Understandings – ***Students will understand that… (Big Ideas)***

1. Solutions are homogeneous mixtures whose concentration can be determined by appropriate selection of spectroscopic techniques.
2. Chemical equilibrium is a dynamic, reversible state in which rates of opposing processes are equal.
3. Systems at equilibrium are responsive to external perturbations , with the response leading to a change in the composition of the system.
4. Chemical equilibrium plays an important role in acid-base chemistry and in solubility.
5. The seven basic science practices (see Appendix 0.A) are intrinsic to any science field.

Essential Questions: ***Students will keep considering…***

1. Why do some reactions in solution reach equilibrium with a mixture of reactants and products, while others go to completion?

2. What is the difference between K, K_{eq}, K_c and K_P? Under what circumstances does each apply?
3. What is the relationship between K_c and K_P for a gaseous system?
4. What does a large K_c imply about a reaction? What does a small value of K_c imply?
5. How are equilibrium constants determined?
6. How can the value of an equilibrium constant be changed?
7. How can equilibrium constants be used to calculate the concentration of all substances in a mixture at equilibrium?
8. What changes can be made to a system at equilibrium to shift the equilibrium one direction or another?
9. How can reactions with small equilibrium constants be used to create a relatively large amount of product?
10. What spectroscopic techniques can be used to measure the concentration of a solution?

Students Will Know…	**Standard**	**Students Will Be Able to …**	**Standard**

Solutions are homogenous mixtures in which the physical properties are dependent on the concentration of the solute and the strengths of all interactions among the particles of the solutes and solvent. a. In a solution (homogeneous mixture), the macroscopic properties do not vary throughout the sample. This is in contrast to a heterogeneous mixture in which the macroscopic properties depend upon the location in the mixture. The distinction between heterogeneous and homogeneous depends on the length scale of interest. As an example, colloids may be heterogeneous on the scale of micrometers, but homogeneous on the scale of centimeters. b. Solutions come in the form of solids, liquids, and gases. c. For liquid solutions, the solute may be a gas, a liquid, or a solid. d. Based on the reflections of their structure on the microscopic scale, liquid solutions exhibit several general properties: 1. The components cannot be separated by using filter paper. 2. There are no components large enough to scatter visible light. 3. The components can be separated using processes that are a result of the intermolecular interactions between and among the components. e. Chromatography (paper and column) separates chemical species by taking advantage of the differential strength of intermolecular interactions between and among the components. f. Distillation is used to separate chemical species by taking advantage of the differential strength of intermolecular interactions between and among the	2.A.3	Science Practices for AP Chemistry (see Appendix 0.A)	
		The student is able to explain how solutes can be separated by chromatography based on intermolecular interactions. [See SP 6.2]	LO 2.7
		The student can draw and/or interpret representations of solutions that show the interactions between the solute and solvent. [See SP 1.1, 1.2, 6.4]	LO 2.8
		The student is able to create or interpret representations that link the concept of molarity with particle views of solutions. [See SP 1.1, 1.4]	LO 2.9
		The student can design and/or interpret the results of a separation experiment (filtration, paper chromatography, column chromatography, or distillation) in terms of the relative strength of interactions among and between the components. [See SP 4.2, 5.1, 6.4]	LO 2.10
		The student is able to apply Coulomb's law qualitatively (including using representations) to describe the interactions of ions, and the attractions between ions and solvents to explain the factors that contribute to the solubility of ionic compounds. [See SP 1.4, 6.4]	LO 2.14
		The student is able to explain observations regarding the solubility of ionic solids and molecules in water and other solvents on the basis of particle views that include intermolecular interactions and entropic effects. [See SP 1.4, 6.2, connects to 5.E.1]	LO 2.15
		The student can use Le Chatelier's principle to make qualitative predictions for systems in which coupled reactions that share a	LO 5.16

components and the effects these interactions have on the vapor pressures of the components in the mixture. g. The formation of a solution may be an exothermic or endothermic process, depending on the relative strengths of intermolecular/interparticle interactions before and after the dissolution process. h. Generally, when ionic compounds are dissolved in water, the component ions are separated and dispersed. The presence of ions in a solution can be detected by use of conductivity measurements. i. Solution composition can be expressed in a variety of ways; molarity is the most common method used in the laboratory. Molarity is defined as the number of moles of solute per liter of solution. j. Understanding how to prepare solutions of specified molarity through direct mixing of the components, through use of volumetric glassware, and by dilution of a solution of known molarity with additional solvent is important for performing laboratory work in chemistry. In many classes of reactions, it is important to consider both the forward and reverse reaction. a. Many readily observable processes are reversible. Examples include evaporating and condensing water, absorption of a gas, or dissolving and precipitating a salt. Relevant and interesting contexts include biological examples (binding of oxygen to hemoglobin and the attachment of molecules to receptor sites in the nose) and environmental examples (transfer of carbon between atmosphere and biosphere and transfer of dissolved substances between atmosphere and hydrosphere). b. Dissolution of a solid, transfer of protons in acid-base reactions, and transfer of electrons in redox reactions are important examples of reversible reactions.	6.A.1	common intermediate drive formation of a product. [See SP 6.4, connects to 6.B.1] The student can make quantitative predictions for systems involving coupled reactions that share a common intermediate, based on the equilibrium constant for the combined reaction. [See SP 6.4, connects to 6.A.2] The student is able to, given a set of experimental observations regarding physical, chemical, biological, or environmental processes that are reversible, construct an explanation that connects the observations to the reversibility of the underlying chemical reactions or processes. [See SP 6.2] The student can, given a manipulation of a chemical reaction or set of reactions (e.g., reversal of reaction or addition of two reactions), determine the effects of that manipulation on Q or K. [See SP 2.2] The student can connect kinetics to equilibrium by using reasoning about equilibrium, such as Le Chatelier's principle, to infer the relative rates of the forward and reverse reactions. [See SP 7.2] The student can, given a set of initial conditions (concentrations or partial pressures) and the equilibrium constant, K, use the tendency of Q to approach K to predict and justify the prediction as to whether the reaction will proceed toward products or reactants as equilibrium is approached. [See SP 2.2, 6.4] The student can, given data (tabular, graphical, etc.) from which the state of a system at equilibrium can be obtained, calculate the equilibrium constant, K. [See SP 2.2] The student can, given a set of initial conditions (concentrations or partial pressures) and the equilibrium constant, K, use	LO 5.17 LO 6.1 LO 6.2 LO 6.3 LO 6.4 LO 6.5 LO 6.6

The current state of a system undergoing a reversible reaction can be characterized by the extent to which reactants have been converted to products. The relative quantities of reaction components are quantitatively described by the reaction quotient, Q. a. Given an initial set of reactant and product concentrations, only those sets of concentrations that are consistent with the reaction stoichiometry can be attained. ICE (initial, change, equilibrium) tables are useful for determining which sets of concentration values are possible. b. The reaction quotient, Q, provides a convenient measure of the current progress of a reaction. Q does not include substances whose concentrations are independent of the amount of substance, such as for a solid in contact with a liquid solution or with a gas, or for a pure solid or liquid in contact with a gas. c. The value of Q (and so also K) changes when a reaction is reversed. When reactions are added together through the presence of a common intermediate, Q (and so also K) of the resulting reaction is a product of the values of Q (or K) for the original reactions.	6.A.2	stoichiometric relationships and the law of mass action (Q equals K at equilibrium) to determine qualitatively and/or quantitatively the conditions at equilibrium for a system involving a single reversible reaction. [See SP 2.2, 6.4] The student is able, for a reversible reaction that has a large or small K, to determine which chemical species will have very large versus very small concentrations at equilibrium. [See SP 2.2, 2.3] The student is able to use Le Chatelier's principle to predict the direction of the shift resulting from various possible stresses on a system at chemical equilibrium. [See SP 1.4, 6.4] The student is able to use Le Chatelier's principle to design a set of conditions that will optimize a desired outcome, such as product yield. [See SP 4.2] The student is able to connect Le Chatelier's principle to the comparison of Q to K by explaining the effects of the stress on Q and K. [See SP 1.4, 7.2] <u>Common Core Writing Standards for Grades 11-12</u>	LO 6.7 LO 6.8 LO 6.9 LO 6.10 WHST.2
When a system is at equilibrium, all macroscopic variables, such as concentrations, partial pressures, and temperature, do not change over time. Equilibrium results from an equality between the rates of the forward and reverse reactions, at which point Q = K. a. When equilibrium is reached, no observable changes occur in the system. 1. Reactant and product molecules are present. 2. Concentration of all species remains constant. b. If the rate of the forward reaction is greater than the reverse reaction, there is a net conversion of reactants	6.A.3	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. a. Introduce a topic and organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension. b. Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and	

to products. If the rate of the reverse reaction is greater than the forward reaction, there is a net conversion of products to reactants. An equilibrium state is reached when these rates balance, at which point the progress of reaction, Q, becomes equal to the equilibrium constant, K. c. Comparing Q to K allows the determination of whether the reaction is at equilibrium, or will proceed toward products or reactants to reach equilibrium. d. Equilibrium constants can be determined from experimental measurements of the concentrations of the reactants and products at equilibrium. e. Given a single reaction, initial concentrations, and K, the concentrations at equilibrium may be predicted. f. Graphs of concentration over time for simple chemical reactions can be used to understand the establishment of chemical equilibrium.		examples appropriate to the audience's knowledge of the topic. c. Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts. d. Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers. e. Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic).	
The magnitude of the equilibrium constant, K, can be used to determine whether the equilibrium lies toward the reactant side or product side. a. For many aqueous reactions, K is either very large or very small, and this may be used to reason qualitatively about equilibrium systems. b. Particulate representations can be used to describe the relationship between the numbers of reactant and product particles present at equilibrium, and the value of the equilibrium constant.	6.A.4	Students' narrative skills continue to grow in these grades. The Standards require that students be ab le to incorporate the narrative elements effectively into arguments and information/explanatory texts. In science, students must be able to write precise descriptions of the step-by-step procedures they use in their investigations that others can replicate them and (possibly) reach the same results.	WHST.3
Systems at equilibrium respond to disturbances by partially countering the effect of the disturbance (Le Chatelier's principle). a. Le Chatelier's principle can be used to predict the response of a system to the following stresses: addition or removal of a chemical species, change in temperature, change in volume/pressure of a gas phase	6.B.1	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.	WHST.4

system, and dilution of a reaction system with water or other solvent. b. Le Chatelier's principle can be used to reason about the effects a stress will have on experimentally measurable properties, such as pH, temperature, and color of a solution. A disturbance to a system at equilibrium causes Q to differ from K, thereby taking the system out of the original equilibrium state. The system responds by bringing Q back into agreement with K, thereby establishing a new equilibrium state. a. Le Chatelier's principle involves qualitative reasoning that is closely connected to the quantitative approach of 6.A.3. b. Some stresses, such as changes in concentration, cause a change in Q. A change in temperature causes a change in K. In either case, the reaction shifts to bring Q and K back into equality.	6.B.2		

EVIDENCE of LEARNING			
<u>Understanding</u> #1, #5	<u>Standards</u> 2.A.3 WHST.2	**<u>Unit Performance Assessment</u>**: *Lab Investigation #2: How can color be used to determine the mass percent of copper in brass?* See AP Chemistry Guided-Inquiry Experiments Investigation #2 (Student Manual), pages 23-28. Students measure the absorbance of various copper (II) salt solutions every 20 nm in the visible range (400 nm- 700 nm) to determine the wavelength of maximum absorbance for aqueous Cu^{+2} ions. Students then use stock 0.400 M $Cu(NO_3)_2$ solutions to make Cu^{+2} solutions of the following concentrations: 0.200 M, 0.100 M, 0.0500 M, and 0.0250 M. A graph of A vs. $[Cu^{+2}]$ is then constructed to determine the molar absorptivity of aqueous Cu^{+2} at the wavelength of maximum absorbance. Finally, an impure sample of copper, (in the form of a brass tack or nail) is dissolved in	**<u>R/R Quadrant</u>** **D**

		nitric acid and diluted with distilled water in a volumetric flask. The absorbance of the resulting solution is measured, and the percent copper in brass is determined. **Teacher will assess:** 1. The students' ability to correctly determine the correct wavelength for accurate analysis of Cu^{+2} ions. 2. The correct use of an Absorbance vs. [Cu^{+2}] graph to determine the molar absorptivity [Cu^{+2}] at the wavelength of maximum absorbance 3. The calculations used to determine the percent copper in brass based upon the results of the experiments. **<u>Performance:</u>** **Mastery:** Students will show that they really understand when they… 1. Achieve a Level 3, Level 4, or Level 5 **Scoring Guide:** See Appendix 3.A	

SAMPLE LEARNING PLAN

Pre-assessment: *Please see Appendix 0.C - AP Chemistry Pre-Assessment.*

<u>Understanding</u>	**<u>Standards</u>**	**<u>Major Learning Activities:</u>**	**<u>Instructional Strategy</u>:**	**<u>R/R Quadrant:</u>**
#3, #5	6.A.1 6.A.3 WHST.4	1. Activity: Frontloading Activity: Reversible Reactions Video www.bozemanscience.com/ap-chemistry	Technology Based Anticipatory Set	**C**

	ISTE-S.3	• Objective: Students are introduced to reversible reactions by going to www.bozemanscience.com/ap-chemistry and viewing video #62 on reversible chemical reactions. Students will complete Cornell-style notes on this short video. • Appendix Documents: Appendix 0.D – Cornell Notes Template Blank Appendix 0.E – Cornell Notes Grading Rubric		
#2, #3, #4, #5	6.B.1 6.B.2	2. Activity: LeChatelier's Principle • Objective: To stress a series of systems at equilibrium, and explain observations in terms of LeChatelier's Principle • Appendix Documents: Appendix 3.B – LeChatelier's Principle Lab Appendix 3.C – LeChatelier's Principle Lab Data Sheet	Generating and Testing Hypotheses Identifying Similarities and Differences	**C**
#4, #5	6.A.1 6.A.3 6.B.1 6.B.2	3. Activity: Case Study: A Case of Respiratory Distress • Objective: A patient reports to the emergency room complaining of a shortness of breath. Vital signs are taken, and students use Chemical Equilibrium to determine the likely cause of this patient's medical condition. • Appendix Documents: Appendix 3.D – Solution Equilibria Case Study (with scoring guide included).	This is a collaborative, scaffolded, multistep process that can take a number of directions based on student input.	**D**

UNIT RESOURCES
Teacher Resources: • Brown Lemay 12th Edition AP Chemistry, The Central Science, Teacher Manual • Laboratory Experiments for Advanced Placement Chemistry, by Sally Ann Vanderbrink, • Lab: LeChatelier's Principle (Lab #17 in cited book)

Student Resources:

- Brown Lemay 12th Edition AP Chemistry, The Central Science, Student Version
- Laboratory Experiments for Advanced Placement Chemistry, by Sally Ann Vanderbrink,
- Online learning platform provided by textbook Company
- AP Chemistry Guided-Inquiry Experiments (Student Manual)
- The website: www.bozemanscience.com/ap-chemistry
- "Color Vision Interactive Simulation." University of Colorado at Boulder, PhET Interactive Simulations (http://colorado.edu/en/simulation/color-vision

Vocabulary:

- Chemical Equilibrium – A state of dynamic balance in which the rate of formation of the products of a reaction equals the rate of formation of the reactants.
- K_c – The ratio of the concentrations of the products to the concentrations of the reactants (expressed in units of mol/L) for a gaseous system at equilibrium.
- Homogeneous Equilibria – The equilibrium established between reactant and product substances that are all in the same phase.
- Heterogeneous Equilibria – The equilibrium established between substances in two or more different phases.
- Reaction Quotient – The value that is obtained when concentrations of reactants and products are inserted into the equilibrium expression.
- Le Chatelier's Principle – A principle stating that when we disturb a system at chemical equilibrium, the relative concentrations of reactants and products shift so as to partially undo the effects of the disturbance.
- ICE Table – A table created to list or determine the initial concentration, change in concentration, and equilibrium concentration of a system at equilibrium.

Unit Description: This unit will focus on acid-base chemistry. Acid-base equilibria will be included. The use of ICE tables as well as LeChatelier's Principle will be applied to systems at equilibrium subjected to a stress.	**Unit Timeline:** Approximately 3 weeks.

DESIRED RESULTS
<u>Transfer Goal</u> - *Students will be able to independently use their learning to…* Develop advanced inquiry and reasoning skills, such as designing a plan for collecting data, analyzing data, applying mathematical routines in order to connect concepts in and across domains.

<u>Understandings</u> – *Students will understand that… (Big Ideas)*

1. Chemical equilibrium is a dynamic, reversible state in which rates of opposing processes are equal.
2. Systems at equilibrium are responsive to external perturbations, with the response leading to a change in the composition of the system.
3. Chemical equilibrium plays an important role in acid-base chemistry and in solubility.
4. The seven basic science practices (see Appendix 0.A) are intrinsic to any science field.

<u>Essential Questions</u>: *Students will keep considering…*

1. What is the definition of an Arrhenius acid, Arrhenius base, Bronsted-Lowry acid, and Bronsted-Lowry base?
2. What is the difference between K_c, K_a, K_b and K_w? Under what circumstance does each apply?
3. What is the difference in molecular structure between a weak acid and a strong acid?
4. What is pH and how can it be calculated for acids and bases?
5. What is a buffer solution? How can a buffer solution be made?
6. What is the relationship between a titration curve and the nature of the acid and base used in the titration?

Students Will Know…	Standard	Students Will Be Able to …	Standard
In a neutralization reaction, protons are transferred from an acid to a base. a. The amphoteric nature of water plays an important role in the chemistry of aqueous solutions, since water can both accept protons from and donate protons to dissolved species. b. Acid-base reactions: 1. Only reactions in aqueous solutions are considered. 2. The Brønsted-Lowry concept of acids and bases is the focus of the course.	3.B.2	Science Practices for AP Chemistry (see Appendix 0.A) The student is able to identify compounds as Brønsted-Lowry acids, bases, and/or conjugate acid-base pairs, using proton-transfer reactions to justify the identification. [See SP 6.1] The student is able to, given a set of experimental observations regarding physical, chemical, biological, or environmental processes that are reversible, construct an explanation that connects the observations to the reversibility of the underlying chemical reactions or processes. [See SP 6.2]	 LO 3.7 LO 6.1
In many classes of reactions, it is important to consider both the forward and reverse reaction. a. Many readily observable processes are reversible. Examples include evaporating and condensing water, absorption of a gas, or dissolving and precipitating a salt. Relevant and interesting contexts include biological examples (binding of oxygen to hemoglobin and the attachment of molecules to receptor sites in the nose) and environmental examples (transfer of carbon between atmosphere and biosphere and transfer of dissolved substances between atmosphere and hydrosphere). b. Dissolution of a solid, transfer of protons in acid-base reactions, and transfer of electrons in redox reactions are important examples of reversible reactions.	6.A.1	The student can, given a manipulation of a chemical reaction or set of reactions (e.g., reversal of reaction or addition of two reactions), determine the effects of that manipulation on Q or K. [See SP 2.2] The student can connect kinetics to equilibrium by using reasoning about equilibrium, such as Le Chatelier's principle, to infer the relative rates of the forward and reverse reactions. [See SP 7.2] The student can, given a set of initial conditions (concentrations or partial pressures) and the equilibrium constant, K, use the tendency of Q to approach K to predict and justify the prediction as to whether the reaction will proceed toward products or reactants as equilibrium is approached. [See SP 2.2, 6.4]	LO 6.2 LO 6.3 LO 6.4
The current state of a system undergoing a reversible reaction can be characterized by the extent to which reactants have been converted to products. The relative quantities of reaction components are quantitatively described by the reaction quotient, Q.	6.A.2	The student can, given data (tabular, graphical, etc.) from which the state of a system at equilibrium can be obtained, calculate the equilibrium constant, K. [See SP 2.2] The student can, given a set of initial conditions (concentrations or partial pressures) and the equilibrium constant, K, use	LO 6.5 LO 6.6

a. Given an initial set of reactant and product concentrations, only those sets of concentrations that are consistent with the reaction stoichiometry can be attained. ICE (initial, change, equilibrium) tables are useful for determining which sets of concentration values are possible. b. The reaction quotient, Q, provides a convenient measure of the current progress of a reaction. Q does not include substances whose concentrations are independent of the amount of substance, such as for a solid in contact with a liquid solution or with a gas, or for a pure solid or liquid in contact with a gas. c. The value of Q (and so also K) changes when a reaction is reversed. When reactions are added together through the presence of a common intermediate, Q (and so also K) of the resulting reaction is a product of the values of Q (or K) for the original reactions.		stoichiometric relationships and the law of mass action (Q equals K at equilibrium) to determine qualitatively and/or quantitatively the conditions at equilibrium for a system involving a single reversible reaction. [See SP 2.2, 6.4]	
		The student is able, for a reversible reaction that has a large or small K, to determine which chemical species will have very large versus very small concentrations at equilibrium. [See SP 2.2, 2.3]	LO 6.7
		The student is able to use Le Chatelier's principle to predict the direction of the shift resulting from various possible stresses on a system at chemical equilibrium. [See SP 1.4, 6.4]	LO 6.8
		The student is able to use Le Chatelier's principle to design a set of conditions that will optimize a desired outcome, such as product yield. [See SP 4.2]	LO 6.9
When a system is at equilibrium, all macroscopic variables, such as concentrations, partial pressures, and temperature, do not change over time. Equilibrium results from an equality between the rates of the forward and reverse reactions, at which point Q = K. a. When equilibrium is reached, no observable changes occur in the system. 1. Reactant and product molecules are present. 2. Concentration of all species remains constant. b. If the rate of the forward reaction is greater than the reverse reaction, there is a net conversion of reactants to products. If the rate of the reverse reaction is greater than the forward reaction, there is a net conversion of products to reactants. An equilibrium state is reached when these rates balance, at which point the progress of reaction, Q, becomes equal to the equilibrium constant, K.	6.A.3	The student is able to connect Le Chatelier's principle to the comparison of Q to K by explaining the effects of the stress on Q and K. [See SP 1.4, 7.2]	LO 6.10
		The student can generate or use a particulate representation of an acid (strong or weak or polyprotic) and a strong base to explain the species that will have large versus small concentrations at equilibrium. [See SP 1.1, 1.4, 2.3]	LO 6.11
		The student can reason about the distinction between strong and weak acid solutions with similar values of pH, including the percent ionization of the acids, the concentrations needed to achieve the same pH, and the amount of base needed to reach the equivalence point in a titration. [See SP 1.4, 6.4, connects to 1.E.2]	LO 6.12
		The student can interpret titration data for monoprotic or polyprotic acids involving titration of a weak or strong acid by a	LO 6.13

c. Comparing Q to K allows the determination of whether the reaction is at equilibrium, or will proceed toward products or reactants to reach equilibrium. d. Equilibrium constants can be determined from experimental measurements of the concentrations of the reactants and products at equilibrium.		strong base (or a weak or strong base by a strong acid) to determine the concentration of the titrant and the pKa for a weak acid, or the pKb for a weak base. [See SP 5.1, 6.4, connects to 1.E.2]	
e. Given a single reaction, initial concentrations, and K, the concentrations at equilibrium may be predicted. f. Graphs of concentration over time for simple chemical reactions can be used to understand the establishment of chemical equilibrium.		The student can, based on the dependence of Kw on temperature, reason that neutrality requires [H+] = [OH–] as opposed to requiring pH = 7, including especially the applications to biological systems. [See SP 2.2, 6.2]	LO 6.14
The magnitude of the equilibrium constant, K, can be used to determine whether the equilibrium lies toward the reactant side or product side.	6.A.4	The student can identify a given solution as containing a mixture of strong acids and/or bases and calculate or estimate the pH (and concentrations of all chemical species) in the resulting solution. [See SP 2.2, 2.3, 6.4]	LO 6.15
a. For many aqueous reactions, K is either very large or very small, and this may be used to reason qualitatively about equilibrium systems. b. Particulate representations can be used to describe the relationship between the numbers of reactant and product particles present at equilibrium, and the value of the equilibrium constant.		The student can identify a given solution as being the solution of a monoprotic weak acid or base (including salts in which one ion is a weak acid or base), calculate the pH and concentration of all species in the solution, and/ or infer the relative strengths of the weak acids or bases from given equilibrium concentrations. [See SP 2.2, 6.4]	LO 6.16
Systems at equilibrium respond to disturbances by partially countering the effect of the disturbance (Le Chatelier's principle).	6.B.1	The student can, given an arbitrary mixture of weak and strong acids and bases (including polyprotic systems), determine which species will react strongly with one another (i.e., with K >1) and what species will be present in large concentrations at equilibrium. [See SP 6.4]	LO 6.17
a. Le Chatelier's principle can be used to predict the response of a system to the following stresses: addition or removal of a chemical species, change in temperature, change in volume/pressure of a gas phase system, and dilution of a reaction system with water or other solvent.		The student can design a buffer solution with a target pH and buffer capacity by selecting an appropriate conjugate acid-base pair and estimating the concentrations needed to achieve the desired capacity. [See SP 2.3, 4.2, 6.4]	LO 6.18
b. Le Chatelier's principle can be used to reason about the effects a stress will have on experimentally measurable properties, such as pH, temperature, and color of a solution.		The student can relate the predominant form of a chemical species involving a labile proton (i.e., protonated/deprotonated	LO 6.19

A disturbance to a system at equilibrium causes Q to differ from K, thereby taking the system out of the original equilibrium state. The system responds by bringing Q back into agreement with K, thereby establishing a new equilibrium state. a. Le Chatelier's principle involves qualitative reasoning that is closely connected to the quantitative approach of 6.A.3. b. Some stresses, such as changes in concentration, cause a change in Q. A change in temperature causes a change in K. In either case, the reaction shifts to bring Q and K back into equality.	6.B.2	form of a weak acid) to the pH of a solution and the pKa associated with the labile proton. [See SP 2.3, 5.1, 6.4] The student can identify a solution as being a buffer solution and explain the buffer mechanism in terms of the reactions that would occur on addition of acid or base. [See SP 6.4] The student can predict the solubility of a salt, or rank the solubility of salts, given the relevant Ksp values. [See SP 2.2, 2.3, 6.4]	LO 6.20 LO 6.21
Chemical equilibrium reasoning can be used to describe the proton-transfer reactions of acid-base chemistry. a. The concentrations of hydronium ion and hydroxide ion are often reported as pH and pOH, respectively. b. Water autoionizes with an equilibrium constant, K_w. For pure water, pH = pOH, and this condition is called "neutrality," or a neutral solution. At 25°C, $pK_w = 14$, and thus pH and pOH add to 14. In pure water at 25°C, pH = pOH = 7. c. Common strong acids include HCl, HBr, HI, $HClO_4$, H_2SO_4, and HNO_3. The molecules of strong acids completely ionize in solution to produce hydronium ions. In other words, 100 percent of the molecules of the strong acid are ionized in a solution (assuming that the concentration is not extremely high). As such, the concentration of $H3O^+$ in a strong acid solution is equal to the initial concentration of the strong acid, and thus the pH of the strong acid solution is easily calculated. d. Common strong bases include group I and II hydroxides. When dissolved in solution, strong bases completely dissociate to produce hydroxide ions. Note	6.C.1	The student can interpret data regarding solubility of salts to determine, or rank, the relevant Ksp values. [See SP 2.2, 2.3, 6.4] The student can interpret data regarding the relative solubility of salts in terms of factors (common ions, pH) that influence the solubility. [See SP 5.1, 6.4] The student can analyze the enthalpic and entropic changes associated with the dissolution of a salt, using particulate level interactions and representations. [See SP 1.4, 7.1, connects to 5.E] Common Core Writing Standards for Grades 11-12 Write arguments focused on *discipline-specific content*. a. Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence. b. Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and	LO 6.22 LO 6.23 LO 6.24 WHST.1

that some group II hydroxides are slightly soluble in water. However, 100 percent of the dissolved base is ionized. e. Weak acid molecules react with water to transfer a proton to the water molecule. However, weak acid molecules only partially ionize in this way. In other words, only a small percentage of the molecules of a weak acid are ionized in a solution (assuming that the initial concentration is not extremely low). Thus, the concentration of H3O+ does not equal the initial concentration of the molecular acid, and the vast majority of the acid molecules remain un-ionized. A solution of a weak acid thus involves equilibrium between an un-ionized acid and its conjugate base. The equilibrium constant for this reaction is Ka, often reported as pKa. The pH of a weak acid solution can be determined from the initial acid concentration and the pKa. The common weak acids include carboxylic acids. The relative magnitudes of Ka's are influenced by structural factors such as bond strength, solvation, and electronegativity of the atom bonded to the labile proton. f. The common weak bases include ammonia, amines and pyridines, other nitrogenous bases, and conjugate bases (defined below in g). Weak base molecules in aqueous solutions react with water molecules to produce hydroxide ions. However, only a small percentage of the molecules of a weak base in a solution ionize in this way (assuming that the initial concentration is not extremely low). Thus, the concentration of OH^- in the solution does not equal the initial concentration of the molecular base, and the vast majority of the base molecules remain un-ionized. A solution of a weak base thus involves an equilibrium between an un-ionized base and its conjugate acid. The equilibrium constant for this		evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience's knowledge level, concerns, values, and possible biases. c. Use words, phrases, and clauses as well as varied syntax to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims. d. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing. e. Provide a concluding statement or section that follows from or supports the argument presented. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.	WHST.4

reaction is Kb, often reported as pKb. The pH of a weak base solution can be determined from the initial base concentration and the pKb.

g. When an acid molecule loses its proton, it becomes a base, since the resultant ion could react with water as a base. The acid and base are referred to as a conjugate acid-base pair. The ionization constants for the acid-base pair are related to Kw, and at 25°C, pKa + pKb = 14. This relation can be used to reason qualitatively about the relative strengths of conjugate acids and bases. For example, the conjugate base of a strong acid is a much weaker base than H2O, and therefore does not react as a base in aqueous solutions.

h. The pH of an acid solution depends on both the strength of the acid and the concentration of the acid. If we compare solutions of a weak acid and of a strong acid at the same pH, we find that both solutions have the same concentration of H3O+ (aq). However, the strong acid is completely dissociated into ions in solution, whereas the weak acid is only partially dissociated into ions in solution. Thus, there are vastly more un-ionized acid molecules in the weak acid solution than in the strong acid solution at the same pH. Thus, to achieve solutions of equal pH, the weak acid solution must be a much greater concentration than the strong acid solution. If we compare solutions of a weak acid and of a strong acid of the same initial concentration, the concentration of H3O+ in the strong acid solution is much larger (and the pH thus lower) since the strong acid is 100 percent ionized.

i. Reactions of acids and bases are called neutralization reactions, and these reactions generally have K > 1, and thus can be considered to go to completion.
    - For a mixture of a strong acid with a strong base, the neutralization reaction is H3O+ + OH– → H2O. The K for this reaction is 1014

at 25°C, so the reaction goes to completion. This allows the pH of mixtures of strong acids and bases to be determined from the limiting reactant, either the acid or the base.

- When a strong base is added to a solution of a weak acid, a neutralization reaction occurs: conjugate acid + OH- → conjugate base + H2O.
- When a strong acid is added to a solution of a weak base, a neutralization reaction occurs: conjugate base + H3O+ → conjugate acid + H2O.

j. For a weak acid solution and a strong acid solution with the same pH, it takes much more base to neutralize the weak acid solution because the initial acid concentration is much larger. The weak acid solution contains a large amount of un-ionized acid molecules. Therefore, a weak acid solution resists changes in pH for a much greater amount of added base.

k. A titration technique exists for neutralization reactions. At the equivalence point, the moles of titrant and the moles of titrate are present in stoichiometric proportions. In the vicinity of the equivalence point, the pH rapidly changes. This can be used to determine the concentration of the titrant.

l. As base is added to either a strong acid solution or a weak acid solution, the H3O^{+} (aq) concentration does not change much. The change in pH is less than ~1.5 for the region where 10 to 90 percent of the base needed to reach the equivalence point has been added.

m. The pKa of an acid can be determined from the pH at the half equivalence point of the titration if the equivalence point is known (i.e., the concentration of both the titrant and analyte are known).

n. For polyprotic acids, the use of titration curves to evaluate the number of labile protons is important, as well as knowing which species are present in large concentrations at any region along the curve. o. Halfway to the equivalence point, the contents of a solution, formed by titrating a weak acid, is different from that formed by titrating a strong acid. For a strong acid, the main species in a solution halfway to the equivalence point are H3O+(aq), the anion from the acid (e.g., Cl–, NO3–), and the cation from the base (e.g., Na+). The total positive charge is equal to the total negative charge. For a weak acid, the main species in a solution halfway to the equivalence point are H3O+(aq), the anion from the acid (e.g., CH3COO–, F–), the cation from the base (e.g., Na+), and undissociated acid, HA. The total positive charge is equal to the total negative charge, and [HA] = [A–].			
The pH is an important characteristic of aqueous solutions that can be controlled with buffers. Comparing pH to pKa allows one to determine the protonation state of a molecule with a labile proton. --- The pH of an aqueous solution is determined by the identity and concentration of the substance that is dissolved in water. The value of the pH is an important feature of the solution because it characterizes the relative tendency of the solution to accept a proton from an acid added to the solution, or to donate a proton to a base that is added. For acid- base systems, pH characterizes the relative availability of protons, much as temperature characterizes the relative availability of kinetic energy in the environment. It is often desirable to use a solution as an environment that maintains a relatively constant pH so that the addition of an acid or base does not change the pH (e.g., amino acids and proteins in the body — the blood maintains a relatively constant pH). a. A buffer solution contains a large concentration of both members in a conjugate acid-base pair. The	6.C.2		

conjugate acid reacts with added base and the conjugate base reacts with added acid. The pH of the buffer is related to the pKa and the concentration ratio of acid and base forms. The buffer capacity is related to absolute concentrations of the acid and base forms. These relationships can be used both quantitatively and qualitatively to reason about issues such as the ratio of acid to base forms in a given buffer, the impact of this on the buffer capacity for added acid or base, and the choice of an appropriate conjugate acid-base pair for a desired buffer pH (including polyprotic acids). b. If [A–]/[HA] starts as 1, it is not until the ratio changes by a factor of 10 that a 1 pH unit change occurs; adding small amounts of either acid or base does not change the ratio much, so the pH changes are much smaller for buffers than unbuffered solutions. c. Weak acids and their conjugate bases make good buffers. Strong acids and bases do not. It takes much more base to change the pH of a weak acid solution because there is a large reservoir of undissociated weak acid. d. By comparing the pH of a solution to the pKa of any acid in the solution, the concentration ratio between the acid and base forms of that acid (the protonation state) can be determined. For example, if pH < pKa, the acid form has a higher concentration than the base form. If pH > pKa, the base form has a higher concentration than the acid form. Applications of this relationship include the use of acid-base indicators, the protonation state of protein side chains (including acids or proteins with multiple labile protons), and the pH required for acid- catalyzed reactions in organic chemistry.	6.C.3		

The solubility of a substance can be understood in terms of chemical equilibrium. a. The dissolution of a substance in a solvent is a reversible reaction, and so has an associated equilibrium constant. For dissolution of a salt, the reaction quotient, Q, is referred to as the solubility product, and the equilibrium constant for this reaction is denoted as Ksp, the solubility-product constant. b. The solubility of a substance can be calculated from the Ksp for the dissolution reaction. This relation can also be used to reason qualitatively about the relative solubility of different substances. c. The free energy change ($\Delta G°$) for dissolution of a substance reflects both the breaking of the forces that hold the solid together and the interaction of the dissolved species with the solvent. In addition, entropic effects must be considered. Qualitative reasoning regarding solubility requires consideration of all of these contributions to the free energy. d. All sodium, potassium, ammonium, and nitrate salts are soluble in water. e. A salt is less soluble in a solution that has an ion in common with the salt. This has important consequences for solubility of salts in sea water and other natural bodies of water. This phenomenon can be understood qualitatively using Le Chatelier's principle. f. The solubility of a salt will be pH sensitive when one of the ions is an acid or base. Applications include the iron hydroxides of acid-mine drainage and the effects of acid rain on solubility of carbonates. These effects can be understood qualitatively with Le Chatelier's principle.			

EVIDENCE of LEARNING			
<u>Understanding</u> #1, #2, #3, #4	<u>Standards</u> 6.C.1 WHST.1 WHST.4	**<u>Unit Performance Assessment</u>**: *Lab Investigation #14: How do the structure and initial concentration of an acid and a base influence the pH of the resultant solutions during a titration?* See AP Chemistry Guided-Inquiry Experiments Investigation #14 (Student Manual), pages 117-124. In this laboratory experience, students experiment with a variety of acids, including strong monoprotic acids (HCl and HNO_3), a weak monoprotic acid ($HC_2H_3O_2$) and a diprotic acid (H_2SO_4). Students then conduct titrations of these acids with various bases (NH_3, NaOH and $Ca(OH)_2$). Titration curves of pH as a function of Volume of Base Added are constructed and students draw conclusions about the relative strength of acids and bases based upon the shape of the resultant graph and the chemical structure of the reactant species. **Teacher will assess:** 1. The correct construction of the titration curves and the correct classification of acids and bases as strong or weak, monoprotic or diprotic. 2. The relative strength of acids and bases is correctly explained in terms of chemical structure and bonding within the reactant species. 3. The 8 post-lab questions will be assessed in terms of accuracy and depth of understanding. **<u>Performance:</u>** **Mastery:** Students will show that they really understand when they… 1. Achieve a Level 3, Level 4, or Level 5 **Scoring Guide:** See Appendix 4.A	**<u>R/R Quadrant</u>** **D**

SAMPLE LEARNING PLAN

Pre-assessment: *Please see Appendix 0.C - AP Chemistry Pre-Assessment.*

Understanding	Standards	Major Learning Activities:	Instructional Strategy:	R/R Quadrant:
#3, #4	6.C.1 WHST.4 ISTE-S.3	1. Activity: Frontloading Activity: pH Video • Objective: Students are introduced to pH and weak acid chemical equilibria by going to www.bozemanscience.com/ap-chemistry and viewing video #69 on pH. Students will complete Cornell-style notes on this short video. • Appendix Documents: Appendix 0.D – Cornell Notes Template Appendix 0.E – Cornell Notes Grading Rubric	Technology Based Anticipatory Set	**C**
#2, #3, #4	6.C.2 WHST.4	2. Activity: Lab: Equivalent Mass and PK_a of a weak acid. • Objective: To stress a series of systems at equilibrium, and explain observations in terms of LeChatelier's Principle. • Appendix Documents: Appendix 4.B - Equivalent Mass and pK_a of a Weak Acid Lab Appendix 4.C - Equivalent Mass and pK_a of a Weak Acid Data Sheet	Inquiry Based Laboratory	**D**
#1, #2, #3, #4	3.B.2 6.A.1 6.C.1 6.C.2	3. Activity: Case Study – The Case of the Mortified Mom • Objective: A young person has accidentally ingested a large amount of acetylsalicylic acid (aspirin). Students must apply acid-base equilibria to diagnose and treat this person's dilemma. • Appendix Documents:	This is a collaborative, scaffolded, multistep process that can take a number of	**D**

		Appendix 4.D - The Case of the Mortified Mom Appendix 4.E - The Case of the Mortified Mom Power Point	directions based on student input.	

UNIT RESOURCES

Teacher Resources:

- Brown Lemay 12th Edition AP Chemistry, The Central Science, Teacher Manual
- Laboratory Experiments for Advanced Placement Chemistry, by Sally Ann Vanderbrink,
- Lab: Equivalent Mass and PK_a of an Unknown Acid (Lab #16 in cited book)

Student Resources:

- Brown Lemay 12th Edition AP Chemistry, The Central Science, Student Version
- Laboratory Experiments for Advanced Placement Chemistry, by Sally Ann Vanderbrink,
- Online learning platform provided by textbook Company
- The titration simulation available at: http://group.chem.iastate.edu/Greenbowe/sections/projectfolder/flashfiles/stoichiometry/a_b_phtitr.html
- "Acid-Base Titrations." University of Colorado at Boulder, PhET Interactive Simulations. http://phet.colorado.edu/en/simulation/acid-base-solutions

Vocabulary:

- Acid – A substance capable of donating a H^+ ion (a proton).
- Base – A substance that is an OH- donor or an H^+ acceptor.
- Hydronium ion – Takes the formula H_3O^+ and is the predominant form of the proton in aqueous solution
- Brownsted-Lowry Acid – A substance that acts as a proton donor
- Bronsted-Lowry Base – A substance that acts as a proton acceptor
- Conjugate Acid-Base Pair – An acid and a base, that differ only in the presence or absence of a proton.
- pH – The negative log (in base 10) of the hydrogen ion concentration: $pH = -log[H^+]$
- pOH - The negative log (in base 10) of the hydroxide ion concentration: $pH = -log[OH^-]$
- Indicator – A substance added to a solution that changes color when the added solute has reacted with all the solute present in solution.
- Percent ionization – The percent of a substance that undergoes ionization when dissolved in water.
- Polyprotic Acid – a substance capable of dissociating more than one proton in water.
- Chemical Equilibrium – A state of dynamic balance in which the rate of formation of the products of a reaction equals the rate of formation of the reactants.
- K_c – The ratio of the concentrations of the products to the concentrations of the reactants (expressed in units of mol/L) for a gaseous system at equilibrium.

- K_w – The equilibrium constant for the dissociation of water, generally taken to be 1.00 X 10^{-14} at 25 °C, $K_w = [H^+][OH^-]$= 1.00 X 10^{-14}
- K_a – The dissociation constant for weak acids.
- K_b – The dissociation constant for weak bases
- Homogeneous Equilibria – The equilibrium established between reactant and product substances that are all in the same phase.
- Heterogeneous Equilibria – The equilibrium established between substances in two or more different phases.
- Reaction Quotient – The value that is obtained when concentrations of reactants and products are inserted into the equilibrium expression.
- Le Chatelier's Principle – A principle stating that when we disturb a system at chemical equilibrium, the relative concentrations of reactants and products shift so as to partially undo the effects of the disturbance.
- ICE Table – A table created to list or determine the initial concentration, change in concentration, and equilibrium concentration of a system at equilibrium.
- Common- ion Effect – A shift of an equilibrium induced by an ion common to the equilibrium.
- Buffered Solutions – A solution that undergoes a limited change in pH upon addition of a small amount of acid or base.
- Buffer Capacity – The amount of acid or base a buffer can neutralize before the pH begins to change appreciable
- pH titration curve – A graph of pH as a function of added titrant.
- Equivalence Point – The point in a titration at which the added solute reacts completely with the solute present in the solution
- K_{sp} – Used to represent the solubility product expression
- Selective Precipitation – Precipitation of one ion while leaving other ions present in solution

Content Area: Science	Course: AP Chemistry II	Unit 5: Electronic Structure & Periodic Trends
Unit Description: The chemical properties of an atom are determined by its electron structure, i.e., the number and arrangement of electrons about the nucleus. One can use the electronic structure of an atom to predict much of the chemical behavior of the corresponding element. Scientists constantly seek ways to organize factual material so that similarities, differences, and trends become more apparent. The most useful device for this purpose is the periodic table. As one moves down a family or across a period, the physical properties of the elements change in a smooth regular fashion. Within a group, the elements show very similar chemical properties.		**Unit Timeline:** Approximately 3 weeks.

DESIRED RESULTS
<u>Transfer Goal</u> - *Students will be able to independently use their learning to…* Develop advanced inquiry and reasoning skills, such as designing a plan for collecting data, analyzing data, applying mathematical routines in order to connect concepts in and across domains.

<u>Understandings</u> – *Students will understand that… (Big Ideas)*

1. Elements display periodicity in their properties when the elements are organized according to increasing atomic number. This periodicity can be explained by the regular variations that occur in the electronic structures of atoms. Periodicity is a useful principle for understanding properties and predicting trends in properties.
2. Atoms are so small that they are difficult to study directly; atomic models are constructed to explain experimental data on collections of atoms.

3. The seven basic science practices (see Appendix 0.A) are intrinsic to any science field.

<u>Essential Questions</u>: *Students will keep considering…*

1. How can periodicity be used to predict properties of elements?
2. How can atomic models be used to indirectly study atoms?
3. How can PES data, ionization energy data, and/or Coulomb's law be used to construct explanations of how the energies of electrons within shells in atoms vary?

Students Will Know…	Standard	Students Will Be Able to …	Standard

The electronic structure of the atom can be described using an electron configuration that reflects the concept of electrons in quantized energy levels or shells; the energetics of the electrons in the atom can be understood by consideration of Coulomb's law. a. Electron configurations provide a method for describing the distribution of electrons in an atom or ion. b. Each electron in an atom has a different ionization energy, which can be qualitatively explained through Coulomb's law. c. In multielectron atoms and ions, the electrons can be thought of as being in "shells" and "subshells," as indicated by the relatively close ionization energies associated with some groups of electrons. Inner electrons are called core electrons, and outer electrons are called valence electrons. d. Core electrons are generally closer to the nucleus than valence electrons, and they are considered to "shield" the valence electrons from the full electrostatic attraction of the nucleus. This phenomenon can be used in conjunction with Coulomb's law to explain/rationalize/predict relative ionization energies. Differences in electron-electron repulsion are responsible for the differences in energy between electrons in different orbitals in the same shell.	1.B.2	Science Practices for AP Chemistry (see Appendix 0.A)	
		The student is able to explain the distribution of electrons in an atom or ion based upon data.	LO 1.5
		The student is able to analyze data relating to electron energies for patterns and relationships.	LO 1.6
		The student is able to describe the electronic structure of the atom, using PES data, ionization energy data, and/or Coulomb's law to construct explanations of how the energies of electrons within shells in atoms vary.	LO 1.7
		The student is able to explain the distribution of electrons using Coulomb's law to analyze measured energies.	LO 1.8
		The student is able to predict and/or justify trends in atomic properties based on location on the periodic table and/or the shell model.	LO 1.9
		Students can justify with evidence the arrangement of the periodic table and can apply periodic properties to chemical reactivity.	LO 1.10
		The student can analyze data, based on periodicity and the properties of binary compounds, to identify patterns and generate hypotheses related to the molecular design of compounds for which data are not supplied.	LO 1.11
Many properties of atoms exhibit periodic trends that are reflective of the periodicity of electronic structure. a. The structure of the periodic table is a consequence of the pattern of electron configurations and the presence of shells (and subshells) of electrons in atoms. b. Ignoring the few exceptions, the electron configuration for an atom can be deduced from the element's position in the periodic table.	1.C.1	The student is able to explain why a given set of data suggests, or does not suggest, the need to refine the atomic model from a classical shell model with the quantum mechanical model.	LO 1.12
			LO 1.13

c. For many atomic properties, trends within the periodic table (and relative values for different atoms and ions) can be qualitatively understood and explained using Coulomb's law, the shell model, and the concept of shielding/effective nuclear charge. These properties include: 1. First ionization energy 2. Atomic and ionic radii 3. Electronegativity 4. Typical ionic charges d. Periodicity is a useful tool when designing new molecules or materials, since replacing an element of one group with another of the same group may lead to a new substance with similar properties. For instance, since SiO_2 can be a ceramic, SnO_2 may be as well.		Given information about a particular model of the atom, the student is able to determine if the model is consistent with specified evidence. The student is able to use data from mass spectrometry to identify the elements and the masses of individual atoms of a specific element. The student can justify the selection of a particular type of spectroscopy to measure properties associated with vibrational or electronic motions of molecules. The student can design and/or interpret the results of an experiment regarding the absorption of light to determine the concentration of an absorbing species in a solution.	LO 1.14 LO 1.15 LO 1.16
The currently accepted best model of the atom is based on the quantum mechanical model. a. Coulomb's law is the basis for describing the energy of interaction between protons and electrons. b. Electrons are not considered to follow specific orbits. Chemists refer to the region of space in which an electron is found as an orbital. c. Electrons in atoms have an intrinsic property known as spin that can result in atoms having a magnetic moment. There can be at most two electrons in any orbital, and these electrons must have opposite spin. d. The quantum mechanical (QM) model addresses known problems with the classical shell model and is also consistent with atomic electronic structures that correspond with the periodic table. e. The QM model can be approximately solved using computers and serves as the basis for software that calculates the structure and reactivity of molecules.	1.C.2	<u>Common Core Reading Standards for Grades 11-12</u> Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11–12 texts and topics*. Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible	RST.1 RST.2 RST.4 RST.8

As is the case with all scientific models, any model of the atom is subject to refinement and change in response to new experimental results. In that sense, an atomic model is not regarded as an exact description of the atom, but rather a theoretical construct that fits a set of experimental data. a. Scientists use experimental results to test scientific models. When experimental results are not consistent with the predictions of a scientific model, the model must be revised or replaced with a new model that is able to predict/explain the new experimental results. A robust scientific model is one that can be used to explain/predict numerous results over a wide range of experimental circumstances. b. The construction of a shell model of the atom through ionization energy information provides an opportunity to show how a model can be refined and changed as additional information is considered. An early model of the atom stated that all atoms of an element are identical. Mass spectrometry data demonstrate evidence that contradicts this early model. a. Data from mass spectrometry demonstrate evidence that an early model of the atom (Dalton's model) is incorrect; these data then require a modification of that model. b. Data from mass spectrometry also demonstrate direct evidence of different isotopes from the same element. c. The average atomic mass can be estimated from mass spectra. The interaction of electromagnetic waves or light with matter is a powerful means to probe the structure of atoms and molecules, and to measure their concentration. a. The energy of a photon is related to the frequency of the electromagnetic wave through Planck's equation ($E = hv$). When a photon is absorbed (or emitted) by a	1.D.1 1.D.2 1.D.3	and corroborating or challenging conclusions with other sources of information. Common Core Writing Standards for Grades 11-12 Write arguments focused on *discipline-specific content*. a. Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence. b. Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience's knowledge level, concerns, values, and possible biases. c. Use words, phrases, and clauses as well as varied syntax to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims. d. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing. e. Provide a concluding statement or section that follows from or supports the argument presented.	 WHST.1 WHST.3

molecule, the energy of the molecule is increased (or decreased) by an amount equal to the energy of the photon. b. Different types of molecular motion lead to absorption or emission of photons in different spectral regions. Infrared radiation is associated with transitions in molecular vibrations and so can be used to detect the presence of different types of bonds. Ultraviolet/visible radiation is associated with transitions in electronic energy levels and so can be used to probe electronic structure. c. The amount of light absorbed by a solution can be used to determine the concentration of the absorbing molecules in that solution, via the Beer-Lambert law.		Students' narrative skills continue to grow in these grades. The Standards require that students be ab le to incorporate the narrative elements effectively into arguments and information/explanatory texts. In science, students must be able to write precise descriptions of the step-by-step procedures they use in their investigations that others can replicate them and (possibly) reach the same results. <u>ISTE Technology Standards</u> Critical Thinking, Problem Solving, and Decision Making: Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources. a. Identify and define authentic problems and significant questions for investigation b. Plan and manage activities to develop a solution or complete a project c. Collect and analyze data to identify solutions and/or make informed decisions d. Use multiple processes and diverse perspectives to explore alternative solutions	ISTE-S.4

EVIDENCE of LEARNING			
<u>Understanding</u> #1, #2, #3	<u>Standards</u> LO 2.10 LO 2.13 WHST.3 ISTE-S.4	**<u>Unit Performance Assessment</u>**: **Description of Assessment Performance Task(s):** *Lab Investigation #5: Sticky Question: How Do You Separate Molecules That Are Attracted to One Another?* See AP Chemistry Guided-Inquiry Experiments Investigation #5 (Student Manual). . **Teacher will assess:** 1. Students design a new method of separation to improve the results. 2. Students collect data using different solvents to identify the optimal solvent for separation. 3. Students illustrate the intermolecular forces that are acting on the molecules in the separation. 4. Students evaluate the selected solvents based on the tenets of green chemistry and rank the possible solvents based upon the resources about green chemistry solvent ranking. **<u>Performance:</u>** **Mastery:** Students will show that they really understand when they… 2. Achieve a Level 3, Level 4, or Level 5 **Scoring Guide:** See Appendix 5.A	**<u>R/R Quadrant</u>** **D**

SAMPLE LEARNING PLAN				
Pre-assessment: *Please see Appendix 0.C - AP Chemistry Pre-Assessment.*				
Understanding	**Standards**	**Major Learning Activities:**	**Instructional Strategy:**	**R/R Quadrant:**
#1	LO 1.9 LO 1.10	1. Activity: Cracking the Periodic Table Code: Process oriented guided inquiry learning activity Students work cooperatively in pairs to analyze and answer guided inquiry learning questions on the design of the periodic table. Students will use the Rally Coach structure in which students alternate the responsibilities of performing the written procedure and answering questions as the other person coaches and gives feedback. ● Objective: The objective of the inquiry activity is to gain an understanding how position on the periodic table determines electronic structure. ● Appendix Documents: Appendix 5.C – Cracking the Periodic Table Code	Cooperative Learning	**D**
#1 and #2	LO 1.9 LO 1.10	2. Activity: Learning Activity to reinforce Electronic Structure and Periodicity ● Objective: Students will use knowledge about electronic structure and periodicity to explain why one atom has a larger ionization energy than another atom.	Process Oriented Guided Inquiry	**C**

		● Appendix Documents: Appendix 5.D – Periodicity and Electronic Structure Activity #2	Generating and Testing Hypotheses	
#1 and #2	LO 1.8 LO 1.9 WHST.4 ISTE-S.3	3. Activity: Periodicity Video *http://www.bozemanscience.com/ap-chem-006-periodicity* ● Objective: Students are introduced why atoms in the periodic table show trends in ionization energy, atomic radii, electronegativity and charge. All of these trends are explained through Coulomb's Law. A brief description of Dmitri Mendeleev and the power of predictability are included. After viewing the video, students complete Cornell notes. ● Appendix Documents: Appendix 0.D – Cornell Notes Template Appendix 0.E – Cornell Notes Grading Rubric	Technology Based Anticipatory Set Summarizing and Note Taking	**B**

UNIT RESOURCES

Teacher Resources:

Links

- "Chemistry Tutorial: Redox." AUS-e-TUTE. Accessed July 29, 2012. *http://www.ausetute.com.au/redoxtitr.html*
- Chieh, Chung. "Solutions Stoichiometry." University of Waterloo. Accessed July 29, 2012. *http://www.science.uwaterloo.ca/~cchieh/cact/c120/sltnstoich.html*
- "Redox Titration an Animation." Journal of Chemical Education. Accessed July 29, 2012. *http://www.jce.divched.org/JCESoft/CCA/CCA3/MAIN/TITREDO/PAGE1.HTM*

References

- Rees, Thomas. "The Stability of Potassium Permanganate Solutions." *Journal of Chemical Education* 64, no. 12 (1987):1058.
- Webb, Michael J. "Aqueous Hydrogen Peroxide: Its Household Uses and Concentration Units." *Journal of Chemical Education* 62, no. 2 (1985):152.
- Worley, John D. "Hydrogen Peroxide in Cleansing Antiseptics." *Journal of Chemical Education* 60, no. 8 (1983): 678.
- Young, J. A. "Hydrogen Peroxide, 3%." *Journal of Chemical Education* 80, no. 11, (2003): 1132.
- Young, J. A. "Potassium Permanganate *Journal of Chemical Education* 80, no. 8 (2003): 873.

Student Resources:

Links

- "Chemistry Tutorial: Redox." AUS-e-TUTE. Accessed July 29, 2012. *http://www.ausetute.com.au/redoxtitr.html*

- Chieh, Chung. “Solutions Stoichiometry.” University of Waterloo. Accessed July 29, 2012. http://www.science.uwaterloo.ca/~cchieh/cact/c120/sltnstoich.html
- “Redox Titration an Animation.” Journal of Chemical Education. Accessed July 29, 2012. http://www.jce.divched.org/JCESoft/CCA/CCA3/MAIN/TITREDO/PAGE1.HTM

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- Young, J. A. “Hydrogen Peroxide, 3%.” *Journal of Chemical Education* 80, no. 11, (2003): 1132.
- Young, J. A. “Potassium Permanganate *Journal of Chemical Education* 80, no. 8 (2003): 873.

Vocabulary:

- Coulomb’s Law- the energy of interaction between a pair of ions
- Core electrons- an inner electron in an atom
- Valence electrons- electron in the outer most principal energy level
- First Ionization energy-the amount of energy required to remove the highest-energy electron of an atom.
- mass spectrometry – a method used to determine the masses of atoms by the deflection of their ions on a magnetic field
- frequency- the number of waves(cycles) per second that pass a given point in space.
- Wavelength-the distance between two consecutive peaks or troughs in a wave.
- Electron affinity- the energy change associated with the addition of an electron to a gaseous atom
- Atomic radius-half the distance between the nuclei in a molecule consisting of identical atoms
- Aufbau principle- the principle stating that as protons are added one by one to the nucleus to build up the elements, electrons are similarly added to hydrogen-like orbitals
- Hund’s rule- the lowest energy configuration for an atom is the one having the maximum number of unpaired electrons allowed by the Pauli exclusion principle in a particular set of degenerate orbitals, with all unpaired electrons having parallel spins.
- Heisenberg uncertainty principle-a principle stating that there is a fundamental limitation to how precisely both the position and momentum of a particle can be known at a given time.
- Planck’s constant- 6.626×10^{-34} J s

Content Area: Science	**Course: AP Chemistry II**	**Unit 6: Chemical Bonding, Organic and Condensed States of Matter**
Unit Description: This unit will discuss chemical bonding and organic chemistry. Chemical structure will be used to explain phenomena involving condensed states of matter.		**Unit Timeline:** Approximately 3 weeks.

DESIRED RESULTS
Transfer Goal - *Students will be able to independently use their learning to…* Develop advanced inquiry and reasoning skills, such as designing a plan for collecting data, analyzing data, applying mathematical routines in order to connect concepts in and across domains.

Understandings – *Students will understand that… (Big Ideas)*

1. Matter can be described by its physical properties. The physical properties of a substance generally depend on the spacing between the particles (atoms, molecules, ions) that make up the substance and the forces of attraction among them.

2. Forces of attraction between particles (including the noble gases and also different parts of some large molecules) are important in determining many macroscopic properties of a substance, including how the observable physical state changes with temperature.
3. The strong electrostatic forces of attraction holding atoms together in a unit are called chemical bonds.
4. The type of bonding in the solid state can be deduced from the properties of the solid state.
5. Electrostatic forces exist between molecules as well as between atoms or ions, and breaking the resultant intermolecular interactions requires energy.
6. The seven basic science practices (see Appendix 0.A) are intrinsic to any science field.

<u>Essential Questions</u>: ***Students will keep considering…***

1. What is the relationship between the shape (as predicted by VSEPR) and polarity of a molecule, and its macroscopic properties such as vapor pressure, boiling point and melting point?
2. What is the difference between a molecular solid, ionic solid, metallic solid and a network solid?
3. How can valence bond theory be used to predict the characteristics of a bond within a molecule?
4. What is organic chemistry? What special characteristic of carbon allows it to be the central element in organic chemistry?
5. How can functional groups be used to name organic compounds?

Students Will Know…	Standard	Students Will Be Able to …	Standard

The atom is composed of negatively charged electrons, which can leave the atom, and a positively charged nucleus that is made of protons and neutrons. The attraction of the electrons to the nucleus is the basis of the structure of the atom. Coulomb’s law is qualitatively useful for understanding the structure of the atom.	1.B.1	Science Practices for AP Chemistry (see Appendix 0.A)	
		Students can predict properties of substances based on their chemical formulas, and provide explanations of their properties based on particle views.	LO 2.1
The different properties of solids and liquids can be explained by differences in their structures, both at the particulate level and in their supramolecular structures.	2.A.1	The student is able to explain the relative strengths of acids and bases based on molecular structure, interparticle forces, and solution equilibrium.	LO 2.2
London dispersion forces are attractive forces present between all atoms and molecules. London dispersion forces are often the strongest net intermolecular force between large molecules.	2.B.1	The student is able to use aspects of particulate models (i.e., particle spacing, motion, and forces of attraction) to reason about observed differences between solid and liquid phases and among solid and liquid materials.	LO 2.3
Dipole forces result from the attraction among the positive ends and negative ends of polar molecules. Hydrogen bonding is a strong type of dipole-dipole force that exists when very electronegative atoms (N, O, and F) are involved.	2.B.2	The student is able to explain the trends in properties and/or predict properties of samples consisting of particles with no permanent dipole on the basis of London dispersion forces.	LO 2.11
Intermolecular forces play a key role in determining the properties of substances, including biological structures and interactions.	2.B.3	The student is able to explain the properties (phase, vapor pressure, viscosity, etc.) of small and large molecular compounds in terms of the strengths and types of intermolecular forces.	LO 2.16
In covalent bonding, electrons are shared between the nuclei of two atoms to form a molecule or polyatomic ion. Electronegativity differences between the two atoms account for the distribution of the shared electrons and the polarity of the bond.	2.C.1	The student can predict the type of bonding present between two atoms in a binary compound based on position in the periodic table and the electronegativity of the elements.	LO 2.17
		The student is able to rank and justify the ranking of bond polarity on the basis of the locations of the bonded atoms in the periodic table.	LO 2.18
Ionic bonding results from the net attraction between oppositely charged ions, closely packed together in a crystal lattice.	2.C.2	The student can create visual representations of ionic substances that connect the microscopic structure to macroscopic properties, and/or use representations to connect the microscopic structure to macroscopic properties (e.g., boiling point, solubility, hardness,	LO 2.19

		brittleness, low volatility, lack of malleability, ductility, or conductivity).	
Metallic bonding describes an array of positively charged metal cores surrounded by a sea of mobile valence electrons.	2.C.3	The student is able to explain how a bonding model involving delocalized electrons is consistent with macroscopic properties of metals (e.g., conductivity, malleability, ductility, and low volatility) and the shell model of the atom.	LO 2.20
The localized electron bonding model describes and predicts molecular geometry using Lewis diagrams and the VSEPR model.	2.C.4	The student is able to use Lewis diagrams and VSEPR to predict the geometry of molecules, identify hybridization, and make predictions about polarity.	LO 2.21
Ionic solids have high melting points, are brittle, and conduct electricity only when molten or in solution.	2.D.1		
Metallic solids are good conductors of heat and electricity, have a wide range of melting points, and are shiny, malleable, ductile, and readily alloyed.	2.D.2	The student is able to design or evaluate a plan to collect and/or interpret data needed to deduce the type of bonding in a sample of a solid.	LO 2.22
Covalent network solids generally have extremely high melting points, are hard, and are thermal insulators. Some conduct electricity.	2.D.3	The student can create a representation of an ionic solid that shows essential characteristics of the structure and interactions present in the substance.	LO 2.23
Molecular solids with low molecular weight usually have low melting points and are not expected to conduct electricity as solids, in solution, or when molten.	2.D.4	The student is able to explain a representation that connects properties of an ionic solid to its structural attributes and to the interactions present at the atomic level.	LO 2.24
Potential energy is associated with a particular geometric arrangement of atoms or ions and the electrostatic interactions between them.	5.C.1	The student is able to compare the properties of metal alloys with their constituent elements to determine if an alloy has formed, identify the type of alloy formed, and explain the differences in properties using particulate level reasoning.	LO 2.25
Potential energy is associated with the interaction of molecules; as molecules draw near each other, they experience an attractive force.	5.D.1	Students can use the electron sea model of metallic bonding to predict or make claims about the macroscopic properties of metals or alloys.	LO 2.26
At the particulate scale, chemical processes can be distinguished from physical processes because chemical bonds can be distinguished from intermolecular interactions.	5.D.2	The student can create a representation of a metallic solid that shows essential characteristics of the structure and interactions present in the substance.	LO 2.27

Noncovalent and intermolecular interactions play important roles in many biological and polymer systems.	5.D.3	The student is able to explain a representation that connects properties of a metallic solid to its structural attributes and to the interactions present at the atomic level. The student can create a representation of a covalent solid that shows essential characteristics of the structure and interactions present in the substance. The student is able to explain a representation that connects properties of a covalent solid to its structural attributes and to the interactions present at the atomic level. The student can create a representation of a molecular solid that shows essential characteristics of the structure and interactions present in the substance. The student is able to explain a representation that connects properties of a molecular solid to its structural attributes and to the interactions present at the atomic level. The student is able to make claims and/or predictions regarding relative magnitudes of the forces acting within collections of interacting molecules based on the distribution of electrons within the molecules and the types of intermolecular forces through which the molecules interact. The student can support the claim about whether a process is a chemical or physical change (or may be classified as both) based on whether the process involves changes in intramolecular versus intermolecular interactions. The student is able to identify the noncovalent interactions within and between large molecules, and/or connect the shape and function of the large molecule to the presence and magnitude of these interactions.	LO 2.28 LO 2.29 LO 2.30 LO 2.31 LO2.32 LO 5.9 LO5.10 LO 5.11

		<u>Common Core Reading Standards for Grades 11-12</u>	
		Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.	RST.1
		Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.	RST.2
		Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.	RST.3
		Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11–12 texts and topics*.	RST.4
		Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas.	RST.5
		Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, identifying important issues that remain unresolved.	RST.6
		Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.	RST.7
		Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a	RST.9

		process, phenomenon, or concept, resolving conflicting information when possible.	RST.10
		By the end of grade 12, read and comprehend science/technical texts in the grades 11–CCR text complexity band independently and proficiently.	
		<u>Common Core Writing Standards for Grades 11-12</u>	WHST.1
		Write arguments focused on *discipline-specific content*. a. Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence. b. Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience's knowledge level, concerns, values, and possible biases. c. Use words, phrases, and clauses as well as varied syntax to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims. d. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing. e. Provide a concluding statement or section that follows from or supports the argument presented.	WHST.2
		Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.	

		a. Introduce a topic and organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension. b. Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic. c. Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts. d. Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers. e. Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic).	WHST.3
		Students' narrative skills continue to grow in these grades. The Standards require that students be ab le to incorporate the narrative elements effectively into arguments and information/explanatory texts. In science, students must be able to write precise descriptions of the step-by-step procedures they use in their investigations that others can replicate them and (possibly) reach the same results.	WHST.4
		Produce writing in which the organization, development, substance, and style are appropriate to task, purpose, and audience.	

EVIDENCE of LEARNING			
Understanding	Standards	**Unit Performance Assessment**:	**R/R Quadrant**
#1, #2, #3, #4, #5, #6	LO 2.1 LO 2.13 WHST.4	*Lab investigation #5: How do you separate molecules that are attracted to one another?* See AP Chemistry Guided-Inquiry Experiments Investigation #5 (Student Manual). **Teacher will assess:** Students will use the SHW process (Science Writing Heuristic) to structure a formal report. Since this lab is inquiry based, the traditional method of formal report method doesn't work in this instance. Students will address a question, set up of investigation, safety, observations and measurements, claims with supporting evidence, comparison of results with others and to literature, and changing of ideas. **Performance:** **Mastery:** Students will show that they really understand when they… Achieve a Level 3, Level 4, or Level 5 **Scoring Guide:** See Appendix 6.A	D

SAMPLE LEARNING PLAN				
Pre-assessment: *Please see Appendix 0.C - AP Chemistry Pre-Assessment.*				
Understanding	**Standards**	**Major Learning Activities:**	**Instructional Strategy:**	**R/R Quadrant:**
#1, #6	2.C.4	1. Activity: Organic Alphabet Brainstorming Activity ● Objective: The objective of this activity is to familiarize students with the vocabulary of the unit. ● Appendix Documents: Appendix 6.B – Organic Alphabet Brainstorming Sheet	Frontloading of Vocabulary	**A**
#2	2.A.1 RST.2	2. Activity: Guided Reading – Camping Stoves ● Objective: Students will read and engage in text that illustrates a working real-world application of the phase changes and thermodynamic relationships being taught in this unit. ● Appendix Documents: Appendix 6.C – Camping Stoves Guided Reading Article Appendix 6.D – Camping Stoves Reading Guide	Generating and Testing Hypotheses Homework and Practice	**B**
#4	LO 2.1	3. Activity: Organic Foldable ● Objective: Using a manipulative, students discover relationships between structure, name, and functional group. ● Appendix Document: Appendix 6.E – Organic Foldable	Nonlinguistic Representations Homework and Practice	**B**

UNIT RESOURCES
Teacher Resources: ● Brown Lemay 12th edition ● AP Chemistry Guided-Inquiry Experiments Teacher Manual
Student Resources: ● Brown Lemay 12th Edition ● AP Chemistry Guided Inquiry Experiments Student Manual ● Online Learning Platform provided by textbook company
Vocabulary: ● Lattice Energy – The energy required to separate completely the ions in an ionic solid ● Electronegativity – A measure of the ability of the an atom that is bonded to another atom to attract electrons to itself ● Polar Molecule – A molecule that possesses a nonzero dipole moment ● Nonpolar Molecule – A molecule that possesses zero dipole moment ● Formal Charge – The number of valence electrons in an isolated atom minus the number of electrons assigned to the atom in the Lewis structure. ● Resonance Structures – Individual Lewis structures in cases where two or more Lewis structures are equally good descriptions of a single molecule. ● Bond Energy – The energy required to break a covalent bond. ● VSEPR – Valence Shell Electron Pair Repulsion Theory ● Hybrid Orbital – An orbital that results from the mixing of different kinds of atomic orbitals on the same atomic level.

Content Area: Science	Course: AP Chemistry II	Unit 7: Thermochemistry
Unit Description: The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter. All changes in matter involve some form of energy change. Thus, the availability or disposition of energy plays a role in virtually all observed chemical processes. Thermodynamics provides a number of tools for understanding this key role, particularly the conservation of energy, including energy transfer in the forms of heat and work. Chemical bonding is central to chemistry, so one key concept associated with energy is that the breaking of a chemical bond inherently requires an energy input, and because bond formation is the reverse process, it will release energy. One key determinant of chemical transformations is the change in potential energy that results from changes in electrostatic forces. In addition to the transfer of energy, the thermodynamic concept of entropy is an important component in determining the direction of chemical or physical change.		**Unit Timeline: Approximately 3 weeks**

DESIRED RESULTS
Transfer Goal - *Students will be able to independently use their learning to…* Develop advanced inquiry and reasoning skills, such as designing a plan for collecting data, analyzing data, applying mathematical routines in order to connect concepts in and across domains.

Understandings – *Students will understand that… (Big Ideas)*

1. Chemical and physical transformations may be observed in several ways and typically involve a change in energy.
2. Energy is neither created nor destroyed, but only transformed from one form to another.
3. Breaking bonds requires energy, and making bonds releases energy.

4. Chemical or physical processes are driven by a decrease in enthalpy or an increase in entropy, or both.
5. The seven basic science practices (see Appendix 0.A) are intrinsic to any science field.

<u>Essential Questions</u>: *Students will keep considering…*

1. How are chemical and physical processes driven by a change in entropy and enthalpy?
2. How do breaking and making chemical bonds drive changes in energy?
3. How is energy transferred in a chemical reaction?

Students Will Know…	Standard	Students Will Be Able to …	Standard
Net changes in energy for a chemical reaction can be endothermic or exothermic. a. Macroscopic observations of energy changes when chemicals react are made possible by measuring temperature changes. b. These observations should be placed within the context of the language of exothermic and endothermic change. c. The ability to translate observations made at the macroscopic level in the laboratory to a conceptual framework is aided by a graphical depiction of the process called an energy diagram, which provides a visual representation of the exothermic or endothermic nature of a reaction. d. It is important to be able to use an understanding of energy changes in chemical reactions to identify the role of endothermic and exothermic reactions in real world processes.	3.C.2	Science Practices for AP Chemistry (see Appendix 0.A)	
		The student is able to interpret observations regarding macroscopic energy changes associated with a reaction or process to generate a relevant symbolic and/or graphical representation of the energy changes.	LO 3.11
		The student is able to create or use graphical representations in order to connect the dependence of potential energy to the distance between atoms and factors, such as bond order (for covalent interactions) and polarity (for intermolecular interactions), which influence the interaction strength.	LO 5.1
		The student can generate explanations or make predictions about the transfer of thermal energy between systems based on this transfer being due to a kinetic energy transfer between systems arising from molecular collisions.	LO 5.3
The process of kinetic energy transfer at the particulate scale is referred to in this course as heat transfer, and the spontaneous direction of the transfer is always from a hot to a cold body. a. On average, molecules in the warmer body have more kinetic energy than the molecules in the cooler body. b. Collisions of molecules that are in thermal contact transfer energy. c. Scientists describe this process as "energy is transferred as heat." d. Eventually, thermal equilibrium is reached as the molecular collisions continue. The average kinetic energy of both substances is the same at thermal equilibrium. e. Heat is not a substance, i.e., it makes no sense to say that an object contains a certain amount of heat. Rather, "heat exchange" or "transfer of energy as heat" refers	5.A.2	The student is able to use conservation of energy to relate the magnitudes of the energy changes occurring in two or more interacting systems, including identification of the systems, the type (heat versus work), or the direction of energy flow.	LO 5.4
		The student is able to use conservation of energy to relate the magnitudes of the energy changes when two nonreacting substances are mixed or brought into contact with one another.	LO 5.5
		The student is able to use calculations or estimations to relate energy changes associated with heating/cooling a substance to the heat capacity, relate energy changes associated with a phase transition to the enthalpy of fusion/	LO 5.6

to the process in which energy is transferred from a hot to a cold body in thermal contact. f. The transfer of a given amount of thermal energy will not produce the same temperature change in equal masses of matter with differing specific heat capacities.		vaporization, relate energy changes associated with a chemical reaction to the enthalpy of the reaction, and relate energy changes to PΔV work.	
Energy is transferred between systems either through heat transfer or through one system doing work on the other system. a. Heating a cold body with a hot body is a form of energy transfer between two systems. The transfer of thermal energy is an important concept in thermodynamics. b. An additional form of energy transfer is through work. Work is described by other scientific frameworks, such as Newtonian Mechanics or electromagnetism. c. In this course, calculations involving work are limited to that associated with changes in volume of a gas. An example of the transfer of energy between systems through work is the expansion of gas in a steam engine or car piston. Reasoning about this energy transfer can be based on molecular collisions with the piston: The gas is doing work on the piston, and energy is transferred from the gas to the piston.	5.B.1	The student is able to design and/or interpret the results of an experiment in which calorimetry is used to determine the change in enthalpy of a chemical process (heating/cooling, phase transition, or chemical reaction) at constant pressure. The student is able to draw qualitative and quantitative connections between the reaction enthalpy and the energies involved in the breaking and formation of chemical bonds. The student is able to use representations and models to predict the sign and relative magnitude of the entropy change associated with chemical or physical processes. The student is able to predict whether or not a physical or chemical process is thermodynamically favored by determination of (either quantitatively or qualitatively) the signs of both $\Delta H°$ and $\Delta S°$, and calculation or estimation of $\Delta G°$ when needed.	LO 5.7 LO 5.8 LO 5.12 LO 5.13
When two systems are in contact with each other and are otherwise isolated, the energy that comes out of one system is equal to the energy that goes into the other system. The combined energy of the two systems remains fixed. Energy transfer can occur through either heat exchange or work. a. When energy is transferred from system 1 to system 2, the energy transferred from system 1 is equal in magnitude to the energy transferred to system 2. b. If a system transfers energy to another system, its energy must decrease. Likewise, if energy is transferred into a system, its energy must increase.	5.B.2	The student is able to determine whether a chemical or physical process is thermodynamically favorable by calculating the change in standard Gibbs free energy. The student is able to explain how the application of external energy sources or the coupling of favorable with unfavorable reactions can be used to cause processes that are not thermodynamically favorable to become favorable. <u>Common Core Reading Standards for Grades 11-12</u>	LO 5.14 LO 5.15

Chemical systems undergo three main processes that change their energy: heating/cooling, phase transitions, and chemical reactions. a. Heating a system increases the energy of the system, while cooling a system decreases the energy. A liter of water at 50°C has more energy than a liter of water at 25°C. b. The amount of energy needed to heat one gram of a substance by 1°C is the specific heat capacity of that substance. c. Energy must be transferred to a system to cause it to melt (or boil). The energy of the system therefore increases as the system undergoes a solid-liquid (or liquid-gas) phase transition. Likewise, a system gives off energy when it freezes (or condenses). The energy of the system decreases as the system undergoes a liquid-solid (or gas-liquid) phase transition. d. The amount of energy needed to vaporize one mole of a pure substance is the molar enthalpy of vaporization, and the energy released in condensation has an equal magnitude. The molar enthalpy of fusion is the energy absorbed when one mole of a pure solid melts or changes from the solid to liquid state and the energy released when the liquid solidifies has an equal magnitude. e. When a chemical reaction occurs, the energy of the system decreases (exothermic reaction), increases (endothermic reaction), or remains the same. For exothermic reactions, the energy lost by the reacting molecules (system) is gained by the surroundings. The energy is transferred to the surroundings by either heat or work. Likewise, for endothermic reactions, the system gains energy from the surroundings by heat transfer or work done on the system. f. The enthalpy change of reaction gives the amount of energy released (for negative values) or absorbed (for	5.B.3	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11–12 texts and topics*. Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. Common Core Writing Standards for Grades 11-12 Write arguments focused on *discipline-specific content*. a. Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence. b. Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths	RST.1 RST.2 RST.4 RST.8 WHST.1

positive values) by a chemical reaction at constant pressure. Calorimetry is an experimental technique that is used to determine the heat exchanged/transferred in a chemical system. a. The experimental setup for calorimetry is the following: A chemical system is put in thermal contact with a heat bath. The heat bath is a substance, such as water, whose heat capacity has been well established by previous experiments. A process is initiated in the chemical system (heating/cooling, phase transition, or chemical reaction), and the change in temperature of the heat bath is determined. b. Because the heat capacity of the heat bath is known, the observed change in temperature can be used to determine the amount of energy exchanged between the system and the heat bath. c. The energy exchanged between the system and the heat bath is equal in magnitude to the change in energy of the system. If the heat bath increased in temperature, its energy increased, and the energy of the system decreased by this amount. If the heat bath decreased in temperature, and therefore energy, the energy of the system increased by this amount. d. Because calorimetry measures the change in energy of a system, it can be used to determine the heat associated with each of the processes listed in this manner, calorimetry may be used to determine heat capacities, enthalpies of vaporization, enthalpies of fusion, and enthalpies of reactions. *Only constant pressure calorimetry is required in the course.* The net energy change during a reaction is the sum of the energy required to break the bonds in the reactant molecules and the energy released in forming the bonds of the product molecules. The net change in energy may be positive for	5.B.4 5.C.2	and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience's knowledge level, concerns, values, and possible biases. c. Use words, phrases, and clauses as well as varied syntax to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims. d. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing. e. Provide a concluding statement or section that follows from or supports the argument presented. <u>Common Core Writing Standards for Grades 11-12</u> Students' narrative skills continue to grow in these grades. The Standards require that students be ab le to incorporate the narrative elements effectively into arguments and information/explanatory texts. In science, students must be able to write precise descriptions of the step-by-step procedures they use in their investigations that others can replicate them and (possibly) reach the same results. Produce writing in which the organization, development, substance, and style are appropriate to task, purpose, and audience. <u>ISTE Technology Standards</u> Research and Information Fluency: Students apply digital tools to gather, evaluate, and use information. a. Plan strategies to guide inquiry	 WHST.3 WHST.4 ISTE-S.3

endothermic reactions where energy is required, or negative for exothermic reactions where energy is released. a. During a chemical reaction, bonds are broken and/or formed, and these events change the potential energy of the reaction system. b. The average energy required to break all of the bonds in the reactant molecules can be estimated by adding up the average bond energies or bond enthalpies for all the bonds in the reactant molecules. Likewise, the average energy released in forming the bonds in the products can be estimated. If the energy released is greater than the energy required, then the reaction is exothermic. If the energy required is greater than the energy released, then the reaction is endothermic. c. For an exothermic reaction, the products are at a lower potential energy compared with the reactants. For an endothermic reaction, the products are at a higher potential energy than the reactants. d. In an isolated system, energy is conserved. Thus, if the potential energy of the products is lower than that of the reactants, then the kinetic energy of the products must be higher. For an exothermic reaction, the products are at a higher kinetic energy. This means that they are at a higher temperature. Likewise, for an endothermic reaction, the products are at a lower kinetic energy and, thus, at a lower temperature. e. Because the products of a reaction are at a higher or lower temperature than their surroundings, the products of the reaction move toward thermal equilibrium with the surroundings. Thermal energy is transferred to the surroundings from the hot products in an exothermic reaction. Thermal energy is transferred from the surroundings to the cold products in an endothermic reaction. f. Although the concept of “state functions” is not required for the course, students should understand		b. Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media c. Evaluate and select information sources and digital tools based on the appropriateness to specific tasks d. Process data and report results	

these Hess's law ideas: When a reaction is reversed, the sign of the enthalpy of the reaction is changed; when two (or more) reactions are summed to obtain an overall reaction, the enthalpies of reaction are summed to obtain the net enthalpy of reaction. g. Tables of standard enthalpies of formation can be used to calculate the standard enthalpy of reactions. Uses should go beyond algorithmic calculations and include, for instance, the use of such tables to compare related reactions, such as extraction of elemental metals from metal oxides. Entropy is a measure of the dispersal of matter and energy. a. Entropy may be understood in qualitative terms rather than formal statistical terms. Although this is not the most rigorous approach to entropy, the use of qualitative reasoning emphasizes that the goal is for students to be able to make predictions about the direction of entropy change, $\Delta S°$, for many typical chemical and physical processes. b. Entropy increases when matter is dispersed. The phase change from solid to liquid, or from liquid to gas, results in a dispersal of matter in the sense that the individual particles become more free to move, and generally occupy a larger volume. Another way in which entropy increases in this context is when the number of individual particles increases when a chemical reaction precedes whose stoichiometry results in a larger number of product species than reacting species. Also, for a gas, the entropy increases when there is an increase in volume (at constant temperature), and the gas molecules are able to move within a larger space. c. Entropy increases when energy is dispersed. From KMT, we know that the distribution of kinetic energy among the particles of a gas broadens as the	 5.E.1		

temperature increases. This is an increase in the dispersal of energy, as the total kinetic energy of the system becomes spread more broadly among all of the gas molecules. Thus, as temperature increases, the entropy increases.			
Some physical or chemical processes involve *both* a decrease in the internal energy of the components ($\Delta H° < 0$) under consideration *and* an increase in the entropy of those components ($\Delta S° > 0$). These processes are necessarily "thermodynamically favored" ($\Delta G° < 0$). a. For the purposes of thermodynamic analysis in this course, the *enthalpy* and the *internal energy* will not be distinguished. b. The phrase "thermodynamically favored" means that products are favored at equilibrium ($K > 1$). c. Historically, the term "spontaneous" has been used to describe processes for which $\Delta G° < 0$. The phrase "thermodynamically favored" is used here to avoid misunderstanding and confusion that can occur because of the common connotation of the term "spontaneous," which students may believe means "immediately" or "without cause." d. For many processes, students will be able to determine, either quantitatively or qualitatively, the signs of both $\Delta H°$ and $\Delta S°$ for a physical or chemical process. In those cases where $\Delta H° < 0$ and $\Delta S° > 0$, there is no need to calculate $\Delta G°$ in order to determine that the process is thermodynamically favored. e. As noted below in 5.E.5, the fact that a process is thermodynamically favored does not mean that it will proceed at a measurable rate. f. Any process in which both $\Delta H° > 0$ and $\Delta S° < 0$ are **not** thermodynamically favored, ($\Delta G° > 0$) and the process *must* favor reactants at equilibrium ($K < 1$).	5.E.2		

Because the signs of $\Delta S°$ and $\Delta H°$ reverse when a chemical or physical process is reversed, this must be the case. If a chemical or physical process is not driven by *both* entropy and enthalpy changes, then the Gibbs free energy change can be used to determine whether the process is thermodynamically favored. a. Some exothermic reactions involve decreases in entropy. b. When $\Delta G° > 0$, the process **is not** thermodynamically favorable. When $\Delta G° < 0$, the process **is** thermodynamically favorable. c. In some reactions, it is necessary to consider both enthalpy and entropy to determine if a reaction will be thermodynamically favorable. The freezing of water and the dissolution of sodium nitrate in water provide good examples of such situations.	 5.E.3		
External sources of energy can be used to drive change in cases where the Gibbs free energy change is positive. a. Electricity may be used to cause a process to occur that is not thermodynamically favored. Useful examples are charging of a battery and the process of electrolysis. b. Light may also be a source of energy for driving a process that in isolation is not thermodynamically favored. Useful examples are as follows: 1. The photoionization of an atom, because although the separation of a negatively charged electron from the remaining positively charged ion is highly endothermic, ionization is observed to occur in conjunction with the absorption of a photon. 2. The overall conversion of carbon dioxide to glucose through photosynthesis, for which	5.E.4		

$6\ CO_2(g) + 6\ H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6\ O_2(g)$ has $\Delta G° = +2880$ kJ/mol*rxn*, yet is observed to occur through a multistep process that is initiated by the absorption of several photons in the range of 400–700 nm. c. A thermodynamically unfavorable reaction may be made favorable by coupling it to a favorable reaction, such as the conversion of ATP to ADP in biological systems. In this context, coupling means the process involves a series of reactions with common intermediates, such that the reactions add up to produce an overall reaction with a negative ΔG°. Vocabulary: *Entrophy*- a thermodynamic function that measures randomness or disorder *Enthalapy*- a property of a system equal to E=PV, where E is the internal energy of the system, P is the pressure of the system, and V is the volume of the system. At constant pressure the change in the enthalpy equals the energy flow as heat. *Gibbs Free Energy*- the change in enthalapy (ΔH) minus the product of the Kelvin Temperature and the change in entrophy (TΔS). ΔG= ΔH- TΔS			

EVIDENCE of LEARNING

Understandin g	Standards	**Unit Performance Assessment**:	**R/R Quadrant**
# 5	LO 5.6 LO 5.7 WHST.4 ISTE-S.3	**Description of Assessment Performance Task(s):** *Lab Investigation #12: The Hand Warmer Design Challenge: Where Does the Heat Come From?* See AP Chemistry Guided-Inquiry Experiments Investigation #12 (Student Manual). Students are challenged to use chemistry to design an effective, safe, environmentally benign, and inexpensive hand warmer. The ideal hand warmer increases in temperature by 20°C (but no more) as quickly as possible, has a volume of about 50 mL, costs as little as possible to make, and uses chemicals that are as safe and environmentally friendly as possible. Students will carry out an experiment to determine which substances, in what amounts, to use in order to make a hand warmer that meets these criteria.	D

		Teacher will assess: 1. Students view pre-lab animation, answer questions, participate in group discussion, and explain how particulate interactions result in heat during solution formation. 2. Students use calorimetry to determine temperature change during solution format. 3. Students evaluate safety and cost information and temperature change data to select an appropriate material for a hand warmer. 4. Students do calculations to determine heat of reaction for dissolving processes. 5. In the post-lab assessment, students analyze experimental errors, classify reactions as endothermic or exothermic, and classify solution formation as a physical or chemical process. **<u>Performance:</u>** **Mastery:** Students will show that they really understand when they… Achieve a Level 3, Level 4, or Level 5 **Scoring Guide:** See Appendix 7.A **Performance Assessment and Assessment Blueprint**: See 7.B and 7.C in Performance Assessment Folder.	

SAMPLE LEARNING PLAN				
Pre-assessment: *Please see Appendix 0.C - AP Chemistry Pre-Assessment.*				
<u>Understanding</u>	**<u>Standards</u>**	**<u>Major Learning Activities</u>:**	**<u>Instructional Strategy</u>:**	**<u>R/R Quadrant:</u>**
#4 and 5	LO 5.8 WHST.4	*1.* Activity: Measuring Energy Change- Heat of Fusion	Cooperative Learning	**C**

	ISTE-S.4	• Objective: The purpose of this experiment is to determine the temperature and heat changes that occur when ice melts. Students will then use the temperature change when ice melts in order to determine the heat of fusion. • Appendix Documents: Appendix 7.B – Thermochemistry Activity #1: Heat of Fusion		
#3	LO 5.8	2. Activity: Bonding Energy: What makes a reaction endothermic or exothermic? • Objective: Students will use bond energy data to determine if a reaction is endothermic or exothermic. • Appendix Documents: Appendix 7.C – Bond Energy Thermochemistry Activity #2	Process Oriented Guided Inquiry	**C**
#2	LO 5.13 LO 5.14 WHST.4 ISTE-S.3	3. Activity: Video on Gibbs-Free Energy *http://www.bozemanscience.com/ap-chem-059-using-gibbs-free-energy* • Objective: Students will learn how one can use the Gibbs Free Energy equation to determine if a process is spontaneous or not spontaneous. If the ΔG is less than zero the process is spontaneous. If the ΔG is greater than zero the process is not spontaneous. After viewing the video, students complete Cornell notes. • Appendix Documents: Appendix 0.D – Cornell Notes Template Blank Appendix 0.E – Cornell Notes Grading Rubric	Technology Based Anticipatory Set Summarizing and Note Taking	**B**

UNIT RESOURCES
Teacher Resources:

Links

- "Calorimetry." Sparknotes SAT Chemistry Common Experiments. Accessed August 3, 2012. *http:// alpha.chem.umb.edu/chemistry/genchem/103/files/103lab/7CoffeeCupCalorimeterRevised.pdf*
- "Heats of Reaction." University of Massachusetts Boston. Accessed July 31, 2012. *http://alpha.chem.umb.edu/chemistry/genchem/103/files/103lab/7CoffeeCupCalorimeterRevised.pdf*

References

- Barlag, Rebecca E., Phyllis Arthasery, and Frazier Nyasulu. "Electrical Determination of the Heat Capacity of a Calorimeter in Approximately One Minute." *Journal of Chemical Education* 87, no. 9 (2010): 992–992.
- Brouwer, Henry. "Small-Scale Thermochemistry Experiment." *Journal of Chemical Education* 68, no. 7 (1991): A178.
- Marzacco, Charles J. "The Enthalpy of Decomposition of Hydrogen Peroxide: A General Chemistry Calorimetry Experiment." *Journal of Chemical Education* 76, no. 11 (1999): 1517.
- Vannatta, Michael W., Michelle Richards-Babb, and Robert J. Sweeney. "Thermochemistry to the Rescue: A Novel Calorimetry Experiment for General Chemistry." *Journal of Chemical Education* 87, no. 11 (2010): 1222–1224.

Student Resources:

Links

- "Calorimetry." Sparknotes SAT Chemistry Common Experiments. Accessed August 3, 2012. *http:// alpha.chem.umb.edu/chemistry/genchem/103/files/103lab/7CoffeeCupCalorimeterRevised.pdf*
- "Heats of Reaction." University of Massachusetts Boston. Accessed July 31, 2012. *http://alpha.chem.umb.edu/chemistry/genchem/103/files/103lab/7CoffeeCupCalorimeterRevised.pdf*

References

- Barlag, Rebecca E., Phyllis Arthasery, and Frazier Nyasulu. "Electrical Determination of the Heat Capacity of a Calorimeter in Approximately One Minute." *Journal of Chemical Education* 87, no. 9 (2010): 992–992.
- Brouwer, Henry. "Small-Scale Thermochemistry Experiment." *Journal of Chemical Education* 68, no. 7 (1991): A178.
- Marzacco, Charles J. "The Enthalpy of Decomposition of Hydrogen Peroxide: A General Chemistry Calorimetry Experiment." *Journal of Chemical Education* 76, no. 11 (1999): 1517.
- Vannatta, Michael W., Michelle Richards-Babb, and Robert J. Sweeney. "Thermochemistry to the Rescue: A Novel Calorimetry Experiment for General Chemistry." *Journal of Chemical Education* 87, no. 11 (2010): 1222–1224.

Vocabulary:

- Entrophy- a thermodynamic function that measures randomness or disorder
- Enthalapy- a property of a system equal to E=PV, where E is the internal energy of the system, P is the pressure of the system, and V is the volume of the system. At constant pressure the change in the enthalpy equals the energy flow as heat.
- Gibbs Free Energy- the change in enthalapy (ΔH) minus the product of the Kelvin Temperature and the change in entrophy ($T\Delta S$). $\Delta G= \Delta H- T\Delta S$
- First law of thermodynamics
- Calorimetry-the science of measuring heat flow
- Heat capacity-the amount of energy needed to raise the temperature of an object by one degree Celsius
- Specific heat of capacity-the energy required to raise the temperature of one gram of a substance by one degree Celsius
- Molar heat capacity- the energy required to raise the temperature of one mole of a substance by one degree Celsius
- Standard enthalpy of formation-the enthalpy change that accompanies the formation of one mole of a compound at 25 °C from its elements, with all substances in their standard states at that temperature

Content Area: Science	Course: AP Chemistry II	Unit 8: Electrochemistry
Unit Description: This unit will focus on electrochemistry. Oxidation-reduction (Re-dox) reactions will be investigated with specific emphasis on transfer of electrons within chemical reactions and how those electron interactions are used to convert chemical energy into electrical energy. Both galvanic and electrolytic cells will be studied.		**Unit Timeline:** Approximately 3 weeks

DESIRED RESULTS
Transfer Goal - *Students will be able to independently use their learning to…* Develop advanced inquiry and reasoning skills, such as designing a plan for collecting data, analyzing data, applying mathematical routines in order to connect concepts in and across domains.

Understandings – *Students will understand that… (Big Ideas)*

1. In oxidation-reduction reactions, there is a net transfer of electrons.
2. Electrochemistry shows the inter-conversion between chemical and electrical energy in a galvanic and electrolytic cell.
3. The seven basic science practices (see Appendix 0.A) are intrinsic to any science field.

Essential Questions: *Students will keep considering…*

1. How does electrochemistry explain the inter-conversion between chemical and electrical energy in a galvanic and electrolytic cell?
2. What is the chemistry involved in making electrical current from batteries?

Students Will Know…	Standard	Students Will Be Able to …	Standard
Electrochemistry shows the inter-conversion between chemical and electrical energy in galvanic and electrolytic cells. a. Electrochemistry encompasses the study of redox reactions that occur within electrochemical cells. The reactions either generate electrical current in galvanic cells, or are driven by an externally applied electrical potential in electrolytic cells. Visual representations of galvanic and electrolytic cells are tools of analysis to identify where half-reactions occur and the direction of current flow. b. Oxidation occurs at the anode, and reduction occurs at the cathode for all electrochemical cells. c. The overall electrical potential of galvanic cells can be calculated by identifying the oxidation half-reaction and reduction half-reaction, and using a table of Standard Reduction Potentials. d. Many real systems do not operate at standard conditions and the electrical potential determination must account for the effect of concentrations. The qualitative effects of concentration on the cell potential can be understood by considering the cell potential as a driving force toward equilibrium, in that the farther the reaction is from equilibrium, the greater the magnitude of the cell potential. The standard cell potential, Eo, corresponds to the standard conditions of $Q = 1$. As the system approaches equilibrium, the magnitude (i.e., absolute value) of the cell potential decreases, reaching zero at equilibrium (when $Q = K$). Deviations from standard conditions that take the cell further from equilibrium than $Q = 1$ will increase the magnitude of the cell potential relative to E°. Deviations from standard conditions that take the cell closer to equilibrium than $Q = 1$ will decrease the	3.C.3	Science Practices for AP Chemistry (see Appendix 0.A)	
		The student is able to design and/or interpret the results of an experiment involving a redox titration. [See SP 4.2, 5.1]	LO 3.9
		The student can make qualitative or quantitative predictions about galvanic or electrolytic reactions based on half-cell reactions and potentials and/or Faraday's laws. [See SP 2.2, 2.3, 6.4]	LO 3.12
		The student can analyze data regarding galvanic or electrolytic cells to identify properties of the underlying redox reactions. [See SP 5.1]	LO 3.13
		The student can design, and/or interpret data from, an experiment that uses titration to determine the concentration of an analyte in a solution. [See SP 4.2, 5.1, 6.4]	LO 1.20
		<u>Common Core Writing Standards for Grades 11-12</u>	
		Produce writing in which the organization, development, substance, and style are appropriate to task, purpose, and audience.	WHST.4
		<u>ISTE Technology Standards</u>	
		Research and Information Fluency: Students apply digital tools to gather, evaluate, and use information. a. Plan strategies to guide inquiry b. Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media c. Evaluate and select information sources and digital tools based on the appropriateness to specific tasks	ISTE-S.3

magnitude of the cell potential relative to E°. In concentration cells, the direction of spontaneous electron flow can be determined by considering the direction needed to reach equilibrium. e. ΔG° (standard Gibbs free energy) is proportional to the negative of the cell potential for the redox reaction from which it is constructed. f. Faraday's laws can be used to determine the stoichiometry of the redox reactions occurring in an electrochemical cell with respect to the following: i. Number of electrons transferred ii. Mass of material deposited or removed from an electrode iii. Current iv. Time elapsed v. Charge of ionic species		d. Process data and report results	

EVIDENCE of LEARNING			
<u>Understanding</u>	<u>Standards</u>	**<u>Unit Performance Assessment</u>**:	**<u>R/R Quadrant</u>**
#1, #2, #3	3.C.3 LO 3.9 LO 1.20 WHST.4 ISTE-S.3	**Description of Assessment Performance Task(s):** *Lab #8: How Can We Determine the Actual Percentage of H_2O_2 in a Drugstore Bottle of Hydrogen Peroxide?* See AP Chemistry Guided-Inquiry Experiments Investigation #8 (Student Manual). This lab has two major tasks. The first task is to standardize the concentration of a $KMnO_4$ solution. This task is necessary in order to complete the second task, which is to evaluate how close commercial H_2O_2 solutions are to their labeled concentrations. Different groups of students will work with different brands and then share their results. **Teacher will assess:**	**D**

		1. Student's ability to standardize a solution and conduct an oxidation reduction titration. 2. Student's ability to calculate the concentration of an unknown solution using oxidation– reduction titration data and stoichiometric ratios 3. Student's ability to improve experimental design and use critical analysis skills to analyze the H_2O_2 solutions **Performance:** **Mastery:** Students will show that they really understand when they… Achieve a Level 3, Level 4, or Level 5 **Scoring Guide:** See Appendix 8.A **Performance Assessment:** See Performance Assessment Folder 8.B Assessment and 8.C Assessment Scoring Blueprint	

SAMPLE LEARNING PLAN				
Pre-assessment: *Please see Appendix 0.C - AP Chemistry Pre-Assessment.*				
Understanding	**Standards**	**Major Learning Activities:**	**Instructional Strategy:**	**R/R Quadrant:**
#2	3.C.3	1. Activity: AP Chemistry Dice Game Students will work in cooperative learning groups (pre-determined as heterogeneous mixing) to determine who is responsible for a specific learning target tied to the description and interpretation of a galvanic cell.	Cooperative Learning Activity with specific focus on PIES.	**C**

		● Objective: The Dice Game is directed at the skills required to achieve a Level 3 or Level 4 mastery level by: ▪ Writing a half cell reaction ▪ Prediction of reaction occurrence based on cell potentials ▪ Prediction of movement of electrons ▪ Description of galvanic cell vs. electrolytic cell ● Appendix Documents: Appendix 8.B – AP Chemistry Dice Game		
#2	3.C.3	2. Activity: AP Practice Problems ● Students will complete a guided worksheet that utilizes AP questions to frontload the learning. ● Appendix Document: Appendix 8.C – AP Practice Problems – Set #1	Homework and Practice	**B**
#1, #2	3.C.3	3. Activity: Oxidation Reduction - Find Someone Who ● Objective: This activity is a cooperative learning structure to be used as an exit ticket after presentation of a lecture. ● Appendix Documents: Appendix 8.D - Oxidation Reduction - Find Someone Who	Cooperative Learning	**B**

UNIT RESOURCES
<u>Teacher Resources</u>: ● Brown-LeMay AP Editio

n Chemistry: The Central Science

- AP Chemistry Lab Manual (AP College Board Publication)
- "Chemistry Tutorial: Redox." AUS-e-TUTE. Accessed July 29, 2012.

http://www.ausetute

.com.au/redoxtitr.html ● Chieh, Chung. "Solutions Stoichiometry." University of Waterloo. Accessed July 29, 2012. http://www.science.uwaterloo.ca/~cchieh/cact/c120/sltnstoich.html ● "Redox Titration an

Animation." Journal of Chemical Education. Accessed July 29, 2012. http://www.jce.divched.org/JCESoft/CCA/CCA3/MAIN/TITREDO/PAGE1.HTM
Student Resources: • Brown-LeMay AP Edition

Chemistry: The Central Science • AP Chemistry Lab Manual (AP College Board Publication) • “Chemistry Tutorial: Redox.” AUS-e-TUTE. Accessed July 29, 2012. http://www.ausetute.com.au/re

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doxtitr.html • Chieh, Chung. "Solutions Stoichiometry." University of Waterloo. Accessed July 29, 2012. http://www.science.uwaterloo.ca/~cchieh/cact/c120/sltnstoich.html • "Redox Titration an Anima

tion." Journal of Chemical Education. Accessed July 29, 2012. http://www.jce.divched.org/JCESoft/CCA/CCA3/MAIN/TITREDO/PAGE1.HTM
Vocabulary: • Oxidizing species: A species that has lost

one or more electrons.

- Reducing species: A species that has gained one or more electrons.
- Galvanic (voltaic) cell: A device in which a spontaneous oxidation-reduction reaction occurs with the

passage of electrons through and external circuit.

- Anode: An electrode at which oxidation occurs.
- Cathode: An electrode at which reduction occurs.
- Electromotive Force (EMF): A measu

re of the driving force, or electrical pressure, for the completion of an electrochemical reaction. Electromotive force is measure in volts. This is also called cell potential.

- Cell potential:

The potential difference between the cathode and anode in an electrochemical cell. It is measured in volts. Also called electromotive force.

- Standard hydrogen electrode (SHE): An electrode based on the half reaction $2H^+(1 M) + 2e^- \rightarrow H_2(1 atm)$. The standard electrode potential of the standard hydrogen electrode is defined as 0 volts.

- Electrolytic cell: A device in which a nonspontaneous

	oxidation-reduction reaction is caused to occur by passage of a current.

Content Area: Science	**Course: AP Chemistry II**	**Unit 9: Chemical Kinetics**
Unit Description: Chemical changes occur over a wide range of time scales. Practically, the manner in which the rate of change is observed is to measure changes in concentration of reactant or product species as a function of time. There are a number of possible factors that influence the observed speed of reaction at the macroscopic level, including the concentration of reactants, the temperature, and other environmental factors. Measured rates for reactions observed at the macroscopic level can generally be characterized mathematically in an expression referred to as the rate law. In addition to these macroscopic-level characterizations, the progress of reactions at the particulate level can be connected to the rate law. Factors that influence the rate of reaction, including speeding of the reaction by the use of a catalyst, can be delineated as well.		**Unit Timeline:** Approximately 3 weeks

DESIRED RESULTS
Transfer Goal - *Students will be able to independently use their learning to…* Develop advanced inquiry and reasoning skills, such as designing a plan for collecting data, analyzing data, applying mathematical routines in order to connect concepts in and across domains.

Understandings – *Students will understand that… (Big Ideas)*

1. Reaction rates that depend on temperature and other environmental factors are determined by measuring changes in concentrations of reactants or products over time.
2. Elementary reactions are mediated by collisions between molecules. Only collisions having sufficient energy and proper relative orientation of reactants lead to products.
3. Many reactions proceed via a series of elementary reactions.
4. Reaction rates may be increased by the presence of a catalyst.
5. The seven basic science practices (see Appendix 0.A) are intrinsic to any science field.

Essential Questions: *Students will keep considering…*

1. How are the rates of chemical reactions determined by the details of molecular collisions?
2. How do catalysts, concentration, temperature, surface area, and the nature of the reactants affect the rate of a chemical reaction?

3. How can the rate law be determined form experimental data?

Students Will Know…	Standard	Students Will Be Able to …	Standard
The rate of a reaction is influenced by the concentration or pressure of reactants, the phase of the reactants and products, and environmental factors such as temperature and solvent. a. The rate of a reaction is measured by the amount of reactants converted to products per unit of time. b. A variety of means exist to experimentally measure the loss of reactants or increase of products as a function of time. One important method involves the spectroscopic determination of concentration through Beer's law. c. The rate of a reaction is influenced by reactant concentrations (except in zero order processes), temperature, surface area, and other environmental factors.	4.A.1	Science Practices for AP Chemistry (see Appendix 0.A) The student is able to design and/or interpret the results of an experiment regarding the factors (i.e., temperature, concentration, surface area) that may influence the rate of a reaction. The student is able to analyze concentration vs. time data to determine the rate law for a zeroth-, first-, or second-order reaction. The student is able to connect the half-life of a reaction to the rate constant of a first-order reaction and justify the use of this relation in terms of the reaction being a first-order reaction.	 LO 4.1 LO 4.2 LO 4.3
The rate law shows how the rate depends on reactant concentrations. a. The rate law expresses the rate of a reaction as proportional to the concentration of each reactant raised to a power. The power of each reactant in the rate law is the order of the reaction with respect to that reactant. The sum of the powers of the reactant concentrations in the rate law is the overall order of the reaction. When the rate is independent of the concentration of a reactant, the reaction is zeroth order in that reactant, since raising the reactant concentration to the power zero is equivalent to the reactant concentration being absent from the rate law. b. In cases in which the concentration of any other reactants remain essentially constant during the course of the reaction, the order of a reaction with respect to a reactant concentration can be inferred from plots of the concentration of reactant versus time. An	4.A.2	The student is able to connect the rate law for an elementary reaction to the frequency and success of molecular collisions, including connecting the frequency and success to the order and rate constant, respectively. The student is able to explain the difference between collisions that convert reactants to products and those that do not in terms of energy distributions and molecular orientation. The student is able to use representations of the energy profile for an elementary reaction (from the reactants, through the transition state, to the products) to make qualitative predictions regarding the relative temperature dependence of the reaction rate. The student is able to evaluate alternative explanations, as expressed by reaction mechanisms, to determine	LO 4.4 LO 4.5 LO 4.6 LO 4.7

appropriate laboratory experience would be for students to use spectrophotometry to determine how concentration varies with time. c. The method of initial rates is useful for developing conceptual understanding of what a rate law represents, but simple algorithmic application should not be considered mastery of the concept. Investigation of data for initial rates enables prediction of how concentration will vary as the reaction progresses.		which are consistent with data regarding the overall rate of a reaction, and data that can be used to infer the presence of a reaction intermediate.	
		The student can translate among reaction energy profile representations, particulate representations, and symbolic representations (chemical equations) of a chemical reaction occurring in the presence and absence of a catalyst.	LO 4.8
The magnitude and temperature dependence of the rate of reaction is contained quantitatively in the rate constant. a. The proportionality constant in the rate law is called the rate constant. b. The rate constant is an important measurable quantity that characterizes a chemical reaction. c. Rate constants vary over many orders of magnitude because reaction rates vary widely. d. The temperature dependence of reaction rates is contained in the temperature dependence of the rate constant. e. For first-order reactions, half-life is often used as a representation for the rate constant because they are inversely proportional, and the half-life is independent of concentration. For example, radioactive decay processes provide real-world context.	4.A.3	The student is able to explain changes in reaction rates arising from the use of acid-base catalysts, surface catalysts, or enzyme catalysts, including selecting appropriate mechanisms with or without the catalyst present.	LO 4.9
		The student can explain why a thermodynamically favored chemical reaction may not produce large amounts of product (based on consideration of both initial conditions and kinetic effects), or why a thermodynamically unfavored chemical reaction can produce large amounts of product for certain sets of initial conditions.	LO 5.18
		<u>Common Core Reading Standards for Grades 11-12</u>	
Elementary reactions can be unimolecular or involve collisions between two or more molecules. a. The order of an elementary reaction can be inferred from the number of molecules participating in a collision: unimolecular reactions are first order, reactions involving bimolecular collisions are second order, etc.	4.B.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.	RST.1
		Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.	RST.2

b. Elementary reactions involving the simultaneous collision of three particles are rare. Not all collisions are successful. To get over the activation energy barrier, the colliding species need sufficient energy. Also, the orientations of the reactant molecules during the collision must allow for the rearrangement of reactant bonds to form product bonds. a. Unimolecular reactions occur because collisions with solvent or background molecules activate the molecule in a way that can be understood in terms of a Maxwell-Boltzmann thermal distribution of particle energies. b. Collision models provide a qualitative explanation for order of elementary reactions and the temperature dependence of the rate constant. c. In most reactions, only a small fraction of the collisions leads to a reaction. Successful collisions have both sufficient energy to overcome activation energy barriers and orientations that allow the bonds to rearrange in the required manner. d. The Maxwell-Boltzmann distribution describes the distribution of particle energies; this distribution can be used to gain a qualitative estimate of the fraction of collisions with sufficient energy to lead to a reaction, and also how that fraction depends on temperature. A successful collision can be viewed as following a reaction path with an associated energy profile. a. Elementary reactions typically involve the breaking of some bonds and the forming of new ones. It is usually possible to view the complex set of motions involved in this rearrangement as occurring along a single reaction coordinate.	4.B.2 4.B.3	Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11–12 texts and topics*. Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. Common Core Writing Standards for Grades 11-12 Write arguments focused on *discipline-specific content*. a. Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence. b. Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience's knowledge level, concerns, values, and possible biases. c. Use words, phrases, and clauses as well as varied syntax to link the major sections of the text,	RST.3 RST.4 RST.7 WHST.1

b. The energy profile gives the energy along this path, which typically proceeds from reactants, through a transition state, to products. c. The Arrhenius equation can be used to summarize experiments on the temperature dependence of the rate of an elementary reaction and to interpret this dependence in terms of the activation energy needed to reach the transition state. The mechanism of a multistep reaction consists of a series of elementary reactions that add up to the overall reaction. a. The rate law of an elementary step is related to the number of reactants, as accounted for by collision theory. b. The elementary steps add to give the overall reaction. The balanced chemical equation for the overall reaction specifies only the stoichiometry of the reaction, not the rate. c. A number of mechanisms may be postulated for most reactions, and experimentally determining the dominant pathway of such reactions is a central activity of chemistry. In many reactions, the rate is set by the slowest elementary reaction, or rate-limiting step. a. For reactions in which each elementary step is irreversible, the rate of the reaction is set by the slowest elementary step (i.e., the rate-limiting step). Reaction intermediates, which are formed during the reaction but not present in the overall reaction, play an important role in multistep reactions. a. A reaction intermediate is produced by some elementary steps and consumed by others, such that it is present only while a reaction is occurring.	4.C.1 4.C.2 4.C.3 4.D.1	create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims. d. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing. e. Provide a concluding statement or section that follows from or supports the argument presented. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. a. Introduce a topic and organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension. b. Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic. c. Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts. d. Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers.	WHST.2

b. Experimental detection of a reaction intermediate is a common way to build evidence in support of one reaction mechanism over an alternative mechanism. Catalysts function by lowering the activation energy of an elementary step in a reaction mechanism, and by providing a new and faster reaction mechanism. a. A catalyst can stabilize a transition state, lowering the activation energy and thus increasing the rate of a reaction. b. A catalyst can increase a reaction rate by participating in the formation of a new reaction intermediate, thereby providing a new reaction pathway or mechanism.	4.D.2	e. Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic). Students' narrative skills continue to grow in these grades. The Standards require that students be ab le to incorporate the narrative elements effectively into arguments and information/explanatory texts. In science, students must be able to write precise descriptions of the step-by-step procedures they use in their investigations that others can replicate them and (possibly) reach the same results. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.	WHST.3 WHST.4
Important classes in catalysis include acid-base catalysis, surface catalysis, and enzyme catalysis. a. In acid-base catalysis, a reactant either gains or loses a proton; this changes the rate of the reaction. b. In surface catalysis, either a new reaction intermediate is formed, or the probability of successful collisions is modified. c. Some enzymes accelerate reactions by binding to the reactants in a way that lowers the activation energy. Other enzymes react with reactant species to form a new reaction intermediate. A thermodynamically favored process may not occur due to kinetic constraints (kinetic vs. thermodynamic control). a. Many processes that are thermodynamically favored do not occur to any measurable extent, or they occur at extremely slow rates. b. Processes that are thermodynamically favored, but do not proceed at a measurable rate, are said to be under	4.D.3	Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information. <u>ISTE Technology Standards</u> Research and Information Fluency: Students apply digital tools to gather, evaluate, and use information. a. Plan strategies to guide inquiry b. Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media c. Evaluate and select information sources and digital tools based on the appropriateness to specific tasks d. Process data and report results	WHST.6 ISTE-S.3

"kinetic control." High activation energy is a common reason for a process to be under kinetic control. The fact that a process does not proceed at a noticeable rate does not mean that the chemical system is at equilibrium. If a process is known to be thermodynamically favored (through qualitative and/or quantitative analysis of $\Delta H°$ and $\Delta S°$), and yet it is not occurring at a measurable rate, then the conclusion is that the process is under kinetic control. Vocabulary: Reaction rate- the change in concentration of a reactant or product per unit time Instantaneous rate-the value of the rate at a particular time found by calculating the slope of the line tangent to the curve Rate law- the relationship that shows how the rate depends on the concentration of the reactants Rate constant-the proportionality constant- Differential rate law- a rate law that expresses how the rate depends on the concentration Integrated rate law- expresses how the concentration depends on time Zero order- the rate is constant and does not change with concentration First order –the rate of the reaction depends on the reactant to the first power		Critical Thinking, Problem Solving, and Decision Making: Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources. a. Identify and define authentic problems and significant questions for investigation b. Plan and manage activities to develop a solution or complete a project c. Collect and analyze data to identify solutions and/or make informed decisions d. Use multiple processes and diverse perspectives to explore alternative solutions	ISTE-S.4

Second order –the rate shows that a plot of the inverse of the concentration versus time will be linear Reaction mechanism-chemical reactions that occur by a series of steps Intermediate-a species that is neither a reactant nor a product but is formed and consumed in the reaction sequence. Activation energy- a threshold hold energy that must be overcome to produce a chemical reaction			

EVIDENCE of LEARNING			
Understanding	Standards	**Unit Performance Assessment**:	**R/R Quadrant**
#1, #2, #3, #5	LO 4.1 LO 4.2 WHST.6 ISTE-S.3 ISTE-S.4	**Description of Assessment Performance Task(s):** *Lab Investigation #9: What is the Rate Lab of the Fading of Crystal Violet Using Beer's Law* See AP Chemistry Guided-Inquiry Experiments Investigation #9 (Student Manual). **Teacher will assess:** Students must perform several mathematical transformations of their raw absorbance data and produce several plots while interpreting the results in terms of Beer's law and the integrated rate laws found in their textbook. All analysis and calculations, other than those in the prelab, can be performed after collecting the data. **Performance:** **Mastery:** Students will show that they really understand when they… Achieve a Level 3, Level 4, or Level 5 **Scoring Guide:** See Appendix 9.A **Performance Assessment and Assessment Blueprint:** See Performance Assessment folder 9.B & 9.C	**D**

SAMPLE LEARNING PLAN				
Pre-assessment: *Please see Appendix 0.C - AP Chemistry Pre-Assessment.*				
Understanding	**Standards**	**Major Learning Activities:**	**Instructional Strategy:**	**R/R Quadrant:**
#1, #2, #3, # 5	4 A.2 4.C.1 4.C.2 4.C.3 WHST.1 ISTE-S.3 ISTE-S.4 ISTE-S.6	1. Activity: Determine the rate law and reaction mechanism for the reaction of sodium thiosulfate and hydrochloric acid using experimental data provided to the student. Students will plot data using Excel. ● Objective: Students will determine the rate law and develop a rate mechanism that agrees with the rate law for the reaction of sodium thiosulfate with hydrochloric acid. ● Appendix Documents: Appendix 9.B – Determining the Rate Law Kinetics Activity #1	Cooperative Learning Technology Based Learning Practice	**D**
#1, #2, #3	4.B.1 4.B.2 4.C.1 ISTE-S.4	2. Activity: Virtual Chemistry Kinetics http://www.chm.davidson.edu/vce/kinetics/ ● Objective: Students will run various simulations to determine how the rate law is written. ● Appendix Documents: Appendix 9.C – Virtual Chemistry Kinetics	Technology Based Learning Activity	**D**
#1, #2, #3	4 A.1 4 A.2 4 A.3 4 B.1 4 B.2 4 B.3 4 C.1 4 C.2 4 C.3 ISTE-S.4	3. Activity: Study Island-Kinetics Unit ● Objective: Students will take practice multiple choice questions to reviews concepts of kinetics. ● Appendix Documents: Appendix 9.D – Study Island-Kinetics	Technology Based Learning Practice	**C**

UNIT RESOURCES
Teacher Resources: ● Brown LeMay 12^{th} Edition ● AP Chemistry Guided-Inquiry Experiments Teacher manual
Student Resources: ● Brown LeMay 12^{th} Edition ● AP Chemistry Guided-Inquiry Experiments Student manual ● Online learning platform provided by textbook company
Vocabulary: ● Reaction rate- the change in concentration of a reactant or product per unit time ● Instantaneous rate-the value of the rate at a particular time found by calculating the slope of the line tangent to the curve ● Rate law- the relationship that shows how the rate depends on the concentration of the reactants ● Rate constant-the proportionality constant ● Differential rate law- a rate law that expresses how the rate depends on the concentration ● Integrated rate law- expresses how the concentration depends on time ● Zero order- the rate is constant and does not change with concentration ● First order –the rate of the reaction depends on the reactant to the first power ● Second order –the rate shows that a plot of the inverse of the concentration versus time will be linear ● Reaction mechanism-chemical reactions that occur by a series of steps ● Intermediate-a species that is neither a reactant nor product but is formed and consumed in the reaction sequence. ● Activation energy- a threshold hold energy that must be overcome to produce a chemical reaction