Chino Valley Unified School District
High School Course Description

A. CONTACTS	
1. School/District Information:	School/District: Chino Valley Unified School District Street Address: 5130 Riverside Dr., Chino, CA 91710 Phone: (909) 628-1201 Web Site: chino.k12.ca.us
2. Course Contact:	Teacher Contact: Office of Secondary Curriculum Position/Title: Director of Secondary Curriculum Site: District Office Phone: (909) 628-1201 X1630
B. COVER PAGE - COURSE ID	
1. Course Title:	Chemistry in the Earth System
2. Transcript Title/Abbreviation:	Chem in Earth Syst
3. Transcript Course Code/Number:	5S03
4. Seeking Honors Distinction:	No
5. Subject Area/Category:	Science
6. Grade Level(s):	9-12
7. Unit Value:	5 credits per semester/10 credits total
8. Course Previously Approved by UC:	No
9. Classified as a Career Technical Education Course:	No
10. Modeled after an UC-approved course:	Yes
11. Repeatable for Credit:	No
12. Date of Board Approval:	May 3, 2018

13. Brief Course Description: Chemistry in the Earth Systems entails the understanding of the nature of matter and its transformations when they study atomic and molecular structure, the effects of electron interaction, chemical bonds, and stoichiometry. Additionally, the course offers the study of the properties of gases, acids and bases, solutions, and organic and inorganic compounds and an exploration of chemical systems through reactions and nuclear processes.

14. Prerequisites:	Biology; Co-requisite: Integrated Math1 or Higher

15. Context for Course: Chemistry in the Earth System Honors is one of three courses in California's three-course model for high schools implementing NGSS. To highlight the nature of Earth and space sciences (ESS) as an interdisciplinary pursuit with crucial importance in California, the course presents an integration of ESS and Chemistry.

16. History of Course Development:
The course was developed to meet the 2013 state adopted NGSS standards for the advanced learner. It is one course from a three-course model that combines all high school performance expectations into three courses.

17. Textbooks:	Wilbraham, A. C., & Prentice-Hall, Inc. (2007). Prentice Hall Chemistry. Upper Saddle River, NJ: Prentice Hall.
18. Supplemental Instructional Materials:	Teacher-created materials as needed

C. COURSE CONTENT

1. Course Purpose:
This course is a laboratory science course designed for the college-bound student that emphasizes students' ability to demonstrate their knowledge of chemistry within the context of the Science and Engineering Practices delineated in the Next Generation Science Standards. This course specifically examines the role of chemical properties and processes in driving the Earth system.

The sequence of this course is based on a specific storyline about climate ***change*** modeled in the CA State Science Framework. It begins with a tangible example of combustion and food calorimetry, and indeed the combustion of fossil fuels and release of heat, carbon dioxide, and water is a fundamental thread that ties together most of the sections of the course and ensures that chemistry concepts are able to be placed in the context of Earth's systems.

While many chemistry courses begin with the study of the atom, this course begins with macroscopic observations of a familiar phenomenon (combustion) and then zooms into the microscopic, but begins with simple interactions between particles to explain thermal ***energy*** and how it is exchanged within systems. Students then apply their understanding of heat flow to see its role in driving plate tectonics within the Earth system and only after students are firmly thinking about matter as particles do they zoom in and look at the nature of the particles themselves by studying atoms and how their behaviors are categorized into the periodic table. Once students are equipped to model simple chemical reactions, they return to the combustion chemical reaction and consider the impact its reaction product, carbon dioxide, has on the global climate system and students consider more advanced chemical reactions, then applying their understanding of chemical equilibrium to the very real problem of ocean acidification, which is also due to changes in carbon-dioxide concentrations in the atmosphere. In the end, students will have explored the fundamentals of chemistry and essential roles that these processes play in Earth's solid geosphere, its liquid hydrosphere, and its gaseous atmosphere.

2. Course Outline:

Instructional Segment 0 - Science Skills and Engineering Practices

Sample Guiding Questions:

- How do scientists and engineers collect data?
- What skills are necessary to be a scientist or an engineer?

Learning Targets:

- Students will to build upon foundational skills in scientific inquiry and strengthen mathematical skills needed to analyze data, skills to present data, and refine their understanding of engineering principles needed to develop a solution to a problem within given constraints. These skills will be called upon and further developed throughout the course.
- Topics of study and coursework will include engaging in arguments from evidence, systems and system models, accuracy and precision, types of data, mathematical manipulation, recording of results, analyzing raw data, constructing tables, drawing graphs, describing statistics and the spread of data, and engineering principles (define->develop->optimize).

Unit 1: COMBUSTION

In this unit students will work to answer the guiding questions:

- "What is energy, how is it measured, and how does it flow within a system?"
- "What mechanisms allow us to utilize the energy of our foods and fuels?"
- Learning Targets:
- Students investigate the amount of stored chemical potential energy in food. They make observations of material properties at the bulk scale that they will later explain in the atomic scale. The themes of combustion and CO_2 introduced in this unit will tie together several of the units throughout the course.

- Students will begin by examining nutrition labels of different foods where they will find a surprising amount of chemistry and develop and ***ask questions*** about what different items mean, like calories, and why they are included on the label. These questions will drive an investigation using a standard calorimetry experiment to measure the energy output of different foods. Students will ***analyze the data*** from the whole class, notice ***patterns, and*** represent this system with a pictorial ***model*** of the components and interactions including ***energy flows*** and an explanation of the ***cause and effect*** relationships articulating how the energy transfers from one place to another. The experimental results tend to systematically underestimate of the energy of the

food compared to nutrition labels. Students can use their model to speculate about the reasons for the difference.
- Before moving on, students should relate the combustion in this experiment to the real world. They should make a list of all the places that they know where things burn and they will revisit them in unit 5 as they discuss the impact of burning fossil fuels on global climate.

Unit 2: HEAT AND ENERGY IN THE EARTH SYSTEM

In this unit students will work to answer the guiding questions:
- "How is energy transferred and conserved?"
- "How can energy be harnessed to perform useful tasks?"

Learning Targets:
- Students will **develop models** of ***energy*** conservation within ***systems*** and the mechanisms of heat flow. They relate macroscopic heat transport to atomic scale interactions of particles, which they will apply in later units to **construct models** of interactions between atoms. They **use evidence** from Earth's surface to infer the heat transport processes at work in the planet's interior.
- An inquiry-driven investigation to monitor temperatures culminates with a **scientific explanation** resembling the Second Law. Students perform experiments such as measuring the temperature of two bodies of water before and after mixing, and the temperatures of metal blocks and water prior to and following immersion. By repeating these **investigations** with differing quantities of materials, students will apply the concept of ***scale, proportion, and quantity*** to predict temperature ***changes***, equilibrium conditions, and magnitudes of energy transferred.
- Students will explore the 2nd Law of Thermodynamics and relate the processes of conduction, convection, and radiation to the motion of individual particles. Students will **construct an explanation** about why solids are much better at transferring heat by conduction than liquids or gases because of their greater density.
- Students must **develop a model** of Earth's interior and use evidence to **support the claim** that its interior is convicting.
- Students will apply their **model** of density driven flow in rock not only to help understand heat transfer, but also to see how these flows give rise to plate tectonics.

Unit 3: ATOMS, ELEMENTS, AND MOLECULES

In this unit students will work to answer the guiding questions:
- "What is inside atoms and how does this affect how they interact?"
- "What models can we use to predict the outcomes of chemical reactions?"

Learning Targets:
- Students recognize patterns in the properties and behavior of elements, as illustrated on the periodic table. They use these patterns to develop a **model** of the interior structure of atoms and to predict how different atoms will interact based on their electron configurations. They use chemical equations to represent these interactions and begin to make simple stoichiometric calculations.
- Students will build a mental model of how the periodic table is arranged by using a physical model to arrange color chips from a paint store into a matrix based on color and hue. Students will understand the power of such models by predicting the existence of color/hue chips that were removed from the final matrix before the chips were distributed, mirroring the process Mendeleev used to predict the existence of elements not yet known.
- As students **analyze** plots of the properties of the elements as a function of atomic number, they should notice and discuss trends and patterns such as the comparatively low ionization energies of the alkali metals versus the high ionization energies of the noble gasses.

- Students should understand the basis for trends and ***patterns*** in the periodic table, and be able to **explain** the types of chemical reactions and resulting bonds that occur between elements.
- Students will use chemical equations as mathematical models to illustrate the cycle of matter within these chemical systems. Students will apply these basic principles of stoichiometry through laboratory **investigations**, problem solving, and reinforcement with apps and programs.

Unit 4: CHEMICAL REACTIONS

In this unit students will work to answer the guiding questions:

- "What holds atoms together in molecules?"
- "How do chemical reactions absorb and release energy?"

Learning Targets:

- Students compare the strength of different types of bonds and attractions and develop **models** of how ***energy*** is stored and released in chemical reactions.
- When students **conduct an investigation** to measure the conductivity of different solutions (salts, acids, bases, hydrocarbons, and oxides), they gather evidence that there must be some relationship between electricity and material properties and when they **investigate** the boiling points of water with different concentrations of salt and other solutes, they gather evidence that the salt must somehow be 'attracting' the water and preventing it from escaping as a gas. Students also notice patterns in the results of these experiments where materials that conduct electricity when they dissolve have a larger effect on boiling point.
- Students will use this evidence to support a **model** of different types of chemical bonds and attractions and learn how the nucleus of one atom has enough attractive force to pull one, two, or three electrons away from nuclei that does not have the same attractive force on its own electrons. Students will also **investigate** other forms of attraction such as polar attractions and intermolecular forces, **investigate** properties like surface tension and viscosity, and provide a model-based explanation of how these properties relate to microscopic electromagnetic attractions. Students will also develop and **explain models** of covalent, polar covalent, and ionic bonding and build on their model of the ionic bond breaking between sodium and chlorine when salt is dissolved in water.
- Students conduct **investigations** to **collect and analyze data** (both quantitative and descriptive observations) to discover that some reactions appear to release energy to their environment while others absorb it. By comparing the bond energy of the products with the bond energy of the reactants, students will construct mathematical **models** of the ***energy*** in the ***system*** and predict whether or not energy will be absorbed or released. Students observed differences in the relative strength of different types of bonds and attractions and students will **analyze data** about binding energy from published data tables or from their own investigations to look for ***patterns***.

Unit 5: CHEMISTRY OF CLIMATE CHANGE

In this unit students will work to answer the guiding questions:

- "What regulates weather and climate?"
- "What effects are humans having on the climate?"

Learning Targets:

- Students develop **models** of energy flow in Earth's climate as they revisit combustion reactions from Unit 1 to focus on emissions from fossil fuel energy sources. They apply **models** of the structures of molecules to explain how different molecules trap heat in the atmosphere and then **evaluate** different chemical engineering solutions that can reduce the impacts of climate change.
- Students will make a **conceptual model** of Earth's energy budget using accessible analogies like the line for a ride at an amusement park and the constant stream of eager visitors arriving at the end of the line represents solar radiation.

- Students will research the recent major Methane leak in southern California and **ask questions** about how gases other than CO_2 interact with infrared energy. Students will begin to develop **models** of how greenhouse gases absorb infrared energy with a basic computer simulation showing how molecules can absorb energy as the atoms in the bond vibrate towards and away from one another. Students will then use **evidence** from the simulator to construct an **argument** about why methane, water vapor, and carbon dioxide are strong greenhouse gases while oxygen and nitrogen are not.
- Students next **analyze** the past data related to earth's climate including atmospheric composition, average temperature, solar cycles, and Milankovitch cycles to refine and inform their models of energy flow in Earth's Climate system.
- Students will **evaluate** the scientific arguments made in media sources using a checklist called the Science Toolkit, discuss the content and graphs from different sources and construct an **argument** about which graph contains stronger **evidence**. To conclude the lesson, students write letters articulating their arguments about the claims in the articles to the editors of the media sources**.**

Unit: 6 THE DYNAMICS OF CHEMICAL REACTIONS AND OCEAN ACIDIFICATION

In this unit students will work to answer the guiding questions:

- "How can you alter chemical equilibrium and reaction rates?"
- "How can you predict the relative quantities of products in a chemical reaction?"

Learning Targets:

- Students will investigate the effects of fossil fuel combustion on ocean chemistry, develop models of equilibrium in chemical reactions, and design systems that can shift the equilibrium. During this unit, students conduct original research on the interaction between ocean water and shell-building organisms.
- Throughout the unit, students will gather evidence to construct a **scientific explanation** about what ***causes*** these variations in the rates of chemical changes in the ocean and **investigate** the response of reaction rates to varying temperatures and concentrations of reactants.
- Once students understand the ***effect*** of changing the concentration of reactants and products on reaction rates, they are ready to apply their understanding to novel situations. By applying *Le Chatlier's principle*, students can predict ways to increase the amount of product in a chemical reaction and refine the design of a chemical system by first measuring the output and then testing the effectiveness of changing the temperature and relative concentrations of reactants and products.
- Students will examine data showing trends in CO_2 concentrations in the ocean and atmosphere as evidence of a balancing feedback between two of Earth's ***systems*** that slows the rate of climate change and then design a simple **investigation** to generate CO_2 (gas released by a baking soda/vinegar reaction, a combusting candle, or yeast foaming) and measure the resulting pH. Students will also investigate the ***effect*** that temperature and salinity have on the ability of CO_2 to dissolve into the water and then apply their **models** of chemical equilibrium to predict the impacts of changing CO_2 levels in the ocean on these organisms.
- As students apply their **model** of equilibrium reactions from Le Chatelier's principle, they see that as the concentration of CO_2 increases, the ***system*** compensates by producing more products on the right side. Students will observe these effects themselves by planning an **investigation** to measure the rate of shell dissolution at different pH levels and they will obtain **information** on the health of coral reefs and coral bleaching, due in part to these pH changes.

3. Key Assignments:

- Various labs including; Measurement lab, Density lab, and Burning the Candle lab
- Using a simple calorimeter, students light a nut or other high Calorie snack food on fire below a metal can containing a measured amount of water. By measuring the temperature increase in the water and change in mass of the food item, students calculate the amount of ***energy*** transferred, which can be measured in the familiar unit of Calories, pool and analyze their class data, and represent their understanding of energy transfer

in a pictorial model with labels.

- Warm Embrace – Students explore how life has become more convenient as the fundamentals of thermochemistry are used to make instant hot and cold packs; along with which particular chemical process is most economically viable.
- Students dehydrate copper sulfate pentahydrate ($CuSO_4$-$5H_2O$) into the anhydrous salt ($CuSO_4$) by heating, and measure the mass of the resulting copper sulfate and water.
    - Students will present their observations, describe trends, construct explanations, and argue from evidence about the ratio of the mass of the resulting copper sulfate (dry mass) to water (the mass lost in dehydration). Students will have to defend with evidence and reasoning the claim that because the ratio of the component molecules in such a dehydration reaction remains constant, then the ratio of component elements must also remain constant. By **applying mathematical thinking**, students learn to balance chemical reactions and predict relative quantities of products.
- Students **plan and conduct investigations** to continuously monitor the temperature change accompanying the following reactions:

    1. $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$ (lime + water)
    2. $NH_4NO_3(s) + H_2O\ (l) \rightarrow NH_4^+(aq) + NO_3(aq)$ (ionization of ammonium nitrate, a fertilizer)
    3. $HCl(dilute) + NaOH(dilute) \rightarrow H_2O(l) + NaCl$ (neutralization)
    4. $NaCl(s) + H_2O(l) \rightarrow Na^+(aq) + Cl^-\ (aq)$ (dissolving table salt)
    5. $CaCl_2(s)+ H_2O \rightarrow Ca+\ (aq) +2Cl^-\ (aq)$ (de-icing roads)
    6. $NaHCO_3(s) + HCl(aq) \rightarrow H_2O(l) + CO_2(g) + NaCl(aq)$ (neutralization)
    7. $CH_3COOH(aq)+NaHCO_3(s) \rightarrow CH_3COONa(aq)+H_2O(l)+CO_2(g)$ (baking soda& vinegar)
    8. $C_{12}H_{22}O_{11} + H_2O$ (in 0.5M HCl) $\rightarrow C_6H_{12}O_6$ (glucose) + $C_6H_{12}O_6$ (fructose)(decomposing table sugar)
    9. $KCl(s) + H_2O(l) \rightarrow K^+(aq) + Cl^-\ (aq)$ (dissolving potassium chloride)
    10. $NaCl(s) + CH_3COOH(aq) \rightarrow Na^+(aq) + CH_3COO^-(aq) + HCl$ (preparing HCl to clean tarnished metals)
    11. $2H_2O_2 \rightarrow 2H_2O + O_2$ (Decomposition Reaction using a catalyst)

    - Students take screen captures of the temperature plots, classify each reaction as endothermic or exothermic, and represent it using two or more of the specified model-types, or an additional model type that they develop on their own. When writing their lab reports, students apply scientific principles and evidence to construct explanations for the thermal ***changes*** that they have observed in each reaction.
- Students will plot historic climate data provided by the teacher on chart paper and display their posters around the classroom. Students will next **analyze** the past data and draw a graph predicting the next 5 years, extrapolating both the long-term trend of increasing CO_2 and the annual variation and then **calculate** the year in which atmospheric CO_2 will reach 540 ppm (approximately double the pre-industrial CO_2 levels), assuming that current trends continue. Students will compare their predictions and discuss assumptions they made

about how quickly the CO_2 would increase.

- By mixing baking soda (sodium bicarbonate, $NaHCO_3$) and vinegar (acetic acid, CH_3COOH) in sealed sandwich bags, students will gauge the speed and degree of reaction by the rate and amount of CO_2 gas produced as indicated by the swelling of the bag measured by volume of water displacement: $NaHCO_3$ (aq) + CH_3COOH (aq) ---> CO_2 (g) + H_2O (l) + CH_3COONa (aq). Students **investigate** the role of the quantity of molecular collisions by repeating the activity with differing concentrations of vinegar and then **investigate** the role of temperature by warming or cooling the reactants while keeping their concentrations constant. By observing the swelling of the bags in response to varying temperatures and concentrations, students will discover that those factors that increase the number and ***energy*** of molecular collisions (increased concentration and temperature of reactants) result in increased reaction rates. Combining a **conceptual model** with experimental evidence, students will then write reasoned **explanations** for factors influencing chemical reaction rates.

4. Instructional Methods and/or Strategies:

- Lab-based learning (skills based labs as well as student designed and implemented labs)
- Cross Cutting Concepts (Patterns, Similarity & Diversity; Cause & Effect; Scale, Proportion & Quantity; Systems & Systems Models; Energy & Matter; Structure & Function; Stability & Change)
- Science & Engineering Practices (Asking Questions & Defining Problems; Developing & Using Models; Planning & Carrying out Investigations; Analyzing & Interpreting Data; Using Mathematics, Information & Computer Technology & Computational Thinking; Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence; Obtaining, Evaluating & Communication Information)
- Four Corners discussions (Agree, Strongly Agree, Disagree, Strongly Disagree)
- Data interpretation and predictions
- Jigsaw research projects (students or student groups research different aspects of a topic and report their learning back to the whole class, e.g. different types of invasive species or genetic disorders)
- Computer based research projects: individual students or groups research
- Evidence based data interpretation (Claim, Evidence and Reasoning writing from labs or research projects)
- Student centered and created activities (e.g. Evolution Island where students determine changes over time to organisms (e.g. rats) on islands with different ecosystems)
- Scientific article reading, annotation and/or class report/presentation
- Using CER (claims, evidence, and reasoning) graphic organizer
- Project Based Learning
- Argument Driven Instruction
- "5 E" Lessons (Engage, Explore, Explain, Elaborate & Evaluate)
- Phenomena

5. Assessment Including Methods and/or Tools:

The evaluation of student progress and evaluation will be based on the following criteria outlined in Board Policy:

- Assessments: 60-75% of the final grade
- Assignments and class discussions: 25-40% of the final grade