IS1

Chemistry in the Earth System Instructional Segment 1: Combustion

Understanding chemistry allows us to understand the world around us and to make decisions and discoveries to improve the quality of life. Often we do not notice the direct influence of chemistry in our lives, but it is all around us. From the neodymium magnets that vibrate our cell phones to the chemical reactions that go on inside our bodies, chemistry is often overlooked and taken for granted. In this short introductory instructional segment, students **investigate [SEP-3]** a simple chemical system and begin to **ask questions [SEP-1]** about it. This instructional segment lays the foundation for achieving several performance expectations but is not designed in a way that students fully meet any of them upon completion. The instructional segment is instead used to set the stage for the entire course, illustrating many of the phenomena that students will investigate, model, and explain.

CHEMISTRY IN THE EARTH SYSTEM INSTRUCTIONAL SEGMENT 1: COMBUSTION

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?

Performance Expectations

Students who demonstrate understanding can do the following:

HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. [Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] *[Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.]* (Introduced, but not assessed until IS3)

HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. [Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] *[Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]* (Introduced, but not assessed until IS4)

HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. [Clarification Statement: Emphasis is on using

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mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem- solving techniques.] *[Assessment Boundary: Assessment does not include complex chemical reactions.]* (Introduced, but not assessed until IS3. Revisited in IS4 and IS6)

HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] *[Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.]* (Introduced, but not assessed until IS2)

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-2] Developing and Using Models [SEP-3] Planning and Carrying Out Investigations [SEP-5] Using Mathematical and Computational Thinking	PS1.A: Structure and Properties of Matter PS1.B: Chemical Reactions PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer PS3.D: Energy and Chemical Processes in Everyday Life	[CCC-1] Patterns [CCC-4] Systems and System Models [CCC-5] Energy and Matter: Flows, Cycles, and Conservation

CA CCSS Math Connections: N-Q.1–3; MP.4

CA CCSS for ELA/Literacy Connections: SL.11–12.5; RST.11–12.1; WHST.9–12.7, 8, 9

CA ELD Connections: ELD.PI.11–12.1, 5, 6a–b, 9, 10, 11a

Students begin by examining nutrition labels of different foods where they will find a surprising amount of chemistry. They might notice familiar measures of mass or volume, names of chemical elements, and some ingredients with complex multi-syllabic names of chemical compounds. Students should **ask questions [SEP-1]** about what different items mean and why they are included on the label. Students are commonly familiar with the idea of Calories, but may ask what Calories are, and how they are measured. These questions drive an investigation using a standard calorimetry experiment to measure the energy output of different foods. The experiment can be done with a soda can. Students light a nut or other high-Calorie snack food on fire[8] below a metal can containing a measured amount of water. The burning food transfers energy to the water in the can. By measuring the temperature increase in the water, students calculate the amount of **energy [CCC-5]** transferred, which can be measured in the familiar unit of Calories (HS-PS3-1). The experimental results tend to be inconsistent, so different lab groups should pool their results to identify outliers before comparing their results to nutrition label values. As they **analyze the data [SEP-4]** from the whole class, they notice **patterns [CCC-1]**, such as the larger the change in food mass, the greater the temperature increase of the water. Students will investigate the detailed mechanism of that energy release related to **changes [CCC-7]** in bond **energy [CCC-5]** in IS4 (HS-PS1-4).

Students then represent this system with a pictorial **model [SEP-2]** by drawing a diagram of the components and interactions. **Energy flows [CCC-5]** represent **cause and effect [CCC-2]** relationships and students should label them as arrows with specific descriptions articulating how the energy flows from one place to another. In grade five, students calculated that mass is conserved during heating (5-PS1-2), but the mass of this chemical system appears to have **changed [CCC-7]**. Many students will incorrectly state that the mass of the food was converted to the energy of the heating (a process that only occurs in nuclear fusion). In IS4, students will revisit this system and realize that the missing atoms escaped the **system [CCC-4]** as hot gases—the products of combustion—and not because they disappeared completely (HS-PS1-7). The experimental results tend to systematically underestimate the energy of the food compared to nutrition labels. Students can use their model to speculate about the reasons for the difference.

When given time devoted to **asking questions [SEP-1]** about their experiment, students wonder if the results would differ if they used a tin can instead of an aluminum one or a different liquid instead of water, perhaps the soda that was originally in the aluminum can. This question motivates an extension to the original investigation that allows students to recognize specific heat capacity and thermal conductivity as bulk properties of substances, which they will later explain in terms of electrical forces between particles (HS-PS1-3). Students repeat the experiment using different liquids and different cans, while monitoring the temperature **change [CCC-7]** over time both while the nut is burning and afterwards as

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[8] This activity is an optimal time to discuss lab safety with students at the beginning of the year, including fire safety and attentiveness to nut allergies.

the liquid and the room converge to a more uniform temperature (HS-PS3-4). With careful measurements, students should discover a slight difference between freshwater and water with sugar or salt added. The difference in bulk properties must relate to some sort of microscopic interaction between the salt and the water that students will investigate in IS3.

The difference is more dramatic when they try cooking oil. (Safety reminder: students should always wear protective lab wear including goggles and aprons.) Students might wonder what the difference is between cooking oil and water that makes these materials respond to the heat differently. 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 IS5 as they discuss the impact of burning fossil fuels on global climate (ESS3.D).

IS2

Chemistry in the Earth System Instructional Segment 2: Heat and Energy in the Earth System

As a precursor to understanding endothermic and exothermic chemical reactions, reaction kinetics, or gas laws, students need a robust model of matter moving around as discrete particles that interact. In IS2, students investigate the laws of thermodynamics in systems as small as atoms and as large as the entire Earth.

CHEMISTRY IN THE EARTH SYSTEM INSTRUCTIONAL SEGMENT 2: HEAT AND ENERGY IN THE EARTH SYSTEM

Guiding Questions

- How is energy transferred and conserved?
- How can energy be harnessed to perform useful tasks?

Performance Expectations

Students who demonstrate understanding can do the following:

HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] *[Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.]*

HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects). [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]