FLINN SCIENTIFIC

360STORYLINES

THE MOST ADAPTABLE SOLUTION FOR NGSS LEARNING

360STORYLINES

A storyline is a logical sequence of activities that help students "figure out" the science behind phenomena, things observable in the natural world. A 360Storyline provides all of the tools needed to guide students to a clear understanding of a phenomenon, including an implementation guide, daily planner, driving question template, four versions of each laboratory activity and videos that help students perform unfamiliar techniques and connect what they do to what is observable in the world.

Meet the Scientists

Flinn's expert team of advance degreed & PhD leveled scientists are responsible for the creation of each 360Storyline. With many years of teaching experience, they are uniquely qualified to create these tools.

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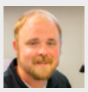

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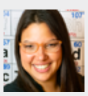

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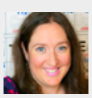

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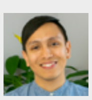

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360Storyline—**Forest Fires**

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Catalog Number

AP10995

Key Concepts

- Combustion Reactions
- Bond Energies
- Law of Conservation of Mass
- Law of Conservation of Energy
- Chemical Potential Energy

Synopsis

Lead students to a written understanding/working model of forest fires. Forest fires are examples of fuel sources undergoing exothermic reactions, such as hydrocarbons reacting with oxygen in the atmosphere to produce water vapor and carbon dioxide. The process releases significant amounts of energy because the energy needed to break the bonds in the fuels is smaller than the energy released by the formation of the products: carbon dioxide and water. For a fire to burn, there must be heat, fuel and oxygen. A forest provides a large amount of fuel in the form of trees densely packed together. The energy given off by a single tree can serve as the activation energy that causes an adjacent tree to burn and so on.

What Students Do

Lab 1—Energy Densities of Organic Fuels

Students use calorimetry to determine the amount of energy (on a per gram basis) in multiple fuel sources including wood and ethanol.

Lab 2—Matter Transformation in Combustion

Students combust organic compounds, including sucrose and dextrose, in a closed system.

Lab 3—Measure Energy Flow in Chemical Reactions

Students react calcium oxide with water and barium hydroxide with ammonium thiocyanate. Students carry out each reaction multiple times, varying the masses of starting materials across trials.

Lab 4—Climate Change and the Carbon Cycle

Students create mixtures that contain plant life, water and acid-base indicators. They expose the mixtures to light or darkness.

DAILY PLANNER

360Storyline Guide - Forest Fires

Lead students to a written understanding/working model of forest fires. Forest fires are examples of exothermic reactions that result from fuel sources such as hydrocarbons reacting with oxygen in the atmosphere to produce water vapor and carbon dioxide. This process releases significant amounts of energy, because the energy needed to break the bonds in the fuels is smaller than the energy released by the formation of the products (carbon dioxide and water). For a fire to burn there must be heat, fuel, and oxygen. A forest provides a large amount of fuel in the form of trees densely packed together. The energy given off by a single tree can serve as the activation energy that causes an adjacent tree to burn, and so on. Forest fires exacerbate the negative consequences of climate change because burning trees release carbon dioxide into the atmosphere and are rendered incapable of recycling carbon dioxide.

Sequence and Pace

Lab 1—Energy Densities of Organic Fuels (60–75 minutes)

Lab 2—Matter Transformation in Combustion (60–75 minutes)

Lab 3—Measure Energy Flow in Chemical Reactions (60–75 minutes)

Lab 4—Climate Change and the Carbon Cycle (60–75 minutes)

Total time = 240–300 minutes (5–7 class periods)

Outcomes

In **Lab 1**, students discover that different fuels release different amounts of energy owing to their different compositions. In **Lab 2**, students discover that matter is not destroyed in a combustion reaction, but conserved. In **Lab 3**, students discover that there is chemical potential energy stored in bonds and that this energy is released during combustion. In **Lab 4**, students discover that forest fires release carbon dioxide into the atmosphere and also destroy carbon-recycling trees, thus exacerbating the negative consequences of climate change.

Standards Introduced

HS-ESS2-6: Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
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.
HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
HS-PS3-1: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Concepts and Subconcepts

1. Combustion Reactions
    a. Chemical reactions represent the processes by which matter transforms
    b. Combustion reactions typically involve the reaction of hydrocarbons with oxygen to form carbon dioxide and water. They are generally exothermic because the energy associated with the formation of bonds in the products exceeds the energy required to break the bonds in the reactants.

2. Bond Energies
    a. The bond energy associated with a chemical bond, often reported in Kilojoules/mole, refers to the amount of energy released or absorbed when the bond is formed or broken, respectively.
    b. Large bond energies indicate strong bonds, i.e., bonds that require more energy to break than weak bonds, those with small bond energies. For example, we would expect the triple bond between two nitrogen atoms in a diatomic nitrogen molecule to have a higher bond energy than the double bond between two oxygen atoms in a diatomic oxygen molecule.

3. Law of Conservation of Mass
    a. All matter is made up of atoms, which are identified based on the number of protons in their nuclei.
    b. Atoms' physical and chemical properties are dependent on their electronic structures, i.e., the number of electrons and their arrangement about the nucleus.
    c. Atoms can form bonds with other atoms by transferring or sharing electrons. When atoms bond with other atoms they form compounds.
    d. The atoms in compounds can rearrange or be transferred to other compounds by taking part in chemical reactions. Atoms are not created or destroyed in chemical reactions. Rather, they are transformed, such as when the carbon atoms in a tree or wood splint are burned, and thereby transformed into carbon dioxide molecules.

4. Law of Conservation of Energy
    a. Energy cannot be created or destroyed, it can only be changed from one form into another.
    b. The energy from the sun is converted to biomass through the chemical process of photosynthesis.
    c. When trees burn in combustion reactions the chemical potential energy in the chemical bonds that comprise a tree is released as heat.

5. Chemical Potential Energy

   a. There is energy stored in the bonds between atoms.
   b. The amount of energy stored in a chemical bond can be determined experimentally, using processes such as calorimetry.
   c. The energy stored in a chemical bond is typically accessed by breaking the bond, e.g., in a chemical reaction such as a combustion reaction.
   d. The amount of energy in a chemical bond can be inferred from the type of bond, and the amount of energy required to break it.

Daily Plan: Activities are indicated in black font; what students figure out in each activity is indicated in purple font. Activity durations are indicated in parentheses.
Day 1 - Energy Densities of Organic Fuels View *Introductory Video* (5 min.) There is energy associated with the breaking and forming of chemical bonds during chemical reactions, observable in the natural world in many ways including as forest fires. Respond to *IP* question located in the top left quadrant of the *DQT* (10 min.) When fuels burn the atoms are not created or destroyed, but transformed. Carry out short, guided, open, or advanced laboratory procedure (30–50 min.) Observe that different fuel samples cause the temperature of water to change by different amounts when the fuels are heated adjacent to the water.
Day 2 - Energy Densities of Organic Fuels Respond to *Analyze and Interpret* questions (10–15 min.) The different temperature changes in water caused by the different fuel sources are attributable to the fact that the fuel sources are composed of different types of atoms with different kinds of bonds. These bonds must have different amounts of energy associated with them. View *Summary* Video (5 min.) When trees and organic matter burns in a forest fire, the bonds that hold the atoms in the tree and in the oxygen molecules together break, and the separated atoms reform into carbon dioxide and water molecules. Energy is released as this process occurs and this energy is observable as a temperature change, large flames, and general destruction.

Record a *Revised Explanation* to the *IP* question, in the bottom left quadrant of the *DQT* (5 min.) When fuels with different numbers of atoms burn they release different amounts of energy. For example, wood and ethanol have different chemical formulas and so when they burn they cause different temperature changes to water held in an adjacent calorimeter. These different temperature changes indicate the release of different amounts of energy. Record a response to the *AP* question in the top right quadrant of the *DQT* (5 min.) Forests provide large reserves of fuel. The scale of a forest fire is many orders of magnitude greater than the scale of this experiment. Dry fuel burns more readily than wet fuel. Forest fires require an energy input, or activation energy, such as that provided by a match.
Day 3 - Matter Transformation in Combustion Reactions View *Introductory Video* (5 min.) Matter is not created or destroyed in chemical reactions, rather it changes from one form to another. Respond to *IP* question located in the top left quadrant of the *DQT* (10 min.) Atoms rearrange when the compounds they compose react. Carry out short, guided, open, or advanced laboratory procedure (30–50 min.) Observe that the mass of a closed system that contains a combustion reaction remains constant throughout the reaction.
Day 4 - Matter Transformation in Combustion Reactions Respond to *Analyze and Interpret* questions (10–15 min.) Matter must be transformed in combustion reactions because burning sugar changes its outward appearance, but when the combustion reaction is carried out in a closed system, the pre-combustion and post-combustion masses are equal. View *Summary* Video (5 min.) Although trees appear “destroyed” following forest fires, the atoms that compose them have been transformed into carbon dioxide and water molecules. Record a *Revised Explanation* to the *IP* question, in the bottom left quadrant of the *DQT* (5 min.) When a fuel source burns the atoms in the fuel source are separated from each other, i.e. chemical bonds are broken, and the atoms combine into new compounds, i.e. chemical bonds are formed. Because atoms are not created or destroyed in this

process, mass does not change.

Record a response to the *AP* question in the top right quadrant of the *DQT* (5 min.)
When trees and homes burn in forest fires they are not literally destroyed, rather the matter that composes them is transformed.

Summarize what is known about forest fires to this point, in the *Working Model* quadrant of the DQT. (5 min.)
Forests provide large fuel sources and forest fires convert the atoms that compose plant life into carbon dioxide and water. Forest fires do not start spontaneously, but need an initial energy input. The energy from a forest fire derives from chemical reactions in which bonds between atoms break and reform as matter is transformed.

Day 5 - Measure Energy Flow in Chemical Reactions
View *Introductory Video* (5 min.)
Chemical reactions can absorb or release energy and result in temperature decreases or temperature increases.

Respond to *IP* question located in the top left quadrant of the *DQT* (10 min.)
The energy associated with chemical reactions derives from the breaking and forming of the bonds that hold atoms together.

Carry out short, guided, open, or advanced laboratory procedure (30–50 min.)
Some chemical reactions absorb energy and result in observable temperature drops, whereas others release energy and result in observable temperature increases. As the number of chemical bonds that form or break increases, the amount of energy associated with a reaction increases.

Day 6 - Measure Energy Flow in Chemical Reactions
Respond to *Analyze and Interpret* questions (10–15 min.)
There is a direct relationship between the amount of energy absorbed or released by a chemical reaction or a system, and the temperature change associated with the reaction or system. The amount of energy absorbed or released by a chemical reaction depends on the types of bonds, and thus the types of atoms, and the quantity of bonds or amount of reacting material.

View *Summary* Video (5 min.)
The trees that burn in forest fires contain large amounts of chemical potential energy that is released when the bonds that hold their composite atoms together break and reform primarily into carbon dioxide and water molecules.

Record a *Revised Explanation* to the *IP* question, in the bottom left quadrant of the *DQT*
(5 min.)
Compounds composed of atoms of different elements can have very different energies associated with them. For example, the reaction with ammonium thiocyanate leads to a temperature decrease. The energy associated with a chemical reaction depends on the types of atoms and the fact that they have different connectivities. In chemical reaction bonds break and reform, and it is the balance of energy associated with these processes that results in a temperature increase (release of energy) or a temperature decrease (absorption of energy).

Record a response to the *AP* question in the top right quadrant of the *DQT* (5 min.)
The energy given off in a forest fire derives from chemical reactions, specifically the combustion of trees with excess atmospheric oxygen. In a fire the bonds between the atoms that compose trees are broken as are the bonds in oxygen molecules. The atoms reform into carbon dioxide and water and there is a net release of energy macroscopically observable as a temperature change.

Summarize what is known about forest fires to this point, in the *Working Model* quadrant of the DQT. (5 min.)
The energy given off by a forest fire derives from the breaking and reforming of the bonds that connect the atoms in trees as well as the bonds in oxygen molecules. Forest fires are not spontaneous, but once they start they are difficult to extinguish because trees are usually densely packed and forest fires often occur in dry climates, where wood burns more readily. The material burned in a forest fire is not destroyed but is converted to carbon dioxide, water, and other minor products.

Day 7 - Climate Change and the Carbon Cycle
View *Introductory Video* (5 min.)
Plant life such as trees can recycle carbon dioxide into energy through photosynthesis.

Respond to *IP* question located in the top left quadrant of the *DQT* (10 min.)
Trees remove carbon dioxide from the atmosphere by turning into energy, thus mitigating its negative environmental impact.

Carry out short, guided, open, or advanced laboratory procedure (30–50 min.)
Plants remove carbon dioxide from their environments, thus they raise the pH of aqueous solutions exposed to light in which they are submerged

Day 8 - Climate Change and the Carbon Cycle
Respond to *Analyze and Interpret* questions (10–15 min.)
Trees are net consumers of carbon dioxide because the rate of photosynthesis exceeds the rate of respiration.

View *Summary* Video (5 min.)
Carbon dioxide contributes to global temperature increases. When trees are destroyed their ability to transform carbon dioxide into harmless by-products is lost, and the problems associated with global warming are exacerbated.

Record a *Revised Explanation* to the *IP* question, in the bottom left quadrant of the *DQT*
(5 min.)
Plant life is able to remove carbon dioxide from water, which implies that plant life is able to remove carbon dioxide from the atmosphere. The rate of photosynthesis exceeds the rate of respiration and that plants are therefore net carbon reducers.

Record a response to the *AP* question in the top right quadrant of the *DQT* (5 min.)
Forest fires, or deforestation, removes carbon dioxide recyclers from the earth system as well as directly vents carbon dioxide into the atmosphere. These things together lead forest fires to be net increasers of carbon dioxide.

Summarize what is known about forest fires in the *Final Model* quadrant of the DQT. (5 min.)
The energy associated with a forest fire derives from the potential energy in chemical bonds. Forest fires are hard to put out because the atmosphere provides an excess of oxygen and the forest provides a large amount of closely packed fuel, i.e., each burning tree can supply the energy to burn another tree(s). Forest fires are pronounced in dry climates because dry fuel burns more readily than wet fuel. Forest fires put carbon dioxide directly into the atmosphere and removes organisms that are capable of converting carbon dioxide into sugar from the earth system.

IMPLEMENTATION GUIDE

THE NEXT GENERATION SCIENCE STANDARDS

The Next Generation Science Standards (NGSS) advocate an exploratory style of science education that would have students discover science's universally accepted truths, or disciplinary core ideas (DCIs), rather than read or hear about them. Students derive these facts during their efforts to understand phenomena, things observable in the natural world, by using seven Science and Engineering Practices (SEPs). Moreover, the NGSS imply that DCIs are best understood from interdisciplinary perspectives called Cross-cutting Concepts (CCCs). For example, a student will come to a deeper understanding of the Law of Conservation of Mass, a topic typically found in Chemistry courses, by relating it to photosynthesis, a topic typically found in Biology courses. Broad titles such as *High School Physical Sciences* therefore organize the NGSS. In essence, adoption of the NGSS by a teacher, school or district implies a belief that better long-term outcomes will result if students are trained to do science as it is done in an academic, government, or commercial research laboratory.

PEDAGOGICAL STANCE

We believe that when students do science the way it has been practiced since the advent of the Scientific Method, by figures like Marie Curie, Ernest Rutherford and countless others in research laboratories, they will better retain science's core facts and develop problem-solving skills increasingly valued in a complex world prone to automation of jobs. We also believe that such an approach to science education poses challenges, including time and resource constraints; unfamiliarity with this style of learning; and student groups of varying abilities and comfort levels. We therefore developed 360Storylines to be a practical solution for teachers, schools and districts wanting to adopt the NGSS. It is a tactile curriculum that lets teachers facilitate student-driven learning in reasonable time blocks, so that students figure out as much "content" as possible in a way that adheres to the vision of science education implied by the NGSS. We describe below how to use the elements of the curriculum to replicate for students the experience of being a scientist.

PROFESSIONAL DEVELOPMENT

One of the biggest hurdles to the implementation of a new teaching style is training, particularly where technology is involved. Please reach out to set up a one-on-one session with our implementation specialists and staff scientists.* We enjoy helping teachers implement this new, practical curriculum, and welcome opportunities to converse about all things science and science education, including the NGSS.

THE COMPONENTS OF A 360STORYLINE

Synopsis

- A pdf document that provides: a storyline summary, descriptions of the three to eight experiments that comprise the storyline, a recommended sequence, performance expectations, and key concepts.
- Use to determine whether a particular storyline engages with targeted performance expectations, standards, or concepts.

Experiment Overview

- A pdf document that provides: a description of each of the four levels in an experiment, key concepts, a list of performance expectations; applicable DCIs, SEPs and CCCs; and learning outcomes.
- Use to determine whether a particular experiment engages with targeted performance expectations, standards, or concepts; and to judge which level of a lab is most appropriate for a student or cohort of students.

Driving Question Template

- A set of downloadable and editable MSWord documents that provides experiment-level driving questions related to investigative phenomena, storyline-level driving questions related to anchoring phenomena, and prompts to describe and refine a working model of the phenomena. The document set includes a student version with space for written or typed answers, and a teacher version with sample answers and reasoning.
- Use to guide students through a storyline. The driving question templates ask students to draw conclusions from observations and use their conclusive evidence to progressively render increasingly refined explanations of phenomena. It is important to note that the driving questions in these documents can be altered by teacher or student. They can also be shared in a public place such as in a Google Drive folder to allow for discourse both within and across student groups, and at the classroom level if desired.

Background Information

- A digital webpage accessible with an electronic device such as a Chromebook, iPad or PC that presents information students must know, or is helpful to know, in order to perform an experiment. This document can also be downloaded as a pdf and distributed to students or posted to a Learning Management System or Google classroom.
- Use to help students prepare for an experiment, especially when the material under study is complex and therefore may require a level of what some in the NGSS community refer to as “learning about.”[**]

Experiment Templates

- A set of digital web pages that contain the traditional "content" associated with a laboratory experiment, including: Overview, Materials, Safety, Procedure, Summary, and Analyze and Interpret sections. The set includes four versions of a lab: a **short version** that can be done in a single period, a prescriptive, **guided version** that requires 1-2 periods, an **open version** that requires independent experimental design, and an **advanced** version that requires students "do science" in accordance with Achieve's *A Framework to Evaluate Cognitive Complexity in Science Assessments.*[***] The templates also include videos, writable data tables and writable answer boxes, in which procedures, data and answers may be recorded and submitted digitally. Every section of an experiment template is completely editable - the platform allows for this by rendering modifiable html code into an easy-to-use interface. Each version of a particular laboratory experiment is also available as a downloadable pdf, that can copied for distribution to students or posted to an Learning Management System or Google classroom.
- Use to help students apply SEPs to discover targeted DCIs. Students make observations and draw conclusions that they use to understand investigative and anchoring phenomena laid out in *Driving Question Templates*. For example, in an **open** version students must decide what data to collect to answer experiment-level driving questions, and how to do so in a controlled fashion. Students not accustomed to an exploratory style of learning can engage in a **guided** version of the lab. Also, you can modify any section of a lab, including the procedure, to suit a target learning outcome or student comfort level. This ability to provide a personal experience for each student allows for practical implementation of the NGSS vision of science education, because some students struggle with independent decision-making, and require a slow transition that can begin with prescriptive lab experiences.

Videos

- A set of videos that helps students understand DCIs and connect them to phenomena, and understand unfamiliar equipment and lab techniques.
- Use to facilitate understanding of DCIs and their relationships to phenomena, and unfamiliar lab techniques. Students can view videos anytime on any internet-capable device. For example, students might watch videos before an experiment to gain a higher degree of comfort prior to participation, or during lab as they encounter difficulty. We believe that multimedia is a powerful complement to hands-on science. This idea is discussed in several very interesting manuscripts in the science education literature.[****]

Assessments

- Opportunities for students to demonstrate their understanding of DCIs and CCCs, and proficiency in applying SEPs. These include gradable procedures, gradable data tables, gradable analyze and interpret questions, and responses recorded in *Driving Questions Templates.*

- Prior to implementation of any NGSS curriculum, we recommend reading Achieve's *A Framework to Evaluate Cognitive Complexity in Science Assessments.*[***] The framework describes a qualitative scale for assessing single items and multi-component tasks, that ranges from *Scripted* to *Doing Science*. A student performs at the "*Doing Science"* level if the student can engage in a task *"...with limited to no scaffolding across all three dimensions; [and] decide how to engage and execute within the task."* A 360Storyline allows you to make and record this type of judgement. For example, you can assign a four-point scale to a student-written procedure wherein "4" represents "*Doing Science.*" The empirical score can be combined with feedback like: "The student was able to design an experiment to answer a relevant question by identifying appropriate independent, control and dependent variables; and was able to set up an appropriate apparatus to enable data collection. The student drew reasonable conclusions from her data and was able to connect them to the phenomenon under study."

Simulations

- Virtual reality experiences that help students connect the sub-microscopic to the macroscopic. For example, a student can observe a glass of water but it is impossible to see the hydrogen-bonding interactions present between the molecules, that are in part responsible for water's physical properties.
- Use to help students connect the submicroscopic world to the macroscopic world, to better understand DCIs and connect them to phenomena.

Teacher Notes

- A set of four downloadable and editable MSWord documents that provides sample answers to assessments, sample data, sample procedures, preparation and safety information, and helpful tips and suggestions.
- Use to assess student performance against model answers, data and responses. You can print hard copies of the lab procedures using these documents, if desired.

Supplies

- The necessary consumables and some durable equipment needed to carry out an experiment. Lists of the materials associated with each 360Storlyine are available as downloadable documents on www.flinnsci.com and www.flinn 360science.com. We believe that most of the NGSS DCIs require manipulation of physical materials, as opposed to theoretical study only, to truly understand. This idea is discussed in a fascinating study performed at the University of Chicago that describes a positive, causal relationship between hands-on science and learning outcomes.[*****]

HOW TO USE THE COMPONENTS OF A 360STORYLINE: Lesson Structure

Carry out the following steps prior to, during and after each laboratory.

Pre-lesson preparation

1. Distribute the driving question template (DQT) for the storyline to students. You may print copies out for distribution or post as a downloadable document to a Learning Management System or a Google classroom.
2. Assign each student or student group the lab version appropriate to that student or group's ability/comfort level. The short and guided versions are very prescriptive and provide detailed descriptions of the steps students must take to carry out a procedure. The open and advanced versions provide a low level of scaffolding and ask students to create their own procedures to gather relevant data. You may assign all students the same procedure (short, guided, open, advanced) or you may assign different procedures based on student readiness.
3. Ask students to answer the IP question located in the DQT for the lab by working in groups. Remind students that their answers at this point do not have to be correct, because they are going to be changed once the experiment is complete. In some cases, students may even write "we have no idea." Allow no more than 10 minutes for all groups to come up with an answer to the IP question.
4. Review with students the safety information provided in the *Teacher Notes* of the lab.
5. Ask students to carry out the laboratory procedure in the version assigned to them. (Note: you may choose to have students watch the laboratory videos prior to the labs, e.g. the night before, so that they feel more comfortable engaging in the hands on experience and are better prepared to connect the hands-on experience to the phenomenon under study.)

During the lesson

1. Remind students to, at regular intervals, intentionally consider how their observations might inform their understanding of the anchoring phenomenon, forest fires. The connections students make do not need to be fully formed or entirely accurate, but they must be made so that they can be refined later. For example, students observing a burning wood splint in lab 1 of the *Forest Fires* Storyline might draw a parallel between the splint and a tree and wonder what happens when the splint burns. Questions such as "Is it destroyed?" and "What happened to the stuff that makes it up?" are examples of possible lines of inquiry that can be captured in the driving question template.
2. If you find that students are struggling you may choose to have them watch or re-watch the introductory video associated with a lab. Or, if the students are working from the open or advanced procedure you may choose to provide more scaffolding, by giving them the short or guided procedure. These procedures provide much more direction and steps to follow, and are therefore useful to students not accustomed to designing their own procedures.
3. Once students have carried out their procedures and recorded their data, they should complete the *Analyze and Interpret* questions.

Post-lesson

1. Once students have completed the *Analyze and Interpret* questions, they should provide a revised answer to the IP question, in the "Revised Explanation" quadrant of the driving question template; and they should answer the *AP* question located in the top right quadrant of the driving question template.
2. You may choose to have students watch the summary video associated with the lab, because it provides help connecting the phenomenon under study to the hands-on lab experience.
3. You may choose to have students share information across groups by posting their answers in a shared space, such as on a blackboard or in a shared Google folder. Or, you may choose to elect a spokesperson from each group to share the group's *revised explanation* as well as the group's answer to the *AP* question. This kind of process allows for discussion to happen at a class level and provides an opportunity to address misconceptions. Provide consistent reminders that all answers are welcome, so that students feel comfortable offering their unique perspectives.

Post-lesson Assessment

1. Each lesson within a storyline may be assigned a score of 1-4, according to Achieve's *A Framework to Evaluate Cognitive Complexity in Science Assessments*. This framework describes a qualitative scale for assessing single items and multi-component tasks, that ranges from *Scripted* to *Doing Science*. A student performs at the "*Doing Science"* level if the student can engage in a task *"...with limited to no scaffolding across all three dimensions; [and] decide how to engage and execute within the task."*
2. The lesson score a student earns should reflect your interpretation of the student's written work as well your interpretation of the student's ability to "do science" as judged by your observations and verbal interactions with them throughout the lesson, such as responses to questions including "Why do you think that is an important procedural step?" or "What is your control variable?" Written work includes self-designed procedures, data, answers to *Analyze and Interpret* questions and responses recorded on the *Driving Questions Template.* Written work may be judged against the rubrics provided in the *Teacher's Notes* section of each lab. Though it is difficult to assess a student's ability to "do science" based on their response, verbal or written, to a single query, their engagement with a full lesson or storyline provides ample evidence to form a holistic assessment of their ability.
3. A 360Storyline allows for multiple points of feedback to the student. For example, you can assign a four-point scale to a student-written procedure wherein "4" represents "*Doing Science.*" The empirical score can be combined with feedback like: "The student was able to design an experiment to answer a relevant question by identifying appropriate independent, control and dependent variables; and was able to set up an appropriate apparatus to enable data collection. The student drew reasonable conclusions from her data and was able to connect them to the phenomenon under study." These observations can be further combined with students' responses to post-lab questions and *Driving Question Templates* to provide holistic feedback.

* Please get in touch by emailing Chrystie Kovalev at ckovalev@flinnsci.com.
** The term “learning about” is often used to describe the “traditional” means by which students are exposed to science content, wherein teachers tell them the facts or they read about them. This is in contrast to the style espoused by the NGSS, often called “figuring out.”
*** Accessed at https://www.achieve.org/cognitive-complexity-science; December 2019.
**** 1. Stieff, M; Werner, S. M.; Fink, B.; Meador, D. Online Prelaboratory Videos Improve Student Performance in the General Chemistry Laboratory. *J. Chem. Educ.* 2018, *95*, 1260-1266.
2. Cresswell, S. L.; Loughlin, W. A.; Coster, M. J.; Green, D. M. Development and Production of Interactive Videos for Teaching Chemical Techniques during Laboratory Sessions. *J. Chem. Educ.* 2019, *96(5)*, 1033-1036.
***** Kontra, C.; Lyons, D. J.; Fischer, S. M.; Beilock, S. L. Physical Experience Enhances Science Learning. *Psych. Science*. 2015, *26(5)*, 737-749.

TEACHER EDITION—DRIVING QUESTIONS

Lab 1: Energy Densities of Organic Fuels

IP: What happens when fuels burn? Write a possible explanation of this phenomenon.	**AP:** Why are forest fires hard to extinguish? Based on what you learned in this experiment, try to formulate an explanation to answer this question. What evidence did this experiment supply to aid in your understanding?
Students may note that when fuels burn the area around them gets hotter, or that fuels "go away" when they burn. At this point they may not be able to make claims about energy densities, or why different fuels contain different amounts of energy. They may note that different fuels are made of different types of "stuff," or they may make very broad statements such as "different fuels release varying amounts of energy because they are different."	Students should recognize that forests provide large reserves of fuel. The scale of a forest fire is many orders of magnitude greater than the scale at which their experiment takes place. They should also recognize that dry fuel burns more readily than wet fuel. This is evident when they try to burn a wet wood splint and compare the energy released by the wet wood splint to the dry wood splint. Students may also note that a forest fire needs some energy input, such as a match. This is evident by the fact that the wood splint must be lit with a lighter.
Revised Explanation: After performing the experiment, what revisions need to be made to your explanation of the ***IP***? What observations did you make that led to these revisions? Write your new explanation.	
Students should recognize that fuels are chemical compounds composed of atoms. When fuels with different numbers of atoms burn they release different amounts of energy. Students should observe that wood and ethanol have different chemical formulas and that when they burn they cause different temperature changes to water held in an adjacent calorimeter. These different temperature changes indicate the release of different amounts of energy.	

Lab 2: Matter Transformation in Combustion

IP: What happens to the matter in a fuel source when the fuel source burns? Write a possible explanation of this phenomenon.	**AP:** In what way(s) do you think this lab experiment relates back to the anchoring phenomenon? How does the evidence collected in this experiment add to your understanding of forest fires?
If students have been exposed to the Law of Conservation of Matter in a previous setting they may know that mass is not created or destroyed. Less experienced students may state that when matter in a fuel source burns it changes.	Students should now know that when trees or homes burn in a forest fire the atoms that compose them are not destroyed, but converted into other forms. Their pre-combustion and post-combustion data confirm this idea. Students may note, if they view the summary video, that some of the matter in combustion reactions is transformed into carbon dioxide and some into water.
Revised Explanation: After performing the lab experiment, what revisions need to be made to your explanation of the ***IP***? What observations did you make that led to these revisions? Write your new explanation below.	**Working Model:** Apply what you have learned in labs 1–2 to formulate an explanation of forest fires.
Students should note that the pre and post-combustion masses of the samples are the same despite the pre and post-combustion appearances of the samples changing. This should lead students to note that matter is neither created nor destroyed during a chemical reaction, but it must be turned into something else, or a combination of things, some of which cannot be seen.	Students should at this point recognize that forests provide large fuel sources and that forest fires convert the atoms that compose plant life into carbon dioxide and water. They should note that forest fires do not start spontaneously, but need an initial energy input. They should also recognize that the energy from a forest fire derives from chemical reactions in which bonds between atoms break and reform as matter is transformed.

Lab 3: Measure Energy Flow in Chemical Reactions

IP: Where does the energy come from in a chemical reaction? Is energy always released? Write a possible explanation of this phenomenon.	**AP:** Where does the energy or heat given off in a forest fire come from? In what way(s) do you think this lab experiment relates back to the anchoring phenomenon? How does the evidence collected in this experiment add to your understanding of forest fires?
Student answers at this point will likely be simple. They may reference “changes” or “rearrangements” related to atoms, but it is unlikely that they will know that some chemical reactions release energy while others absorb it, or have observable temperature decreases.	At this point students should recognize that the energy given off in a forest fire derives from chemical reactions, specifically the combustion of trees with excess atmospheric oxygen. They see in this experiment that when compounds interact there can be associated energy changes. Specifically, they should note that in a fire the bonds between the atoms that compose trees are broken as are the bonds in oxygen molecules. The atoms reform into carbon dioxide and water and there is a net release of energy macroscopically observable as a temperature change.
Revised Explanation: After performing the lab experiment, what revisions need to be made to your explanation of the ***IP***? What observations did you make that led to these revisions? Write your new explanation below.	**Working Model:** Apply what you have learned in labs 1–3 to formulate an explanation of forest fires.
Students should note that compounds composed of atoms of different elements can have very different energies associated with them. For example, they should note that the reaction with ammonium thiocyanate leads to a temperature decrease. They should thus reason that the energy derives from an association with the types of atoms and the fact that they have different connectivities. They may note that in a chemical reaction bonds break and reform and it is the balance of energy associated with these processes that results in a temperature increase (release of energy) or a temperature decrease (absorption of energy).	Students should note that the energy given off by a forest fire derives from the breaking and reforming of the bonds that connect the atoms in trees as well as the bonds in oxygen molecules. Students will know that forest fires are not spontaneous, but that once they start they are difficult to extinguish because trees are usually densely packed and forest fires often occur in dry climates, where wood burns more readily. Students will know that the material burned in a forest fire is not destroyed but is converted to carbon dioxide, water, and other minor products

Lab 4: Climate Change and the Carbon Cycle

IP: Do trees remove carbon dioxide from the atmosphere? Write a possible explanation of this phenomenon.	**AP:** What role do forest fires play in the carbon cycle? Do they result in a net increase in atmospheric CO_2? In what way(s) do you think this lab experiment relates back to the anchoring phenomenon? How does the evidence collected in this experiment add to your understanding of forest fires?
Students may know from the information they consume daily that trees process CO_2 into energy. They may also know as much from a previous science course. Some students may note a simple "yes" or "no." It is important that students gather evidence to support whatever position they take.	Students should note that forest fires, or deforestation, removes carbon dioxide recyclers from the Earth system as well as directly vents carbon dioxide into the atmosphere. These things together lead forest fires to be net increasers of carbon dioxide.
Revised Explanation: After performing the lab experiment, what revisions or additions need to be made to your explanation of the ***IP***? What observations did you make that led to these revisions? Write your new explanation below.	**Final Model:** Apply what you have learned in labs 1–4 to formulate an explanation of forest fires.
Students should note that plant life is able to remove carbon dioxide from water, which implies that plant life is able to remove carbon dioxide from the atmosphere. In this lab, aqueous solutions of a plant sprig and acid-base indicator become less acidic (more basic) when exposed to light because plants are able to photosynthesize carbon dioxide into sugar. Students may note that plants also respire and thus give off carbon dioxide. They will not know without further research that the rate of photosynthesis exceeds the rate of respiration and that plants are therefore net carbon reducers.	Students should note that the energy associated with a forest fire derives from the potential energy in chemical bonds. They should note that forest fires are hard to put out because the atmosphere provides an excess of oxygen and the forest provides a large amount of closely packed fuel, i.e., each burning tree can supply the energy to burn another tree(s). Students should also note that forest fires are pronounced in dry climates because dry fuel burns more readily than wet fuel. Finally, students should note that forest fires put carbon dioxide directly into the atmosphere and remove organisms that are capable of converting carbon dioxide into sugar, from the earth system.

MATERIALS LIST

ENERGY DENSITIES OF ORGANIC FUELS – MATERIALS LIST

Materials Included in Kit *(for 10 groups of students)*

- Aluminum foil, roll
- Charcoal, 90 g
- Wood splints, package of 100

The kit includes materials to conduct one of the leveled inquiry labs. The following lists convey which materials (per group) are needed for each. Both included and any additional materials that may be needed are presented.

Short Inquiry

Included in Kit:

- Aluminum foil, 3 in. x 3 in. square
- Charcoal, small lump

Additional Materials Required:

- Water, distilled or tap, 50 mL
- Balance (0.01-g precision)
- Butane safety lighter
- Graduated cylinder, 50-mL
- Metal ring with clamp
- Soda can, empty and clean
- Stirring rod, glass
- Support stand
- Thermometer

Guided Inquiry

Included in Kit:

- Aluminum foil, 3 in. x 3 in. square, 2
- Charcoal, small lump
- Wood splint

Additional Materials Required:

- Water, distilled or tap, 50 mL
- Balance (0.01-g precision)
- Butane safety lighter
- Graduated cylinder, 50-mL
- Metal ring with clamp
- Soda can, empty and clean
- Stirring rod, glass
- Support stand
- Thermometer

Open Inquiry

Included in Kit:

- Aluminum foil, 3 in. x 3 in. square, 2
- Charcoal, small lump
- Wood splint

Additional Materials Required:

- Water, distilled or tap, 50 mL
- Balance (0.01-g precision)
- Butane safety lighter
- Graduated cylinder, 50-mL
- Metal ring with clamp
- Soda can, empty and clean
- Stirring rod, glass
- Support stand
- Thermometer

Advanced Inquiry

Included in Kit:

- Aluminum foil, 3 in. x 3 in. square, 2
- Charcoal, small lump
- Wood splint

Additional Materials Required:

- Water, distilled or tap, 50 mL
- Balance (0.01-g precision)
- Butane safety lighter
- Graduated cylinder, 50-mL
- Metal ring with clamp
- Soda can, empty and clean
- Stirring rod, glass
- Support stand
- Thermometer

Additional Materials available from Flinn Scientific, Inc.

Catalog No	Description
OB2142	Flinn Scientific Electronic Balance, 410 x 0.01-g
AP8960	Butane Safety Lighter
GP2015	Cylinder, Borosilicate Glass, 50 mL
AP8232	Ring Support, with Rod Clamp, 4"
GP5075	Stirring Rods, Glass
AP8228	Support Stand, 6" x 9"
AP8716	Flinn Digital Thermometer

LAB BACKGROUND

Measuring the Energy Densities of Organic Fuels: Introduction

Concepts

- Calorimetry
- Conservation of energy
- First law of thermodynamics

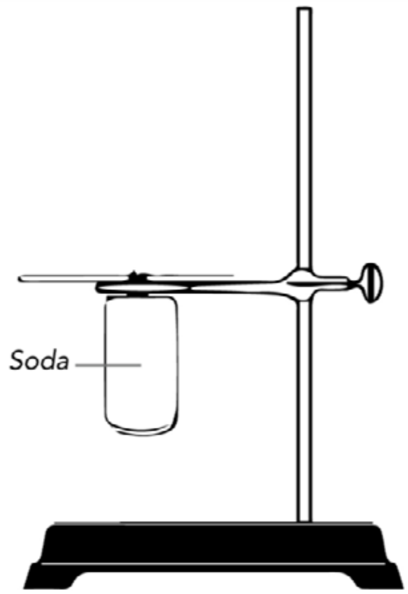
Background

The law of conservation of energy states that energy cannot be created or destroyed, only converted from one form to another. This fundamental law was used by scientists to derive new laws in the field of thermodynamics—the study of heat energy, temperature, and heat transfer. The First Law of Thermodynamics states that the heat energy lost by one body is gained by another body. Heat is the energy that is transferred between objects when there is a difference in temperature. Objects contain heat as a result of the small, rapid motions (e.g., vibrations, rotational motion, electron spin) that all atoms experience. The temperature of an object is an indirect measurement of its heat. Particles in a hot object exhibit more rapid motion than particles in a colder object. When hot and cold objects are placed in contact with one another, the faster moving particles in the hot object will begin to bump into the slower moving particles in the colder object making them move faster (and vice versa, the faster particles will then move more slowly). Eventually, the two objects will reach the same equilibrium temperature—the initially cold object will now be warmer, and the initially hot object will now be cooler. This principle is the basis for calorimetry or the measurement of heat transfer.

Different materials have their own unique ability to retain heat energy. Some materials, like water, can gain a large amount of heat energy without a significant change in temperature while other materials, such as metals, will have a more dramatic temperature change for the same amount of heat energy gained. This property is based mainly on the structure of the material, the size of the atoms and molecules, and the interactions between them. This is known as the specific heat of the substance. The specific heat is defined as the heat energy required to raise the temperature of one gram of a substance by one degree Celsius. The unit of energy commonly associated with heat is called a calorie. Water has a defined specific heat of 4.186 joules/g °C so it takes one calorie of energy to raise the temperature of one gram of water by one degree Celsius. (The reverse is also true—remove one calorie of heat from one gram of water, and the temperature will decrease by one degree Celsius.) With the specific heat of a substance known, the amount of heat energy gained or lost by a substance can then be calculated if the temperature change is measured.

In this experiment, the specific heat of water and its change in temperature will be used to determine the energy content of charcoal. During calorimetry, fuel burns and its stored energy is converted into heat energy and products of combustion (carbon dioxide and water). The “stored” energy is chemical potential energy that is released when, during burning, the forces that hold atoms together in a fuel, such as CH_4 (methane), are broken and then recombine to form new compounds with the same total number of atoms now connected in different ways. The heat energy that is released is transferred into the water above it in the calorimeter. See Figure 1. The temperature change in the water is then measured and used to calculate the amount of heat energy released from the burning fuel. The heat energy is calculated using Equation 1.

Figure 1



Equation 1: $q = mC\Delta T$

q = heat energy

m = mass of the water

c = specific heat of the water

T = change in water temperature, $T_{final} - T_{initial}$

("Δ" is the Greek letter Delta, which means "change in")

SHORT-ON-TIME INQUIRY

Measuring the Energy Densities of Organic Fuels: Short-on-time Inquiry Lab

Overview

How much energy is released when an object burns? One way to determine this is to measure the heat flow from the object to its surroundings. If heat flows from the object to its surroundings, then the temperature of the surroundings will increase. This activity will introduce the concept of calorimetry and investigate the energy content of organic fuels.

Focus on Science Practices

SEP 3 Planning and Carrying Out Investigations
SEP 4 Analyzing and Interpreting Data
SEP 5 Using Mathematics and Computational Thinking

Materials Per Group

- Aluminum foil, 3 in. x 3 in. square
- Charcoal, small lump
- Water, distilled or tap, 50 mL
- Balance (0.01-g precision)
- Butane safety lighter
- Graduated cylinder, 50-mL
- Metal ring with clamp
- Soda can, empty and clean
- Stirring rod, glass
- Support stand
- Thermometer

Safety

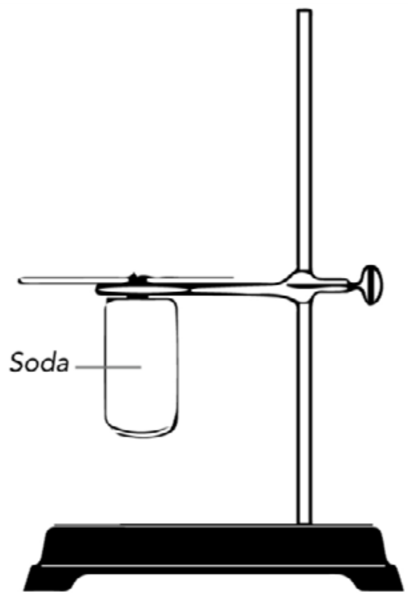
Wear safety goggles when performing this or any lab that uses chemicals, heat, or glassware. Allow charcoal sample to cool before touching or discarding it. Use a glass stirring rod to stir the liquid; never stir with a thermometer. This lab should be performed in a well-ventilated room. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

1. Place a small clump of charcoal on a 3 in. x 3 in. square of aluminum foil.
2. Measure and record the combined mass of the charcoal/aluminum foil. Place the charcoal/aluminum foil on the base of a support stand.
3. Using a graduated cylinder, measure and add 50.0 mL of water to an empty, clean soda can.

4. Bend the tab on the soda can and carefully slide a glass stirring rod through the hole. Suspend the can on a support stand using a metal ring (see Figure 1). Adjust the height of the can so it is about 2.5 cm above charcoal/aluminum foil.

Figure 1



5. Carefully insert a thermometer into the can. Measure and record the initial temperature of the water.

6. Light the charcoal, and center it under the soda can. Allow the water to be heated until the charcoal stops burning. Record the maximum (final) temperature of the water in the can.

7. Measure and record the final mass of the charcoal and aluminum foil.

Data Table — The Experiment

Sample	Initial Mass (sample and foil), g	Final Mass (sample and foil), g	Initial Temperature of Water, °C	Final Temperature of Water, °C
charcoal				

Analyze and Interpret

1. **SEP Calculate** Determine the change in temperature of the water by subtracting the initial water temperature from the final water temperature.

2. **SEP Use Math** Calculate the heat gained by the water when the charcoal burned.

3. **SEP Use Math** Determine how much of the charcoal burned (i.e. the mass of the charcoal converted to heat energy) by subtracting the final mass of the charcoal/aluminum foil from the initial mass.

4. **SEP Use Math** Calculate the energy content per gram of charcoal. This is done by dividing the heat gain of the water by the change in mass of the charcoal/aluminum foil.

5. **SEP Analyze and Interpret Data** Discuss sources of experimental error.

GUIDED INQUIRY

Measuring the Energy Densities of Organic Fuels: Guided Inquiry Lab

Overview

How much energy is released when an object burns? One way to determine this is to measure the heat flow from the object to its surroundings. If heat flows from the object to its surroundings, then the temperature of the surroundings will increase. This activity will introduce the concept of calorimetry and investigate the caloric content of organic fuels.

Focus on Science Practices

SEP 3 Planning and Carrying Out Investigations
SEP 4 Analyzing and Interpreting Data
SEP 5 Using Mathematics and Computational Thinking

Materials Per Group

- Aluminum foil, 3 in. x 3 in. square, 2
- Charcoal, small lump
- Water, distilled or tap, 50 mL
- Balance (0.01 g precision)
- Butane safety lighter
- Graduated cylinder, 50-mL
- Metal ring with clamp
- Soda can, empty and clean
- Stirring rod, glass
- Support stand
- Thermometer
- Wood splint

Safety

Wear safety goggles when performing this or any lab that uses chemicals, heat, or glassware. Allow charcoal sample to cool before touching or discarding it. Thoroughly wet under running water any combusted samples prior to discarding in the trash.Use a glass stirring rod to stir the liquid; never stir with a thermometer. This lab should be performed in a well-ventilated room. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

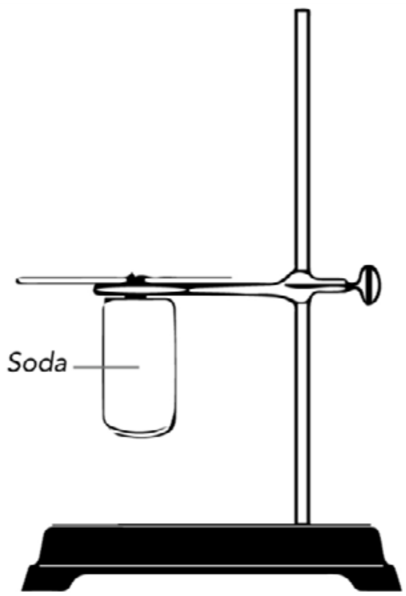
1. Place a small clump of charcoal on a 3 in. x 3 in. square of aluminum foil.

2. Measure and record the combined mass of the charcoal/aluminum foil. Place the charcoal/aluminum foil on the base of a support stand.

3. Using a graduated cylinder, measure and add 50.0 mL of water to an empty, clean soda can.

4. Bend the tab on the soda can and carefully slide a glass stirring rod through the hole. Suspend the can on a support stand using a metal ring (see Figure 1). Adjust the height of the can so it is about 2.5 cm above charcoal/aluminum foil.

Figure 1



5. Carefully insert a thermometer into the can. Measure and record the initial temperature of the water.

6. Light the charcoal and center it under the soda can. Allow the water to be heated until the charcoal stops burning. Record the maximum (final) temperature of the water in the can.

7. Measure and record the final mass of the charcoal and aluminum foil.

8. Repeat steps 1–7 for a wood splint. However, rather than placing the wood splint on foil, hold it with tongs so that as the splint burns, the flame can be kept directly under the soda can.

Data Table — The Experiment				
Sample	Initial Mass (sample and foil), g	Final Mass (sample and foil), g	Initial Temperature of Water, °C	Final Temperature of Water, °C
charcoal				
wood splint				

Analyze and Interpret

1. **SEP Calculate** Determine the change in temperature of the water for each fuel source by subtracting the initial water temperature from the final water temperature.

2. **SEP Use Math** Calculate the heat gained by the water when the fuels burned.

3. **SEP Use Math** Determine how much of the fuel burned (i.e., the mass of the fuel converted to heat energy) by subtracting the final mass of the fuel/foil from the initial mass.

4. **SEP Use Math** Calculate the energy content per gram of fuel. This is done by dividing the heat gain of the water by the change in mass of the sample.

5. **SEP Analyze and Interpret Data** Which material has a higher energy density? Discuss possible causes of the difference in energy densities between the two materials as well as sources of experimental error.

OPEN INQUIRY

Measuring the Energy Densities of Organic Fuels: Open Inquiry Lab

Overview

How much energy is released when an object burns? One way to determine this is to measure the heat flow from the object to its surroundings. If heat flows from the object to its surroundings, then the temperature of the surroundings will increase. This activity will introduce the concept of calorimetry and investigate the caloric content of organic fuels.

Focus on Science Practices

SEP 3 Planning and Carrying Out Investigations
SEP 4 Analyzing and Interpreting Data
SEP 5 Using Mathematics and Computational Thinking

Materials Per Group

- Aluminum foil, 3 in. x 3 in. square, 2
- Charcoal, small lump
- Water, distilled or tap, 50 mL
- Balance (0.01-g precision)
- Butane safety lighter
- Graduated cylinder, 50-mL
- Metal ring with clamp
- Soda can, empty and clean
- Stirring rod, glass
- Support stand
- Thermometer
- Wood splint

Safety

Wear safety goggles when performing this or any lab that uses chemicals, heat, or glassware. Allow fuel samples to cool before touching or discarding them, and thoroughly wet burned samples prior to disposal. Use a glass stirring rod to stir the liquid; never stir with a thermometer. This lab should be performed in a well-ventilated room. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

Design an experiment that uses a soda can calorimeter to measure the energy density of charcoal and a wood splint. The introductory video demonstrates how to set up a soda can calorimeter. Consider the following questions as you design the experiment:

- **a.** How can you measure the mass of fuel that combusts?
- **b.** How do you determine when the water in the soda can has achieved its maximum temperature?
- **c.** What variables should be controlled?
- **d.** What is the independent variable?
- **e.** What is the dependent variable?
- **f.** What are sources of error?
- **g.** What may occur if your water:fuel ration is very high or very low?

Use the area below to record your detailed procedure as well as any materials to be used.

Analyze and Interpret

1. **SEP Construct Explanations** Determine the energy densities, in Joules/gram, of both fuel sources. Discuss factors that might account for any difference between the two values as well as sources of experimental error.

ADVANCED INQUIRY

Measuring the Energy Densities of Organic Fuels: Advanced Inquiry Lab

Overview

How much energy is released when an object burns? One way to determine this is to measure the heat flow from the object to its surroundings. If heat flows from the object to its surroundings, then the temperature of the surroundings will increase. This activity will introduce the concept of calorimetry and investigate the caloric content of organic fuels.

Focus on Science Practices

SEP 3 Planning and Carrying Out Investigations
SEP 4 Analyzing and Interpreting Data
SEP 5 Using Mathematics and Computational Thinking

Materials Per Group

- Aluminum foil, 3 in. x 3 in. square, 2
- Balance (0.01 g precision)
- Butane safety lighter
- Charcoal, small lump
- Graduated cylinder, 50-mL
- Metal ring with clamp
- Soda can, empty and clean
- Stirring rod, glass
- Support stand
- Thermometer
- Water, distilled or tap, 50 mL
- Wood splint

Safety

Wear safety goggles when performing this or any lab that uses chemicals, heat, or glassware. Allow fuel samples to cool before touching or discarding them, and thoroughly wet burned samples prior to disposal. Use a glass stirring rod to stir the liquid; never stir with a thermometer. This lab should be performed in a well-ventilated room. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

1. Design an experiment that uses a soda can calorimeter to measure the energy density of charcoal and a wood splint. The introductory video demonstrates how to set up a soda can calorimeter. Consider the following questions as you design the experiment:
   a. How can you measure the mass of fuel that combusts?
   b. How do you determine when the water in the soda can has achieved its maximum temperature?
   c. What variables should be controlled?
   d. What is the independent variable?
   e. What is the dependent variable?
   f. What are sources of error?
   g. What may occur if your water:fuel ration is very high or very low?

2. Predict the result of subjecting a wet wooden splint to the same procedure.

Use the area below to record your detailed procedure as well as any materials to be used.

3. Carry out the procedure with the wet wood splint, and describe and explain the result.

Analyze and Interpret

1. **SEP Analyze and Interpret Data** Determine the energy densities, in Joules/gram, of both fuel sources. Discuss factors that might account for any difference between the two values as well as sources of experimental error.

2. **SEP Make Observations** Methane (CH_4) and propane (C_3H_8) are two common fuel sources. Methane is sometimes used as one of the gases combusted in furnaces to heat homes, and propane is used to heat gas grills. The chemical structures of the two compounds are shown. Comment on the superficial differences between the two compounds that might contribute to their having different energy densities.

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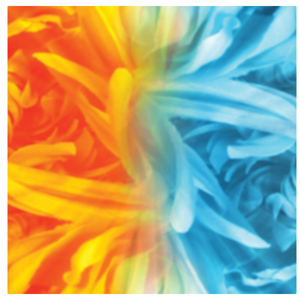

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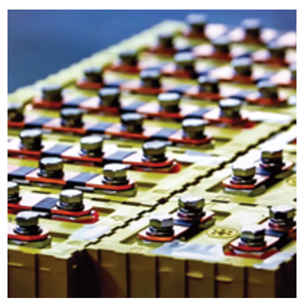

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