Essential Unit Standards

Standards

- SC.912.P.10.1 - Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.
- SC.912.P.10.2 – Explore the Law of Conservation of Energy by differentiating among open, closed, and isolated systems and explain that the total energy in an isolated system is a conserved quantity.
- SC.912.P.10.5 - Relate temperature to the average molecular kinetic energy.
    - "Changes in entropy and energy that accompany chemical reactions influence reaction paths. Chemical reactions result in the release or absorption of energy."
- SC.912.P.10.6 - Create and interpret potential energy diagrams, for example: chemical reactions, orbits around a central body, motion of a pendulum.
- SC.912.P.10.7 - Distinguish between endothermic and exothermic chemical processes.
    - Changes in entropy and energy that accompany chemical reactions influence reaction paths. Chemical reactions result in the release or absorption of energy.

- SC.912.N.1.1 - Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following: (List)
- SC.912.N.1.2 - Describe and explain what characterizes science and its methods.
- SC.912.N.1.6 - Describe how scientific inferences are drawn from scientific observations and provide examples from the content being studied.
- SC.912.N.1.7 - Recognize the role of creativity in constructing scientific questions, methods and explanations.
- SC.912.N.3.5 - Describe the function of models in science, and identify the wide range of models used in science.

Lesson 1: Introduction to Energy Transformation (Technology Lesson)

Section 1: Rationale/Purpose

Topic: The Law of Conservation of Energy & Energy Transformations
Grade level: 9-12 **Duration:** 60-80 minutes (2 class periods)

Standards:
- SC.912.P.10.1 - Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.
- ELD.K12.ELL.SC.1 - English language learners communicate information, ideas and concepts necessary for academic success in the content area of Science.
- SC.912.N.3.5 - Describe the function of models in science, and identify the wide range of models used in science.
- SC.912.N.1.7 - Recognize the role of creativity in constructing scientific questions, methods and explanations.

Content Objectives:
- Using the PhET computer simulation Energy Forms and Changes, students will be able to differentiate between 5 forms of energy (potential energy, kinetic energy, thermal/heat energy, radiant/light energy, mechanical energy, electrical energy, and chemical energy) and recognize that they can be transformed from one form to another.
- Students will be able to draw and label their own model of energy transformation using what they've learned from the simulation. By developing a model themselves, students will recognize the role of creativity in the creation of scientific models.

Language Objectives:
- Students will be able to record written observations in their science notebooks using complete sentences and content-specific scientific terminology (such as the Law of Conservation of Energy, potential energy, kinetic energy, thermal energy, radiant energy, mechanical energy and electrical energy) to describe energy movement and transformation.
- Students will be able to identify critical vocabulary as evidenced by circling important terms to create a "fill-in-the-blank" description of their self-created model.

Section 2: Misconceptions

1. "Some objects (such as blankets) produce their own heat. Students may believe this because they have experienced feeling warmer after covering themselves with a blanket or putting on a sweater" (Fries-Gaither, 2009).

2. Energy can be created (Kruger, 1990; Lovrude, 2004; Papadouris et al., 2008).
3. An object has energy within it that is used up as the object moves (Brook & Driver, 1984; Kesidou & Duit, 1993; Loverude, 2004; Stead 1980).
4. One form of energy cannot be transformed into another form of energy (e.g. chemical energy cannot be converted into kinetic energy) (Brook & Driver, 1984).

Section 3: Detailed Procedures

Introduction / Activation of Prior Knowledge (10 minutes) ● Students are asked to **write** in their science notebooks an explanation of the word "energy". Students are encouraged to create their description by doing one or more of the following differentiated options: **writing** a definition, **using** the word in a sentence, **drawing** an example. (3 mins) ○ Students may use a definition they learned in school or explain how they would use the word with family or friends. ○ Students should get ready to share their answer. ● In small groups of 2-3, students **share** their responses, taking turns **verbally explaining** what they've written down. (5 mins) ● As a group, students **choose** one of their examples to **share** with the whole class (2 mins).	*Access student prior knowledge of the term "energy" and its meaning.*
Engagement Demonstration (10 minutes) ● Students are shown a ball and asked, Does this ball have energy? (Student asked to **volunteer answers**). The ball is dropped. Does the ball have energy now? (Student asked to **volunteer answers**). ● Ball is held up again, and an explanation is given. ○ Yes, it does have energy! When the ball is being held above the ground it has a type of energy called potential energy. Potential energy is stored energy. When the ball is held in the air, it has the potential to do something (in this case it has the potential to fall). ○ If I drop the ball will it still have energy? (Ball is dropped) Yes, the ball still has energy as it falls, but it is no longer just potential energy. When the ball is falling it has a different form of energy called kinetic energy. Kinetic energy is the energy of motion. ○ Take a minute to think: What happened to the potential energy? Was it all lost when the ball was dropped? Was the kinetic energy created to replace the lost potential	*Students watch a teacher-led demonstration to provoke deeper thought.*

energy? (30 second pause given for students to consider the answer) ○ We can explain what is happening to the ball using The Law of Conservation of Energy, which states that the energy of an isolated system cannot be lost, or destroyed. It also cannot be created. It remains constant; all it can do is change forms. This means that the potential energy of the ball was not lost. It was transformed into kinetic energy when it was dropped. Both potential and kinetic energy are types of **mechanical energy**. ● Students are asked to view the following information (either in slides or written on a whiteboard) and copy it all into their science notebooks: ○ <u>Law of Conservation of Energy</u> - In a closed system (a system that is isolated from its surroundings), the total energy of the system is conserved. (One of the basic, universal laws of physics). ○ <u>Forms of Energy</u> - mechanical energy, thermal energy, radiant energy, electrical energy, chemical energy. ○ Students are given 2 quiet minutes to write. Then, while they finish, a brief explanation is given of each form of energy on the board. ○ Students developing literacy will be given a copy of these terms pre-written on paper and may spend the time parsing the words. **Activity (40 minutes)** ● Students split into pairs. Each pair should have at least one computer or laptop. ○ Students are told that one person will manipulates the simulation, while one person records answers on a worksheet. Students will take turns working the simulation and recording answers. ○ *Each student must complete their own worksheet, so will need time to copy answers down themselves as well.* ● Each student receives one worksheet. ○ Students can **<u>read</u>** the introduction on the worksheet as the teacher reads aloud: "In this simulation, you will be able to "see" several different forms of energy and the changes (transfers) that can occur between them. You are also able to work with a system where you can manipulate energy input, observe the process of electrical energy generation and manipulate the output."	*Higher-level Students may also be told they can also research these forms of energy on their own for more detailed definitions, as well as others forms of energy not mentioned here.* *Teacher will facilitate activity by circulating the room to answer any questions, scaffold learning, and extend learning by posing more in-depth questions.* **** Completion of the worksheet will likely take two class periods - first period is introduction and initial exploration, second period is completion and evaluation.***

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- Students are directed to **open the PhET computer simulation** "Energy Forms and Changes" on their computers, and **select the correct options on the screen** as directed to on their worksheet.
- Students complete the worksheet, pages 2-4*, while exploring the simulation visually representing energy transformations.

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Section 4: Evaluation

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Formative Assessment - Evaluation Portion (20 minutes)

1. At the end of the activity, students independently **write in complete sentences** an answer the following question in their science notebooks. Teacher reads out loud and also displays the directions in writing on the board. (5 minutes)
   a. "In your science notebook, **Explain** why this simulation is a good way to illustrate the Law of Conservation of Energy. Use specific examples to support your answer. Please **proof read** your response as well as your partner's response. Make sure your answer is complete and makes logical sense." (Teacher should circulate and give feedback - this portion is not graded, and is a casual formative assessment)
   b. Students developing literacy may have other benchmarks besides writing in complete sentences; such as identifying key concepts or drawing an accurate model. Such students may be grouped together and will proof for that benchmark instead. Teacher will give individual feedback to these students.
2. Students should then complete page 5 of the worksheet, **creating their own labeled sketch** of a system where energy is being transferred. (15 minutes)
   a. Students may either **draw** a real system (from home or the classroom) or draw an imaginary system, involving at least 3 forms of energy.
   b. Students then **write** their own "fill in the blank" description of the forms of energy and energy transfer within the system, involving at least 5 key phrases.

	Advanced (4)	**Proficient (3)**	**Partially Proficient (2)**	**Nonproficient (1)**
Drawing of a valid model	Student's drawing displays	Student's drawing displays	Student's drawing displays some	Student's drawing displays little

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Page 5 of the worksheet may be done as homework or as an in-class extension.

Page 5 should be done completely independently (not in pairs).

Student worksheets will be graded as a formative assessment.

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	advanced understanding of scientific model creation, is understandable and well-labeled.	understanding of scientific model creation, is understandable and has some labeling.	understanding of scientific model creation, but is hard to understand.	understanding of scientific model creation, and is either irrelevant to the task or hard to understand.
Displayed understanding of energy transfor-mations	Student has three or more energy transformations in model, labeled accurately and used in the proper context.	Student has three or more energy transformations in model, at least two of which are used in the proper context.	Student has two or more energy transformations in model, at least one of which are used in the proper context.	Student has one to two energy transformations in a model, but none are used in the proper context or are very poorly labeled.
Written description of model displays understanding of model and of energy transformation.	Student excels in their written literacy benchmark, and clearly communicates transformations in the model in written format, with complete sentences (if applicable)	Student meets their written literacy benchmark, with two or fewer minor errors that do not distract from the purpose of the writing.	Student shows room for improvement on their written literacy benchmark, with three or more minor errors or one or more major error.	Student shows little improvement on their written literacy benchmark, with many errors and/or wording irrelevant to the task.
Labeling of critical content in description.	Students identify five or more critical content terms for their “fill in the blank” section by circling the terms, all of which are relevant and well-chosen.	Students identify five or more terms, at least four of which are critical content terms. May have 1-2 minor errors.	Students identify 2-3 critical content terms. May mistakenly include others that are not actually critical content.	Students identify 1 critical content term. May mistakenly include others that are not actually critical content.

Section 5: Plan for Individual Differences

1. All activities within student's science notebook are differentiated; options of drawing, writing complete sentences, writing key phrases/incomplete sentences, and drawing graphic organizers are all available.
2. Displayed definitions of "Conservation of Energy" and the five forms of energy allow student understanding without individual research. Higher-level students may choose to do additional research to better understand different forms of energy.
3. The worksheet scaffolds understanding of the concepts, and repeatedly models examples of energy transformation systems and descriptive fill-in-the-blank explanations prior to the student creating one of their own.
4. ELL Students may be provided the worksheet the day beforehand to highlight and translate any difficult words.

Section 6: Materials

- Ball (any kind, 1 per class)
- A chalkboard, whiteboard, or projection apparatus to display slides with definitions.
  - Pre-printed definitions to hand to students developing literacy.
- Computers with Internet access and the latest version of Java (1 per group)
  - Free Java Download: https://java.com/en/download/
- Link to PhET Simulation (ensure it is not blocked by any school filters): https://phet.colorado.edu/en/simulation/legacy/energy-forms-and-changes
- Energy Forms and Changes Simulation Worksheet (5 pages, 1 worksheet per student)
  - Worksheet may be printed from https://drive.google.com/open?id=1QDWSjtKKgX2WJsRQ_lkjLREM1_UuLDkr
  - Worksheet is adapted from the worksheet by A. Norberg, original available on PhET website (Norberg, 2014).
- Pencils (1 per student)
- Crayons or colored pencils (if page 5 of worksheet is completed in class)
- Students should have their science notebooks and a pen or pencil.

Section 7: Safety

- Prior to this lesson, students must be instructed in digital conduct expectations.
- Students should not handle or throw the ball used in the demonstration.
- Students should be warned not to try to mimic any of the digital models in real life; handling electricity or chemicals without proper training may lead to injury or death.

Section 8: References

Florida Department of Education. (2008). *Florida Sunshine State Standards (K-12 science)*. Retrieved from http://www.cpalms.org/homepage/index.aspx

Brook, A., & Driver, R. (1984). Aspects of secondary students' understanding of energy: Full report. Leeds, UK: The University of Leeds, Centre for Studies in Science Education and

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Fries-Gaither, J., (2009). Common Misconceptions about Heat and Insulation. Retrieved from http://beyondpenguins.ehe.osu.edu/issue/keeping-warm/common-misconceptions-about-heat-and-insulation
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Norberg, A. (2014, February 25). Energy Forms and Changes Simulation [Worksheet]. Retrieved from https://phet.colorado.edu/en/contributions/view/3810
Papadouris, N., Constantinou, C. P., & Kyratsi, T. (2008). Students' use of the energy model to account for changes in physical systems. *Journal of Research in Science Teaching, 45*(4), 444–469.
Stead, B. (1980). Energy, Working Paper No. 17. In *Learning in Science Project*. Hamilton, New Zealand: Science Education Research Unit, University of Waikato.
Wilbraham, A., Staley, D., Matta, M., & Waterman, E. (2012). Pearson Chemistry (Florida Ed). Boston, MA: Pearson.

Lesson 2: Systems and Surroundings

Section 1: Rationale/Purpose

Topic: Types of Systems
Grade level: 9-12 **Duration:** 30 minutes (1 class period)

Standards:

- SC.912.P.10.2 – Explore the Law of Conservation of Energy by differentiating among open, closed, and isolated systems and explain that the total energy in an isolated system is a conserved quantity.
- ELD.K12.ELL.SC.1 - English language learners communicate information, ideas and concepts necessary for academic success in the content area of Science.
- SC.912.N.3.5 - Describe the function of models in science, and identify the wide range of models used in science.

Content Objectives:

- Students will be able to differentiate among Open, Closed and Isolated Systems through exploration of the Law of Conservation of Energy.

Language Objectives:

- Students will be able to draw and verbally explain the movement of energy and matter in open, closed and isolated systems.

Section 2: Misconceptions

1. "When two objects at different temperatures are in contact with each other, thermal energy is transferred from the warmer object to the cooler object and 'coldness' or 'cold energy' is transferred from the cooler object to the warmer object (AAAS Project 2061, n.d.)" (American Association for the Advancement of Science, 2017).
2. "Water in an open container is absorbed by the container, disappears, changes into air, or dries up and goes into the air" (Fries-Gaither, 2008).

Section 3: Detailed Procedures

Introduction / Activation of Prior Knowledge (10 minutes) - Students review the forms of energy by viewing slide 1 of slide set. - Slide set for this sections: https://docs.google.com/a/ocps.net/presentation/d/1v9fqt8Ed5hwjdk163uX-Obibd8G0oPjYn8rNU0L3gsU/edit?usp=sharing	

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● Bellwork (on board): "Yesterday you sketched out a system showing at least three forms of energy.
○ Please share your system with your shoulder partner now, and explain the energy transformations occurring.
○ Your partner will draw your system in their notebook below theirs, labeling the transformations."
● After a few minutes:
○ Together, consider the word "system" and "surroundings". Your drawing is the "system," and the "surroundings" is everything around your system. In either drawing, Do you think some energy might be lost to the surroundings? Perhaps light, or heat?
■ Show an example system; A glowing electric stove (electrical energy) boils water in a kettle (thermal energy), steam releases from the kettle and turns a wheel above (mechanical energy).
● Identify other forms of energy exiting the system - the glowing electric coils release radiant (light) energy.
● As the kettle boils and steam exits, it may whistle; this is sound energy.
■ Teacher will likely have to walk around and clarify, offering suggestions.

Lecture & Demo (20 min)

● Students take notes as teacher lectures, using slides 2-6. At slide 6, the demo takes place.
● On the board is written the following chemical equation for the reaction between baking soda and vinegar:
○ $NaHCO_3(s) + CH_3COOH(l) \rightarrow CO_2(g) + H_2O(l) + Na^+(aq) + CH_3COO^-(aq)$
● Students <u>observe</u> three demos. For each demo, students <u>write</u> in their science notebook:
○ <u>Label</u> the type of system (open, closed or isolated)
○ <u>Draw</u> a quick sketch of the reaction.
○ <u>Describe</u> the reactant and the products in general terms.
○ <u>Determine</u> what is the energy transformation? (What form is turning into what form?
○ <u>Describe</u> the energy and mass movements between the system and the surroundings. (use arrows)
● Demo 1: Open system
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Students may be asked to come closer to the demo to observe better.

Responsible students may be asked to assist in the demo with appropriate PPE.
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◦ In an Erlenmeyer flask, place a tablespoon of baking soda (sodium bicarbonate). In a graduated cylinder, pour 50mL Acetic Acid. ◦ Weigh the entire system. ◦ Add the acetic acid to the flask slowly (so as not to allow overflow); point out gas formation and release of heat. ◦ Weigh the system after; mass should be less. Discuss where the mass has gone. • **Demo 2: Closed system** ◦ Repeat above procedure, but quickly place a balloon over the top of the flask after adding the acetic acid. ◦ Weigh entire system before and after; weight should be similar. ◦ Discuss that energy (heat) has been lost, but matter has remained in the system. • **Demo 3: Isolated system** ◦ Repeat the above procedure, within a thermos. ◦ Use only about half a spoonful of baking soda and 20mL vinegar. Quickly seal the thermos. ◦ Weigh before and after - weight should be similar (or same). ◦ Heat should be felt minimally (if at all). ◦ Discuss how the thermos creates an isolated system, where neither matter nor energy is lost to the surroundings. **Activity** • After demo, students draw each type of system and use arrows to show movement of energy and matter into or out of the system, appropriate to the type. • Worksheet given: https://docs.google.com/document/d/13xSwtYdu8hvD23ZuW8XOo6HkYtOv4oON8ObxKraIabs/edit?usp=sharing	
Section 4: Evaluation	
Formative Assessment 1. After watching and answering questions about the demos, students are asked to share their responses (selected randomly using a method such as student index cards) 2. Student drawings are questions are evaluated through random selection to share; students may make edits to their own notebooks to correct any errors.	

3. Student worksheets may be checked for accuracy	

Section 5: Plan for Individual Differences

- All activities within student's science notebook are differentiated; options of drawing, writing complete sentences, writing key phrases/incomplete sentences, and drawing graphic organizers are all available.
- Students draw systems and are given a template to start from.
- Notes can be taken in the form of sentences with strategic blanks.

Section 6: Materials

- A chalkboard, whiteboard, or projection apparatus to display slides with information.
- Random student selection method (such as deck of student names on index cards)
- Slide set (linked in Procedures)
- Sodium bicarbonate (several tablespoons full)
- Acetic Acid: 150 ml
- 2 Erlenmeyer flasks.
- One balloon.
- 2 Graduated cylinders
- 1 Thermos
- Gloves, Goggles, Aprons.
- Balances
- Student worksheets (linked in procedures, one for each student)
- Students should have their science notebooks and a pen or pencil.

Section 7: Safety

- Always wear safety goggles when handling chemicals in the lab.
- Wash your hands thoroughly before leaving the lab.
- Follow the teacher's instructions for cleanup of materials and disposal of chemicals.
- When working with acids and bases, if any solution gets on your skin immediately rinse the area with water.
- Wear proper safety gear during chemistry demonstrations. Safety goggles and lab apron are required.

Section 8: References

American Association for the Advancement of Science. (2017). Energy: Forms, Transformation, Transfer, and Conservation. Retrieved from http://assessment.aaas.org/misconceptions/NGM016/248

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Lesson 3: Heat & Temperature (Inquiry Lesson)

Section 1: Rationale/Purpose

Topic: Distinguishing between Heat and Temperature
Grade level: 9-12 **Duration:** 40 minutes (1 class period)

Standards:
- SC.912.P.10.5 - Relate temperature to the average molecular kinetic energy. Recognize that the internal energy of an object includes the energy of random motion of the object's atoms and molecules, often referred to as thermal energy.
- SC.912.P.10.4 - Describe heat as the energy transferred by convection, conduction, and radiation, and explain the connection of heat to change in temperature or states of matter.
- ELD.K12.ELL.SC.1 - English language learners communicate information, ideas and concepts necessary for academic success in the content area of Science.
- SC.912.N.1.6 - Describe how scientific inferences are drawn from scientific observations and provide examples from the content being studied.

Content Objectives:
- Through experimental observation (touch and measurement) of several different materials (wood, acrylic, copper and aluminum), students will be able to distinguish between the specific heat of an object and its temperature, and understand the ways in which heat and temperature are commonly confused.
- Students will be able to explain how specific heat affects how warm or cool an object feels to the touch, regardless of the object's actual temperature, and design an exploration similar to the one presented in class in which the temperature of an object is misinterpreted as its specific heat.

Language Objectives:
- Students will be able to write observations with increasing precision through a process of reviewing and refining their written observations throughout the activity.
- Students will be able to communicate an experimental procedure in their own words using scientific terms from the lesson (including specific heat, thermal conductivity, and temperature), and/or draw a scientific model to help explain the expected results of the experimental procedure.
- Students developing literacy skills will be able to complete a "Claim-Evidence-Reasoning" template with guided sentences in order to communicate their experimental findings to their peers.

Section 2: Misconceptions

1. "Temperature is a property of a particular material or object. (For example, students may believe that metal is naturally cooler than plastic)" (Fries-Gaither, 2009).
2. "When two objects at different temperatures are in contact with each other, thermal energy is transferred from the warmer object to the cooler object and 'coldness' or 'cold energy' is transferred from the cooler object to the warmer object (AAAS Project 2061, n.d.)" (American Association for the Advancement of Science, 2017).

Section 3: Detailed Procedures

Engage

- **Using Nearpod (student-paced preview at https://share.nearpod.com/vsph/Poz3ndmcNu , live code will be given during lesson), Students will be asked to provide, in their own words a definition to the word "Temperature."**
    - Teacher will address the most popular answer submissions in a class discussion before presenting the class definition of Temperature to the students.
    - If needed, students may also use Google Translate to assist them in finding a definition.
- **Definition of "Temperature" from Google displayed on the board**: "*Temperature - the degree or intensity of heat present in a substance or object, especially as expressed according to a comparative scale and shown by a thermometer or perceived by touch.*"
    - Teacher reads it clearly out loud as well as leaving it on the board. If 1-to-1 technology available, then students with very low English language proficiency may also look up the definition in their native language.
- **Ask students if they agree with this definition**. Lead them to discuss with their groups and, in their science notebook, write answers: ***(5 minutes)***
    - What is temperature? (Students may revise their previous answer after considering the given definition)
    - How do we measure an object's temperature?
    - What makes an object hot?
    - What makes an object cold?
- Students may choose to add drawings to help add to their explanations.
    - Each group provided with a worksheet that also has the questions, if they need to refer back to the prompts later.

Explore

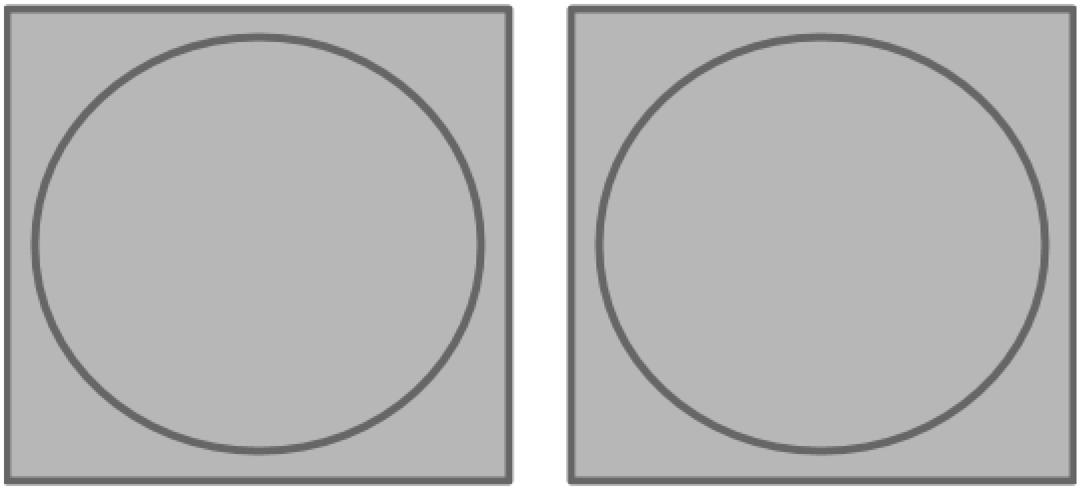
1. **Divide students into groups**
    a. The number of groups should match the number of density cube sets available, 2-4 students per group.
    b. Jigsaw grouping used to create random groups mixing background/ability. Jigsaw accomplished by handing out numbers (1-4) and then asking students to create a group with one of each number.
2. **Provide materials**
    a. Each table is provided a set of density cubes. Cubes include wood, acrylic, aluminum, and copper.
    b. Emphasize to the students not to pick up or hold the cubes in their hands; they may touch them briefly with one finger at a time. (This is important to reduce heat transfer between the students and the blocks).
    c. Cubes are labeled with their identities written on tape.
3. **Provide Students with activity**
    a. Students will order the blocks from warmest to coldest, and record the order on their worksheet. (5 mins)
        i. *Worksheet: https://docs.google.com/document/d/1_gw4856lclnFTptOaRQ6Aam_VMvRYYRgxWY0wQZEY20/edit?usp=sharing*
    b. Students will also record in their own science notebooks the order they choose and the observations that led to this order.
    c. Each group is asked their order and a brief reason (one or two sentences) they chose this order. Students should explain using claim, evidence, reasoning (CER guide is in each packet)
    d. Worksheet is provided to guide student thinking and ensure they know the procedure.
4. **Provide Students with Infrared Temperature Thermometer**
    a. Students will use the Infrared Thermometer to measure the temperature of their objects.
    b. Students will record their data in their science notebooks and/or worksheet.
        i. *Students should notice that the temperatures are all the same (or very similar).*

Explain

1. Students will compare their temperature results to their initial warmer/cooler predictions for their objects.
2. Students will have 3 quiet minutes to read the table on page 2 of the worksheet and think about the questions. Students may also ask questions of teacher to help understand table, or look up terms; additional time provided as needed; differentiation/extra support may be supplied if needed.
3. Students will write in pencil an initial answer to the questions.

Elaboration

1. Students will discuss the answers to the questions in their small group.
2. Students will revise their answers after discussing (if necessary).
    a. Students are provided with the data table needed to inform their writing. Students may choose to use drawings to assist with their explanations.
3. Students watch a video explaining specific heat misconceptions. (Closed captions provided for video).
    a. **Video link**: https://www.youtube.com/watch?v=hNGJ0WHXMyE
4. Students may revise their answers a final time.
    a. Several Students are asked to share their answer to the questions on page 2. Other students are asked if they agree/disagree, would like to add, etc.
5. **Students are then shown a set of ice melting blocks. They are passed around; these two identical black blocks look similar, but one feels cooler than another.**
    a. Students may take the temperature of the blocks with the IR thermometer to confirm that they are indeed the same temperature.
    b. Students are asked to describe why one block feels cooler than another. They may use either words or drawings (Nearpod Draw-It feature used).



c. Students are then told we will melt a piece of ice on each one, and asked which piece of ice will melt first.
d. After students make predictions, the melting ice is shown, and students compare the results to their initial predictions.

6. Students finish up by filling out page 4 of the Worksheet: Post-Video Thoughts

Section 4: Evaluation

Formative Assessment

Students will complete a writing-based homework activity that acts as a formative assessment for the lesson. **Students will choose one option for displaying their mastery of the content:**

- **Option 1**: Student will develop a procedure for an experiment which explores specific heat and perceived temperature. Procedure should be detailed enough to fully explain the concept to another student (but different from the experiment today) and include the materials needed, and some table in which to record data or some guiding questions. *(Extension option: Student also creates a conclusion statement to explain the concept to another student).*
- **Option 2**: Students will write a short essay (no more than one page) explaining the role of specific heat and/or thermal conductivity in the perception of temperature, and comparing that to the thermal energy of a substance. The essay should display good scientific writing skills, and involve claim, evidence, and reasoning. (*Extension*

option: student may do independent research and select an article or scholarly source supporting their claim).

- **ELL/IEP Option:** Students will complete an exit slip which guides student responses (option offered only to certain students who need accommodations).

Students provided with rubric **so they understand expectations.**

Section 5: Plan for Individual Differences

While ELL accommodations are listed within throughout the lesson plan, there are several pieces of the overall lesson which are planned with differentiated learning in mind.

- The hands-on inquiry lesson engages all students, and the differences observed between the temperature sensation while touching the objects vs. the temperature recorded by the gun should be sufficient to instigate a learning experience based on cognitive dissonance, regardless of whether a student understands the properties given in the chart (specific heat, thermal conductivity, and density).
- Definitions are provided for all the science terms, and sufficient time is provided for students to do personal research on the terms during the inquiry lesson in case they have questions, need to translate, or need alternative explanations.
- Questions and procedures are on the students' handouts as well as on the slides in order to ensure everyone understands the procedure; those with 504 plans who may become distracted or need refocusing will have resources to get them back on track with the lesson.
- ELL students and students with IEPs can take advantage of an alternative exit slip assignment, better suited to their personal capabilities and their individualized education goals.
- This lesson plan accommodates students who are audio learners (all instructions and questions are read aloud) as well as visual learners (all instructions and questions are shown on the board, and they will also benefit from the inclusion of the video in the Elaboration phase) and kinesthetic learners (who will be able to touch the density blocks and take temperature readings themselves with the infrared thermometer).
- All activities within student's science notebook are differentiated; options of drawing, writing complete sentences, writing key phrases/incomplete sentences, and drawing graphic organizers are all available.

Section 6: Materials

- Slide Set: https://docs.google.com/presentation/d/1puh6xKlHMp4qzz17iVcpNg54x-mwylyFsO_TEKcYkY4/edit?usp=sharing
- Video: https://www.youtube.com/watch?v=hNGJ0WHXMyE
- One set of density cubes per group (or any pure materials of different heat capacities)
- One or more Infrared Thermometers (one per group is ideal)
- Document (https://docs.google.com/document/d/1_gw4856lcInFTptOaRQ6Aam_VMvRYYRgxWY0wQZEY20/edit?usp=sharing) Containing:
    - Handouts with table of properties & guiding questions (one per student)
    - Claim-Evidence-Reasoning template (one per student)
    - Exit Slip Assignment (one per EL student)
    - Grading Rubric
- Students should have their science notebooks and a pen or pencil.

Section 7: Safety

- Do not look directly into the infrared thermometer; may cause injury to eyes.

Section 8: References

American Association for the Advancement of Science. (2017). *Energy: Forms, Transformation, Transfer, and Conservation*. Retrieved from http://assessment.aaas.org/misconceptions/NGM016/248

Fries-Gaither, Jennifer. (2009). *Common Misconceptions about Heat and Insulation.* Retrieved from Ohio State University website http://beyondpenguins.ehe.osu.edu/issue/keeping-warm/common-misconceptions-about-heat-and-insulation

Florida Department of Education. (2008). *Florida Sunshine State Standards (K-12 science)*. Retrieved from http://www.cpalms.org/homepage/index.aspx

Muller, D. [Veritasium]. (2011, June 29). Misconceptions about heat [Video File]. Retrieved from https://www.youtube.com/watch?v=hNGJ0WHXMyE

National Science Teachers Association. (2014). *Science and Engineering Practices*. Retrieved from http://ngss.nsta.org/PracticesFull.aspx

Lesson 4: Thermochemistry in Engineering: Design a Thermos

Section 1: Rationale/Purpose

Topic: Engineering Applications of Thermochemistry
Grade level: 9-12 **Duration:** 90 minutes (2 class periods)

Standards:
- SC.912.P.10.2 – Explore the Law of Conservation of Energy by differentiating among open, closed, and isolated systems and explain that the total energy in an isolated system is a conserved quantity.
- ELD.K12.ELL.SC.1 - English language learners communicate information, ideas and concepts necessary for academic success in the content area of Science.
- SC.912.N.1.7 - Recognize the role of creativity in constructing scientific questions, methods and explanations.
- SC.912.N.3.5 - Describe the function of models in science, and identify the wide range of models used in science.

Content Objectives:
- With the aid of different manipulatives, students will be able to:
  - Differentiate among open, closed, and isolated systems and explain that the total energy in an isolated system is a conserved quantity.
  - Design their own thermos using their understanding of the First Law of Thermodynamics.

Language Objectives:
- Students will be able to record written observations in their science notebooks using complete sentences and content-specific terms such as the Law of Conservation of Energy, open systems, closed systems, isolated systems, and surroundings.

Section 2: Misconceptions

1. Students fail to note that the first law of thermodynamics *is* the law of conservation of energy. The fancy name "First Law of Thermodynamics" refers in fact to the Law of Conservation of Energy (they are the same) (Laney College, 2014).

Section 3: Detailed Procedures

Introduction / Activation of Prior Knowledge	*Slide set guiding*

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- **(Slide 2) Review prior knowledge**. The students should have a basic working definition of energy and matter. From the previous lessons, they should have an understanding of how energy and matter flow between a system and its surroundings, and be able to differentiate between open systems, closed systems, and isolated systems. They should also understand The First Law of Thermodynamics and The Law of Conservation of Energy.
- **(Slide 3) Bellwork**: Students will complete a brief, anonymous, online survey to assess how confident they are with their own understanding of the following terms: Law of Conservation of Energy, insulator, open system, closed system, isolated system.
    - Survey Link: https://pollev.com/ericazah648

Lecture & Activity

Part 1: Engineering Design Challenge (EDC)

- Students will have the opportunity to use the Engineering Design Process to develop, try, revise, and implement their own methods to gather data on how energy is conserved between a system and its surroundings. The students will apply what they've been learning by investigating the difference between a water bottle without any insulation (control) and an insulated water bottle designed by the students (manipulated variable).
- **(Slide 4)** Ask the students the following guiding investigative questions:
    - How can we keep ice water at a low temperature using household materials?
    - How does insulation make our lives better?
    - Why would scientists want to keep a system as isolated as possible?
    - What are some flaws of using an open or closed system in science experiments?
- **(Slide 5)** Show students the presentation slide that outlines the Engineering Design Process. Explain each step of the process.
    - <u>Ask</u>: What do you need to know to solve the problem? What information is available?
    - <u>Imagine</u>: What are some possible solutions to the problem? Brainstorm ideas.
    - <u>Plan</u>: Design the solution by drawing a diagram and including a list of materials, costs, etc.
    - <u>Create</u>: Follow the plan and create the design.
        - Test it out!

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lecture: *https://docs.google.com/presentation/d/1qlk7AR4-xtZFOHf3Mfj23XW90ZV8GNV02fMblB1_Ins/edit?usp=sharing*

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- Improve: How can your design be more successful? Use the results from the test to determine what improvements must be made to the original design.
  - Test again!
- **(Slide 6) Introduce the engineering goal.** Students will design and create a thermos to insulate a bottle of cold water for 10 minutes. The thermos must keep the bottle of water noticeably colder than a similar bottle that has no insulation.
- **(Slide 7)** Students are given a few minutes to openly ***ask*** questions about what they think they will need to know in order to accomplish their goal. Teacher will answer the questions to the best of their ability.
  - Questions may include:
    - What makes an insulator effective?
    - What materials will we use?
    - How much do the materials cost?
    - How much time will we have?
- Provide each student with a handout, *Engineering a Thermos: Student Lab Report* (sample provided at the end of this lesson plan), and begin the activity.

Part 2: Activity Procedure

- The teacher will divide the students into teams of 3 or 4, and pass out the materials that each team will start with: Thermometer, scissors, rubber stopper, and two plastic water bottles.
- **(Slide 8)** The students are given 5 minutes to individually *imagine* a design for a thermos and determine materials for their insulator (they may choose up to 3 different materials). They will sketch the design in the "Imagine" section of their handout.
  - **(Slide 9)** Students are shown a list of materials that they can choose from: Styrofoam packing peanuts, paper napkins, paper plates, felt cloth, duct tape, rubber bands, bubble wrap, and plastic trash liners.
- **(Slide 10)** The teams are given 5 minutes to share their designs with each other and *plan* one final team design. The designs should be labeled, and include what materials are being used. They will sketch the design in the "Plan" section of their handout.
- **(Slide 11)** The students are given 20 minutes to collect the materials and *create* an insulator.
- The teacher distributes 20 mL of ice-cooled water to each team when they are ready to test their designs.

• To test the designs, the teams will make temperature readings of their insulator every 30 seconds for a time of 10 minutes (depends on total class time available). ○ The teams will record their data on the table in their lab reports, then graph the data. ○ The teacher will record temperatures for the control water bottle and post them for the whole class to see. ○ The teacher will have each group plot graphs of control and manipulated variables. **Part 3: Wrap-Up and Assessment** • **(Slide 12)** The teacher will discuss how the students know if their insulator worked compared to control data. The teacher will collect group data and display for class. Then in a discussion students will determine which combinations of materials insulate the best. Groups can share what they did, and from that, determine what worked best, and how they would choose to *improve* their designs in the future. • The teacher will facilitate a discussion about the lab and relate it to terms: Law of Conservation of Energy, open system, closed system, isolated system and insulation. • **(Slide 3)** The teacher will reopen the online survey from before and assess whether students feel more comfortable with key terms. • **(Slide 13)** The teacher will assess comprehension by having students answer the real world example by using all the key terms correctly. ○ Writing assignment: Using your conclusions from the lab and the key terms (law of conservation of energy, insulation, open, closed, and isolated system), give examples and explain where there are open, closed, and isolated systems in real life. In addition, give a reason why scientists would want a system to be as isolated as possible when conducting experiments. Response must be a minimum of 8-10 complete sentences.	***Alternatively, students who need certain accommodations may choose to draw real-world examples of the three systems.*
Section 4: Evaluation	
Formative Assessments 1. The online survey is a more informal and subjective, yet still allows the teacher to assess and gain insight into how students	

feel about their own understanding of the content vocabulary: Law Of Conservation Of Energy, Insulation, Open System, Closed System, Isolated System. The teacher will review progress with the survey at the beginning and end of the lesson. 2. Class/team discussions allow the teacher to address any issues or concerns throughout and at the end of the lesson, and provide immediate feedback to help facilitate students understanding. The open-ended style of a discussion also allows the teacher enough flexibility to make the lesson more personal, extend knowledge, and probe more a more-in depth understanding of the material. 3. The teacher can use the completed student lab reports (along with visual observations during the class period) to verify that each student was actively participating in the activity. The reports also offers insight into how well the students were able to apply their knowledge to an engineering design challenge. 4. The writing assignment at the end of the lab report is a more direct method for measuring how well the students have learned the content based on their ability to apply that information to new and different real-world situations. Example Rubric for grading the written response.	

Section 5: Plan for Individual Differences

- The online survey that the students complete for the bellwork activity includes emoticons that correlate to each response for each question. This will help EL students with lower English-language proficiency complete the activity. The fact that the survey is online and anonymous also encourages more participation from those students who may not feel comfortable responding in a group/class discussion.
- The presentation slides are designed to have simplified language and sentence structure to accommodate for the needs of students with lower English-language proficiency. Some of the slides also include pictures to accompany text. For example, Slide 8 lists the materials that students can choose from, but if a student has never seen those words before, then pictures are included to show what the material is or looks like.
- For advanced students or to go more in depth with students, there can be a class discussion about r-value and the importance of insulation in home building:
    1. How Stuff Works
    2. Energy Star

Section 6: Materials

- A computer or laptop (with access to the internet)
- A projector or SmartBoard (or something similar)
- Presentation slides

- https://docs.google.com/presentation/d/1qlk7AR4-xtZFOHf3Mfj23XW90ZV8GNV02fMblB1_Ins/edit?usp=sharing
- Engineering a Thermos: Student Lab Report (1 copy per student)
    - https://docs.google.com/document/d/12AVS53TGBluTHegczdXBMoOA5xJUXGT2yhlr1qW0dZU/edit?usp=sharing
- For the class:
    - A large cooler of ice water (enough so each group can get 20 mL of cold water)
    - Styrofoam packing peanuts
    - Paper plates
    - Paper napkins
    - Felt cloth
    - Duct tape (cut into 12” lengths)
    - Rubber bands
    - Bubble wrap
    - Plastic trash liners
- For each group:
    - Scissors (one per students)
    - 1 Thermometer
    - 1 Rubber stopper (to hold the thermometer in place)
    - 1 Plastic empty water bottle

Section 7: Safety

- No specific safety concerns.

Section 8: References

Florida Department of Education. (2008). *Florida Sunshine State Standards (K-12 science)*. Retrieved from http://www.cpalms.org/homepage/index.aspx

Lefkowitz, E. (n.d.). *Make Your Own Thermos*. Retrieved from http://www.cpalms.org/Public/PreviewResource/PrintResource/71426?display=block&Private=true&IsPrintPreview=true

Laney College. (2014). *Chapter 5 Thermochemistry Common Misconceptions.* Retrieved from http://laney.edu/abraham-reyes/wp-content/uploads/sites/229/2014/06/Chapter-5-Thermochemistry-Common-Misconceptions.pdf

Lesson 5: Reactions and Heat Transfer (Endothermic, Exothermic, and Specific Heat)

Section 1: Rationale/Purpose

Topic: Exothermic and Endothermic Systems and their Surroundings.
Grade level: 9-12 **Duration:** 60-80 minutes (2 class periods)

Standards:
- SC.912.P.10.7 - Distinguish between endothermic and exothermic chemical processes.
- SC.912.P.10.6 - Create and interpret potential energy diagrams
- ELD.K12.ELL.SC.1 - English language learners communicate information, ideas and concepts necessary for academic success in the content area of Science.
- SC.912.N.1.1 - Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following:
    - Use tools to gather, analyze, and interpret data (this includes the use of measurement in metric and other systems, and also the generation and interpretation of graphical representations of data, including data tables and graphs)

Content Objectives:
- Students will be able to differentiate between endothermic and exothermic processes and their respective effects on the surroundings.

Language Objectives:
- Students will be able to verbally describe what is occurring in a simplified potential energy diagram using content specific vocabulary such as heat transfer, exothermic, endothermic, systems, surroundings, and energy.
- Students will practice reading and interpreting word problems about specific heat, determining what information has been given and what is being asked.

Section 2: Misconceptions

1. Burning must be an endothermic reaction because it takes energy to get it started (Horton, n.d.)
2. “Students thought burning of candle as an endothermic reaction since heat was needed to initiate the reaction” (Yalçınkaya, Özgecan, & Boz, 2009, p. 2).
3. “Endothermic reactions cannot be spontaneous” (Yalçınkaya, Özgecan, & Boz, 2009, p. 2).

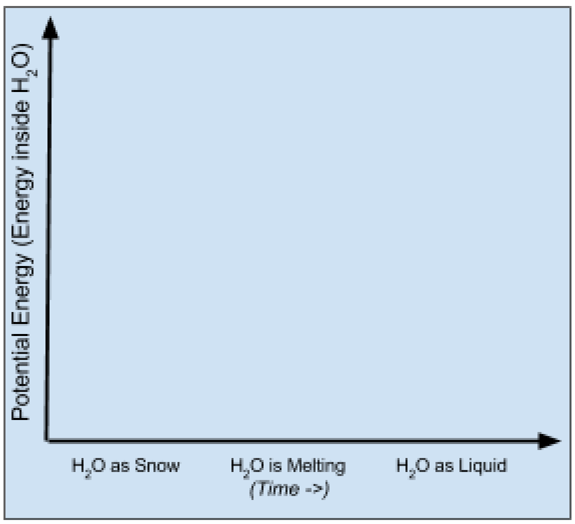
Section 3: Detailed Procedures

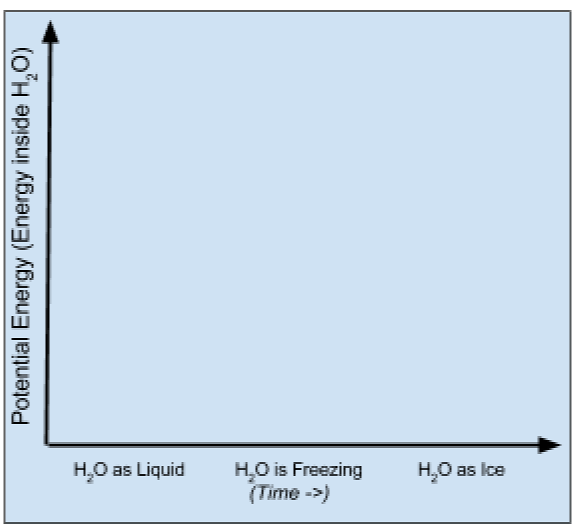
Introduction / Activation of Prior Knowledge	
Introduction / Activation of Prior Knowledge • **Bellwork**: Students copy two sentences into their science notebook with the blanks filled in. ○ “Thermochemistry is the study of _________ changes that occur during chemical reactions and changes in state.” ○ “Every substance has a certain amount of Chemical energy stored inside it. Where is it stored? ***chemical potential energy*** is the energy stored in the ________ _____of a substance.” • **Demo**: Students view Slide 9 and are then shown the demo “The ‘whoosh’ bottle demonstration”. Details here: https://drive.google.com/open?id=1_DBFzXC0Zw3p25byRs-7gq8grmtWosck (for this demonstration, only isopropyl alcohol is needed). **Lecture & Activity - DAY ONE** **Part 1: Endothermic vs Exothermic: Concepts** • Students are shown slides 10-12 and introduced to endothermic and exothermic processes. Slide contents are discussed out loud. • Students asked to describe any endothermic or exothermic processes they know from life or have seen in the class so far (participants selected randomly). • At slide 15 (“Recognizing Endothermic and Exothermic Processes ”, last page of this slide set), students answer this question in their science notebook: ○ *“On a sunny winter day, the snow on a rooftop begins to melt. As the melted water drips from the roof, it refreezes into icicles. Describe the direction of heat flow as the water first melts, then freezes. Which process is endothermic? Exothermic?”* ○ Student responses are checked through selection of random students to share their responses. Students encouraged to discuss the similarities and differences among their responses; Teacher addresses any misconceptions and allows students to revise the answers in their notebooks. ○ **Ideal responses would reflect the following ideas:** ■ *The snow on the rooftop starts with little heat, or internal energy. It absorbs solar energy, and starts to melt. This is an endothermic process, since the system (the snow) is absorbing heat.*	*Slide set guiding lecture. Pick up at slide 7: https://docs.google.com/a/ocps.net/presentation/d/1v9fqt8Ed5hwjdk163uX-Obibd8G0oPjYn8rNU0L3gsU/edit?usp=sharing*

- *As the melted snow drips from the roof, it probably doesn't have direct contact with the sun anymore. Therefore, it has no solar energy to absorb, and the surroundings at the edge of the roof has less heat energy. The water then gives off its heat to the cooler surroundings and re-freezes in the process; since the water is losing heat to the surroundings, this is an exothermic process.*

Part 2: Potential Energy Diagrams

- Students are then asked: "Do you think there is a way to draw a graph of what you've just described?"
- Students are guided to draw two graphs such as these:





- Students are asked to first think about (1 minute) and then fill in the graphs in pencil on their own (3 minutes).

- Students are asked to exchange graphs with the person behind/in front of them (*not* the same person as their shoulder partner). Students consider the other student's graph for one minute. - Is it different? The same? Do you see any errors? - After one minute, students turn and discuss with each other their thoughts on each other's graphs. Revisions may be made at this time. - Students are told that temperatures were taken at various points in this process. This is the data: 10:20 - H_2O as snow: -5℃ 10:30 - H_2O as snow: -2℃ 10:40 - H_2O melting: 0℃ 10:50 - H_2O melting: 0℃ 11:00 - H_2O as liquid: 2℃ 11:10 - H_2O as liquid: 5℃ 11:20 - H_2O as liquid: 6℃ 11:30 - H_2O as liquid: 2℃ 11:40 - H_2O freezing: 0℃ 11:50 - H_2O freezing: 0℃ 12:00 - H_2O as ice: -4℃ 12:10 - H_2O as ice: -6℃ - Teacher draws the graphs on the board, plotting the data. - Example of melting graph: https://drive.google.com/open?id=1zs15QCye75kOA69cBnm9694KT8Q1-IDY - Students are then asked: - When graphing the potential energy of an endothermic reaction over time, does the potential energy rise or fall? Why? - When graphing the potential energy of an exothermic reaction over time, does the potential energy rise or fall? Why? **Homework** - Students receive the following handout (Print Pages 3-5 only): - https://drive.google.com/open?id=15N3GPTy8P2TdUwtFIH31qvnnWdBTY9pw (Horlock, Moules, Keogh, & Naylor, 2015) - Students are asked to consider the question overnight. If their parent allows them to, light a candle and consider the question in the packet. - Students should prepare an answer for tomorrow.	

Lecture & Activity - DAY TWO **Introduction** ● Students provide an answer to the question from the handout: Is the burning of a candle an endothermic or exothermic reaction? Students will have a brief discussion (5 minutes) **Part 3: Describing Heat Transfer in Quantitative Terms** ● Students are told that, now that they understand the concept of heat flowing into or out of a system, we need ways to *quantify* that information. ● Students are introduced to the terms needed to perform heat transfer calculations through slides 1-6 of https://docs.google.com/a/ocps.net/presentation/d/1SsC98HHDPgBDiQMGXlmd16sv2YA1yqRy-Ca3PD89eBE/edit?usp=sharing ○ Topics covered: ■ Heat flow in terms of Calorie & Joule ■ Heat capacity ■ Specific Heat ● **At slide 7, Student understanding checked with quiz (using an instant-response formative method such as Nearpod or Goformative in order to gauge student understanding before moving forward)** **** Mid-Lesson Evaluation** ○ Question 1: The various forms of energy are… (select all that apply) ■ Mechanical, Natural, Chemical, Hydrogen Bonding, Sound, Thermal, Radiant (Light), Nuclear, Pressure, Sub-space ○ Question 2: The Law of Conservation of Energy is used in thermochemistry because ■ Energy of the products equals the reactants ■ Energy of the reactants is equal to the products plus or minus the surroundings ■ The energy of the products never changes from that of the reactants ○ Question 3: The SI unit used to measure energy is ■ Calorie (capital C) ■ calorie (lowercase c) ■ Joule ○ Question 4: Heat capacity is… ■ The amount of heat needed to increase the temperature of an object exactly 1 degree C	

■ The amount of heat needed to increase the temperature of water exactly 1 degree C ■ he amount of heat it takes to raise the temperature of 1 g of the substance 1℃. ○ Question 5: Specific Heat is… ■ The amount of heat needed to increase the temperature of an object exactly 1 degree C ■ The amount of heat needed to increase the temperature of water exactly 1 degree C ■ The amount of heat it takes to raise the temperature of 1 g of the substance 1℃. **Part 4: Using the Specific Heat Formula** ● On slide 8, Students are introduced to: ○ Specific heat formula ($C = \frac{q}{m*\Delta T}$) & ○ Temperature change calculation ($\Delta T = T_{final} - T_{initial}$). ● On slides 9-11, Students are walked through an example problem: ○ “The temperature of a 95.4-g piece of copper increases from 25.0℃ to 48.0℃ when the copper absorbs 849 J of heat. What is the specific heat of copper?” ● Students are told that tomorrow the lesson will begin with a quiz of three of these questions.	
Section 4: Evaluation	
Formative Assessments 1. On Day 1, Student drawings, notebook answers, and discussion responses are informally evaluated for misconceptions. 2. On Day 2, Student mid-lesson evaluation quiz is evaluated for accuracy and misconceptions.	
Section 5: Plan for Individual Differences	
1. Student quizzes are multiple choice in order to provide student with instant feedback on minor errors if their answers do not match an answer choice. 2. Problem solving strategy is modeled prior to student questions 3. Individualized assistance can be provided to certain students. 4. Students building literacy and/or math skills can be given a problem-solving worksheet with the steps labeled and formulas pre-written in with blanks. ● Notes can be taken in the form of sentences with strategic blanks.	
Section 6: Materials	

- A chalkboard, whiteboard, or projection apparatus to display slides with information.
- Slide sets (Two used in this lesson, both linked in Procedures)
- Isopropyl Alcohol, CH3H8O(l), (VERY FLAMMABLE) - see CLEAPSS Hazcard.
- Large polycarbonate bottle (for reaction vessel). The bottle must be made of polycarbonate (marked PC) and of no other material (Nuffield Foundation and the Royal Society of Chemistry, 2015).
- Beaker
- Wooden splint
- Meter rule
- Adhesive tape
- Lighter or matches
- Quizzes set up on an instant formative quiz program (like Nearpod or GoFormative or Google Forms)
- Students should have their science notebooks and a pen or pencil.

Section 7: Safety

- Both demonstrator and class should be wearing eye protection (Nuffield Foundation and the Royal Society of Chemistry, 2015).
- Select a safe, level place for the demonstration, with at least 2.5m clearance above the top of the vessel to the ceiling above, and no flammable materials above it. If the laboratory bench does not allow for this, four stable laboratory stools supporting a large wooden tray may give sufficient clearance and stability (Nuffield Foundation and the Royal Society of Chemistry, 2015).
- Set out the bottles containing the alcohols and the beakers at least 1 m away from the demonstration. No flames within 1 m. Students at least 4 m away (Nuffield Foundation and the Royal Society of Chemistry, 2015).
- Isopropyl Alcohol, CH3H8O(l) is very flammable, and can be toxic if swallowed.

Section 8: References

Florida Department of Education. (2008). *Florida Sunshine State Standards (K-12 science)*. Retrieved from http://www.cpalms.org/homepage/index.aspx

Horlock, J., Moules, J., Keogh, B. & Naylor, S. (2015). Science concept cartoons set 2: 5.8 exothermic/endothermic reactions. Retrieved from http://www.rsc.org/learn-chemistry/resource/res00002127/science-concept-cartoons-exothermic-endothermic-reactions?cmpid=CMP00007136

Horton, M. (n.d.). [Audio File Transcript]. Combustion reactions are endothermic because it takes energy to get them started. *Science Misconception Podcast*. Retrieved from https://scienceinquirer.wikispaces.com/misconception

Nuffield Foundation and the Royal Society of Chemistry. (2015, October). *The 'whoosh' bottle demonstration*. Retrieved from http://www.rsc.org/learn-chemistry/resource/res00000708/the-whoosh-bottle-demonstration?cmpid=CMP00005923

Wilbraham, A., Staley, D., Matta, M., & Waterman, E. (2012). Pearson Chemistry (Florida Ed). Boston, MA: Pearson.

Yalçınkaya, E., Özgecan, T., & Boz, Y. (2009). High school students' conceptions about energy in chemical reactions. Eğitim Fakültesi Dergisi, Pamukkale Üniversitesi, pp. 1-11. Retrieved from http://pauegitimdergi.pau.edu.tr/DergiPdfDetay.aspx?ID=187

Lesson 6: Enthalpy and Calorimetry Calculations

Section 1: Rationale/Purpose

Topic: Using the Calorimetry Equation to solve Calorimetry & Enthalpy Problems
Grade level: 9-12 **Duration:** 30 minutes (1 class period)

Standards:

- SC.912.P.10.5 - Relate temperature to the average molecular kinetic energy.
    - "Changes in entropy and energy that accompany chemical reactions influence reaction paths. Chemical reactions result in the release or absorption of energy."
- SC.912.P.10.7 - Distinguish between endothermic and exothermic chemical processes.
- ELD.K12.ELL.SC.1 - English language learners communicate information, ideas and concepts necessary for academic success in the content area of Science.
- SC.912.N.1.6 - Describe how scientific inferences are drawn from scientific observations and provide examples from the content being studied.
    - Collect data/evidence and use tables/graphs to draw conclusions and make inferences based on patterns or trends in the data.
- SC.912.N.1.1 - Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following:
    - Pose answers, explanations, or descriptions of events,

Content Objectives:

- Students will be able to use the calorimetry equation to solve calorimetry and enthalpy problems.
- Students will use the correct sign (positive or negative) for their answers to indicate whether the change in enthalpy (ΔH) represents endothermic or exothermic processes.

Language Objectives:

- Students will read and decode calorimetry word problems, gather the relevant information given, and determine what the question is that must be answered.

Section 2: Misconceptions

1. "When objects are in contact an equal amount of energy is transferred between them, this causes no change in temperature (AAAS Project 2061, 2017)" (American Association for the Advancement of Science, 2017).
2. "Energy can be created" (American Association for the Advancement of Science, 2017).

Section 3: Detailed Procedures

Introduction / Activation of Prior Knowledge (10 mins) ● **Bellwork Quiz**: Yesterday, students learned about specific heat calculations and were walked through an example problem. Today, they start off with a quiz to check their understanding. *Reteach is provided as necessary.* ● Students are provided the "Specific Heat" formula image during bellwork quiz: https://drive.google.com/file/d/1BMFFsjTAT56IZoN7Fl1qrqSw60yPIGgH/view?usp=sharing **Specific Heat Bellwork Quiz:** 1. A 15.75 g of iron absorbs 1086.75 joules of heat energy. and its temperature changes from 25 to 175 degrees C. Calculate the Specific Heat of iron. a. 114.1 J/(g·°C) b. 0.46 J/(g·°C) c. 2.17 J/(g·°C) 2. How many joules of heat are needed to raise the temperature of 10.0 g of aluminum from 22 to 55 degrees C? The specific heat of aluminum is 0.90 J/g C. a. 297 J b. 366 J c. 2.55 J 3. An unknown mass of water will change its temperature by 3 degrees C when 525 J of heat is added to it. What is the mass of the water? The specific heat of water is 4.18 J/g C. a. 7.32 g b. 6590 g c. 41.87 g **Lecture / Activity** **Part 1: Calorimetry Problem** ● **Lecture Begins on Slide 1 of slide set.** Students are reminded about the role of specific heat, and asked to consider the following question: ○ **How can you measure the amount of heat released when a match burns?** *Remember: The concept of specific heat*	*The correct answer for each question is provided in red.* *** See plan for individualized differences for helping students in need of differentiation for this quiz.*

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allows you to measure heat flow in chemical and physical processes.

- **On Slide 2**, students are <u>shown</u> a rewritten form of the "specific heat formula", rearranged so that q is isolated on one side rather than C. This is introduced as the **calorimetry equation**.
  - Students are given time to <u>write the calorimetry equation in their notebooks</u> along with the meaning of each variable
- **On Slide 3**, a calorimeter is shown and the parts of it are described.
  - Students <u>take notes</u> and <u>draw the important parts</u> of a calorimeter in their notebooks.
- **On Slides 4-8**, students <u>observe</u> a calorimetry problem and the class <u>solves the problem together</u>, breaking down the problem-solving steps.
  - Teacher may lead or, if students are comfortable, they may try each step on their own.
- **On slide 9,** Students are again shown the calorimetry equation and allowed to <u>ask any clarifying questions</u> they have.

Part 2: Introduction to Concepts of Enthalpy & Thermochemical Equations

- **On Slide 10, Enthalpy is introduced as ΔH.**
  - positive for endothermic reaction
  - negative for exothermic reaction.
- **Thermochemical equations** are introduced, along with the concept of "**Heat of Reaction**".
  - **Content covers only concepts - through slide 18. ****
- Students <u>take notes</u> & <u>fill in the table</u> in the "Evaluation" section.
- Students are told tomorrow they will do a calorimetry lab to extend and practice the concepts introduced today.

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Slide set:
https://docs.google.com/a/ocps.net/presentation/d/1akkztPboAOe_7dbEeQNBoAWOhIe990YruNOZ3ha1DR8/edit?usp=sharing

***** Heat of Reaction note:*** *Students are only introduced to this concept today, not **using** heats of formation to determine heat of reaction, which is dealt with in lesson 7.*

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<td colspan="2">Section 4: Evaluation</td>
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Formative Assessment

Students <u>copy & fill out this table</u> in their science notebooks:

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By looking at the following Heats of Reaction, Label each as belonging to an exothermic or endothermic reaction. Also identify if you would find the heat on the reactants or products side in a thermochemical equation.

Heat of Reaction	Exothermic or Endothermic?	Reactants or Products side in Thermochemical Equation:
+226.7		
-31.8 kJ		
+52.3		
-1128.4 kJ		

Section 5: Plan for Individual Differences

1. Student quizzes are multiple choice in order to provide student with instant feedback on minor errors if their answers do not match an answer choice. For higher level students, multiple choice can be changed to open-ended.
2. Problem solving strategy has been modeled prior to student questions; For differentiation, one or two problems may be done together as a class, leaving fewer problems for students to do alone.
3. Individualized assistance can be provided to certain students, particularly in decoding word problems.
4. Students building literacy and/or math skills can be given a page with the word problems written with important words bolded, underlined, and key information already pulled out.

- Notes can be taken in the form of sentences with strategic blanks.

Section 6: Materials

- Bellwork Quiz: Ideally set up on an instant-feedback formative platform such as Nearpod or GoFormative.
    - Prepared handouts for quiz differentiation as needed.
- Slide Set (linked in procedures)
- Students should have their science notebooks and a pen or pencil.

Section 7: Safety

- There are no major safety concerns in this lesson.

Section 8: References

American Association for the Advancement of Science. (2017). Energy: Forms, Transformation, Transfer, and Conservation. Retrieved from http://assessment.aaas.org/misconceptions/NGM066/248

Florida Department of Education. (2008). *Florida Sunshine State Standards (K-12 science)*. Retrieved from http://www.cpalms.org/homepage/index.aspx

Wilbraham, A., Staley, D., Matta, M., & Waterman, E. (2012). *Pearson Chemistry (Florida Ed)*. Boston, MA: Pearson.

Lesson 7: Calorimetry Lab

Section 1: Rationale/Purpose

Topic: Calorimetry Lab
Grade level: 9-12 **Duration:** 60 minutes (2 class periods)

Standards:

- SC.912.P.10.1 - Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.
- SC.912.P.10.2 – Explore the Law of Conservation of Energy by differentiating among open, closed, and isolated systems and explain that the total energy in an isolated system is a conserved quantity.
- SC.912.P.10.7 - Distinguish between endothermic and exothermic chemical processes.
- ELD.K12.ELL.SC.1 - English language learners communicate information, ideas and concepts necessary for academic success in the content area of Science.
- SC.912.N.1.6 - Describe how scientific inferences are drawn from scientific observations and provide examples from the content being studied.
    - Collect data/evidence and use tables/graphs to draw conclusions and make inferences based on patterns or trends in the data.

Content Objectives:

- Through experimental observation, students will be able to perform calorimetric calculations to determine how much heat is absorbed or released by a substance.

Language Objectives:

- Students will be able to explain what their calculations represent using scientific terminology.

Section 2: Misconceptions

1. Students often cannot tell the difference between enthalpy of a reaction ΔHrxn (in kJ) and molar enthalpy (per one mole of one of the reacting species, in kJ/mol) (Chapter 5 Thermochemistry: Common Student Misconceptions).

Section 3: Detailed Procedures

Introduction / Activation of Prior Knowledge (10 mins) ● Students are provided the “Specific Heat” formula image during bellwork quiz: https://drive.google.com/file/d/1BMFFsjTAT56IZoN7Fl1qrqSw60yPIGgH/view?usp=sharing	

• **Bellwork Quiz**: In the previous lesson, students learned how to apply the specific heat formula to solve several calorimetry problems. They will use what they've learned to solve the following review problem: In a coffee-cup calorimeter, 100.0 mL of H_2O and 100.0 mL of HCl are mixed. The HCl had an initial temperature of 44.6 °C and the water was originally at 24.6 °C. After the reaction, the temperature of both substances is 31.3 °C. a. Was the reaction exothermic or endothermic? Explain. *For the water: endothermic. The temperature increased from 24.6 °C to 31.3 °C indicating energy was absorbed by the water.* *For the HCl: exothermic. The temperature decreased from 44.6 °C to 31.3 °C indicating energy was released by the HCl.* b. Calculate how much heat the water lost or gained. *Q_{water} = 2800.6 J = 2.8 x 10^3 J (answer rounded for sig. figs.)* **Calorimetry Lab Activity** **Part 1: Background Info and Setup (20 min)** • Teacher explains that students will be performing a calorimetry experiment to determine the heat of solution for sodium hydroxide, NaOH. By using a calorimeter and measuring the change in the temperature of the water during the dissolving process, you can calculate the heat of solution. • ***Heat of Solution*** is the change in energy that occurs as one mole of a given solute dissolves in water. During the dissolving process, solutes either absorb or release energy. ○ If solutes absorb energy from the water as they dissolve, the water gets colder and the reaction is *endothermic*. ○ If solutes release energy to the water as they dissolve, the water gets warmer and the reaction is *exothermic.* • In calorimetry, an assumption is made that the change in heat of the substance (ΔH_{solute}) is equal to the change in heat of the water (ΔH_{water}). • The change in heat of the water is calculated using the formula: $\Delta H_{water} = mass_{water} \times \Delta T_{water} \times specific\ heat_{water}$ ○ Where: ΔH_{water} = change in heat of the water $mass_{water}$ = mass of the sample of water ΔT_{water} = change in temperature of the water $specific\ heat_{water}$ = 4.18 J/g•°C	*The answers are provided for each question in red text.*

- Students are split into their preassigned lab groups, and given a copy of the *Calorimetry: Student Lab Report*.
    - The first page of the report is almost entirely blank; only indicating where the materials, procedure, and diagram need to be shown. The second page of the report has a detailed table that students will complete throughout their experiment.
- Before the students can begin their lab, they must complete the first page of the lab report at their desks.
    - The students are shown a slide that displays all of the equipment/materials needed for their calorimetry lab. They will list these items in the section of their lab reports titled "Equipment and Materials Needed." Example of slide is shown below.

    - In the section titled "Procedure," the students will write out a detailed procedure for how they plan to use a calorimeter to measure the change in enthalpy during a reaction of NaOH and water.
        - *Note: Students should use the list of materials and the table on the second page of the lab report to help them determine each step of the procedure.*
        - Procedures may vary slightly, which is okay. The teacher can use this as an opportunity to address how scientific investigations use a variety of methods.
    - Students will also create a visual diagram to show how they are going set up their laboratory equipment/materials.
        - *Note: Students should use the notes that they took from the previous lesson to help them remember what a calorimeter looks like.*

● Once a group has completed the first page of their lab reports, and the teacher has approved their procedure and diagram, then they will continue on to Part 2 of the activity. **Part 2: Experiment (20 min)** ● The groups will perform the calorimetry experiment according to their approved procedure. ○ Overall, the procedure should include: measuring out 100-mL of deionized water into the calorimeter, measuring out 5 grams of solid NaOH into the calorimeter, and recording the temperature difference from before and after the NaOH was added. ○ The groups should measure the temperature of the solution for 10 minutes. ● The groups should record all of their data on the table in their handouts. ● The teacher should circulate the room while students are performing their experiments to facilitate safety, encourage proper lab techniques, and answer any questions. **Part 3: Wrap-Up and Assessment** ● Students will clean up their work areas and wash any equipment that was used. ● Students will finish any work on their lab reports, and turn them in for grading. ○ The teacher may want to spend a few minutes with the class to explain how to calculate for the %error at the end of the lab reports if this is their first time doing that kind of calculation.	
Section 4: Evaluation	
Formative Assessment ● The student lab report will be assessed throughout the activity and graded after completion. The teacher can use the completed student lab reports (along with visual observations during the class period) to verify that each student was actively participating in the activity. The lab reports also offer insight into how well the students were able to apply their knowledge with regards to the following Nature of Science concepts: ○ Scientific investigations use a variety of methods ○ Scientific knowledge is based on empirical evidence	

○ Scientific knowledge is open to revision in light of new evidence ○ Scientific models, laws, mechanisms, and theories explain natural phenomena ○ Science is a way of knowing ○ Scientific knowledge assumes an order and consistency in natural systems ○ Science is a human endeavor ○ Science addresses questions about the natural and material world	

Section 5: Plan for Individual Differences

- The bellwork quiz can be modified to include multiple choice answers in order to provide students with instant feedback on minor errors if their answers do not match an answer choice.
- Problem solving strategies for the bellwork quiz question will be modeled prior to student questions.
- Individualized assistance can be provided to certain students, particularly in decoding the word problems.
- Students building literacy and/or math skills can be given a page with the word problems written with important words bolded, underlined, and key information already pulled out.
- The slides include pictures to to accommodate students with lower English-language proficiency. The materials slide lists the materials that students will need for the experiment, but if a student has never seen those words before, then pictures are included to show what the material is or looks like.
- EL students should work in lab groups with other bilingual students at a higher level of English proficiency.
- The lab guide can be supplemented by images to reinforce their understanding of the activity at hand.

Section 6: Materials

- Calorimetry: Student Lab Report (1 copy per student)
    - https://docs.google.com/document/d/1hQPLZhFSmObqiOyYtFgYESktJ28BrXKF9PVmq89OqfQ/edit?usp=sharing
- Nitrile gloves (a class set)
- Digital balances/scales (a class set)
- For each group:
    - Graduated cylinder, 100 mL
    - Funnel, sized for graduated cylinder
    - Weigh boat or weigh paper
    - Scupula
    - Calorimeter

- Thermometer
- Sodium hydroxide, 5 grams
- Distilled/deionized water, 100 mL

Section 7: Safety

- While in the laboratory environment, students should be wearing proper lab attire (nitrile gloves, safety goggles, lab coat, long pants, close-toed shoes, etc.).
- The teacher should assess that students know how to safely handle all of the equipment, and the chemicals being used (solid sodium hydroxide, NaOH).
- The teacher should assess that students know the location of any relevant safety stations, such as the glass disposal box, eyewash station, etc.

Section 8: References

Florida Department of Education. (2008). *Florida Sunshine State Standards (K-12 science)*. Retrieved from http://www.cpalms.org/homepage/index.aspx

Chapter 5 Thermochemistry: Common Student Misconceptions. Retrieved from http://westmonroehigh.opsb.net/common/pages/DisplayFile.aspx?itemId=2589809

Heat of Solution. Retrieved from http://pulse.pharmacy.arizona.edu/resources/heatofsolution.pdf

Lesson 8: Heats of Reaction (Formation & Combustion)

Section 1: Rationale/Purpose

Topic: Calculating Heats of Reaction using Thermochemical Equations
Grade level: 9-12 **Duration:** 40 minutes (1 class period)

Standards:
- SC.912.P.10.7 - Distinguish between endothermic and exothermic chemical processes.
  - "Changes in entropy and energy that accompany chemical reactions influence reaction paths. Chemical reactions result in the release or absorption of energy."
- ELD.K12.ELL.SC.1 - English language learners communicate information, ideas and concepts necessary for academic success in the content area of Science.
- SC.912.N.1.6- Describe how scientific inferences are drawn from scientific observations and provide examples from the content being studied.

Content Objectives:
- Students will be able to determine the heat of reaction by reading a table of heats of formation and doing the correct calculations for the overall reaction.

Language Objectives:
- Students will be able to interpret data presented in a table and obtain relevant information required to solve problems.

Section 2: Misconceptions

1. "Energy appears to be created by burning fuels and that this energy runs out when the fuel is 'used up' [rather than being transformed]" (Denby, 2014).
2. "Students generally have a misconception that bond formation is endothermic and bond breaking is exothermic. They believed that to form something, we must make an effort and so energy should be used up. In addition, because atoms keep energy in themselves, during bond breaking process, energy comes out" (Yalçınkaya, Özgecan, & Boz, 2009).

Section 3: Detailed Procedures

Introduction / Activation of Prior Knowledge (10 mins) • **Bellwork:** Students will review and define the following equation in their Science Notebooks. $Q=mc\Delta T$ -Students will then answer the following questions 1. What is Q? What is its unit?	*OPTIONAL Slide set: LEFT OFF IN LESSON 5 ON SLIDE 18:* https://docs.goog

2. What is m? What is its unit? 3. What is c? What is its unit? 4. What is T? What is its unit? ● **Lecture / Activity (30 mins)** ● **Lecture Begins on Slide 19 of slide set.** Students are shown that the heat of reactions are specific to their reactions and must be changed depending on the number of moles of reactants and products. They are also introduced to the concept of different states releasing/absorbing different amounts of heat. ● **On Slide 20**, students are shown how different states have different heats of reaction associated with them and how using these values, the heat of vaporization can be found. ○ Students are expected to write this example in their science notebook. ● **On Slides 21-22**, A sample problem is given ○ Students should follow along with the problem and review their dimensional problem solving. ● **On Slides 23-26**, Students will follow along as the concept of **Heat of combustion** is shown and elaborated upon. ○ Teacher can provide students with examples of common combustion reactions so students my familiarize themselves with looking up combustion values.	le.com/a/ocps.net/presentation/d/1akkztPboAOe_7dbEeQNBoAWOhIe990YruNOZ3ha1DR8/edit?usp=sharing
Section 4: Evaluation	
Formative Assessment Students will be given the following worksheet to complete for the remainder of class. The worksheet will serve as a formative assessment. If the worksheet is not completed it will be due the following day as homework. Students will be encouraged to work in group and refer back to their notes or slides in order to complete the worksheet.	*https://docs.google.com/document/d/13H35YJhB0MeRHZ7_vCFFooA1WYvLrc5xLKNw_6ya7Pk/edit?usp=sharing*
Section 5: Plan for Individual Differences	
● Problem solving strategy is modeled prior to student questions ● Individualized assistance can be provided to certain students. ● Students building literacy and/or math skills can be given a problem-solving worksheet with the steps labeled and formulas pre-written in with blanks. ● Notes can be taken in the form of sentences with strategic blanks. ● Student can be partnered with another student who speaks the same language to provide additional assistance.	

Section 6: Materials
• Slide Set as linked in the Lesson Plan • Devices to access google doc worksheet (Printed worksheets in case of internet failures) • Students should have their science notebooks and a pen or pencil.
Section 7: Safety
• No safety concerns found in this lesson.
Section 8: References
Florida Department of Education. (2008). *Florida Sunshine State Standards (K-12 science)*. Retrieved from http://www.cpalms.org/homepage/index.aspx Denby, D. (2014, May 07). Chemical energetics: words matter. *Education in Chemistry* [Website]. Retrieved from https://eic.rsc.org/cpd/chemical-energetics-words-matter/2000004.article Yalçınkaya, E., Özgecan, T., & Boz, Y. (2009). High school students' conceptions about energy in chemical reactions. *Eğitim Fakültesi Dergisi, Pamukkale Üniversitesi*, pp. 1-11. Retrieved from http://pauegitimdergi.pau.edu.tr/DergiPdfDetay.aspx?ID=187

Lesson 9: Heat of Fusion/Solidification

Section 1: Rationale/Purpose

Topic: Phase Changes and Heat of Fusion/Solidification
Grade level: 9-12 **Duration:** 45 minutes (1 class period)

Standards:
- SC.912.P.10.6 - Create and interpret potential energy diagrams, for example: chemical reactions, orbits around a central body, motion of a pendulum.
- SC.912.P.10.7 - Distinguish between endothermic and exothermic chemical processes.
  - Changes in entropy and energy that accompany chemical reactions influence reaction paths. Chemical reactions result in the release or absorption of energy.
- ELD.K12.ELL.SC.1 - English language learners communicate information, ideas and concepts necessary for academic success in the content area of Science.
- SC.912.N.1.6- Describe how scientific inferences are drawn from scientific observations and provide examples from the content being studied.

Content Objectives:
- Using the provided slides as a resource, students will research and record information on various energy concepts in order to complete an assigned worksheet.

Language Objectives:
- Students will be able to verbally describe what is occurring at the different stages of a potential energy diagram using content specific vocabulary such as reactants, products, activation energy, exothermic, endothermic, and energy.

Section 2: Misconceptions

1. Thermal energy is not related to the number of molecules that make up an object (Herrmann-Abell & DeBoer, 2009).
2. Thermal energy is not related to the type of molecule that makes up an object (Herrmann-Abell & DeBoer, 2009).

Section 3: Detailed Procedures

Bellwork (10 mins): • Have students predict the answer to the following question in their science notebook • *What happens to the temperature of a substance while it changes phases? Specifically when Ice melts into water? Does the temperature increase, decrease, or stay the same? Why?* **Lecture/Activity (30mins)**	*Slide Set:* *https://docs.google.com/a/ocps.net/presentation/d/1vDDKJwvabNO0ggXkSQd0xFRjK5Y0sL8v6fSb2U3XEH*

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- Students will be randomly broken up into groups of 4. Within each group every will research 1 new concept from the list below and provide
  - A definition
  - A phase diagram labeling its position
  - How to calculate its value.
- The concepts are
  1. Heat of Vaporization
  2. Heat of Solidification
  3. Heat of Fusion
  4. Heat of Condensation
- The students will research their topic and record the information within their science notebooks using the provided slides as resources as well as any credible internet source they can find.
- Students will have 15 mins to work individually after which they will have another 20 mins to share with their group what they have found as well as record the information their group members found.

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Section 4: Evaluation

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Formative Assessment

Students will complete the assigned worksheet for homework. The worksheet will serve as a formative assessment. The worksheet covers all of the phase change concepts that they researched during class. These formative assessment will help students practice and become more familiar with these concepts as we head into the end of the Unit.

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https://docs.google.com/document/d/1xWkQDbQFcPoWAy1Zvp_KP4APUlXcNV_oUXmMrS-jlD4/edit?usp=sharing

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Section 5: Plan for Individual Differences

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- Problem solving strategy is modeled prior to student questions
- Individualized assistance can be provided to certain students.
- Students building literacy and/or math skills can be given a problem-solving worksheet with the steps labeled and formulas pre-written in with blanks.
- Notes can be taken in the form of sentences with strategic blanks.
- Student can be partnered with another student who speaks the same language to provide additional assistance.

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Section 6: Materials

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- Provided Slides
- Devices for internet access
- Provided Worksheet for HW

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- Students should have their science notebooks and a pen or pencil.

Section 7: Safety

- No safety concerns in this lesson

Section 8: References

Florida Department of Education. (2008). *Florida Sunshine State Standards (K-12 science)*. Retrieved from http://www.cpalms.org/homepage/index.aspx

Denby, D. (2014, May 07). Chemical energetics: words matter. *Education in Chemistry* [Website]. Retrieved from https://eic.rsc.org/cpd/chemical-energetics-words-matter/2000004.article

Yalçınkaya, E., Özgecan, T., & Boz, Y. (2009). High school students' conceptions about energy in chemical reactions. *Eğitim Fakültesi Dergisi, Pamukkale Üniversitesi*, pp. 1-11. Retrieved from http://pauegitimdergi.pau.edu.tr/DergiPdfDetay.aspx?ID=187

Lesson 10: Unit Review

Section 1: Rationale/Purpose

Topic: Thermochemistry Unit review
Grade level: 9-12 **Duration:** 80 minutes (2 class periods)

Standards:

- SC.912.P.10.1 - Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.
- SC.912.P.10.2 – Explore the Law of Conservation of Energy by differentiating among open, closed, and isolated systems and explain that the total energy in an isolated system is a conserved quantity.
- SC.912.P.10.5 - Relate temperature to the average molecular kinetic energy.
  - "Changes in entropy and energy that accompany chemical reactions influence reaction paths. Chemical reactions result in the release or absorption of energy."
- SC.912.P.10.6 - Create and interpret potential energy diagrams, for example: chemical reactions, orbits around a central body, motion of a pendulum.
- SC.912.P.10.7 - Distinguish between endothermic and exothermic chemical processes.
  - Changes in entropy and energy that accompany chemical reactions influence reaction paths. Chemical reactions result in the release or absorption of energy.
- ELD.K12.ELL.SC.1 - English language learners communicate information, ideas and concepts necessary for academic success in the content area of Science.
- SC.912.N.1.7 - Recognize the role of creativity in constructing scientific questions, methods and explanations.
- SC.912.N.3.5 - Describe the function of models in science, and identify the wide range of models used in science.

Content Objectives:

- Using the provided materials, Students will create a study guide for their unit exam that covers all the topics in the Thermochemistry unit.

Language Objectives:

- Students will communicate information between fellow students and create visual and written study guides to refer back to, in order to study for the unit exam.

Section 2: Misconceptions

- A substance has the same thermal energy regardless of it temperature or which state

it is in (AAAS Project 2061, n.d.).
- Energy can be created (Kruger, 1990; Lovrude, 2004; Papadouris et al., 2008).

Section 3: Detailed Procedures

Introduction / Prep for activity (5 minutes)
- Students will be divided into groups of 5 with various ability levels based on previous data. Each group will receive one of the following test concepts and will create a study guide/presentation for their classmates on everything that they must need to know for the exam.
    - The teacher will mediate and supervise the activity providing insight and making sure all material is covered within the study guide.

Activity Day 1
- The Concepts for the groups to work on are as follows
    - Group 1: Law of conservation of Energy
    - Group 2: Exothermic and Endothermic Reactions
    - Group 3: Enthalpy calculations
    - Group 4: Calorimetry/ Heat of Reactions
    - Group 5: Heat and Temperature
- Each group's goal will be to create a page long study guide on that concept using their notes and resources. Alternatively students can create a presentation of information to be shared with the class on the next day.

Presentation Day 2
- Students will take turns presenting their study guides to the class. Presentations should be 5-7 minutes long and include some form of visual tool.
- While presentations are going on, students not presenting will take notes on the topic being presented and add it to their final study guide.
    - The teacher should be addressing any incomplete information and make sure the all exam material is covered in presentations.

Section 4: Evaluation

Formative Assessment

- Students will submit their group study guides for a grade and be graded in their presentation using the following rubric.

0	1	2	3	4
Student did not present.	Presentation is lacking relevant content and includes incorrect information.	Presentation does not meet time requirement and is missing most information about the concept.	Presentation does not meet time requirement and is missing some information about the concept.	Presentation meets time requirement and includes all relevant information to the concept.

Section 5: Plan for Individual Differences

All activities within student's science notebook are differentiated; options of drawing, writing complete sentences, writing key phrases/incomplete sentences, and drawing graphic organizers are all available.

Section 6: Materials

- A chalkboard, whiteboard, or projection apparatus to display slides with information.
- Devices to access previous notes and create presentation
- Students should have their science notebooks and a pen or pencil.

Section 7: Safety

- No safety concerns with this lesson.

Section 8: References

Florida Department of Education. (2008). *Florida Sunshine State Standards (K-12 science)*. Retrieved from http://www.cpalms.org/homepage/index.aspx

Lesson based on: http://www.educationworld.com/a_lesson/03/lp306-04.shtml

Thermochemistry Unit: Pre Test

Matching

Match each item with the correct statement/definition below.

a. calorimeter
b. calorie
c. joule
d. enthalpy
e. specific heat

1. quantity of heat needed to raise the temperature of 1 g of water by 1ºC
2. SI unit of energy
3. quantity of heat needed to change the temperature of 1 g of a substance by 1ºC
4. heat content of a system
5. device used to measure the heat absorbed or released during a chemical or physical process

a. heat
b. law of conservation of energy
c. chemical potential energy
d. energy
e. enthalpy (heat) of reaction

6. The ability to do work or produce heat
7. States that energy cannot be created or destroyed
8. The change in enthalpy in a chemical reaction
9. Energy that flows from a warmer object to a cooler object
10. Energy stored in a substance because of its composition

a. thermal
b. electrical
c. nuclear
d. radiant
e. mechanical

11. energy that comes from the sun
12. the energy of moving things
13. energy stored in the nucleus of an atom
14. energy of moving molecules
15. the energy of charged particles (electrons)

a. converted

b. conserved

c. efficiency

d. exothermic

e. endothermic

16. Energy is always________________: never created or destroyed.
17. energy changed from one form to another
18. a reaction that releases heat
19. a reaction that absorbs heat
20. measurement of the amount of work done compared to energy available

Multiple Choice

Identify the choice that best completes the statement or answers the question.

21. What is the specific heat of liquid water?

a. 4.18 cal/g•°C b. 4.18 J/g•°C c. 1.0 J/g•°C d. 4.18 kJ/g•°C

22. Which of the following is the correct relationship between joules and calories?

a. 1 joule = 4.184 calories

b. 1 calorie = 4.184 joules

c. 1 joule = 1000 calories

d. 1 calorie = 4.184 kilojoules

23. Sugars and starches are examples of

a. carbohydrates. b. fats. c. proteins. d. vitamins.

24. What is the amount of heat required to raise the temperature of 200.0 g of aluminum by 10°C? (specific heat of aluminum = 0.90 J/g•°C)

a. 180 joules b. 1800 joules c. 2200 joules d. 22,000 joules

25. In what units is temperature measured?

a. degrees Celsius b. kelvins c. Both (a) and (b) d. None of these

26. The greater the average kinetic energy of the particles in a sample of matter,

a. the higher the temperature is.
b. the lower the temperature is.
c. the more energy is absorbed by the sample in the form of heat.
d. the less energy is released by the sample in the form of heat.

27. The *q* in thermodynamic equations is

a. temperature. b. mass. c. specific heat. d. energy lost or gained.

28. The Greek letter Δ stands for

a. "heat stored in." b. "mass of." c. "rate of." d. "change in."

29. What happens to the water in a calorimeter when an exothermic reaction occurs in it?

a. It absorbs heat; temperature drops

c. It releases heat, temperature drops

b. It absorbs heat, temperature goes up

d. It releases heat, temperature goes up

30. What occurs when solid A (50ºC) is placed in contact with solid B (80ºC)?

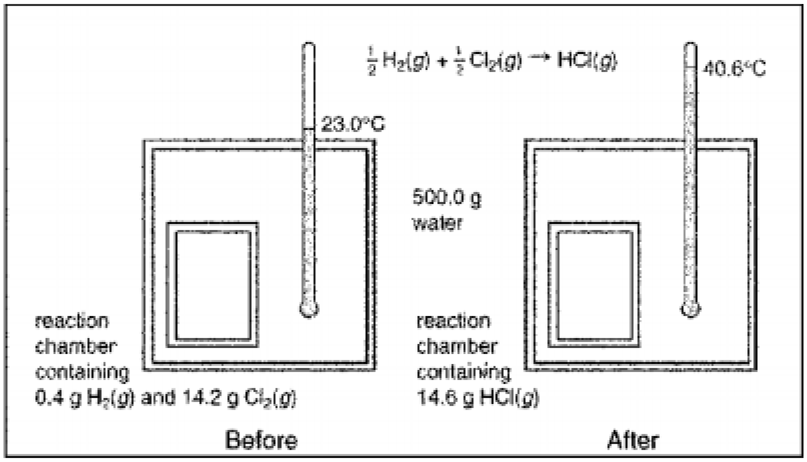
a. Heat energy flows from A to B as the average kinetic energy of particles in A decreases.
b. Heat energy flows from A to B as the average kinetic energy of particles in A increases.
c. Heat energy flows from B to A as the average kinetic energy of particles in B decreases.
d. Heat energy flows from B to A as the average kinetic energy of particles in B increases.

31. 100 grams of an unknown metal is heated to 65 °C. It releases 4.2kJ of heat when it is put into room temperature water(25 °C). Which metal is it?

Metal	**J/g·ºC**
Aluminum	0.90
Lead	0.128
Magnesium	1.05
Copper	0.386

a. aluminum b. lead c. magnesium d. copper

32. What is the temperature change in the water during the course of the reaction in the figure below?

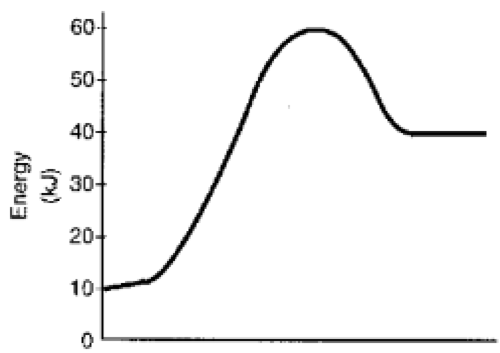


a. 17.6°C b. 23.0°C c. 40.6°C d. 63.6°C

33. Refer to the figure above. Is the reaction endothermic or exothermic, and which contain more stored heat energy, the reactants or the products?

a. Endothermic reaction, reactants contain more energy.
b. Endothermic reaction, products contain more energy.
c. Exothermic reaction, reactants contain more energy.
d. Exothermic reaction, products contain more energy.

34. Is the reaction shown in the graph below exothermic or endothermic?



a. exothermic; reactants have more energy than products
b. exothermic; products have more energy than reactants
c. endothermic; reactants have more energy than products
d. endothermic; products have more energy than reactants

Thermochemistry Unit: Post Test

Multiple Choice

Identify the choice that best completes the statement or answers the question.

1. In a balanced endothermic reaction, where does a heat term appear?

a. on the right side only b. on the left side only c. on both sides d. on neither side

2. At constant pressure, the heat absorbed or released during a chemical reaction is equal to

a. zero. b. the heat capacity. c. the temperature change. d. the enthalpy change.

3. Which of the following correctly relates q_{rxn} and q_{sur}?

a. $q_{rxn} = q_{sur}$ b. $q_{rxn} = 1/q_{sur}$ c. $q_{rxn} = -q_{sur}$ d. $q_{rxn} = 4.184\ q_{sur}$

4. The transfer of kinetic energy from a hotter object to a colder object is called

a. potential energy. b. temperature. c. caloric. d. heat.

Equation	ΔH° (kJ)
(1) $W(s) \rightarrow W(g)$	+60
(2) $W(g) \rightarrow X(g) \rightarrow Y(g)$	−40
(3) $2\ Y(g) \rightarrow Z(g)$	−90
(4) $Z(s) \rightarrow Z(g)$	+30

5. Which reactions in the table above are exothermic?

a. 1 and 4 only b. 2 and 3 only c. all d. none

6. Use the table above to determine the value of ΔH° for the reaction $W(g) \rightarrow W(s)$.

a. +60 kJ b. +30 kJ c. −30 kJ d. −60 kJ

7. Using the table above, determine the value of ΔH° for the reaction $2\ Y(g) \rightarrow Z(s)$.

a. +120 kJ b. +60 kJ c. −120 kJ d. −60 kJ

8. Which of the following best describes temperature?

a. energy as heat absorbed or released in a chemical or physical change
b. a measure of the average kinetic energy of the particles in a sample of matter
c. energy in the form of heat
d. energy of change

9. A 4.0 g sample of iron was heated from 0°C to 20°C. It absorbed 35.2 J of energy as heat. What is the specific heat of this piece of iron?

a. 2816 J/(g·°C) b. 2.27 J/(g·°C) c. 2.27 J/g d. 0.44 J/(g·°C)

10. How much energy does a copper sample absorb as energy in the form of heat if its specific heat is 0.384 J/(g·°C), its mass is 8.00 g, and it is heated from 10.0°C to 40.0°C?

a. 0.0016 J/(g·°C) b. 0.0016 J c. 92.2 J d. 92.2 J/(g·°C)

11. The Greek letter Δ stands for

a. "heat stored in." b. "mass of." c. "rate of." d. "change in."

12.Which of the equations below is an example of a thermochemical equation?

a. $Mg(s) + 2H_3O^+(aq) + Cl^-(aq) \rightarrow Mg^{2+}(aq) + 2Cl^-(aq) + H_2(g) + H_2O(l)$

b. $Mg + 2H_3O^+ + Cl^- \rightarrow Mg^{2+} + 2Cl^- + H_2 + H_2O$

c. $2H_2(g) + 2O_2(g) \rightarrow H_2O(g)$

d. $2H_2(g) + 2O_2(g) \rightarrow H_2O(g) + 483.6\ kJ$

13. For an exothermic reaction, ΔH is always

a. positive. b. negative. c. zero. d. small.

14. For an exothermic reaction, the products

a. are at the same energy level as the reactants.
b. have no energy.
c. are at a lower energy level than the reactants.
d. are at a higher energy level than the reactants.

15. Which of the following substances has the highest specific heat?

a. steel b. Liquid water c. mercury d. copper

16. Which of these statements correctly describes Hess's law of heat summation?

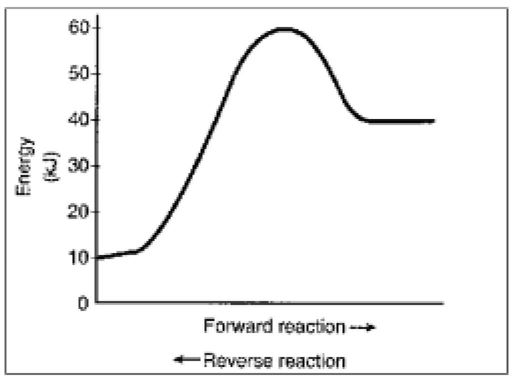
a. It is used to calculate ΔH for complicated chemical reactions.
b. It can be used to calculate the heat of formation of an element.
c. It explains why a calorimeter can be used to determine the heat of reaction.
d. It describes the thermal changes during the vaporization of solids.

17. The ΔH for the reaction of sulfur dioxide with oxygen as shown is –197.8 kJ. What is the ΔH for the decomposition of 2 moles of sulfur trioxide?

$$2\ SO_2\ (g) + O_2\ (g) \rightarrow 2\ SO_3\ (g)$$

a. –98.9 kJ b. –197.8 kJ c. 98.9 kJ d. 197.8 kJ

18. Are the forward reaction and the reverse reaction in the figure below exothermic or endothermic?



a. Both reactions are exothermic.
b. The forward reaction is endothermic, the reverse reaction is exothermic.
c. The forward reaction is exothermic, the reverse reaction is endothermic.
d. Both reactions are endothermic.

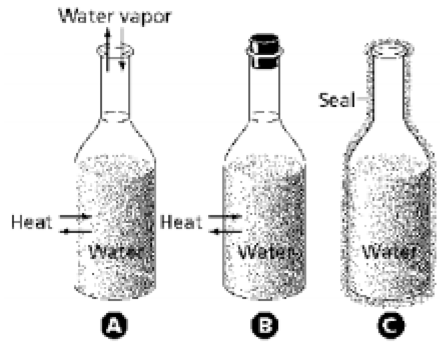
19. In the figure above, what is the value of ΔH for the forward reaction?

a. –20 kJ b. +20 kJ c. –30 kJ d. +30 kJ

20. A burger contains 220 nutritional Calories. Convert this energy into joules.

a. 9.2×10^5 J b. 9.2×10^2 J c. 2.2×10^8 J d. 5.5×10^2 J

21. Which of the systems shown in the diagram is a closed system?



a. B b. C c. B and C d. none

22. Which of the following statements about bonds and energy is correct?

a. Bond breaking and bond formation both require energy.
b. Bond breaking and bond formation both release energy.
c. Bond breaking requires energy and bond formation releases energy.
d. Bond breaking releases energy and bond formation requires energy.

23. The following reaction occurs in a calorimeter which has 400 grams of water.

$$2\ Na(s) + Br_2(l) \rightarrow 2\ NaBr(s)$$

Calculate the energy change of the water given that the initial temperature of the water was 14.0°C and the final temperature of the water was 39.6°C.

a. +42800 kJ b. + 42.8 kJ c. -42800 kJ d. -42.8 kJ

24. The ΔH for the above reaction is

a. + 42800 kJ b. +42.8 kJ c. -42800 kJ d. -42.8 kJ

25. For the following reaction, what is the energy change if 2 moles of PCl_5 decomposes?

$$PCl_5(s) \rightarrow PCl_3(l) + Cl_2(g) \quad \Delta H= +124\ kJ$$

a. 124 kJ absorbed b. 124 kJ released c. 242 kJ absorbed d. 242 kJ released

26. Given the equation below, find the quantity of heat transferred when 635 grams of copper reacts completely.

$$H_2O(g) + Cu(s) + 86.6\ kJ \rightarrow H_2(g) + CuO(s) \quad \Delta H = +86.8\ kJ$$

a. +86.6 kJ b. +8.68 kJ c. +866 kJ d. +8660 kJ

Short Answer

27. Use the information below to calculate ΔH° for the chemical reaction:
$2NO_2\ (g) \rightarrow N_2O_4\ (g)$

$2N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$ ΔH° = 67.7 kJ

$N_2(g) + 2O_2(g) \rightarrow N_2O_4(g)$ ΔH° = 9.7 kJ