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| **Performance Expectation** |
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| HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in the total bond energy. |  |

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| **Learning Objective** |
| Construct an explanation for how release and absorption of energy depends upon breaking and forming bonds using dissolution as a system model. |
| **DCI** | **Science & Engineering Practices(s)** | **Crosscutting Concept(s) Addressed** |
| [PS1.A: Structure and Properties of Matter](http://www.nap.edu/openbook.php?record_id=13165&page=106)[A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.](http://www.nap.edu/openbook.php?record_id=13165&page=106)[PS1.B: Chemical Reactions](http://www.nap.edu/openbook.php?record_id=13165&page=109)[Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.](http://www.nap.edu/openbook.php?record_id=13165&page=109) | -Developing and Using Models-Constructing Explanations-Using Mathematical and Computational Thinking | -Energy and Matter-System and System Models |

**Lesson: Thermochemistry: Grades 9-11**

**Teacher Guide**

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| **#** | **Success Criteria** | **SEP** | **DCI** | **CCC** |
| 1 | I can identify that breaking bonds require energy and making bonds release energy. |  | X |  |
| 2 | I can use evidence to develop a model for identifying system, surroundings and transfer of energy between them in an exo- and endothermic reaction. |  | X |  |
| 3 | I can use mathematical computations using bond energy to predict exo- and endothermic reactions. | X |  |  |
| 4 | Using particulate level models, I can explain energy transfer in terms of bonds broken and formed in exo- and endothermic reactions. |  |  | X |
| 5 | I can construct an explanation from temperature data to explain why exothermic reactions feel warm and endothermic reactions feel cold to touch. | X |  |  |
| 6 | I can track the energy flow in and out of the system in an exo- and endothermic reaction using energy diagrams. |  |  | X |

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| **Grading Rubric** |
| 4 | 3 | 2 | 1 |
| Shows mastery of ALL success criteria and provides evidence understanding of application of DCIs | Provides evidence of understanding of 2/3 of all criteria with at least one criteria in each  | Provides evidence of understanding of ½ of all criteria in each dimension  | Provides insufficient evidence of understanding in half of all criteria. |

**Lesson 1 (Day 1, 45-50 minute period)**

1. **Prior Knowledge (Time: 5 minutes)**

Suggested Prompt: Have you or anyone in your group ever used an ice pack or a hot pack? What are they used for? How are they used?

Sample Responses: Student or someone they know may have used ice packs to prevent swelling from strains and may have used heat packs to keep them warm during their trip to cold places.

 Student responses will vary based upon their experience with cold or hot packs. Teacher may want to bring an ice pack as a demo to show to those students who may not have access or experience of these packs.

Give about 2-3 minutes to generate the ideas and then have whole class discussion. Students then summarize the idea of an ice or a hot pack.

**II. Energy Changes and Bonding (15 minutes)**

Students need access to laptops or chrome books to run this animation or the teacher can decide to project this animation from their laptop. If technology is not available, then a teacher may use molecular model kit to show how breaking bond will require energy and making bond will release energy. Students then reinforce this idea by watching a video and summarize their learning.

1. **Performance Task (20 minutes)**

The goal of the performance task is tounderstand the correlation between temperature change and energy transfer. This performance task is done in groups of four and takes about 10 minutes to conduct and write observations.
**Materials:** two beakers, one thermometer, one DI water bottle, salts (Ammonium Nitrate and Sodium Acetate), and a beaker as a waste container.

Make sure students wear goggles at all times. Amount of water or salt is not critical but should be about the same with both salts to get comparable results. I used around 50 mL of water and a teaspoon of each salt. Students are able to notice temperature rise or decrease easily using a thermometer. All waste goes in the waste beaker.

Students then visualize the particulate level changes during the dissolution of these salts and make their thinking visible by filling in the charts. Student may need scaffolding in terms of drawing particulate level drawing. This activity is best done in the groups of four for collective understanding and support. Students must understand that a salt is an ionic compound made up of ions. Students must have prior knowledge of bonding and naming of ionic compounds.

1. **Exit Slip (5 minutes)**

Student responses must include that bond breaking requires energy and bond forming releases energy.

**Lesson 2: Day 2, Understanding of System and Surroundings and Heat Transfer (45-50 minutes)**

**Teacher will address the misconceptions from Lesson 1 exit slips (5 minutes)**

1. **System and Surroundings (5 minutes):** Teacher clarifies the understanding of system and surroundings by using a beaker with solution**.** Students will label the system and surroundings on the diagrams.
2. **Exothermic and Endothermic Reactions (5 minutes):** Small group and class discussions after completing the questions will lead to deeper understanding. Teacher connects heat released and absorbed during dissolution as observed by the students in lesson 1 to exo- and endothermic reactions.
3. **Understanding Exo- and Endothermic reactions through Mathematical Computations (20 minutes)**

This mathematic computation is out of the assessment boundary for this PE in NGSS, however, this activity helps students understand the net energy after bond breaking and forming clearly.

1. **Energy Diagrams (15 minutes)**

After watching the video, students can engage in small group discussion around energy changes in exo and endothermic reactions as indicated by the following energy diagrams. Some students may need additional support. Teacher modeling and taking examples helps student understanding.

**Day 3: 45-50 Minutes**

1. **Formative Assessment (30 minutes)**

This formative assessment is done in groups of 4 students and provides an opportunity to learn from the collective group knowledge while holding the individual student accountable for his or her own learning. **Students first individually do the following:**

Draw particulate level diagram for dissolution of solid Ammonium Nitrate and solid Sodium Acetate before and after the salt was dissolved. For each of the diagrams, label system, surroundings, bonds broken, bonds formed and exo or endothermic and draw the energy diagram.

Then the individual members of a group put these papers in the middle. Now, they **repeat this activity as a group** writing only ONE group report after discussion and negotiation of ideas. While discussing it with the group, white board or butcher paper can be used to generate ideas that are finally written on a single piece of paper as a group report. Each group turns in individual reports and the group report together. Each member of the group also fills out a reflection sheet, which they keep with them as a guide for going over the concepts that they missed.

This methodology of combining individual and group work during formative assessment proved to be useful. If no white board is available for group work, it can be replaced with the butcher paper. This formative assessment makes for a quick grading.

Whole class discussion (15-20 minutes) can be used to further clarify and reinforce the ideas.

**Lesson 3: Day 4-8 Performance Task 2: Designing a Hand Warmer**

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| Performance Expectation |
| HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability and aesthetics as well as possible social, cultural and environmental impacts. |
| Learning Objective |
| Planning, conducting and modifying an experiment to design the best hand warmer based upon temperature rise, environmental friendliness and cost effectiveness. |
| DCI | Science & Engineering Practices(s) | Crosscutting Concept(s) Addressed |
| ETS1.B: Developing Possible SolutionsWhen evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts | -Planning and carrying out investigations-Constructing explanations and designing solutions-Engaging in argument from evidence-Using mathematical computations | -System and System Models |

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| Performance Expectation |
| HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability and aesthetics as well as possible social, cultural and environmental impacts. |

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| **#** | **Success Criteria** |
| 1 | I can plan and conduct an experiment to identify the best chemical in terms of temperature change for the hand warmer. |
| 2 | I take appropriate safety precautions in the lab including goggle use and disposal of chemicals. |
| 3 | I can construct an explanation to identify the most environmentally friendly chemical based on my research.  |
| 4 | I can I can use mathematical computations to find the most economical chemical for the hand warmer based upon my research. |
| 5 | I engage in argument from evidence in justifying for the best chemical for hand warmer based upon environmental friendliness, cost effectiveness and temperature change. |
| 6 | I can modify my experimental design to get the appropriate data for the best hand warmer. |

**Performance Task and Debate (Days 4-8)** **Overview:** This performance tasks takes about a week but can be shortened depending upon the time available. Some parts of this task are done in groups and others individually. In this performance task, students will evaluate the best salt, Sodium Acetate or Ammonium Nitrate or Calcium Chloride based upon the three given criteria for the hand warmer. Students conduct experimentation to find out the temperature change with time; do online research for the costs of each chemical and around each salt’s environmental friendliness. Students then list the data for all three criteria as class data and find average class data. Students then write claim, evidence and reasoning for the best salt for the hand warmer. Students engage in peer review of CER and edit their first draft after peer review and self-assessment using the grading rubric. Once students are done writing the CER as scientists, they have an option of picking a different role- a manufacturer, a consumer or an environmentalist and engage in a class discussion around how the choice of material will vary with different roles. Each small group of students then designs their own hand warmer after watching the video. Finally, students engage in debate about best material to use if they were a consumer v. a manufacturer v. an environmentalist. This activity is optional, but I found it to be useful and engaging.

* + **Day 4 (45-50 minutes):** Students design and conduct an experiment to find out the best salt for hand warmer use. The criteria are that a good hand warmer should fit comfortably in the palm of your hand and has a volume of 50 mL. Materials needed are goggles, 2-500 mL beakers, two thermometers, 1-50 mL graduated cylinder, watch and a waste beaker. Students struggle with experimental design and must seek teacher approval before conducting the experiment. The salt dissolution should gently increase the temperature by around 20 degrees. Students may do couple iteration to find out the how much solid should they put in 50 mL water to get about 20 degrees rise. What works the best is to extrapolate the values. My students used 5 g of solid and 50 g of water and extrapolated the temperature changes. Time was not a factor because none of the solutions heated too quickly or too slowly. Error Analysis: It is important to let the students know that we are not trapping all the heat due to an open system and these values of temperature change are approximate.
	+ **Day 5 (45-50 minutes)**: Students research online to find the cost and the environmental friendliness of each salt. Teacher may provide preselected sites for getting this data.
	+ **Day 6 (45-50 minutes):** Students write the class data on a big board and write claim, evidence and reasoning for the best salt for the hand warmer according to the three criteria based on class data.
	+ **Day 7 (45-50 minutes):** Students do peer editing for their elbow partner (or randomly assigned partner) and write the second draft. The peer-editing process may be repeated one more time and students reflect on their final draft with grading rubric.
	+ **Day 8 (45-50 minutes):**

**Students design their own hand warmers (30 minutes)**

Materials: Goggles, two Ziploc bags- one snack and one sandwich, desired salt, water and waste container.

Students fill the sandwich Ziploc bag with the desired quantity of the salt. Then they fill the snack bag with water and seal the snack bag. Now, they drop the snack bag with water in the sandwich Ziploc bag. To activate the hand warmer, they squeeze open the water in the snack bag. Salt can be disposed off according to the waste guidelines. To minimize waste, the teacher can show a demo as well.

Students engage in a debate (**20 minutes**) about the best material to use if they were a manufacturer, or a consumer or an environmentalist. Will their favored material change? This

Debate can be graded on participation or just done without points to see the bias of different roles.

**Adapted from Cupertino High School, Cupertino, CA**

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| **Rubric for CER Paragraph** |
| **Criteria** | **4** | **3** | **2** | **1** |
| ClaimEvidenceReasoning | Claim is correct, specific and answers the main question and attempts to generalize to a wider set of circumstancesSufficient evidence is given for each of the three criteria Sufficient reasoning is given for each of the three criteria connecting them to the claim  | Claim is correct, specific and answers main questionInsufficient evidence is given for each of the three criteriaInsufficient reasoning is given for each of the three criteria connecting them to the claim  | Claim answers the main question but can not be backed up by evidence from this activitySufficient evidence is given for two of the three criteriaSufficient reasoning is given for two of the three criteria connecting them to the claim  | Claim contradicts the evidenceSufficient evidence is given for one of the three criteriaSufficient reasoning is given for one of the three criteria connecting it to the claim  |

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| **Grading Rubric** |
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