Teacher Work Sample:

"Thermochemistry" Unit for Chemistry 2017-2018

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Contextual Factors

This unit was developed for a high school honors chemistry course serving students in 10th and 11th grade at a large public school in a central Florida school district. Chemistry is one of two options for students in the high school to complete their physical science requirement for graduation, with the other option being Physics. There is no pre-requisite for the course, so some students have had a physical science course previously while others have not. Honors designation is generally reserved for students with higher GPA who have enrolled in honors courses in the past. However, there are no specific prerequisites, so many students (even in honors sections) have insufficient foundations in algebra. As a result, my lessons often include intensive sessions on solving simple algebraic problems, as well as interpreting variables from word problems. I am the only teacher in this classroom, as my internship is on-the-job.

The high school serves approximately 2500 students from a historically impoverished, diverse metropolis area, which has been in the Title 1 school list in recent years. It is not currently classified as Title 1, but is still considered an at-risk school and has a high percentage of students with free or reduced lunch services. Among the student body, 43.0% self-identify as Black, Non-Hispanic; 25.8% as White, Non-Hispanic; 24.4% as Hispanic; 4.2% as Asian; and the remaining 1.9% as mixed or other self-identification. Approximately 4.2% are English Language Learners and 7.5% are enrolled in Exceptional Student Education.

The school's district report card reports standardized testing performance being slightly below district average and well below state average: ELA scores are 18% below state average, Algebra 2 scores are 59% below state average, and Biology scores are 27% below the state average. Literacy challenges are significant at all levels, and special district-sponsored teacher training has been implemented to encourage literacy instruction. In my classroom, literacy practice is mostly done through reading and interpreting scenario-based word problems.

This unit was taught to three blocks of honors classes. Despite the Honors designation, literacy and math skills are varied. Through a district-wide program called “Unify,” classroom demographics are as follows: Of a total of sixty-seven (67) students enrolled in the sections, forty-eight (48, 71.6%) have free or reduced lunch. Nine students are considered gifted (9, 13.4%). There are no students in these sections who are considered English language learners, though some are bilingual (from observation, since statistics could not be found). There are no students receiving ESE services. There are three students with a 504 plan having to do with attention deficits or time extensions (3, 4.5%). The racial and ethnic makeup of the classroom mimic the school-wide average (from observation, since exact statistics could not be found).

This work sample is based on the “Thermochemistry” unit for the 2017-2018 school year, which covers four of the essential standards for the course and approximately 10% of the questions on the final exam. The unit lasts ten days total (eight instructional days, one review day, and an exam day). In order to accomodate for all learners, a mix of instructional techniques will be used throughout the unit, including inquiry-based exploration, videos, interactive lectures, and short reading exercises. Audio enhancement will be used for all auditory instruction. Formative assessments will range from class discussion, brief written responses, student-generated drawings, full-sentence free response, a variety of multiple choice quizzes (both ungraded and graded), and a review done with the game-style quiz program “Kahoot.”

Students will use individual dry-erase graphic organizers to support algebra skills, and used the blank side of the dry-erase to complete free-form drawings of a heat exchange scenario, as well as to construct and label their own potential energy diagrams.

The classroom itself is arranged in a differentiated manner. There is one front-facing row seating 4 students, 4 tables meant for groups of students to face one another in groups of 4-5, one circular socratic/tutoring area seating 6-7 students, and two individual tables in the back, seating 1-2 students apiece. The seating diagram is provided in Figure 1.

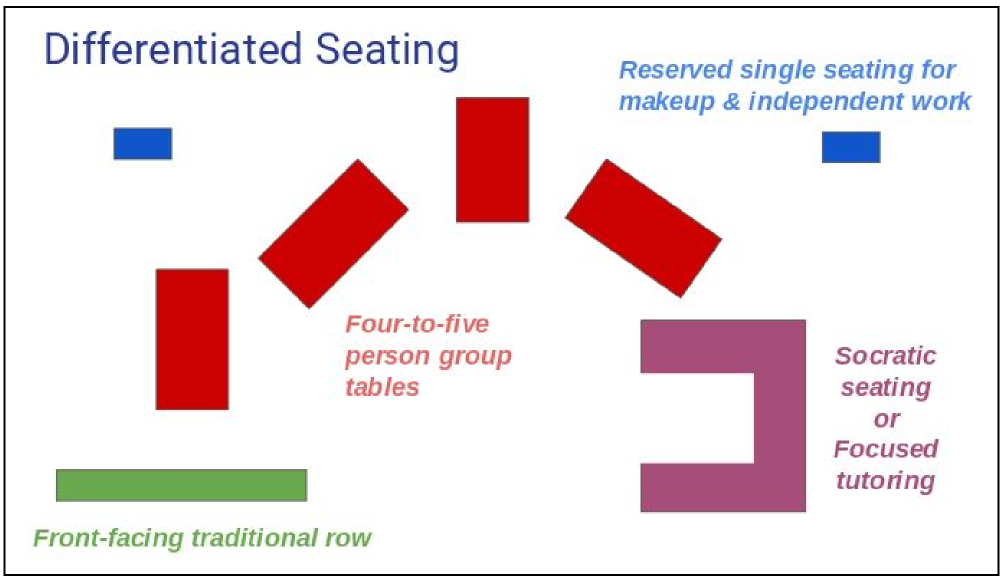


Figure 1: Differentiated Seating

The front-facing, traditional row is meant for students whose prefer a more direct, teacher-focused instruction, but are still relatively independent. The group tables are for the majority of students, and are meant to encourage cooperation and a discussion-based atmosphere. The "socratic" or "focused tutoring" section is sometimes used for re-teaching a small group of students or, during an activity, for students who require extra assistance and/or encouragement.

The single seating toward the back of the class is reserved for students to make up tests or assignments, or to sit away from peers for purposes relating to behavior or focus.

Students are allowed to choose or move their seat unless specifically instructed otherwise. Since implementing this seating arrangement, discussion and cooperative work has increased, and I have only had to reseat students a handful of times. Classroom misbehavior is slightly increased with this setup as compared to traditional front-facing rows, but is handled through individual student interviews. Overall, the benefits of increased engagement and cooperation outweigh the drawbacks of a less “orderly” seating arrangement.

Students in this unit have access to one-to-one technology, as all students have school-issued laptops. Students also have access to a cell phone, though cell phone use is generally discouraged in class. Some exceptions are made for use of calculator applications or an educational application, especially when there is a laptop malfunction. Spare notebooks, folders, and paper are freely available, as well as reference documents, printed versions of all assignments on request, and a variety of writing and markup tools (pens, pencils, highlighters, colored pencils, markers, etc.), which students know how to access quickly and quietly. Bathroom use is open but limited to one student at a time; it is monitored with a laminated pass and a sign out sheet.

The “Thermochemistry” unit follows the “Gas Laws” unit, in which students were introduced to Kinetic Molecular Theory. One of the learning goals of that unit was relating kinetic energy of molecules to temperature. This learning goal continues throughout this unit, and the unit expands upon that big idea to lead into more specific determinations of thermal energy flow, understanding of endothermic and exothermic processes, understanding phase change diagrams, and calculating heat flow.

Learning Goals

There are several learning goals for this unit, all relating to the law of conservation of energy, and based upon the Next Generation Sunshine State Standards. Students will use their prior knowledge as well as their understanding of energy conservation to identify and explain energy changes in specific scenarios. Based on the performance expectations students will be held to on their district-wide common final exam (CFE), they must be able apply these skills to answer conceptual, mathematical, and graphical questions.

Students enter the unit already being able to relate the behavior and kinetic energy of a molecule with the temperature of the substance (SC.912.P.10.5). The specific learning goals for this unit are as follows:

1. Students will be able to answer conceptual questions relating to heat flow between systems and surroundings using relative temperatures and the law of Conservation of Energy (SC.912.P.10.1).
2. Students will be able to perform calculations relating specific heat, mass, temperature, and the heat of a chemical reaction using the calorimetry equation (SC.912.P.10.1).
3. Students will be able to interpret heating curves and describe how thermal energy is used during a phase transition (SC.912.P.10.5).
4. Students will be able to interpret potential energy diagrams, including identifying energy of reactants/products, activation energy, and describing enthalpy changes in terms of the absorption or releasing of heat energy (SC.912.P.10.6).

5. Students will be able to identify and explain differences between exothermic and endothermic changes in both physical and chemical scenarios (SC.912.P.10.7).

For all of these goals, I will consider that a student has mastered the goal when she or he demonstrates a minimum of 70% accuracy on exam questions for the standard. This is the achievement band used throughout my PLC.

Assessment Plan

It is typical in my class for the unit to begin with an inquiry-based activity, to warm students up to the new concepts. Since implementing this strategy as early as Unit 3 in the first grading quarter, it has become a very positive tradition, and so I will delay the Pre-test until after this inquiry introduction. The Pre-test will therefore given on Day 3, after the inquiry activity.

Student learning will be assessed in this unit through a progression of ungraded formatives (guiding questions, informal mid-instruction quizzes, graphic organizer fill-in and drawing activities) followed by graded quizzes on the Canvas platform. There are two graded quizzes this unit: one covering learning goals 1, 2, and 5, and the second covering learning goals 3, 4, and 5. Learning goal 5 is one of the most important and varied in the unit ("identify and explain differences between exothermic and endothermic changes in both physical and chemical scenarios"), and links in to all other goals of the unit; therefore it is repeated in both quizzes, with context-appropriate variations of the questions.

The purpose of the graded quizzes, which are both open-notebook, is for students to test their understanding in a more formalized environment while still providing them the support of their own notes. These quizzes also encourage students to take notes, which is a challenge, even though guided note-taking opportunities are worked into each unit. These checkpoints provide opportunities to practice and deepen learning, as well as an opportunity to practice answering questions in the style of those that might be asked on a summative exam, or on their final. For learning goal 3, notable pieces of instructional content are also provided in the quiz itself, though these materials will also be reviewed in a group environment.

The ungraded formatives leading up to graded quizzes are meant solely for engagement, practice, and scaffolding. Activities are interspersed among lecture slides, using the interacting "Nearpod" presentation program, to keep students connected to the content and to clear up common initial misconceptions. Mid-lecture practice quizzes often lead to meaningful questions, and allow me an opportunity to repeat and highlight the most relevant pieces of information from the lecture as the answers are reviewed. Drawing activities, of which this unit includes several, help scaffold student understanding and act as an important teaching tool to check conceptual understanding beyond memorization.

For this unit, a visual graphic organizer will also be provided for the mathematical portion of the unit, in which students have to solve calorimetry problems using the formula $q=mC\Delta T$ (See Figure 2). Many of the students are weak in algebra (specifically, solving for an unknown) as well as literacy (pulling relevant information about each variable out of a paragraph-style word problem). The graphic organizer will allow them to focus solely on these skills rather than worrying about the formula itself for the first week of the unit.

The graphic organizers will be provided to the students in clear plastic sleeves, which can be written on in dry-erase marker and the marks removed easily with paper towels. For each problem, the students will first identify relevant information from the problem, using the units provided to guide them as to where the value belonged in the formula. It will be fairly simple at this point to check the students' work by having them show or hold up their organizer, or compare with others at their table. Once the variables are identified, the work to solve for the unknown can be done in the blank space provided.

q = m C ΔT Problem Guide

q	=	m	C	ΔT
Heat energy (J or cal)		Mass (g)	Specific Heat Capacity (J/g°C) or (cal/g°C) **may switch °C for K*	T final - T initial (°C or K)
Work:				

TIPS FOR SOLVING ALL WORD PROBLEMS:

- **Read Carefully!**
- Pick out important information.
- Make sure **units** are correct.
- Fill numbers into the appropriate place.
- Put "x" in for the unknown.
- Solve for x:
  - Do the opposite of whatever is happening on the x side:
  - In 8=4x, x is multiplied by 4, so you divide by 4.
  - Whatever you do to one side, you must do to both.
- Stay organized.
- **Check your work!!**

Figure 2: Graphic Organizer for q=mCΔT Problems

The variety of formatives used is intended for three purposes: First, to provide engagement in a lecture-heavy unit; second, to scaffold in meaningful ways; and third, to make the content accessible to a variety of learners. For example, those learners who do not require the assistance of the graphic organizer can instead use the blank space on the back of the page to work out their problems independently. Open-notebook quizzes will allow students to use whatever resources they find most helpful; they will have options such as the graphic organizer, their drawings, their written notes or vocabulary lists, digital lecture slides, and linked online resources such as videos and practice sets.

Assessment Schedule

Class Meetings:	Description of Assessment:	Learning Goals Assessed:
Day #1-2	Inquiry-Based Introduction (5E activity) with Ungraded Discussions, Responses and Drawings. Graded Worksheet turned in on completion.	1
Day #3	Brief Pretest (included at end of TWS).	1, 2, 3, 4, 5
Day #3 *(continued)*	Draw a scenario of snow melting & refreezing on a house, and determine any endothermic or exothermic processes taking place (Ungraded).	1, 5
Day #4	Read a word problem and fill in $q=mC\Delta T$ graphic organizer, using units to guide where to put each value (Ungraded).	1, 2
Day #5	● Complete 2-3 problems involving the $q=mC\Delta T$ calorimetry equations, from fill-in to solve (ungraded) ● Open-book homework quiz (graded); 15 minutes of class time provided: 12.2 Endo/Exo	1, 2, 5
Day #6	Ungraded Nearpod Assessments: ● Brief Quiz: Interpreting potential energy diagrams as exothermic or endothermic, identifying sign of Enthalpy (ΔH) from diagram and from scenario. ● Brief Quiz: Interpreting thermochemical equations: Based on location of energy phrase, identify: exothermic or endothermic; sign of Enthalpy (ΔH). ● In-notebook Drawing of Potential Energy diagram with four labels: Energy of Reactants, Energy of Products, ΔH & Activation Energy.	4, 5
Day #7	Graded Canvas Quiz (Open Notebook): "12.4 Showing Enthalpy Changes: Heating Curves & Potential Energy Diagrams." Questions 1-8 only, topic is interpreting potential energy diagrams.	4, 5
Day #8	CONTINUED Graded Canvas Quiz (Open Notebook): "12.4 Showing Enthalpy Changes: Heating Curves & Potential Energy Diagrams." Questions 9-14 only, topic is heating curves.	3
Day #9	Ungraded Review - Kahoot: https://play.kahoot.it/#/k/e348ddee-95b7-4184-a00c-60feef31962e	1, 2, 3, 4, 5
Day #10 *(Last day of unit)*	Posttest (included at end of TWS)	1, 2, 3, 4, 5

Design for Instruction

The pre-test was designed to assess the existing mastery of standards. Since I designed the test to measure mastery of this unit's standards rather than previously learned content, I expected the students to do relatively poorly on the exam. However, I did want to determine their existing vocabulary knowledge, and their ability to solve the problems given only their relatively advanced test-taking skills. Essentially, my goal was to measure achievement through eliminating the "noise" of their pre-existing test-taking strategies.

The average grade on the pre-test was 37%. Of the 63 students present for the pre-test, only two students demonstrated mastery of standard FL.SC.912.P.10.1; all others failed with a 59% or below. 22 students demonstrated mastery of standard FL.SC.912.P.10.5, unsurprising since we had covered a portion of this standard in the previous unit. 12 students demonstrated mastery of standard FL.SC.912.P.10.6, and only 1 student demonstrated master of standard FL.SC.912.P.10.7.

As a result of this outcome, I decided to focus heavily on standards FL.SC.912.P.10.1 and FL.SC.912.P.10.7 (learning goals 1, 2 and 5), and spend only one day on FL.SC.912.P.10.5. Since they did much better on this standard, I decided students only needed to learn to apply their existing knowledge to the types of questions they can expect to answer for this unit's application of the standard.

The unit will follow the general timeline below. For more detail, I have attached my lesson plans at the end of the TWS document.

General Unit Timeline

- **Days 1 & 2:** Temperature and Heat Misconceptions (LG1) - Students engage in a hands-on inquiry-based activity to activate prior knowledge and curiosity regarding unit topics. Learners with challenges have a variety of hands-on manipulatives and engage in both literacy and drawing activities.
- **Day 3:** Heat Energy: How it is created, How it moves, and How it is described (LG1 & LG5) – Students take guided notes during a lecture, answer guiding questions, and sketch a realistic heat-exchange scenario. Learners with challenges are provided with a full vocabulary list at the start of the day, and finish up with a drawing activity for visual learners.
- **Day 4 & 5:** The Specific Heat Formula & Calorimetry (LG1, LG2 & LG5) – Students extend their understanding of heat exchange from Day 3 and learn the new skill of solving calorimetry problems using the $q=mC\Delta T$ formula. Learners with challenges are provided with a dry-erase graphic organizer and dedicated class time for skillbuilding.
- **Day 6 & 7:** Enthalpy, Heat of Reaction & Potential Energy Diagrams (LG4, LG5) - Students take periodic practice quizzes as another slide set is reviewed, and linked to prior learning through guiding questions to extend their concepts of heat flow to the specific concept of enthalpy in chemical substances. Students develop their own potential energy diagram in their notebook or with dry erase. Students then take an open-notebook quiz for a grade on the Canvas platform.

- **Day 8:** Heating Curves & Thermal Energy during Phase Changes (LG3) - Students spend a short time (about ten minutes) in group instruction and watch a demonstration throughout the class period on thermal energy during phase changes. They then answer questions on their open-notebook quiz with the information provided, their own short-text reading, and interpreting a heating curve diagram given in the quiz itself.
- **Day 9:** Review Day (All LGs) - Students play a “Kahoot” review game with practice questions from past exams, textbook problems, and district-approved questions.
- **Day 10:** Summative Exam (All LGs)

Instructional Decision Making

Example One: Instructional revisions due to student response and assessment were ongoing throughout the unit, which is quite typical. One concrete example of a revision I made was after day 6, when I assessed student understanding of thermochemical equations. Originally, I had assumed that since students are well-acquainted with chemical equations, that the addition of a heat phrase to a chemical equation would be a painless moment in the unit, and might actually assist student's ability to distinguish between endothermic and exothermic processes. However, during my in-class nearpod practice quiz, many students chose incorrect answers at the end of this section.

I decided that additional lecture on this topic would not be helpful, so instead I supplemented my board notes. At the start of each lecture set, I added vocabulary to the board and left it there throughout the unit for student references. I also allowed students to write notes on the board around the vocabulary as a shared-note taking activity; students had already added a variety of notes around the terms "endothermic" and "exothermic", but I created a separate space on the board dedicated to these two terms. In these spaces I also added examples of thermochemical equations, and in each class, I drew attention to these changes.

As I spoke, I made sure to emphasize a memorization technique; to think of the arrow as a channel the substances are passing through. If the heat phrase is on the reactants side (the left side, on the tail of the arrow), they are entering "into" the arrow. Students had already associated the word "into" with "endo". I then suggested that heat phrases on the products side (the right side, at the head of the arrow) are coming "out of" the arrow, which is the phrase I used repeatedly for "exo". I will have the opportunity to provide further practice with thermochemical equations in the next unit, "Reaction Rates and Equilibrium", during which students will practice interpreting the effect of temperature change on a reversible endothermic or exothermic reaction in equilibrium.

On day 8, as students were working through their quiz emphasizing diagrams, I circulated and asked questions to help guide their thinking and connect it to concepts from the previous portion of the unit, including thermochemical equations. I asked students questions such as, "in this reaction represented by this diagram, would heat be on the left side of the arrow, or on the right side? Would they be *going into* to the arrow or *coming out of* the arrow?" I followed up by adding two questions to the review involving thermochemical equations and the concepts therein.

Furthermore, for the thermochemical equation question in the summative exam, I originally had only intended to ask if the reaction was endothermic or exothermic, and give two distractors. Instead, I changed the answer options to encourage students to think critically about *why* they chose the answer they did. I allowed students to choose among options with variations of "The reaction is (exothermic or endothermic) because it (releases or absorbs) heat."

The question, number 19 on the exam, was still one of the more commonly missed questions on the exam, with a success rate of 57%. However, this represented an improvement over the initial assessment of this skill (which was around 35% success rate). In the future, I will place more emphasis on this skill; in retrospect, it may have been useful to have students write their own thermochemical equation and *choose* which side to place the heat phrase on. This would have been a seamless addition to the activity at the conclusion of day 7, where students constructed their own potential energy diagrams.

Example Two: Another point at which I made an instructional decision was at the conclusion of my inquiry activity at the start of the unit. During that activity, I emphasized the idea that the sensation of "cold" is that of heat *leaving* a body, rather than "cold energy" entering the body. The final question on the inquiry worksheet was on this topic, and I noticed that about half the students still believed that "cold energy" could move in the same way that heat did.

Due to the persistence of this very common misconception, I revisited this concept several times throughout the unit. It was incorporated into the lecture on day 3, and at that time I made sure to explicitly state the answer to the problematic question. I did so soon after students had submitted the worksheet so that the question would be fresh in their minds. When I did, I heard responses from several students in all my sections, along the lines of either "I got that right!" or "oh no, I wrote the wrong thing." Some students even asked to revise their worksheet, and I encouraged them to do so for study purposes, though I had not penalized them for answering incorrectly on that sheet. In order to encourage creativity and freedom of thought, I do not penalize incorrect answers based on misconception during an inquiry activity, as long as student has provided rationale.

Several times throughout the unit I reinforced the idea of "cold" as heat leaving a body, and used heat-exchange examples that involved cool or cold systems or surroundings. At the end of day 3, the students completed a drawing task during which they drew arrows for heat flow. For this exercise I chose a scenario given in the textbook about snow melting on a roof and refreezing into icicles. Students generally did well on this assignment, and correctly indicated heat arrows going from the surroundings into the snowy system during melting, and out of the water during the refreezing process. When going over the arrows on my own sample drawing, I used red as a "warm" color on my drawing to further emphasize that *heat* was moving, and asked the students if I should draw any blue arrows to indicate cold movement. All the students at that point agreed I should not.

I revisited the concept yet again with verbal questions as students were working on their unit quizzes, and incorporated the concept into a question on the review, in which students were asked about heat transfer between a human body sitting on a metal bench on a winter day. It was a good idea to review this concept the day before the test, as the misconception had reasserted itself among some students in the interim (again, this misconception is incredibly prevalent, and many adults still hold the belief that cold can be absorbed, so it is to be expected that repetition is important in resolving the error).

On the summative exam, the distractor option "cold can be absorbed" was an option for question 15 involving heat flow in a low-temperature situation. Only 8% of students chose this distractor, and among those, all were absent two or more days during the unit. While the misconception may not be completely resolved among all students, the summative results demonstrate that, as a result of the additional learning opportunities given during the unit, most students are now able to describe negative heat flow in appropriate terms.

Analysis of Student Learning

The pre-test and post-tests are included in the section "Unit Instructional Materials," and the results of those assessments are discussed here. Overall, there was a dramatic improvement between the pre-test and post-test for most students. The average score on the pre-test was 36%, which is only 11 percentage points above what one would expect for random answer selection. The average score on the post-test was 77%. This represents a 41% improvement in test performance, with individual student improvements ranging from 3 points to 73 points.

On the graphs in this section, I display student academic growth in six graphs. The first shows overall improvement, while the following four each focus on a standard. There is one standard per learning goal except for LG1 and LG2, which are both contained in standard FL.SC.912.P.10.1. Because I categorized the test by standard rather than by learning goal for the purposes of district data collection, I will maintain that same custom here. The final graph represents score change by standard.

The graphs contain data for 51 students who were both present for the pre-test and took the post-test in time for the data to be produced. Absenteeism is a consistent problem among a section of students, and others were absent for state testing, so not all 67 could be represented here.

Prior to unit instruction, only one student demonstrated mastery of standard FL.SC.912.P.10.1 (LG1 and LG2), as opposed to 51 demonstrating mastery after unit instruction (Figure 4). This represents a significant gain, and I am mostly satisfied with the results. I do believe more hands-on activities sprinkled throughout the unit may increase academic gains for these learning goals in future years, but due to time limitations, that was not possible this year.

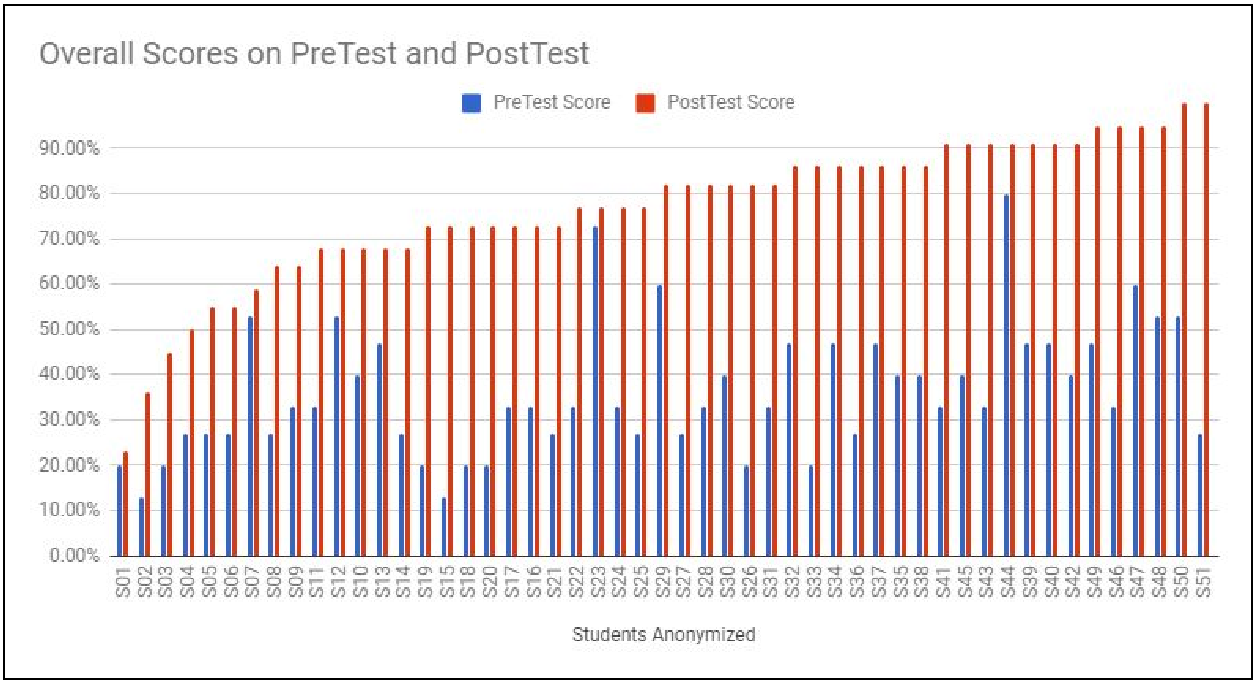


Figure 3: Graph - Overall Scores on PreTest and PostTest

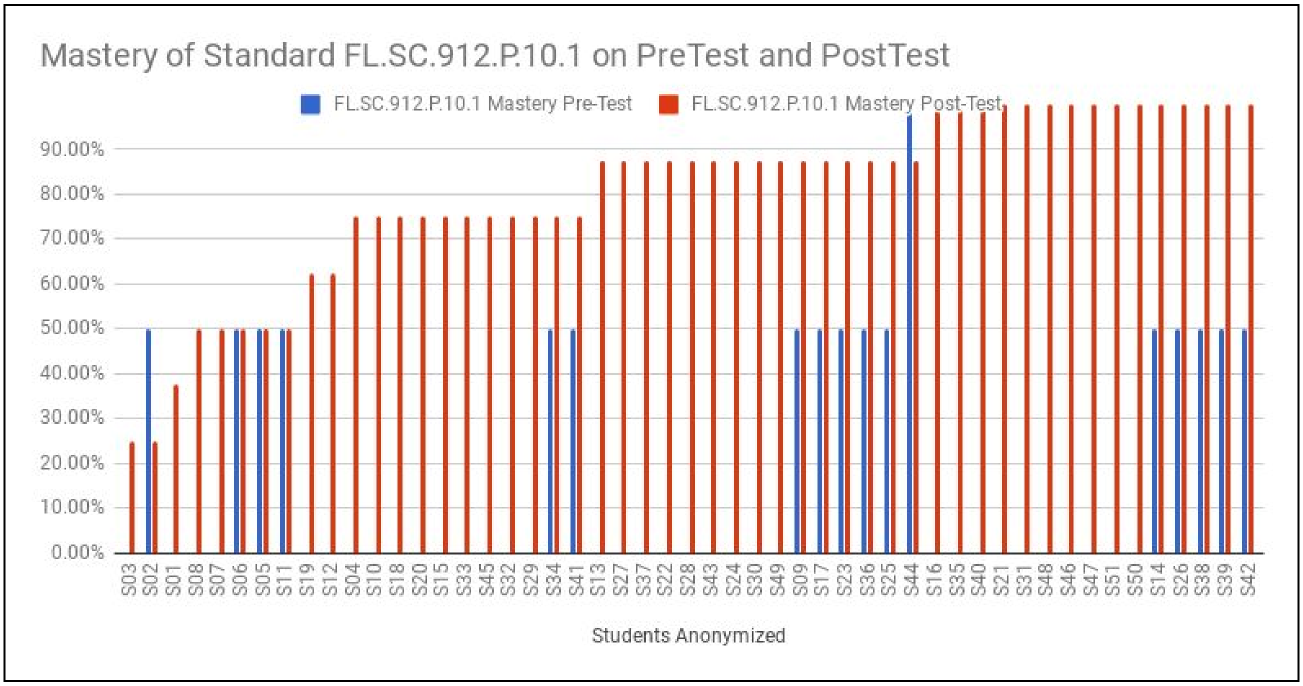


Figure 4: Graph - Mastery of Standard FL.SC.912.P.10.1 on PreTest and PostTest

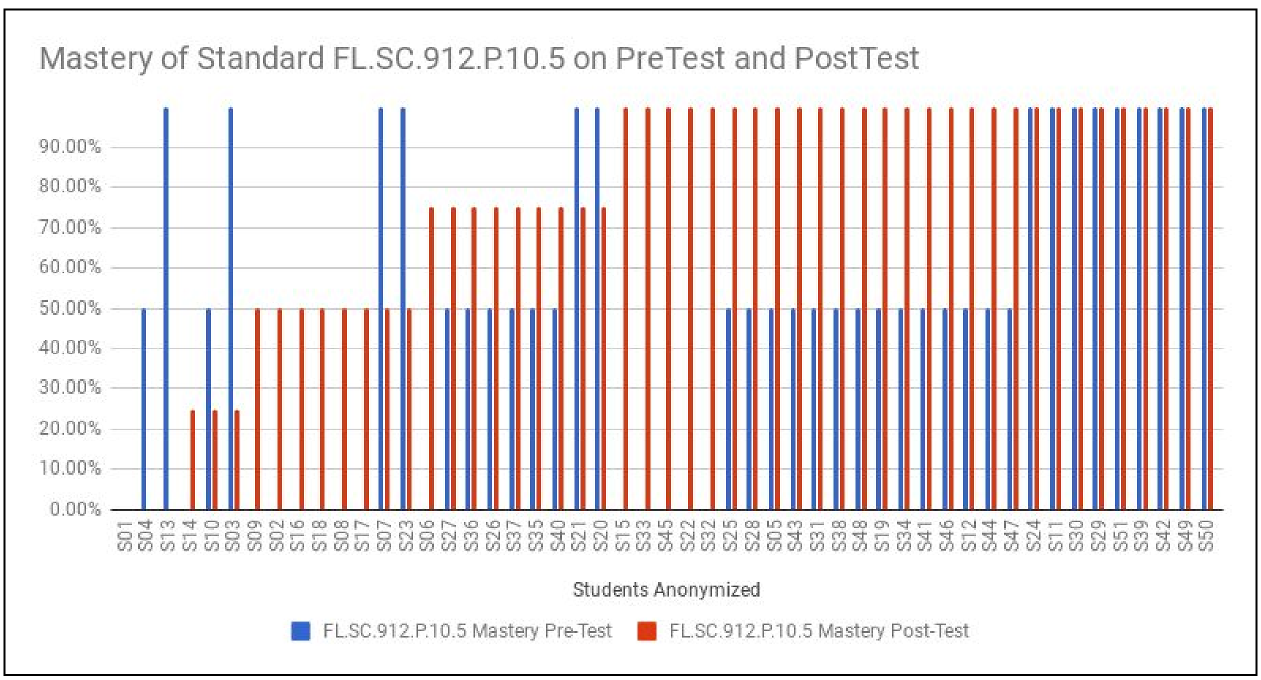


Figure 5: Graph - Mastery of Standard FL.SC.912.P.10.5 on PreTest and PostTest

Fifteen students demonstrated mastery of FL.SC.912.P.10.5 (LG3), as opposed to 37 after the unit (Figure 5); however, this is a somewhat skewed perspective because I made an error in the pre-test and post-test representation of this standard. For the pre-test, I asked questions from the standard that had been reviewed in the unit prior, but I failed to incorporate questions about heat exchange during physical processes (i.e., questions involving the heating curve). I did not anticipate how challenging this particular concept would be for the students, and so that may be the cause of the discrepancy seen in the data; specifically, it was interesting that 7 students actually experienced decreases in mastery standard when the heating curve questions were introduced. This would not have been as serious a problem had I not used the pre-test to make the decision to minimize the time allotted to this standard; obviously, several students could have used slightly more instructional time focused on that learning goal.

The evaluation of learning goal 4 (standard FL.SC.912.P.10.6) exhibited greater student gains as opposed to LG3, with every student either meeting or improving upon their mastery of that standard. Prior to unit instruction, seven students already appeared to be able to interpret potential energy diagrams, either from prior instruction or from inferring based on their conceptual understanding of chemical reactions and context clues. Unit instruction increased this number to 38 students displaying mastery, and most of the others showing at least some improvement.

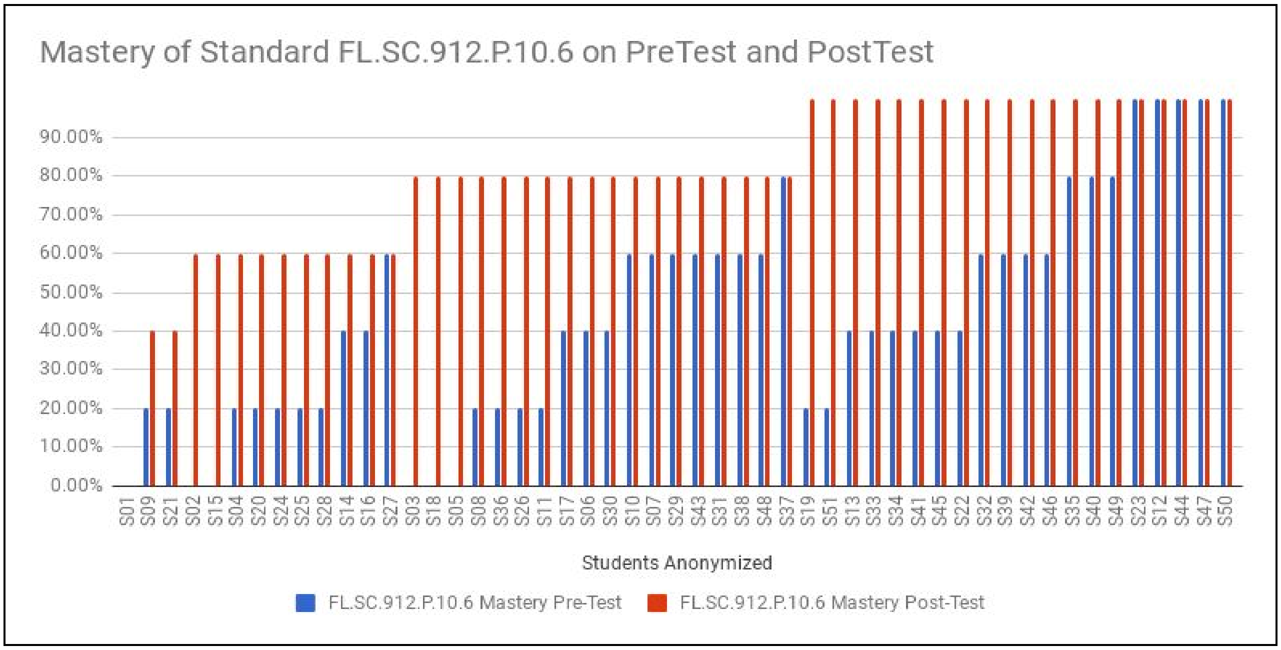


Figure 6: Graph - Mastery of Standard FL.SC.912.P.10.6 on PreTest and PostTest

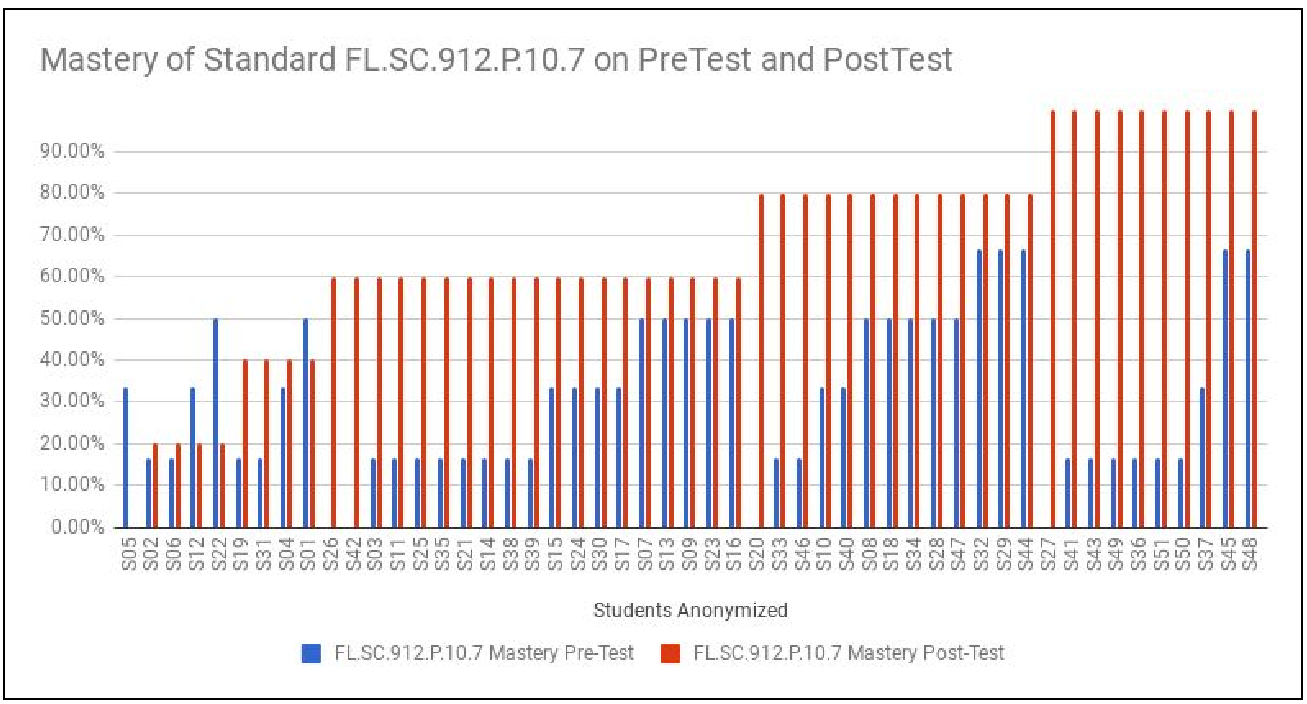


Figure 7: Graph - Mastery of Standard FL.SC.912.P.10.7 on PreTest and PostTest

Learning goal 5 (standard FL.SC.912.P.10.7) was one of the most important of the unit, but also one of the most challenging, despite plenty of instructional time being devoted to the goal. Improvements on LG5 was comparable to improvements on LG4, though four students seem to have had reduced understanding of the learning goal after instruction (Figure 7). However, all of the students who suffered losses on this learning goal on the post-test compared to the pre-test scored quite low on the standard in both assessments, either 50% or below. With such results, it's entirely possible that some of the variation is random, as 25% is expected of random answer selection.

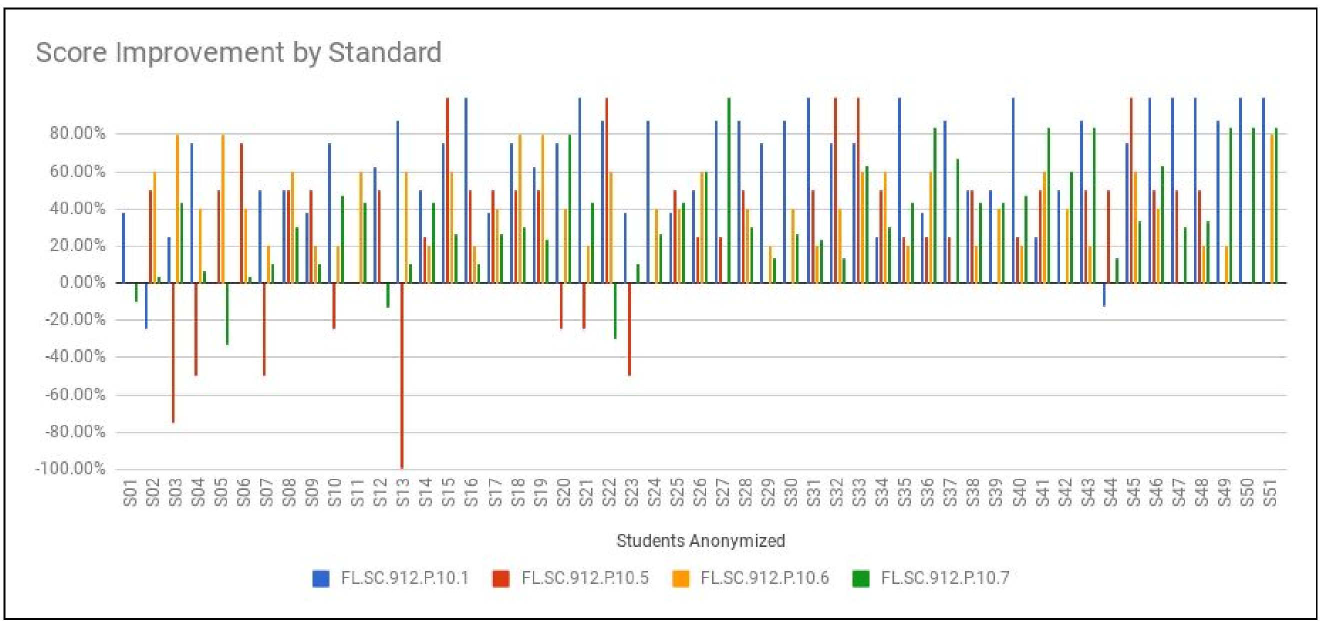


Figure 8: Score Improvement by Standard

Overall, the scores indicate significant gains for most students. On average, students displayed a 62.75% improvement on standard FL.SC.912.P.10.1 (LG1 and LG2), a 26.47%

improvement on FL.SC.912.P.10.5 (LG3), a 36.86% improvement on FL.SC.912.P.10.6 (LG4) and a 35.69% improvement on FL.SC.912.P.10.7 (LG4). The most significant gains were made on LG1 and LG2, on which the most instructional time was spent. The fewest gains were made on LG5, on which only one dedicated instructional day was spent (besides the review day). According to my data, in this unit there seems to be a clear correlation between instructional time spent and learning goal progress.

Seven students failed the post assessment with a score below 60. Of these, four missed at least two days of unit instruction, and all have a history of academic difficulties in the class. Three have displayed behavioral difficulties in class dealing with lack of focus, and have had private conferences regarding the problem and methods to improve. A handful of failing grades is not uncommon in a science classroom, where otherwise capable students sometimes enter with a negative attitude towards the topic, believing erroneously that the subject is too difficult for them, and their self-damaging outlook leads to further failure. However, in my classroom, there are always additional chances to recover from a bad exam grade and resolve confusions regarding the content.

Students are aware of an opportunity to improve on their results through taking a retake exam. In all cases, I require student to first display their renewed commitment and effort by completing a “test correction” process outside of class time. Students may choose to come to an after school extra help session (offered twice a week), or during their lunch or a free period, and attempt to correct their errors and explain why the revised answer is correct. Students may use any written notes or handouts for this process. They may not use internet-enabled devices such as phones or computers, nor may they use other students' notes. If a correct answer is given along with a reasonable explanation, they may earn up to half the points back for that question, added to their original score.

During this process I also meet with and interview the students about their challenges and study strategies, listen to their experiences, and provide them strategy suggestions. Once test corrections have been done and a meeting held with the student, they are eligible to take a retake exam. So far, three of the students who failed the Thermochemistry exam have scheduled to do test corrections, as well as several students who passed but felt they had room for improvement. I consider this an important part of my teaching culture, as it emphasizes student self-efficacy. Furthermore, I intend this process to make chemistry (and physical science in general) a more approachable subject, and allow struggling students to understand that success is not a matter of innate ability, but rather a matter of tenacity.

Test corrections also teach students that knowledge of these topics goes beyond the unit timeline. For many students, these test correction sessions have been the source of important learning moments. In our meetings, I often point out that the process of struggling to come up with answers to questions using notes and textbook is very similar to the studying process, which they will need to familiarize themselves with in order to succeed in college.

Evaluation and Reflection

I consider this unit a successful one, with many students displaying significant comprehension and performance improvements. By incorporated guiding questions, discussions, and inquiry into the unit, many students benefited from developing conceptual understanding and higher-order thinking skills as evidenced by the formative results throughout the unit and through student success on conceptual questions on the post-test. Though I chose a multiple choice assessment, I did so with the goal in mind of students practicing to display their knowledge effectively on their common final exam (CFE). During their CFE, students must be able to interpret and answer novel multiple-choice questions on these standards, and I feel confident that many of them will succeed in that goal.

Furthermore, and perhaps more importantly, many of the students learned how thermochemistry applies to their live. Many gained a new appreciation for what is happening on the molecular level when they experience the sensations of hot and cold to the touch, enhancing their understanding of the natural world. I believe one of my strengths as a teacher is linking classroom learning to their life experiences, and encouraging curiosity through the introductory inquiry activities. In the future I intend to expand upon this strength and strive to make my classroom a place where students are encouraged to ask as many questions as they answer.

The most significant improvements were made on standard FL.SC.912.P.10.1 (LG1 and LG2), on which most instructional time was spent. These learning goals were also the topic of the introductory inquiry activity. My experience teaching this unit has further supported my theory that grounding a learning goal in inquiry and observation supports and extends later understanding, as it provides students with a common shared experience and primes them to better incorporate information later during lecture.

The fewest improvements were made on FL.SC.912.P.10.5 (LG3), which I believe is a directly related to a lack of the very activities that made learning goals 1 and 2 so successful. Though I provided a demonstration of a heating curve, students did not themselves prove the phenomenon and therefore did not have as strong a basis for understanding as they did for the other learning goals. I also made an erroneous assumption that because students understood one aspect of a standard, that their understanding would extend seamlessly to a more sophisticated concept within the same standard. I will have to be much more careful in the future to consider the specific skills I want them to exhibit, and provide sufficient time and experiences for them to deepen their understanding. Identifying, targeting and assessing specific skills is one area I will therefore need to improve upon in my future teaching. Improving my backwards design skills should help me reach mastery of this goal as a teacher.

From my experience with this unit, I have learned that I wish to adapt my future classroom to be more activity- and inquiry-based. It is time-consuming to design and implement inquiry activities, and at times expensive (for example, the infrared thermometers I purchased were twenty dollars apiece). However, if I collect materials slowly over the years and research ways to inexpensively provide students with the hands-on enrichment they need, I believe that one day I will have a truly dynamic and experience-based classroom that supports the higher-level thinking I want my students to develop. There were times earlier in the year that I sacrificed inquiry because I felt rushed for time, and student achievement in those units suffered considerably, much like they did for learning goal 3 in this unit. I've learned that putting in the time for inquiry is actually more efficient in the long run, and is most certainly worth the time and effort.

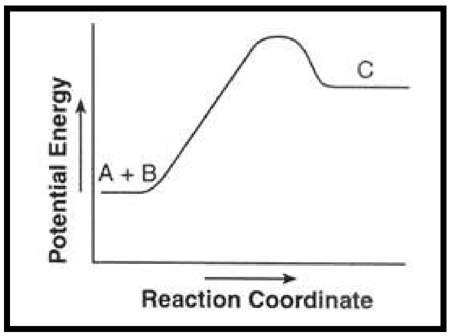
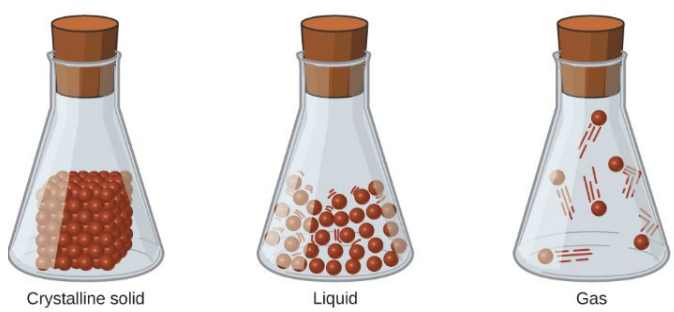
Unit Instructional Materials

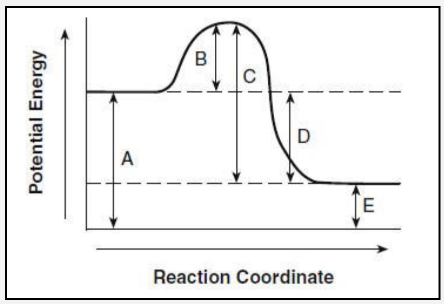
In the pages that follow are the plans and materials used in instruction.

Thermochemistry Pre-test

This pre-test helps me understand what you already know. Don't spend much time on any one question; Do your best, but **please don't leave anything blank.**

Section 1 on Scantron		**Section 2 on Scantron**	
Question & Answer Choices *Choose the option that best answers the question.* *If you don't know, make your best guess!*		**Confidence level of answer** Guessing □ Some idea □ I know it! **1** **2** **3**	
1-1	**A hot pack is activated and gets very hot.** A. This is an endothermic reaction. B. This is an exothermic reaction. C. This is an ectothermic reaction. D. None of the above.	**2-1**	choose 1-3 on scantron (Section 2) to rate confidence levels on questions 1-3 SC.912.P.10.7
1-2	**Water freezes and becomes ice.** A. This is an endothermic reaction. B. This is an exothermic reaction. C. This is an ectothermic reaction. D. None of the above.		
1-3	**Water boils and becomes water vapor in the form of steam.** A. This is an endothermic reaction. B. This is an exothermic reaction. C. This is an ectothermic reaction. D. None of the above.		
1-4	**The reaction $C(s)+O_2(g)\rightarrow CO_2(g)$ has a negative change in enthalpy ($\Delta H = -393.5$ kJ)** A. This is an endothermic reaction. B. This is an exothermic reaction. C. This is an ectothermic reaction. D. None of the above.	**2-2**	choose 1-3 on scantron (Section 2) to rate confidence levels on questions 4-5 SC.912.P.10.7

1-5	**The reaction $N_2(g)+O_2(g)\rightarrow 2NO(g)$ has a positive change in enthalpy ($\Delta H = +180.5$ kJ)** A. This is an endothermic reaction. B. This is an exothermic reaction. C. This is an ectothermic reaction. D. None of the above.		
1-6	 A. This is a diagram of an endothermic reaction. B. This is a diagram of an exothermic reaction. C. This is a diagram of an ectothermic reaction. D. None of the above.	**2-3**	choose 1-3 on scantron (Section 2) to rate confidence levels on question 6 SC.912.P.10.7
1-7	 **As a solid becomes a liquid and then a gas, what happens to its kinetic energy?** A. Kinetic energy decreases, since the molecules are getting farther apart. B. Kinetic energy increases, since the molecules are moving faster. C. Kinetic energy decreases, since the molecules are moving faster. D. Kinetic energy increases, since the molecules are getting farther apart.	**2-4**	choose 1-3 on scantron (Section 2) to rate confidence levels on question 7-8

1-8	**As water freezes:** A. The potential energy of the system remains the same. B. The potential energy of the system increases. C. The potential energy of the system decreases. D. The system never had potential energy to begin with.		SC.912.P.10.5
			
1-9	**In the above diagram, "A" Represents:** A. Activation Energy C. Energy of reactants B. Energy of products D. Change in Enthalpy	**2-5**	choose 1-3 on scantron (Section 2) to rate confidence levels on question 9-12
1-10	**In the above diagram, "B" Represents:** A. Activation Energy C. Energy of reactants B. Energy of products D. Change in Enthalpy		
1-11	**In the above diagram, "D" Represents:** A. Activation Energy C. Energy of reactants B. Energy of products D. Change in Enthalpy		
1-12	**In the above diagram, "E" Represents:** A. Activation Energy C. Energy of reactants B. Energy of products D. Change in Enthalpy		SC.912.P.10.6
1-13	**If energy is lost by a system:** A. The energy disappears. B. The energy flows to the surroundings. C. Some energy disappears, some flows to surroundings. D. The energy is all eventually reabsorbed.	**2-6**	choose 1-3 to rate confidence levels on question 13 SC.912.P.10.6

<table>
<tr><td colspan="4">For the following questions, the formula to use is q=mCΔT.
(You have not learned this formula in this class yet. Do your best or just guess. Again, this is not graded.)</td></tr>
<tr><td>1-14</td><td>The temperature of a 95.4-g piece of copper increases from 25.0°C to 48.0°C when the copper absorbs 849 J of heat. What is the specific heat of copper?
A. 1862875 J/g°C
B. 1.86 J/g°C
C. 3.87 J/g°C
D. 0.387 J/g°C</td><td rowspan="2">2-7</td><td rowspan="2">choose 1-3 on scantron (Section 2)

to rate confidence levels on questions 14-15

SC.912.P.10.1</td></tr>
<tr><td>1-15</td><td>100.0 g of water is heated until its temperature rises by 20°C. Calculate the amount of heat energy needed to cause this rise in temperature. (Specific Heat of H_2O is 4.18 J/g°C)
A. 836 J
B. 8360 J
C. 0.00209 J
D. 2090 J</td></tr>
</table>

Thermochemistry Exam

Multiple Choice: ***Identify the letter of the choice that best completes the statement or answers the question.***

1. A piece of metal is heated, then submerged in water that is at a lower temperature. Which statement below best describes what happens?
    a. The temperature of the water will increase and the temperature of the metal will decrease.
    b. Only the temperature of the metal will increase.
    c. Only the temperature of the water will increase.
    d. Only the temperature of the water will decrease.

2. When energy is changed from one form to another, ____.
    a. a physical change always occurs
    b. energy is transformed but not lost
    c. all of the energy is changed to a useful form
    d. all of the above

3. If heat is released by a chemical system, an equal amount of heat will be ____.
    a. absorbed by the surroundings
    b. absorbed by the system
    c. released by the surroundings
    d. released by the universe

4. Which of the following is transferred due to a temperature difference?
    a. chemical energy
    b. mechanical energy
    c. electrical energy
    d. thermal energy

5. In an **exothermic** reaction, the energy stored in the chemical bonds of the **reactants** is:
    a. equal to the energy stored in the bonds of the products
    b. greater than the energy stored in the bonds of the products
    c. less than the energy stored in the bonds of the products
    d. less than the heat released

6. Which statement correctly describes an **endothermic** chemical reaction?
    a. The products have higher potential energy than the reactants, and ΔH is positive.
    b. The products have lower potential energy than the reactants, and ΔH is negative.
    c. The products have lower potential energy than the reactants, and ΔH is positive.
    d. The products have higher potential energy than the reactants, and ΔH is negative.

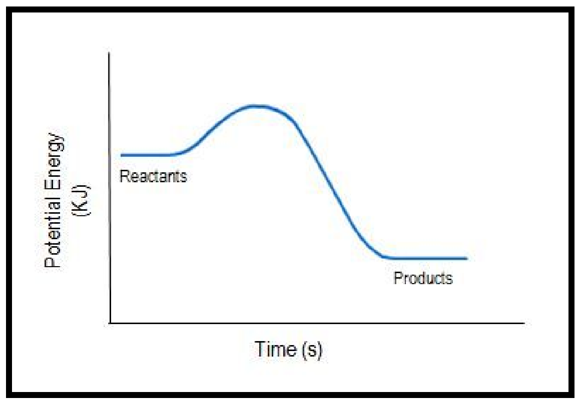
7. What is the amount of heat required to raise the temperature of 200.0 g of aluminum by 10 °C? (specific heat of aluminum = 0.90 J/g°C)
    a. 1,800 J
    b. 18,000 J
    c. 22 J
    d. 0.90 J

8. What is the specific heat of a substance if 1560 J are required to raise the temperature of a 312-g sample by 15°C?
   a. 7.30 J/g°C
   b. 1.33 J/g°C
   c. 0.033 J/g°C
   d. 0.33 J/g°C

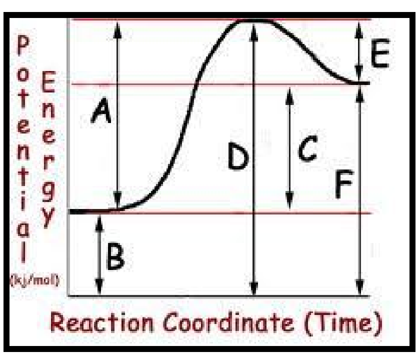
9. According to a heating curve, during a phase change, the temperature of a substance ____.
   a. Always increases
   b. Decreases
   c. Remains constant
   d. May increase or decrease

10. When 45 g of an alloy, at 25°C, are dropped into 100.0 g of water, the alloy absorbs 956 J of heat. If the final temperature of the alloy is 37°C, what is its specific heat in J/g°C?
   a. 0.423 J/g°C
   b. 1.77 J/g°C
   c. 49.9 J/g°C
   d. 0.797 J/g°C

11. Hydrogen peroxide decomposes to produce oxygen gas and water ($2H_2O_2 \rightarrow O_2 + 2H_2O$). The diagram to the **right** shows the energy changes that occur during this process.
    Based on the energy diagram, which of the following statements about the decomposition of hydrogen peroxide is **true**?



   a. Activation energy is not present.
   b. The products release stored energy.
   c. The reaction is endothermic.
   d. The reaction is exothermic.



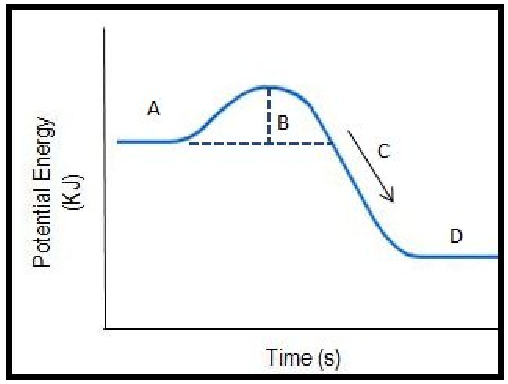
12. For the Potential Energy Diagram to the **left,** which letter represents Δ H (Enthalpy Change / Heat of Reaction), and what is the sign of Δ H ?
   a. Δ H is C, and has a negative sign.
   b. Δ H is C, and has a positive sign.
   c. Δ H is F, and has a negative sign.
   d. Δ H is F, and has a positive sign.

13. Which of the below is an **endothermic** process?
   a. burning a candle
   b. melting ice cream

c. water vapor condensing on a windshield d. water freezing into ice

14. The diagram **to the right** shows the changes in energy during the combustion of propane.

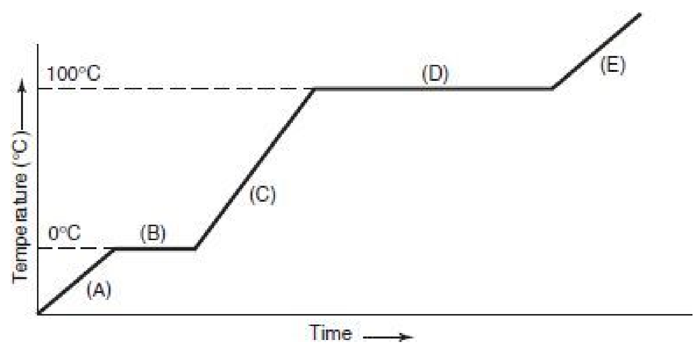
Which part of the energy diagram illustrates the act of adding a spark to start the combustion reaction?



a. A
b. B
c. C
d. D

15. A chunk of ice is added to an insulated cup with room-temperature water. How does heat transfer occur in the cup?
    a. Heat is transferred from the water to the ice.
    b. Heat is transferred from the ice to the water.
    c. Cold is absorbed by the water.
    d. None of the above.

16. To the right is the heating curve of water. What is happening at label "D"?
    a. Water is pure liquid.
    b. Water is pure gas.
    c. Water is melting.
    d. Water is boiling.



17. If the molar heat of a fusion (melting) ΔH_{FUS} is 200 kJ, what is the ΔH of solidification (freezing)?
    a. 200kJ b. 0.005 kJ c. - 200kJ d. - 0.005 kJ

18. As a substance boils, changing from a liquid to a gas, what happens to the temperature?
    a. Temperature rises due to increased motion of particles.
    b. Temperature rises and falls repeatedly due to evaporation during phase change.
    c. Temperature remains constant as heat energy is used for the phase change.
    d. None of the above.

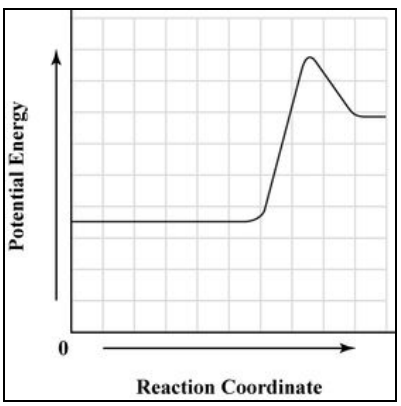
19. The following balanced equation represents a reaction:

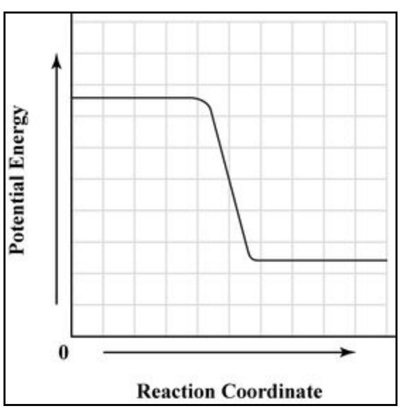
$$\mathbf{CH_4(g) + 2O_2(g) \rightarrow 2H_2O(g) + CO_2(g) + heat}$$

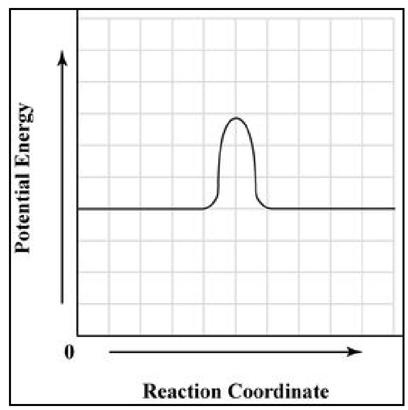
Which statement is true about energy in this reaction?

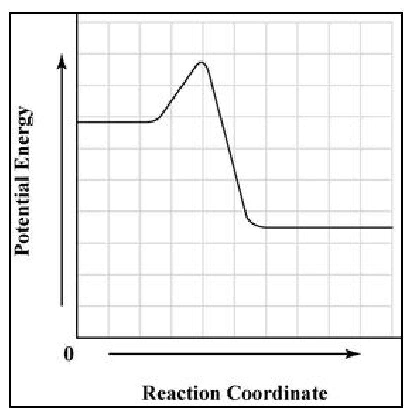
a. The reaction is endothermic because it releases heat.
b. The reaction is exothermic because it releases heat.
c. The reaction is endothermic because it absorbs heat.
d. The reaction is exothermic because it absorbs heat.

20. Which graph represents an **endothermic** reaction?

a.


b.


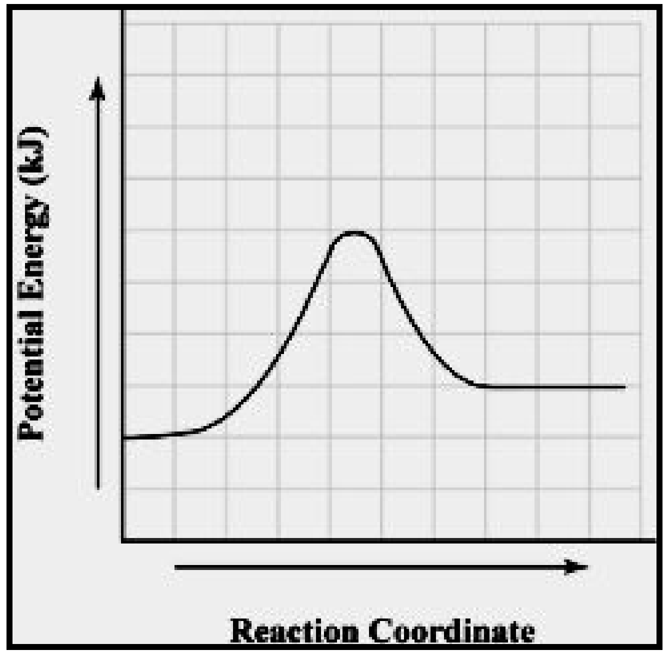
c.


d.


21. Which of the following equations represents an endothermic process?

a. $CO_2\,(g) \rightarrow CO_2\,(l)$
b. $CO_2\,(s) \rightarrow CO_2\,(g)$
c. $H_2O\,(g) \rightarrow H_2O\,(s)$
d. $H_2O\,(l) \rightarrow H_2O\,(s)$

22. The potential energy diagram for a chemical reaction is shown to the **right**. Each interval on the axis labeled "Potential Energy (kJ)" represents 40 kilojoules. What is the heat of reaction?
    a. - 120 kJ
    b. - 40 kJ
    c. + 40 kJ
    d. + 160 kJ



Thermochemistry Lesson Plans

Days 1 & 2	
Topic:	Temperature and Heat Misconceptions
Learning Goal:	Students will be able to relate "Temperature" and "Heat", understanding through observation that how "hot" or "cold" an object feels is linked to its thermal conductivity and specific heat (and the relative temperature of what it's touching), not just its temperature.
Evidence of Learning:	Worksheet Page: "Thoughts After Watching the Video" (Graded for participation and demonstration of thought, not accuracy)
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 (including relationship between specific heat and temperature) • **SC.912.P.10.5** Relate the behavior and kinetic energy of a molecule with the temperature of the substance.
Further Details	

- Students begin by answering four questions: What is temperature? How do we measure an object's temperature? What makes an object hot? What makes an object cold?
- Students view a common definition of "temperature" and discuss it. They are told this is not the same definition a scientist would use. They then share their own revised definitions on a collaborative Nearpod board (they can see and "like" each others' responses).
- Students are grouped in 3-4 and given a set of four cubes of different materials: Wood, Acrylic, Aluminum and Copper. They are instructed: "Leaving the cubes on the table and only touching them briefly with your finger, Rate the cubes from warmest to coolest." After a time, responses are shared. Nearly always, the two metal blocks are ranked cooler than the acrylic and wood.
- Each group is given an infrared thermometer and brief instructions on how to use it. They then take the temperature of each block in Celsius, and report their findings on a shared table on the board. The temperatures are very close to one another, or often the same.
- Students write a response to the question: "Were you surprised at the temperature readings of the blocks? Why or Why not?"
- Students are shown a table with the thermal conductivity and specific heat values for all the materials, as well as the definitions for those terms. They're given time to read

and research the terms, and try to develop a statement that explains why the metals "feel cooler" despite being the same temperature as the other blocks. Guiding question: "Do you think any of these properties correlate with how you ranked the blocks? Why?"

- Students are shown the video "Misconceptions About Heat" (https://www.youtube.com/watch?v=hNGJ0WHXMyE)
- Students are asked to revise their previous answers, with their new understanding. They are then demonstrate their understanding by applying it to a new situation: Ice Melting Blocks (as shown here: https://www.teachersource.com/product/amazing-ice-melting-blocks/energy). Students are allowed to touch each block (one feels cooler than the other), and are shown that they are actually both at room temperature. They are then given a template diagram with the ice blocks shown (on Nearpdo) and asked to draw arrows to show heat flow for each - an example is drawn on the board from the video (Heat flow from oven to hand). Students should draw arrows from outside in for both blocks, but a larger arrow for the "cooler" feeling block, however they may still not understand this fully.
- Students then participate in a poll sharing their predictions as to the outcome of an experiment: Placing a piece of ice on both at the same time. Will ice melt faster on one or the other, or the same on both? After answers are recorded, the experiment is done. The "cooler" feeling block melts ice noticeably more quickly.
- Students discuss the outcome and try to draw heat flow arrows for each case. They then complete the worksheet page "Thoughts After Watching the Video" and turn in for their participation / understanding grade.

Formative Assessment

Worksheet Page: "Thoughts After Watching the Video"

Now that we've watched the video and discussed what's going on, you should have a better understanding of temperature. Consider the following questions:

1. Has your opinion changed about the initial definition of temperature at the beginning of the lesson? If so, how? Make sure to use full sentences and scientific language, including your claim, evidence, and your reasoning/logic.

2. What role does specific heat and/or thermal conductivity play in how we perceive temperature when we touch an object?

3. If temperature cannot be measured (or defined) by what we feel when we touch an object, how might temperature be defined by scientists? You may look up the terms "temperature in science" or "thermal energy" to help you answer this question.

4. When we observed the ice melting on the blocks, which did you think would melt the ice fastest - the one that was cooler to the touch, or the one that was warmer to the touch? Were you surprised? 5. Last unit we learned the temperature of an object is a measure of the kinetic energy of its molecules. Heat is the movement of this energy from one object to another. Heat moves spontaneously from a warmer object to a cooler object. We saw this with the melting ice demonstration. Considering these facts - do you think it's possible for "cold" to move from one object to another? Why or why not?

Day 3	
Topic:	Heat Energy - How it is created, How it moves, and How it is described.
Learning Goal:	Students will be able to predict the direction of heat flow in a realistic scenario by applying the principles of the law of conservation of energy and heat flow from higher temperature systems to lower temperature systems. Using the heat flow direction, students will be able to label the process as either endothermic or exothermic.
Evidence of Learning:	Draw a scenario of snow melting & refreezing on a house, and determine any endothermic or exothermic processes taking place (Ungraded).
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 (including relationship between specific heat and temperature) ● **SC.912.P.10.7** Distinguish between endothermic and exothermic chemical processes. (including whether phase changes are exothermic with negative change in heat, or endothermic with positive change in heat).
Further Details	
● Before lecture begins, students are given a vocab list as a "Word Hunt" to highlight the important concepts of the day. Everyone is given time to copy them down and ask questions; students have computers so may look up their own definitions as well. ○ Heat Energy ○ Chemical Energy ○ Where Chemical Energy is stored	

- Thermochemistry
- The letter "q"
- How heat moves
- The sign of "q"
- Law of Conservation of Energy
- System
- Surroundings
- Endothermic
- Exothermic

- Students participate in a lecture with brief discussion intervals, and write notes for each word or concept. Some guiding questions are:
  - What forms of energy do you remember from previous grades? (after being shown a list) Can anyone give an example of what any of these look like?
  - The title of the unit is called "Thermochemistry". Can anyone guess what two forms of energy we will be focusing on? (Thermal and Chemical).
  - If heat can move, can "cold" move?
  - When gasoline in a car is converted to kinetic energy, the engine gets hot. Is all the energy from the fuel going to move the car? Is any of it transformed into less useful forms of energy?
  - Are endothermic processes always "cold"? Are exothermic processes always "hot"?

Formative Assessment

Ungraded Drawing: "Recognizing Endothermic and Exothermic Processes"

Scenario: "On a sunny winter day, the snow on a rooftop begins to melt. As the melted water drips from the roof, it re-freezes into icicles."

Student instructions: Draw the scenario (example drawing provided, without heat arrows). Describe the direction of heat flow as the water first melts, then freezes. Which process is endothermic? Exothermic?

Students use the blank side of their dry-erasable graphic organizer in order to draw the scenario and arrows representing heat flow. Think-pair-share may be applied here, time allowing, and if students seem to need it - some classes caught on easily, and others needed more processing time. Afterwards, teacher draws in the arrows correctly on their own version of the drawing, and labels each as "endo" or "exo". Below the drawing, students are shown a rudimentary potential energy diagram based on temperature, and how an increasing slope indicates endothermic, and a decreasing slope indicates exothermic.

<table>
<tr><th colspan="2">Day 4</th></tr>
<tr><td>Topic:</td><td>The Specific Heat Formula & Calorimetry</td></tr>
<tr><td>Learning Goal:</td><td>Students will identify variables from a word problem to enter into the specific heat formula (also known as the calorimetry formula, $q=mC\Delta T$).</td></tr>
<tr><td>Evidence of Learning:</td><td>Students will appropriately fill out a graphic organizer, assigning numbers to variables using a word problem.</td></tr>
<tr><td>Standards:</td><td>● SC.912.P.10.1 Differentiate among the various forms of energy and recognize that they can be transformed from one form to others (mathematically apply the relationship between specific heat, mass, temperature, and the heat of a chemical reaction with formula $q=mC\Delta T$)</td></tr>
<tr><td colspan="2">Further Details</td></tr>
<tr><td colspan="2">● Through a slide set, students are introduced to each variable represented in the $q=mC\Delta T$ formula, and the units used for each.
○ q, heat flow, J (joules) or cal (calories)
○ C, specific heat, J/(g·°C) or cal/(g·°C)
○ m, mass, g
○ ΔT, change in temperature, °C or K *new concept: Delta means final - initial</td></tr>
<tr><td colspan="2">Formative Assessment</td></tr>
<tr><td colspan="2">Graphic Organizer Use

Students use dry-erasable graphic organizer (see Figure 2 in section “Assessment Plan”) to fill in values using units to guide them. Example question: “The temperature of a 95.4-g piece of copper increases from 25.0°C to 48.0°C when the copper absorbs 849 J of heat. What is the specific heat of copper?”
○ q = 849 J
○ C = x (unknown)
○ m = 95.4 g
○ ΔT = 48.0 °C - 25.0 °C = 23.0 °C
Once everyone has filled out their graphic organizer correctly, students solve for x. If students have extra time, they may continue on to the next example problems in the slide set:

“The specific heat of ethanol is 2.4 J/(g·°C). A sample of ethanol absorbs 676 J of heat, and the</td></tr>
</table>

temperature rises by 42°C. What is the mass of ethanol in the sample?" Further problems available on Sciencegeek website http://www.sciencegeek.net/Chemistry/taters/Unit5Thermochemical.htm (questions 1-8)

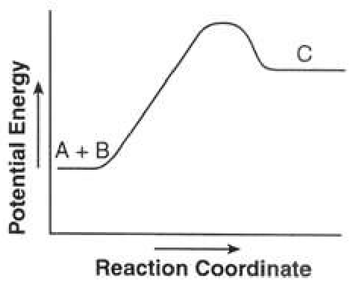
Day 5	
Topic:	The Specific Heat Formula & Calorimetry (continued)
Learning Goal:	Students will apply their knowledge of the calorimetry formula, $q=mC\Delta T$, their conceptual understanding of $q_{sys} = -q_{surr}$, and the relationship between the sign of q with endothermic or exothermic equations, to answer questions relating all three concepts.
Evidence of Learning:	Students will complete a graded, open-notebook quiz (on the Canvas platform) representing sample questions from the two covered 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 (mathematically apply the relationship between specific heat, mass, temperature, and the heat of a chemical reaction with formula $q=mC\Delta T$; conceptually apply the conservation of energy between the system and surroundings to predict outcomes using $q_{sys}= - q_{surr}$) • **SC.912.P.10.7** - Distinguish between endothermic and exothermic chemical processes, physical or chemical. (Includes chemical / mathematical representations of heat of reaction including sign of enthalpy and thermochemical equations)
Further Details	
• Students view three more slides on the "Specific Heat Formula & Calorimetry" slide set, introducing them to the concept of a calorimeter, which measures heat flow from a system using the temperature change of the surroundings, solving for q, and applying the formula $q_{sys} = -q_{surr}$. ○ Students have the option of using the dry-erase graphic organizer for this activity, or if they feel ready, to work on their own in their notebooks. • Example question: "The initial temperature of the water in a constant-pressure calorimeter is 24°C. A reaction takes place in the calorimeter, and the temperature rises to 87°C. The calorimeter contains 367 g of water, which has a specific heat of 4.18 J/(g·°C). Calculate the change in heat energy during this reaction."	
Formative Assessment	

Graded Open-Notebook Quiz: "12.2 Endo/Exo & Heat Quiz"

Students spend the remainder of the period working on a graded open-notebook quiz.

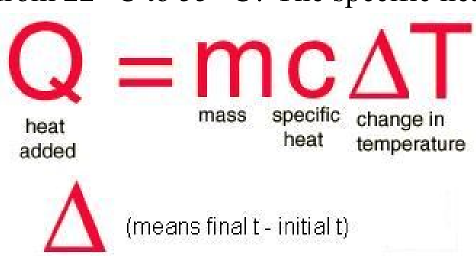
1. For all the following, select endothermic or exothermic depending on the direction of heat flow.
    a. Ice melting:
    b. Gas vapor condensing into liquid:
    c. Liquid vaporizing (boiling) into a gas:
    d. A candle burning:
    e. A reaction with + q:
    f. A reaction with - q:

2. Is that the graph of an endothermic or exothermic reaction?



3. A 15.75 g of iron absorbs 1086 joules of heat energy. and its temperature changes from 25 to 175 degrees Celsius. Calculate the Specific Heat of iron. (THIS FORMULA SHOULD BE IN YOUR NOTES!!! You must memorize it!) * *students are still allowed to use the graphic organizer at this time but must know they need to memorize the formula before the test*
    a. 114.1 J/g°C
    b. 0.46 J/g°C
    c. 2.17 J/g°C

4. How many joules of heat are needed to raise the temperature of 10.0 g of aluminum from 22 °C to 55 °C? The specific heat of aluminum is 0.90 J/g °C.



Please match each letter from this formula with the correct value and unit from the question.
    a. Q

b. m
c. C
d. ΔT

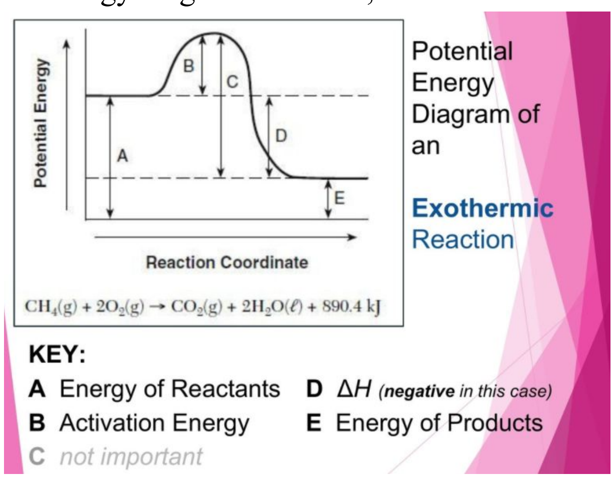
Matching options: 55°C, 33°C, 70kPa, aluminum, 22°C, x (unknown), 0.90 J/g°C, 10.0g

5. In a coffee-cup calorimeter, a reaction takes place in 100.0 g of H2O. During the reaction, the water increased by 6.7 °C. The specific heat of water is 4.19 J/g°C. What is the q of the reaction? (Hint: H2O is the surroundings, the reaction is the system)
   a. 159.9 J
   b. - 2807 J
   c. 2807 J
   d. -159.9 J

Day 6	
Topic:	Enthalpy, Heat of Reaction & Potential Energy Diagrams
Learning Goal:	Students will express energy changes in terms of Enthalpy in Heats of Reaction, and Potential energy diagrams
Evidence of Learning:	Nearpod quizzes & Creation of own potential energy diagram from experimental values.
Standards:	● **SC.912.P.10.6 -** Create and interpret potential energy diagrams for chemical and physical processes. (Create or interpret a diagram relating the potential energy of an object in a defined system to its position given the necessary information including energy of reactants/products, activation energy, absorption or releasing of heat) ● **SC.912.P.10.7 -** Distinguish between endothermic and exothermic chemical processes, physical or chemical. (Includes Graphical representations of the energy of reactants and products to determine whether a reaction is endothermic or exothermic; and chemical / mathematical representations of heat of reaction including sign of enthalpy and thermochemical equations)
Further Details	
● Activating Prior Knowledge: Each table group is giving a small lit tea light (one student put in charge of safety watch for the small flame). Determine: endothermic or exothermic? Guiding questions: What is happening in terms of energy transfer? Where did the energy come from? Where is it going? How does the flame carry on burning?	

- *Students are told to write their guess on their dry-erase page and hold it until later.*

- Interactive slide set started. Students given four new concepts for their list:
  - Enthalpy (H)
  - Change in Enthalpy (ΔH)
  - Heat of Reaction
  - Potential Energy Diagram
  - Activation Energy
- "Q", heat, is energy that is actively flowing, whereas Enthalpy is the thermal energy contained within a substance. Change in Enthalpy (ΔH) is the change in that thermal energy, which is equal to heat flow. ΔH has the same rules as q.
  - Practice Quiz 1
- Additional slides shown introducing the idea of Thermochemical Equations with change in Enthalpy (ΔH) added to either the reactant side (left side, endothermic, +ΔH), or to the product side (right side, exothermic, -ΔH)
  - Practice Quiz 2
- A labeled potential energy diagram is shown, and each relevant interval reviewed.



- Activation Energy explained as energy that needs to be added to start a reaction. Most endothermic and exothermic chemical reaction require at least some activation energy.
  - Think back to the question at the start of the lesson: Is a candle burning endothermic or exothermic? Does it require activation energy?
  - PE diagrams for exothermic **and** endothermic reactions shown.
- A student performed an experiment to determine if a reaction was endothermic or exothermic. (Draw her results in your notebook)
  - Culminating Formative: Draw and Label PE Diagram

Formative Assessment

Ungraded Nearpod Assessments

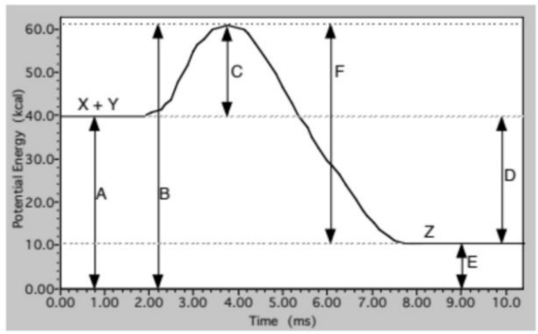
1. Practice Quiz 1:
    a. Look at this potential energy diagram. PE (Potential Energy) on the vertical axis can be thought of as heat energy. Is this an exothermic or endothermic reaction?
    b. Is ΔH positive or negative in this potential energy diagram?
    c. In the beginning of the year, we combined sodium and water. The result was a spontaneous combustion. Was this an endothermic or exothermic reaction?
    d. In the beginning of the year, we combined sodium and water. The result was a spontaneous combustion. Was ΔH positive or negative for this reaction?
2. Practice Quiz 2:
    a. Which of the following thermochemical equations represent an endothermic reaction?

       A. $C_{graphite}(s) + 2\ kJ \longrightarrow C_{diamond}(s)$

       B. $2H_2(g) + O_2(g) \longrightarrow 2H_2O + 483.6\ kJ$
    b. A thermochemical equation is shown, with ΔH given to the side.
       $H_2 + Cl_2 \rightarrow 2HCl \quad \Delta H = -185kJ$
       Which of the following is another way of writing this equation?
        i. $H_2 + Cl_2 \rightarrow 2HCl + 185kJ$
        ii. $H_2 + Cl_2 + 185kJ \rightarrow 2HCl$
    c. A thermochemical equation is shown, with ΔH given to the side.
       $H_2 + Cl_2 \rightarrow 2HCl \quad \Delta H = -185kJ$
       Is this an exothermic or an endothermic reaction?
        i. Exothermic
        ii. Endothermic
3. Culminating Formative: In-notebook Drawing of Potential Energy diagram with four labels: Energy of Reactants, Energy of Products, ΔH & Activation Energy.
    a. Scenario: A student performed an experiment to determine if a reaction was endothermic or exothermic. Draw her results in your notebook.
        i. Give yourself a vertical axis of 0-60 kcal, and a horizontal axis of 0-10 ms (milliseconds). TIP: Create axis and dot your data points first, then connect them as smoothly as you can with a line.
        ii. Here is the data for the reaction:
            1. 40 kcal at 0 ms (Reactants)
            2. 41 kcal at 2 ms
            3. 50 kcal at 3 ms
            4. 60 kcal at 4 ms
            5. 45 kcal at 5 ms

6. 15 kcal at 7 ms
7. 10 kcal at 8 ms
8. 10 kcal at 10 ms

b. Does your graph look something like this? (without the arrows)



c. Now draw arrows and label: Energy of Reactants; Energy of Products; ΔH (Change in Enthalpy); and Activation Energy. Title the Graph: "Potential Energy Diagram for _____thermic Reaction"

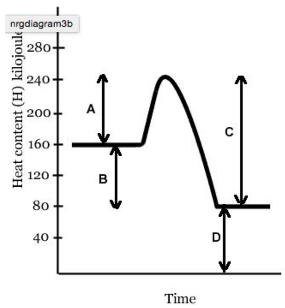
Day 7	
Topic:	Enthalpy, Heat of Reaction & Potential Energy Diagrams (Continued)
Learning Goal:	Students will apply their learning over the previous two days to answer questions regarding changes in Enthalpy, Thermochemical equations and Potential energy diagrams.
Evidence of Learning:	Students will complete a graded, open-notebook quiz (on the Canvas platform) representing sample questions from the two covered standards.
Standards:	• **SC.912.P.10.6 -** Create and interpret potential energy diagrams for chemical and physical processes. (Create or interpret a diagram relating the potential energy of an object in a defined system to its position given the necessary information including energy of reactants/products, activation energy, absorption or releasing of heat) • **SC.912.P.10.7 -** Distinguish between endothermic and exothermic chemical processes, physical or chemical. (Includes Graphical representations of the energy of reactants and products to determine whether a reaction is endothermic or exothermic; and chemical / mathematical representations of heat of reaction including sign of enthalpy and thermochemical equations)

Further Details
• Students spend the period working independently or in groups on the Graded Canvas Quiz (Open Notebook): “12.4 Showing Enthalpy Changes: Heating Curves & Potential Energy Diagrams.” Questions 1-8 only, topic is interpreting potential energy diagrams.

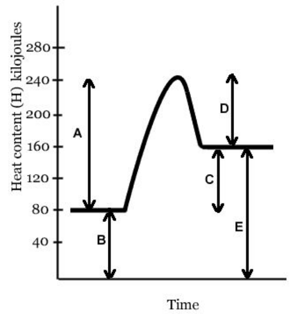
Formative Assessment

Graded Canvas Quiz: 12.4 Showing Enthalpy Changes:
Heating Curves & Potential Energy Diagrams

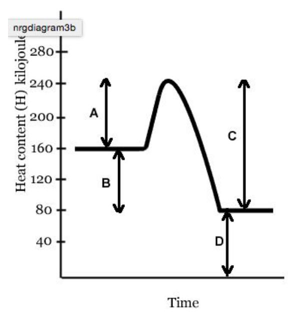
The following section is about Potential Energy Diagrams.
(Refer back to the 12.3 Slides on the Agenda if you need a refresher).



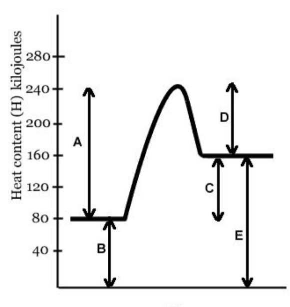
1. Look at this potential energy diagram. The line that represents the enthalpy change (also known as ΔH) of this reaction is:
    a. A
    b. B
    c. C
    d. D
2. According to the graph above, the reactants have an Enthalpy of 160 kJ and the products have an Enthalpy of 80 kJ. The sign and value for ΔH, also known as heat of reaction, is: (Hint: It is possible to solve this algebraically, but I also advise you solve it by looking AT the diagram).
    a. $\Delta H = 80 + 160 = + 240$ kJ
    b. $\Delta H = 160 - 80 = + 80$ kJ
    c. $\Delta H = 80 - 160 = - 80$ kJ
    d. $\Delta H = 80 \times 160 = + 12800$ kJ



3. Look at this potential energy diagram. The line that represents the activation energy (Ea) of this reaction is:
    a. A
    b. B
    c. C
    d. D
    e. E

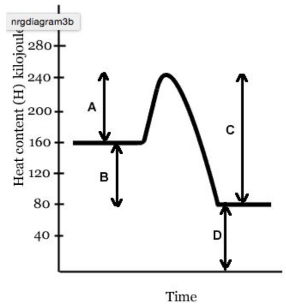


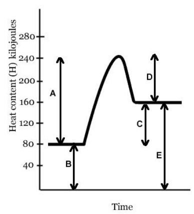
4. Look at this potential energy diagram. The line that represents the activation energy (Ea) of this reaction is:
    a. A
    b. B
    c. C
    d. D

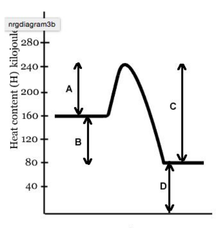


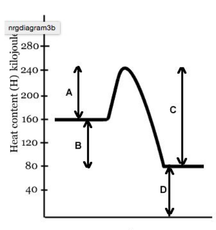
5. In this reaction, what statement describes the relative energy of reactants and products:
    a. the energy content of the products is greater than the energy content of the reactants.

b. the energy content of the reactants is greater than the energy content of the products.
c. the energy content of the products is the same as the energy content of the reactants.



6. Look at this potential energy diagram. The reaction whose energy diagram is shown here is:
    a. Isothermic
    b. Etothermic
    c. Endothermic
    d. Exothermic
7. Which graph would best represent a candle being lit and then burning?
    a. 

Because it's endothermic with activation energy
    b. 

Because it's endothermic with activation energy.
    c. 

Because it's exothermic with activation energy.

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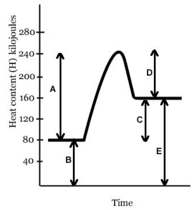
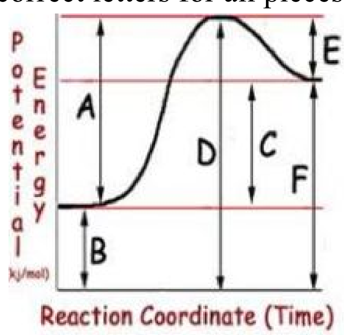
d. 

Because it's exothermic with activation energy

8. Match the labels with the correct letters for all pieces of this diagram:



a. Activation Energy (Ea)
b. Energy (Enthalpy) of Reactants
c. ΔH (Change in Enthalpy)
d. Energy (Enthalpy) of Products
   i. Matching Options: A, B, C, D, E, F
</td></tr>
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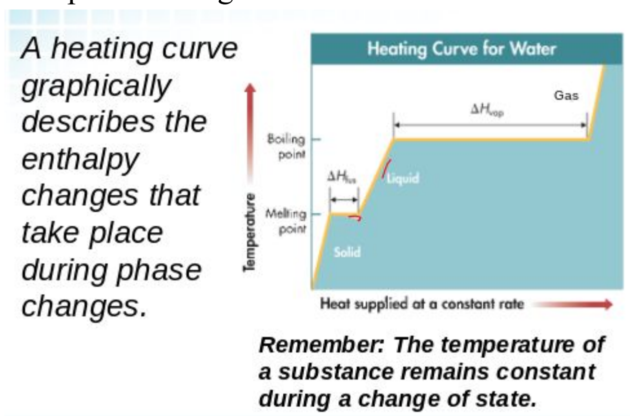
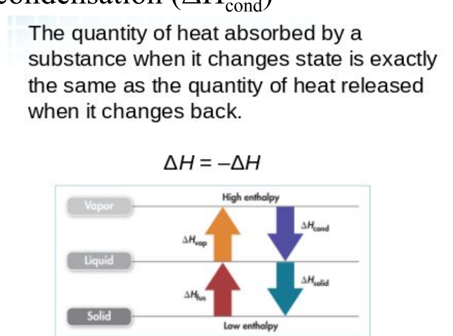
Day 8	
Topic:	Heating Curves & Thermal Energy during Phase Changes
Learning Goal:	Students will interpret energy in phase changes using a "Heating Curve" Diagram.
Evidence of Learning:	Students will complete a graded, open-notebook quiz (on the Canvas platform) representing sample questions from covered standard.
Standards:	• **SC.912.P.10.5 -** Students will be able to relate the behavior and kinetic energy of a molecule with the temperature of the substance. (Students will be able to understand energy and phase transitions using a heating curve and the relationship between heat and temperature, including the energy changes that occur at different points in a heating curve.)
Further Details	

- Introduction: Two beakers of room-temperature water are shown, and their temperature measured with a thermometer (both around 23℃)
  - One beaker is heated on a hot plate, while plentiful ice is added to the other.
  - Temperature is taken at 3-5 minute intervals throughout the period and recorded on the board.
  - The heated beaker will increase steadily in temperature until 100℃, and then remain there. The ice beaker will decrease steadily until 0℃ and then remain. Students may view the thermometers for themselves to verify the phenomenon.
- 4 slides shown to explain heating curves.



- Definitions shown for:
  - molar heat of fusion (ΔH_{fus})
  - molar heat of solidification (ΔH_{solid})
  - molar heat of vaporization (ΔH_{vap})
  - molar heat of condensation (ΔH_{cond})

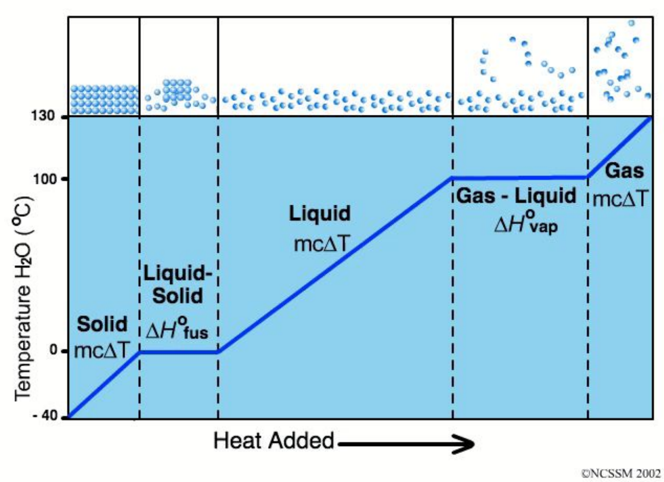


- Students shown video in class: https://drive.google.com/open?id=1prnsWk6lsKJAASXUz_HxlWnqlSp4B9jm
- Students spend the rest of the period working independently or in groups on the Graded Canvas Quiz (Open Notebook): "12.4 Showing Enthalpy Changes: Heating Curves & Potential Energy Diagrams." Questions 9-14 only, topic is heating curves.

Formative Assessment

Graded Canvas Quiz: 12.4 Showing Enthalpy Changes:
Heating Curves & Potential Energy Diagrams

For the following questions, refer to the video and the 12.4 slides.
The image shown from this video is also here:



9. True or False: If you put a bunsen burner under a block of ice, the temperature goes up smoothly.
10. Type in WHOLE NUMBERS ONLY. Refer to the VIDEO shown in class and/or the diagram given above:
    a. What is the freezing point of water? __________ °C
    b. What is the boiling point of water? __________ °C
11. When heating water from solid to liquid to gas, when is the temperature constant (unchanging)? Select ALL that apply.
    a. when it is gas.
    b. when it is liquid.
    c. when it is melting.
    d. when it is solid.
    e. when it is evaporating.
12. When heating water from solid to liquid to gas, when is the temperature rising? Select ALL that apply.
    a. when it is gas.
    b. when it is liquid.
    c. when it is melting.
    d. when it is solid.
    e. when it is evaporating.

13. The Heat of fusion (ΔH_{fus}) for water is 334 J/g. What is the Heat of solidification?
    a. - 1/334 J/g
    b. 1/334 J/g
    c. 334 J/g
    d. - 334 J/g
14. The above makes sense because fusion (melting) is the _____ of solidification (freezing), so they would have _____ amount of energy change but with different signs. Since fusion (melting) is an _____ process, we would expect a/an _____. On the other hand,we would expect a/an _____ when going the other way to solidification (freezing), which is a/an _____ process.
    a. *Drop-down options given.*

Day 9: Review Day

Kahoot Activity https://play.kahoot.it/#/k/e348ddee-95b7-4184-a00c-60feef31962e

Day 10: Summative Exam