Thermochemistry

High School Chemistry
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Idaho State Science Performance Standards:

- **PSC3-HS-2** Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
- **PSC3-HS-3.** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).
- **PSC3-HS-4.** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
- **PSC3-HS-5.** Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperatures are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

Science & Engineering Practices:

- Using Mathematics and Computational Thinking
- Developing and Using Models
- Constructing Explanations and Designing Solutions
- Planning and Carrying Out Investigations

Crosscutting Concepts:

- Systems and System Models
- Energy and Matter

Idaho Math & ELA Standards:

ELA/Literacy

- **SL.11-12.5** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS3-1)
- **WHST.9-12.7** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS3-3)
- **RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS3-4)
- **WHST.11-12.8** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS3-4)
- **WHST.9-12.9** Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS3-4)

Mathematics

- **MP.2** Reason abstractly and quantitatively. (HS-PS3-1)
- **MP.4** Model with mathematics. (HS-PS3-1)
- **HSN.Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS3-1)
- **HSN.Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-1)
- **HSN.Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1)

Learning Objectives:

What will students be able to do, know, understand, etc?

1. Differentiate temperature, energy, and heat.
2. Evaluate the usefulness of various forms of energy.
3. Energy cannot be created or destroyed; it can change forms or transform from one type of energy to another.
4. Energy is invested (absorb) to break bonds and forces of attraction; energy is released when more stable bonds form or new attractions form. Thus during a change, when attractive forces are broken and new attractive forces form, there is always a net change in energy.

5. Define exothermic and endothermic changes and discuss the transfer of energy for each.
6. Be able to interpret and write thermochemical equations.
   Be able to use dimensional analysis and thermochemical data in stoichiometric calculations.
   Define specific heat and explain the difference between chemicals that have high specific heat capacities and chemicals that have low specific heat capacities.
7. Perform calorimetry experiments to gather data including masses and temperature changes.
8. Calculate energy transfers using the equation $q = c\ m\ \Delta\ T$.

Essential Question:

In what ways can the flow of energy be mapped through a system?

Guiding Questions:

What questions will constantly focus the students on the Big ideas/Critical Question within the unit in student language?

1. In what ways can scientist improve, revise, and redesign an experiment to reduce the amount of error when calculating energy transfer?

Misconceptions/Evolving Conceptions:

What might students commonly misunderstand about the subject? How will I directly address these?

1. Heat and temperature are the same thing, and both are talked about as objects.
2. Energy is stored in food.
3. Energy is released when bonds break (not from the formation of more stable bonds)
4. ΔH enthalpy is the same a q heat.
5. Here are some misconceptions about Heat, Temperature, and Energy
   a. Common Misconceptions about Heat and Insulation — Keeping Warm — Beyond Penguins and Polar Bears
6. Students may think heat is a substance or that heat is not energy instead of thinking that heat is energy.
7. Students may think that temperature is a property of a particular materials or object instead of thinking that temperature is not a property of materials or objects. Objects exposed to the same ambient conditions will have the same temperature.
8. Students may think the temperature of an object depends on its size instead of thinking that temperature does not depend on size.
9. Students may think heat and cold are different instead of thinking that cold is the absence of heat. Heat and cold can be thought of as opposite ends of a continuum.

10. Students may think that cold is transferred from one object to another instead of thinking heat is transferred from one object to another. Head moves from the warmer object to the cooler object.
11. Students may think that objects that keep things warm are the sources of heat instead of thinking that objects keep things warm by trapping heat.
12. Students may think that some substances cannot heat up instead of thinking that all substances heat up, although some gain heat more easily than others.
13. Students may think that objects that readily become warm do not readily become cold instead of thinking that conductors gain (and lose) heat easily.

Scaffold of Activities:

What is your lesson sequence you will use to get students to the culminating project?

These lessons span 6 weeks of 53-minute classes.

1. Frontloading/Introduction
    a. Students are instructed to bring food labels from home (a variety is best). Having extra on hand is always a good idea. Students are tasked at the table groups with sorting and restoring the labels based on the following:
        i. Sort from least tasty to most tasty
        ii. Sort from lowest calories to highest calories
        iii. Sort from junk food to healthy
    b. Ask students, "Is there a connection between the printed information on the nutrition label and the way you sorted them? (This will bring on a whole class discussion about sugar, fats, fiber, and protein and calories.)
    c. A Bunsen burner is set up at the demonstration table with a weak flame. Students are asked to make a prediction about what will happen when each of these items are sprinkled over a flame. They are asked to define their claim with evidence from the activity and discussion above. The following items are sprinkled over the flame:
        i. Sugar free powdered coffee creamer
        ii. Powdered sugar
        iii. Granular sugar
        iv. Flour
        v. Fine saw dust
    d. Ask students, 'Did your prediction match reality? Why or why not? If energy is in objects, then way does fiber (like the saw dust) not have any calories? What reasoning might explain this?"
2. Thermochemistry Opener lesson plan Temperature, energy and heat are fundamental to understanding the Laws of Thermodynamics. These terms have very specific uses in science that tends to be misused in our daily life understanding of these concepts. This creates misconceptions which are difficult to clarify. The opening lesson plans are designed to give learners a good foundational understanding to further their knowledge of thermochemistry.
    a. Students will differentiate temperature, energy, and heat

b. Evaluate the usefulness of various forms of energy
c. Energy cannot be created or destroyed; it can change forms or transform from one type of energy to another.

3. Formative assessment on understanding temperature and energy.
4. Students will draw distribution curves of probability versus velocity. Students work in groups of 4 to discuss and draw a curve, then they present it to the class.
5. There are common labs for measuring heat transfer in the high school chemistry lab. Most of these produce rather disappointing results when it comes to the amount of error. Therefore, it is important to help students understand that these experiments are very inaccurate models of how the real standard values are calculated. We do not want students to be left with the misconception that standard values (like specific heats) are not valid or achievable numbers. Students also need to understand that science is a process of retesting and redesigning our experiments to reduce the amount of error leading to the true value. Calculating the specific heat of water, Specific heat of copper lab, Calorimetry lab are three labs that produce results with a high percent error.
   a. Students will define specific heat and explain the difference between chemicals that have high specific heat capacities and chemicals that have low specific heat capacities.
   b. Students will calculate energy transfers using the equation $q = c\ m \Delta\ T$
   c. Students will understand energy is invested (absorbed) to break bonds and forces of attraction; energy is released when more stable bonds from or new attractions form. Thus during a change, when attractive forces are broken and new attractive forces form, there is always a net change in energy.
   d. Students will perform calorimetry experiments to gather data including masses and temperature changes.
   e. Students will define exothermic and endothermic changes and discuss the transfer or energy for each.
6. Mock Thermite Lab
7. Cooling Curve of Dodecanoic Acid
8. Interpreting phase diagrams
9. Triple point of carbon dioxide demonstration

Summative Assessment/Culminating Project:

Science is a body of knowledge which works on knowing things through experimentation. The power of knowing in science is the ability to tell others the degree to which we are certain of our knowledge. Science relies on testing and retesting our beliefs. Throughout this unit, you have performed many experiments, collected data and processed the data sets. You have evaluated each lab's data sets using central tendency statistics and calculations of error. Most of these labs produce results with large degrees of uncertainty. You will be tasked with redesigning one of three labs that we have performed to reduce the uncertainty.

Additional Helpful Resources:

Sources for lessons, website, etc.

- ACS Energy Foundations for High School Chemistry Energy Foundations for High School Chemistry
- Chemistry, Life the Universe and Everything (CLUE)CLUE: Chemistry, Life, the Universe and Everything
- Ian Guch The Cavalcade o' Chemistry | Celebrating 20 years of chemistry goodness. Seriously, we've been around for 20 years!
- POGIL Activities for High School Chemistry Chemistry
- Scoring holistic rubric for lab based assessment has been adapted from IBO 2009 International education - International Baccalaureate®
- The Trouble with Chemical Energy: Why Understanding Bond Energies Requires an Interdisciplinary Systems Approach by Melanie M. Cooper and Michael W. Klymkowsky The Trouble with Chemical Energy: Why Understanding Bond Energies Requires an Interdisciplinary Systems Approach