The In’s and Out’s of Energy in Reactions

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| **Chemistry Topic** | Thermochemical Equations |

**Concept Statement:**

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| * Every chemical reaction involves a transfer of energy in either the forms of heat, light, and/or sound. The form of energy being transferred is chemical potential energy, also known as enthalpy, and this energy transfer is a driving force of chemical reactions. Chemical reactions can be classified as either endothermic or exothermic. Exothermic reactions have a net release of energy from the system to the surroundings. Energy in exothermic reactions is considered a product, and the enthalpy has a negative sign. Endothermic reactions have a net absorption of energy into the system from the surroundings. Energy in endothermic reactions is considered a reactant, and the enthalpy has a positive sign. * In order for reactions to occur, the bonds within molecules must be broken first and the resulting atoms/ions must be in close proximity to each other for the reaction to happen. This requires energy called activation energy. Once a sufficient quantity of activation energy is acquired, new bonds between atoms/ions will form releasing energy. The difference between the bond energy in the reactants and the bond energy in the products determines whether a reaction is endothermic or exothermic. We can represent energy transitions in a chemical reaction using an energy diagram. * We do calorimetry experiments to determine the amount of heat transferred during a chemical reaction. The amount of heat either absorbed or released by a reaction in a calorimetry experiment is equal to the amount of enthalpy absorbed or released by the reaction. * Students need to understand that energy is an important theme in science and will cut across all science disciplines. In chemistry, the study of energy involves chemical reaction processes and will naturally lead into other forms of energy transfer through chemical reactions, notably, electrical energy through redox reactions. * Energy is an important theme that is applied throughout the real world. Combustion of hydrocarbon fuels produces sufficient energy to run transportations, energy production is a key cellular process in biological systems, and energy absorption is important for cold packs and refrigeration. |

**Source of Lesson:**

Flinn Scientific. (2013). Exothermic and endothermic reactions: An energy changes laboratory kit. <http://www.flinnsci.com/store/Scripts/prodView.asp?idproduct=16004>.

Brown, C., Henderson, H., Hook, J., Kirby, L., Leibl, C., McCormick, R., McGaw, L., Payton, M., Richards, D. (2001) 34: Thermodynamics. *Laying the Foundation: A Resource and Strategies Guide for Chemistry*. Dallas, TX: Advanced Placement Strategies, Inc. pp 691-694.

Flinn Scientific. (2007). The Chef: A Chemical Demonstration. *ChemFax!* [online] <http://www.flinnsci.com/media/522046/cf0203.00.pdf>.

**List of appropriate TEKS: 19 TAC § 112.35 (Chemistry)**

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| **TEKS #** | **Student Expectation** |
| 11 (c) | Science concepts. The student understands the energy changes that occur in chemical reactions. The student is expected to: use thermochemical equations to calculate energy changes that occur in chemical reactions and classify reactions as exothermic or endothermic |
| 11(e) | Science concepts. The student understands the energy changes that occur in chemical reactions. The student is expected to: use calorimetry to calculate the heat of a chemical process. |
| 2(F) | Scientific Processes: The students uses scientific methods to solve investigative questions. The student is expected to:  Collect data and make measurements with accuracy and precision. |
| 2(G) | Scientific Processes: The student uses scientific methods to solve investigative questions. The student is expected to: express and manipulate chemical quantities using scientific conventions and mathematical procedures including dimensional analysis, scientific notation, and significant figures. |

|  | **Objectives**  **By the end of the lesson, students will be able to:** | **Evaluation Questions** |
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| 1 | Determine the heat absorbed or released by a chemical reaction using calorimetry. | In a coffee cup calorimeter, 50.0 mL of 1.0 M NaOH and 50.0 mL of 1.0 M HCl are mixed. Both solutions were originally at 23.5°C. After the reaction, the final temperature is 29.9 °C. Assuming that all the solutions have a density of 1.0 g/mL, and a specific heat capacity of 4.184 J/g°C, calculate the enthalpy change for the neutralization of HCl by NaOH. Assume no heat is lost to the surroundings or the calorimeter. |
| 2 | Classify reactions as being either endothermic or exothermic based on experimental data. | Based on your answer to #1, is the reaction endothermic or exothermic? Explain using two pieces of your data. |
| 3 | Write a thermochemical equation that correctly reflects the stoichiometry of the reaction. | Methyl alcohol (CH3OH) is completely combusted. Water vapor is one of its products. Write the balanced thermochemical equation for this reaction showing the enthalpy of the reaction (ΔHrxn = -1277 kJ/mol) as either a reactant or a product. |
| 4 | Use thermochemical equations to calculate energy changes in chemical reactions. | Calculate the enthalpy change for the following reaction if 25.00 g of calcium carbonate were used. |

**Resources, Materials, Handouts, and Equipment List in the form of a table: Example**

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| **ITEM**  **(Specify worksheets)** | **Quantity**  **(How many do you need?)** | **Source**  **(Who is responsible?** | **List who this is for (teacher, student, group)** |
| Goggles | 30 | Already in classroom | Students and teacher |
| Splash apron | 30 | Already in classroom | Students and teacher |
| Styrofoam® cups | two per lab group | Lab supplies | Students |
| Temperature probe | One per lab group | Already in classroom | Students |
| CBR ® and TI-84 plus calculator (or computer with LoggerPro® software) | One per lab group | Already in classroom | Students |
| Ammonium nitrate, solid | 24 g/lab group | Chemical supplies | Students |
| 1.0 M hydrochloric acid solution | 50 mL/lab group | Chemical supplies | Students |
| 1.0 M sodium hydroxide solution | 50 mL/lab group | Chemical supplies | Students |
| Sodium hydroxide flakes | 16 g/lab group | Chemical supplies | Students |
| Distilled or deionized water | 1 gallon | Chemical supplies | Students |
| Balance | 1 per lab table | Lab supplies | Students |
| 400 mL beaker | 1 per lab group | Lab supplies | students |
| 50 mL graduated cylinder | 1 per lab group | Lab supplies | Students |
| Spatula or scoop | 3-4 | Lab supplies | students |
| lump calcium oxide, fresh | 100-200 g | Chemical supplies | teacher |
| Cooking oil | 5 ml (approx. 1 tsp) | Chemical supplies | Teacher |
| Stirring rod | 1 | In classroom | Teacher |
| small aluminum pie pans | 2 | In classroom | Teacher |
| Small egg | 1-2 | Grocery store | Teacher |
| Spatula | 1 | In classroom or at home | teacher |
| Oven mitt | 1 | In classroom or at home | teacher |
| Snack-size Ziploc bag with assorted small opaque and clear Legos® | One per lab group | Lego® store and grocery store | student |

**Safety:**

* Have hard copies of all MSDS for every chemical used in the demonstration and the lab.
* Demo safety: (from “The Chef” demo instruction sheet) Calcium oxide is corrosive and a severe body tissue irritant. Avoid all body tissue contact. Reaction of calcium oxide with water produces large amounts of heat energy and skin burns are possible. A lump of calcium oxide may disintegrate violently and splatter when water is added. Wash hands thoroughly when finished. Do not allow students to perform this procedure. Do not eat the egg. Wear chemical splash goggles, chemical resistant gloves, and a chemical-resistant apron.
* Lab Safety: Ammonium nitrate is a strong oxidizer and may explode if heated under confinement. Ammonium nitrate is slightly toxic by ingestion (LD50 = 2217 mg/kg) and may be a body tissue irritant. Hydrochloric acid solution is toxic by ingestion or inhalation, and is severely corrosive to skin and eyes. Sodium hydroxide, both as a solid and as a solution, is corrosive and may cause skin burns. Much heat is evolved when sodium hydroxide is added to water. It is very dangerous to eyes. Avoid all body tissue contact with all chemicals. Wear chemical splash goggles, chemical resistant gloves, and a chemical resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. (Flinn Scientific, pp 2-3)

**Advanced Preparations:**

1) Prepare bags of Legos® by placing 5 clear small amber pieces, 10 clear small amber pieces (smaller than the amber pieces), two of each of the following small opaque pieces: dark green, red, blue, yellow, and one of each of the following small opaque pieces: white, pink, orange. Prepare handouts for Explore activity.

2) Prepare lab “Exothermic and Endothermic Reactions” according to Teacher Notes page in lab kit.

3) Prepare demonstration “The Chef” according to directions in ChemFax (<http://www.flinnsci.com/media/522046/cf0203.00.pdf>).

**PowerPoint: **

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| **Objective Statement:** The goal of this lesson is to use thermochemical equations to calculate energy changes that occur in chemical reactions, classify reactions as either endothermic or exothermic, and use calorimetry to calculate the heat of a chemical process. | | |
| **ENGAGEMENT Time (Including pre-test): 5 -10 Minutes** | | |
| **What the Teacher Will Do** | **Probing/Eliciting Questions and Students Responses** | **What the Students Will Do** |
| Have everything set up on a demo table for a ‘cooking show.’ Before walking into the classroom, put on chef’s hat and a chef’s attitude. Then greet the class: “Good afternoon! My name is \_\_\_\_ (cool chef’s name) and today I will show you how to cook an egg properly.”  Warn them that this is not a typical way to cook an egg, but a new and fabulous technique from the chemists at Flinn Scientific. (Ham it up as appropriate.)  Complete the demonstration as described in the demonstration instruction sheet (<http://www.flinnsci.com/media/522046/cf0203.00.pdf>).  Show the table for the heats of formation of the substances, then pose the following questions. Tell the students that today’s lesson will involve using this type of information and experimental data to calculate energy changes that occur in chemical reactions and classify reactions as being either endothermic or exothermic. Tell them we will come back to these questions later in the lesson.  State objectives for today’s lesson.  Hand out lab sheets for the Exothermic and Endothermic Reactions. Students should write hypotheses about the reactions.  Instruct students about safety requirements for this lab. | Questions to ask after demo:   1. If the only product is Ca(OH)2 (s), calculate the heat released per mole. (*ΔHrxn = -65.2 kJ/mol)* 2. If the only product is Ca(OH)2 (aq), calculate the heat released per mole.   (*ΔHrxn = -81.9 kJ/mol)*  Questions about safety:   1. Based on what you read, what must you wear throughout the lab? (goggles and splash apron) 2. What should you do if you break something? (notify the teacher immediately and wait for the teacher to give you instructions) 3. How should excess acid/base be disposed of? (Excess acid should be neutralized with baking soda then flushed down the drain with water. Excess base should be neutralized with small amounts of HCl until litmus just turns red, then flushed down the drain with water.) | Students will watch demonstration and answer questions about the demonstration.  Students will form hypothesis about what will happen in the laboratory, answer questions regarding safety in the lab, and answer pre-lab questions. |

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| **EXPLORATION Time: 30 - 45 Minutes** | | |
| **What the Teacher Will Do** | **Probing/Eliciting Questions and Student Responses** | **What the Students Will Do** |
| Teacher will demonstrate how to set up and use the CBL® with temperature probe or LoggerPro® software with temperature probe.  Teacher will instruct students to move quietly to lab area, put on safety gear, then begin working on lab. Teacher will monitor students to make sure safety gear is worn correctly before beginning lab.  What are the directions for the exploration activity? Write them here:  *Follow directions on student handout as written. Dispose of all used chemicals according to the directions.*  What will the teacher do while students are working on exploration activity?  *Teacher will monitor student work in the lab, answer questions posed by students, monitor safety and discipline students accordingly, and ask probing questions to further conceptual understanding.*  What will the teacher do to wrap up the exploration activity?  *Teacher will remind students during last 10 minutes of lab to clean up and put away materials properly. Teacher will also remind students that safety gear must stay on until after they have cleaned up lab area. Those who finish early may sit down and begin calculations. All students will complete calculations before moving on to next part of lesson.* | What do you notice happening to the temperature when you mix \_\_\_\_\_ with \_\_\_\_? (depends on reaction)  How many significant figures should be in your mass measurements? (depends on precision of the balance, usually to the nearest 0.01 g)  How many significant figures should be in your temperature measurements? (depends on the precision of the temperature probe system, usually to the nearest 0.01 °C)  If the temperature is rising, where is the energy coming from? (from the chemicals I mixed together as reactants) Where is the energy going? (To the solution/water)  If the temperature is dropping, where is the energy coming from? (from the solution/water) Where is the energy going? (to the chemicals I mixed together as reactants)  What kind of energy changes are you observing with this reaction? (chemical potential energy being converted to thermal energy if exothermic; thermal energy being converted to chemical potential energy if endothermic)  Where is chemical potential energy stored? (chemical bonds) | Students will work with their lab partner (no more than 3 in a group, 2 is preferred.) to complete lab activity “Exothermic and Endothermic Reactions.” All safety rules are followed. Data is recorded accurately using as many significant digits as the measuring tool will provide.  Students will clean up lab and return to their seats to work on calculations for each reaction. Students can work with their lab partner to calculate the energy either absorbed or released for each reaction using q=mCΔT assuming C = 4.814 J/g°C since every reaction is occurring in an aqueous system.  \*\*Students complete post-lab discussion questions for homework and bring them to class for discussion in the Explain section of the lesson.\*\* |

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| **EXPLANATION Time: 30 Minutes** | | |
| **What the Teacher Will Do** | **Probing/Eliciting Questions and Student Responses** | **What the Students Will Do** |
| 1. Teacher will put spreadsheet on screen that is set up for students to record their calculated results for each reaction in the lab. One cell at the bottom of the column is set to calculate the average of all the groups’ results.   2) Teacher will then review key vocabulary and discuss the concept of thermochemical equations.  3) Teacher will then use the Legos® to model how bond energy changes during a reaction and to draw energy diagrams. Teacher will guide students through Lego® activity and continuously check for understanding as the activity progresses. Answer Key is below:    4) Teacher will go back to “The Chef” demo and finish calculating the energy for the reaction and discuss the use of calcium oxide in construction.  5) Teacher will work example stoichiometric problems involving energy. | 1. Why do we want a class average of all our results for each reaction? (The average of all results is closest to the real value for the enthalpy of the reaction.) 2. A)What does endo- mean? What does exo- mean? What does therm mean? With that in mind what does the term endothermic mean? Exothermic? 3. What does q stand for? How does it relate to enthalpy? 4. If energy is a reactant, where would I put it in the chemical equation? 5. If energy is a product, where would I put it in the chemical equation? 6. Does energy get a coefficient like substances do? Why/why not?   3) a) Does breaking bonds require energy? How do you know?  b) Does making bonds require energy? How do you know?  c) Does making bonds require more energy than breaking bonds? How do you know?  4) How much energy was produced in the demo?  5) See slideshow for sources of questions. | 1) Students will record calculated energy values in spreadsheet for the class. They will record the class average in their lab report.    2) Students will listen and take notes during vocabulary review and concept of thermochemical equations  3) Students will work with their lab partner to investigate and model bond breaking and bond formation through a guided practice and discussion. They will draw an endothermic and an exothermic energy diagram after building models using Legos® then calculate the net energy change for the reaction. Student handout is below:    4) Students will listen and take notes as teacher shows how to work stoichiometry problems. Students will help teacher solve problems. |

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| **ELABORATION Time: 20 Minutes** | | |
| **What the Teacher Will Do** | **Probing/Eliciting Questions and Student Responses** | **What the Students Will Do** |
| Teacher will instruct students to work with their lab partner to complete the post-lab questions and write a conclusion for the lab.  Teacher will then have students complete Thermochemical Equations Problem Set for HW. | What was your hypothesis at the beginning of the lab? Does your data support this hypothesis? Why/why not?  What other evidence of energy changes did you notice as you completed the lab activity? (*increased movement of solid particles due to thermal energy being converted to kinetic energy, noises given off because thermal energy is translated to sound energy*) | Students will work with their lab partner to complete the post-lab questions and write the conclusion for the lab.  \*\*HW: Complete Thermochemical Equations Problem Set\*\* |
| **Closure Statement** | | |
| In this lesson on thermochemical equations, you have observed a number of exothermic and endothermic reactions, calculated the energy either absorbed or released by the reactions, and incorporated the energy of the reaction into the balanced chemical equation. You have also learned how to take a thermochemical equation and use it to do stoichiometric calculations involving mass, moles, and energy. Energy is an important theme in science and will cut across all science disciplines. In chemistry, the study of energy involves chemical reaction processes and will naturally lead into other forms of energy transfer through chemical reactions, notably, electrical energy through redox reactions. Combustion of hydrocarbon fuels produces sufficient energy to run transportations, energy production is a key cellular process in biological systems, and energy absorption is important for cold packs and refrigeration. | | |

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| **EVALUATION Time: 15 Minutes** | | |
| **What the Teacher Will Do** | **Probing/Eliciting Questions** | **What the Students Will Do** |
| The teacher will allow 15 minutes for the post-test. | See evaluation questions with Objectives | Students will clear their desks for the final evaluation.  The students will complete a post-test. |