**Subject area/course**: Science/Chemistry

**Grade level/band**: 9-12

**Task source**: Achieve

**Sub-Zero**

**STUDENT INSTRUCTIONS**

1. **Task context**:  
   The Alaskan Bering Sea is known for producing one of the world’s most prized types of seafood, the Alaskan king crab. Fishermen often endure harsh seas and bone-chilling sub-zero conditions while fishing for these creatures. Staying warm in these difficult conditions is crucial, both for them to survive and to maintain their livelihood. External warming devices, such as hand-warmers, can be very helpful to fishermen and others who face extreme cold temperatures on a regular basis. You will use what you know about electron states, chemical reactions, periodic trends and bond energy to plan a device that uses a chemical reaction to help keep a fisherman’s hands warm.

*Task Components*

1. Using Table A in Attachment 1, select one dissolution and one chemical reaction to analyze for its ability to heat its surroundings. Create a drawing on Attachment 2 representing the molecular level of compounds before and after the chemical processes. Use your knowledge of outer electron statesand patterns of chemical properties (such as the patterns in the periodic table) to construct an explanation of why the chemical reaction occurs or what chemical property leads to dissolution. *(Safety Note: Reactions involving alkali metals and water are dangerous and should not be used.)*
2. The coffee cup calorimeter is often used in lab experiments to evaluate the transfer of energy from one object to another as well as to determine the amount of energy released from a chemical process. The calorimeter is constructed by stacking two coffee cups together and placing a lid on the cups (see Reference Sheet A, Attachment 1). You need to determine whether a coffee cup calorimeter will give you accurate data about the reaction you are considering. Investigate the claim that a coffee cup calorimeter is a closed system and can be used to determine the transfer in energy between two substances, as follows: Make a prediction of the final temperature that a solution of 100 mL of 100 °C water plus 100 mL of 50 °C water would create. Perform sufficient trials of this investigation to provide reliable data, and record findings on Data Sheet B (Attachment 3). Describe the initial conditions of the calorimeter system, including the components inside the calorimeter, the calorimeter and the calorimeter’s surroundings. Using the data from the investigation as evidence, construct an argument that supports or rejects the claim that a coffee cup calorimeter is a closed system. Cite evidence when supporting or refuting the claim that the system is isolated from the surroundings and describe the final system conditions at the point of highest solution temperature. *[Teacher Notes: Students will find that the calorimeter is not a perfectly isolated system. However, because thermal loss is relatively small, the calorimeter provides a simple way of collecting meaningful data for general analysis.]*  
     
   *Additional Option: Quantitative analysis of energy can be completed by calculating enthalpy of energy lost or gained by the components of the system (Q lost by hot water = Q gained by calorimeter + Q gained by water in calorimeter, Q* = (*C*)(m)(∆T). *It can be assumed that the surrounding environment, calorimeter and initial solution in the calorimeter are at the same temperature if water is allowed to reach room temperature by sitting out overnight and that the highest solution temperature also is the final temperature of the calorimeter.*
3. Using the knowledge you have gained about calorimetry as way to measure thermal energy transfer, conduct an investigation to collect evidence that thermal energy is released when bonded atoms are separated, as a means determining whether the reaction you are investigating can be used to create a hand warmer. Using the two processes selected in Task Component A, determine the temperature change generated when compounds are added to 100mL of water (solvation) or to 100mL HCl (chemical reaction) solution in the calorimeter system. Select three or more quantities of each solid compound (10 grams or less for dissolution and 1 gram or less for reactions with HCl) to test and perform a sufficient number of trials to establish validity of the results. Perform trials and record data on Data Sheet C (Attachment 4) and graph the ∆T/mass of each solid (g). Justify why you chose the quantities you selected for each reaction type.
4. Using the data from your experiment and the information provided on Reference Sheet E (Attachment 5), create models and graphs of what is happening at the molecular level to illustrate the change in energy of the system before and after the chemical reactions in your experiment occurred. Your model should show the chemical components in the system and the movement of energy within the system and between the system and the surroundings. Your graph(s) should illustrate the relative change in bond energy before and after the experiment and the relative change in thermal energy before and after the experiment. Use your graphical representations to explain the change in the energy of the chemical system (bond energy or thermal energy) from the start to the end of the experiment as the energy is released or absorbed during the chemical reaction.
5. Using Data Sheet E (Attachment 7), complete the table and graph comparing the theoretical temperature change from Reference Sheet E (Attachment 5) and the actual temperature change from your experiment. For each dataset (theoretical and experimental), write an equation for a line of best fit that can be used to predict the change in temperature based on the mass of the compound.  *Additional Option: Instead of providing students with the theoretical temperature changes on the data table provided, students could calculate them using enthalpy values listed on data table.*
6. Using the data and equations from the previous components, determine whether the experimental temperature change is similar enough to the theoretical temperature change to make accurate predictions about the change in temperature of other substances not tested or other mass amounts not tested. Use evidence from the experiment and plots to support or refute your claim.
7. Temperatures in the Arctic Circle can fall well below 0 °C and can cause extreme frostbite. Fishermen wear gloves to protect their hands from the cold and use hand warmers for supplemental heat. However, temperatures above 49 °C for extended periods of time can cause severe skin burns. Assume that the starting temperature for the hand warmers in a glove is 5 °C. Use the formula written in Task Component F to determine the quantity of solids that would be needed to achieve a peak temperature of 49 °C for each compound selected.
8. **Final product**:

Use evidence collected in Task Components A through G to make a claim stating whether the chemical process tested could be considered a viable and safe option for use as hand warmer components. The claim should take into account the process’s ability to produce heat, the quantity of reactants required, and the safety of the compounds required to achieve sufficient temperature change. Cite specific data and your models as evidence to support your reasoning.

**ADDITIONAL INFORMATION**

1. **Knowledge and skills you will need to demonstrate on this task:**

|  |  |
| --- | --- |
| Knowledge | Skills |
| * the nature of chemical bonds * the forming and breaking of chemical bonds * trends on the periodic table * appropriate chemical safety techniques | * creating and documenting a chemical experiment * Constructing a claim based in evidence and reasoning to support that claim in written form * Find a line of best fit on a scatter plot and explain its meaning in context of the data |

1. **Materials needed:**

To do the experiments for Task Components B and C, you will need access to safety equipment, laboratory space, and reactants and calorimeters as laid out in Attachment 1.

1. **Time requirements:**

This task will take approximately 1-2 weeks to complete. Your teacher will provide details regarding timelines and due dates.

1. **Scoring:**

Your work will be scored using the SCALE Scientific Practices rubric. You should make sure you are familiar with the language that describes the expectations for proficient performance.