SPECIFIC HEAT OF METALS

Performance Standard 12D/11B/13A/.J

Students will apply the concepts, principles and process of technological design to explore thermodynamics accordingly:

- *Knowledge:* Determine the specific heat of unknown metals, based on student hypothesis and design proposal.
- *Application:* Determine a safe and accurate scientific-technological design process to determine the identities of unknown metals and use statistical analysis of percent (%) error to help support or refute hypothesis.
- *Communication:* Express an analysis of findings including question, hypothesis, rationale, data, calculations, and conclusion summary.

Procedure

1. ***In order to know and apply concepts that describe force and motion and the principles that explain them(12D), and the concepts, principles and processes of technological design (11B), and apply the accepted practices of science (13A),*** students should experience sufficient learning opportunities to develop the following:
   - Formulate a proposal to determine specific heat of unknown metals by referencing prior knowledge of thermodynamics and the processes of technological design.
   - Generate ideas for design mechanics, appropriate variables and tolerances for error.
   - Identify design constraints due to access to tools, materials, time, and precision.
   - Research applicable scientific principles and concepts of thermodynamics and applicable procedures to eliminate or reduce safety risks.
   - Design and conduct technological design for process of determining heat gained/lost/transferred in a system.
   - Develop the sequence of the process with visualizations.
   - Incorporate appropriate safety, available technology and equipment capabilities into construction/ manipulation.
   - Repeat procedural steps for multiple trials.
   - Collect and record data accurately, using consistent metric measuring and recording techniques and media with necessary precision.
   - Document data accurately in selected format.
   - Graph data appropriately to show relation to variables in design solution proposal.
   - Interpret and represent results of analysis to produce findings.
   - Compare data sets to design criteria for suitability, acceptability, to determine if data supports or refutes student hypothesis for identification, etc.
   - Propose explanations for sources of error in the data set for process design flaws.
   - Report the process and results of the investigation, including explanations of outliers, sources of error and statistical comparisons of percentage error.
   - Explain the application of investigation to transfer of heat using the laws of thermodynamics.
   - Explain how the experimental specific heat compares to the theoretical specific heat and impact of possible sources of error.
   - Communicate anecdotal and quantitative observations.
   - Analyze/critique a logical explanation of success or errors in other similar investigations.
   - Generate additional design modifications which can be tested later.

   Note to teacher: This activity relates to knowledge associated with standard 12D, while addressing the performance descriptors for stage J within standard 11A and 13A. This activity could be incorporated directly in a curricular study of thermodynamics, heat exchange, and calorimetry.
2. Have students review and discuss the assessment task and how the rubric will be used to evaluate their work.

3. Provide each student with a copy of the Specific Heat of Metals student instruction/task sheets and review lab report write-up requirements. Supply the students with the requested materials, emphasizing safety in the use of chemicals and heating source.
4. Evaluate each student's work using the Science Rubric as follows and add the scores to determine the performance level:
    - *Knowledge:* The hypothesis statement and rationale were complete and expressed a correct understanding of the process for determining specific heats for two unknown metals, calculations were done correctly, and data tables were used appropriately to provide organization.
    - Application*:* The investigation was designed with values expressing correct application of precision and accuracy. Students were able to use resources to identify metals provided, and were able to apply other criteria (color, density, etc.) as secondary support in their identification.
    - *Communication:* The conclusion summary was well-organized, well-detailed, and thoroughly explained the analysis of the hypothesis, the design process sequence with visualizations (as applicable) explanation of outliers, sources of error and their impact, and a reflection of potential design modifications.

Examples of Student Work not available

Time Requirements

- Approximately three class periods

Resources

- Specific Heat of Metals Instruction/Task Sheet
- Science Rubric
- Two metal samples
- Water (from a sink)
- Beakers
- Styrofoam cups
- Electronic balance
- Heating source (Bunsen Burner or Hot Plate)
- Goggles
- Two unknown metals with or without variations among students
- Graduated cylinder
- Access to Internet or tables of specific heats
- Thermometers

Table of Specific Heat Capacity (units used are J/g °C.)	
Metal	**Specific Heat Capacity**
Aluminum	0.903
Carbon	0.710
Copper	0.385
Gold	0.129
Iron	0.449
Lead	0.128
Mercury	0.140
Nickel	0.444
Platinum	0.133
Silver	0.235
Tin	0.227
Tungsten	0.132
Zinc	0.388
$Water_{(l)}$	4.184
$Water_{(s)}$	2.03
$Water_{(g)}$	2.0

Specific Heat of Metals Instructions

Determine the technological design for an investigation which will provide identification of two unknown metals, based on specific heat. Prepare a hypothesis for metal identification, proposal for the technological design of your proposed process including, its design constraints, and a mathematical method for determining the specific heat of an unknown metal.

Investigation Question: *(What are the identities of the two unknown metal samples provided?)*

Hypothesis*: (What do you propose that your sample is? What are the applicable scientific principles to be tested or modeled?)*

Technological Design: *(How will you determine the unknown? What are the design constraints? What technologies are needed? What safety precautions must be considered?)*

Mathematical Method for Determining the Specific Heat of an Unknown Metal: *(What are the appropriate variables?)*

Specific Heat of Metals Investigation (continued)

Materials must include the following:

- Two metal samples
- Goggles
- Appropriate technological support (including probeware, measuring and data-collection equipment, etc.)

Materials may include the following:

- Water (from a sink)
- Beakers
- Styrofoam cups
- Electronic balance
- Heating source (Bunsen Burner or Hot Plate)
- Goggles
- Two unknown metals
- Graduated cylinder
- Thermometers

*****Neither listing is all-inclusive.

In the space below, develop a procedure using the materials listed above that will determine the identity of the metals. Sketches or visualizations of process may be applicable. Specific heat of the metal must be the major criteria used in determining its identity. Determine the criteria for successful investigation and design constraints for this setting. Also, make certain that your procedure provides for precision and accuracy of experimental data. Secure teacher approval for all safety considerations and technical applications. Use extra lines as needed.

Procedure:

Data Table: Create appropriate data table with necessary quantitative variables on this page. Record qualitative observations, additionally.

Calculations: **Show calculations for specific heat and any quantitative factors you will use to identify the metal. Determine % error between the theoretical value and the experimental value for the metal you determine.**

Conclusion:

Write a conclusion summary that incorporates the design proposal, hypothesis, summary of findings, analysis of hypothesis, explanation of outliers, sources of error and their impact, reflection on potential investigation design modification.