Conservation of Energy and Specific Heat (ver. 5)

Purpose

To understand the principle of conservation of energy (thermal energy).
To determine the specific heat of solid body.

Background

The specific heat of a substance is the quantity of heat necessary to raise a unit mass of the substance by a unit temperature difference. When a heat interchange takes place between two bodies initially at different temperatures, the quantity of heat lost by the hot body is equal to that gained by the cold body, and some intermediate equilibrium temperature is finally reached. This is true provided no heat is gained from or lost to the surroundings. In this case, we can apply the principle of conservation of energy.

\[ \text{Heat lost by hot body} = \text{Heat gained by cold body} \]

Experimental Setup

Calorimeter: An insulated container that prevents heat from escaping or entering the system.
Beaker.
Solid samples: Tin (Sn), Silver (Ag), Copper (Cu), Iron (Fe), Aluminium (Al).
Liquid: Water, Ethanol, Isopropanol, Acetone.
Temperature probe.
Stirring rod.

To start the simulation, go to the following link:
https://media.pearsoncmg.com/bc/bc_0media_chem/chem_sim/calorimetry/Calor.php
Part I: Determining the Heat Exchanged

In this experiment, two liquids with different masses and temperatures are mixed. The heat energy $Q$ needed to raise the temperature by $\Delta T$ of a substance is related to its mass $m$ according to the formula,

$$ Q = mc\Delta T $$

(1)

where $c$ is the specific heat capacity of the substance.

Experimental Procedure and Data Analysis

1. Select a substance, mass and temperature for the beaker as per your instructor recommendations.
   1.1 Choose water as the first liquid.
   1.2 Record the specific heat of the liquid $c_w$.
   1.3 Choose the mass of water $m_w$.
   1.4 Choose the initial temperature of water $T_{wi}$.
2. Select a substance, mass and temperature for the calorimeter.
   2.1 Choose a second liquid as per your instructor recommendation.
   2.2 Record the specific heat of the liquid $c_l$.
   2.3 Choose the mass of the liquid $m_l$.
   2.4 Choose the initial temperature of the liquid $T_{li}$.
3. In the Run Experiment box, click on Show graph view.
4. Click the Start button to begin running the experiment.
5. Record the final (equilibrium) temperature $T_f$ indicated by the thermometer.
6. Compare this temperature to that obtained theoretically (% difference). **Show the details of your calculation.**
7. Calculate the experimental amount of heat exchanged $Q$. **Show the details of your calculation.**
8. Compare this energy to that calculated theoretically (% difference).
9. If we assume that, we have measurement errors of 3% for the mass and 3% for the temperature and 5% for the specific heat capacity, calculate the error in the measurement for the heat exchanged. **Show the details of your calculation of error.**
10. Fill the table below.
11. Click the Replay button to run the experiment again if necessary.
12. Click the Reset button to start a new experiment and **choose a different second liquid, assigned to you by your instructor, and repeat steps 2 to 10.**
Part II: Determining the Specific Heat Capacity of a Solid

In this experiment, a solid sample of known mass \((m_{\text{sol}})\) is heated to a certain temperature \((T_{\text{sol}})\). It is then quickly transferred to a calorimeter, which contains cold water of known temperature \((T_w)\) and mass \((m_w)\). When the solid sample and the calorimeter (including water) come to equilibrium, the final temperature \((T_f)\) is noted. It is assumed that the heat loss to the thermometer is negligible and if the heat exchange with the environment is kept small, then the heat lost by the solid sample \((-Q_{\text{sol}})\) is equal to the total heat gained by the calorimeter \((Q_{\text{cal}})\) and the water \((Q_w)\). Thus, applying the principle of conservation of energy to our isolated system (the net heat gained by the system is zero):

\[
Q_{\text{cal}} + Q_w + Q_{\text{sol}} = 0
\]

\[m_w c_w (T_f - T_w) + m_{\text{sol}} c_{\text{sol}} (T_f - T_{\text{sol}}) + m_{\text{cal}} c_{\text{cal}} (T_f - T_w) = 0\]  

\[c_{\text{sol}} = \frac{m_w c_w (T_f - T_w) + m_{\text{cal}} c_{\text{cal}} (T_f - T_w)}{m_{\text{sol}} (T_{\text{sol}} - T_f)}\]  

If we neglect the heat gained by the calorimeter, the equation becomes:

\[c_{\text{sol}} \approx \frac{m_w c_w (T_f - T_w)}{m_{\text{sol}} (T_{\text{sol}} - T_f)}\]  

Experimental Procedure and Data Analysis

1. Select a substance, mass and temperature for the beaker as per your instructor recommendations.
   1.1 Choose the solid metal such as silver (Ag).
   1.2 Choose the mass of the solid.
   1.3 Choose the initial temperature of the solid.
2. Select a substance, mass and temperature for the calorimeter.
   2.1 Choose water as the liquid.
2.2 Choose the mass of the liquid.
2.3 The initial temperature of water is already set at 20 °C.
3 In the Run Experiment box, click on Show graph view.
4 Click the Start button to begin running the experiment.
5 Record the final (equilibrium) temperature indicated by the thermometer.
6 Compare this temperature to that obtained theoretically (% difference) using the nominal specific heats. **Show the details of your calculations.**
7 Calculate the specific heat of the solid and compare it to the known one. **Show the details of your calculations.**
8 If we assume that we have measurement errors of 3% for the mass and 3% for the temperature and 5% for the specific heat capacity, calculate the error in the measurement for the specific heat capacity of the solid. **Show the details of your calculation of error.**
9 Fill the table below.
10 Click the Replay button to run the experiment again if necessary.
11 Click the Reset button to start a new experiment and **repeat the previous steps for a second metal 2 assigned to you by your instructor.**

<table>
<thead>
<tr>
<th></th>
<th>Water</th>
<th>Metal 1</th>
<th>Water</th>
<th>Metal 2</th>
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<tbody>
<tr>
<td>( m ) (g) Metal</td>
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<tr>
<td>( T_i ) (°C)</td>
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<tr>
<td>Specific Heat ( c ) (J/g °C)</td>
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<td>( m_w ) (g)</td>
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<td>( T_{wi} ) (20 °C)</td>
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<tr>
<td>Water Specific Heat ( c_w ) (J/g °C)</td>
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<td>Experimental ( T_f ) (°C)</td>
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<td>Calculated ( T_f ) (°C)</td>
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<tr>
<td>% Difference in Temperature</td>
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<tr>
<td>Calculated Specific Heat ( c ) (J/g °C)</td>
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<td>% Difference in Specific Heat ( c )</td>
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<td>% Error in Specific Heat ( c )</td>
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**Questions**
1. What does the change in internal energy of an ideal gas depend on?
2. How is the principle of conservation of energy for a thermodynamic process expressed?
3. Explain the difference between the processes of thermal conduction and thermal convection. Which one is involved in this experiment?
4. Heat of transformation is related to a certain thermodynamic process. What is this process?
5. Heat and temperature are closely related concepts with precise definitions. Give the definition of each physical quantity.
6. If this simulation was done in a real experiment, what are the sources of experimental errors?

**Conclusion:** What did you learn from this experiment?