Physics 12 IB **Specific Heat Capacity**

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# 1 Aim

To identify an unknown material by measuring its specific heat capacity.

# 2 Planning

## 2.1 Hypothesis

By measuring the density of the unknown material and comparing this value to a table of densities, it is suspected that the unknow material is Copper ($\rho = 8.9\, g/cm^3$).

## 2.2 Materials Required

1. Unknown material
2. Thermometer
3. Calorimeter (with styrofoam cover)
4. Water
5. Glass stirring rod
6. Water heater (kettle)
7. Ice cubes
8. Balance
9. 200- or 400-ml beakers (2)
10. Centimeter ruler

## 2.3 Procedure

### Part I

1. Place around 100$g$ of *cold* water into a clean, dry beaker. Monitor the temperature of the water for 2-3 minutes to make certain it has become constant. Record this temperature along with its uncertainty.
2. Measure approximately 100$g$ of *hot* water from a kettle into another beaker. Allow the beaker to stand for 2-3 minutes, stirring the water occasionally. Record the temperature of this water once it becomes constant along with any uncertainties.
3. Pour the cold and the hot water from the two beakers into the calorimeter. Immediately cover the calorimeter with the thermometer/stirrer apparatus, stir the water with the stirring wire

for about 30 seconds, and begin monitoring the temperature of the water in the calorimeter. Record the *highest* temperature reached by the water in the calorimeter.

4. From the masses of cold and hot water used, and from the two temperature changes, calculate the calorimeter constant.
5. Repeat the above experiment to determine a mean value for the calorimeter constant.

**Part II**

1. Record the mass of the unknown material.
2. Repeat the procedures outlined in Part I, but by placing the unknown material inside the calorimeter before pouring any liquid into it.
3. Using the same principle of conservation of energy, and assuming no heat has been lost to the surroundings, calculate the amount of heat (in joules) absorbed per unit mass of the unknown material. This value will be its specific heat capacity.

**Part III**

1. Determine the volume of the unknown material and find its density in $g/cm^3$. If the unknown material is a regular solid, calculate its volume by measuring its dimensions.
2. Predict the material's composition by looking up the material's density on density tables.

# 3 Data Collection

**Part I**

| | Hot | Cold |
|---|---|---|
| Mass of water | $(269-159) = 110g \pm 0.5g$ | $(271-161) = 116g \pm 0.5g$ |
| Initial Temp. | 79 ℃ ± 0.5 ℃ | 18 ℃ ± ℃ |

Equilibrium Temp. = 44.0 ℃ ± 0.5 ℃

**Part II**

| | Hot | Cold |
|---|---|---|
| Mass of water | $(257-159) = 98g \pm 0.5g$ | $(268-161) = 107g \pm 0.5g$ |
| Initial Temp. | 70 ℃ ± 0.5 ℃ | 8 ℃ ± ℃ |

Equilibrium Temp. = 35.5 ℃ ± 0.5 ℃
Mass of unknown material = $192g \pm 0.5g$

**Part III**

Radius of unknown material (cylinder) = $1.25cm \pm 0.50cm$
Height of unknown material = $4.2cm \pm 0.5cm$

## 4 Data Analysis

**Part I**

Heat lost = Heat Gained
$m_h c_w \Delta T = m_c c_w \Delta T + C\Delta T$
$(0.11)(4186)(79 - 44) = (.116)(4186)(44 - 18) + C(44 - 9)$
$16116.1 = 12624.976 + 35C$
$\therefore C = 99.7464$ J/℃

**Part II**

$m_h c_w \Delta T = m_c c_w \Delta T + C\Delta T + m_m c_m \Delta T$
$(0.098)(4186)(70-35.5) = (0.107)(4186)(35.5-8) + (99.7464)(35.5-23.5) + (0.192)(c_m)(35.5-23.5)$
$14152.866 = 12317.305 + 1996.9568 + 2.304c_m$
$\therefore c_m = 277.17$ J/kg ℃

**Part III**

$\rho = \frac{m}{\pi r^2 h} = \frac{192}{\pi 25^2 \times 4.2} = 9.31\ g/cm^3$

## 5 Evaluation

Based on our value for $m_c$, it seems that our known material may be copper. However, the density of copper is about 8.9 $g/cm^3$ and our calculated value was $9.31 g/cm^3$. Similarly, the theoretical specific heat for copper is 387 J/(kg ℃) while that obtained by experimentation was 277 J/(kg ℃).

Percentage Difference $= \frac{387-277}{387}$

$= 28.4\ \%$

This is a significant error in terms of specific heat capacities.

The procedure as such is very efficient, and contains little errors. Very little heat was allowed to escape into the surroundings, and this makes our measurements all the more accurate. Errors in measurement could have risen from not measuring the *highest* temperature reached (the equilibrium temperature), and by assuming that the initial temperatures of the unknown material and the calorimeter were the same as the room temperature.

These two factors have been accounted for by suggesting some procedural improvements.

### 5.1 Procedural Improvements

1. Instead of beginning with the cold and hot waters in separate beakers, it would be much better to start off with the cold water in the calorimeter itself, and then pour the hot water into it. That way, we could say that the initial temperature of the calorimeter apparatus is the same as that of the cold water inside it.
2. An more accurate method to find out the density of a solid, cylindrical object would be to measure the volume of water displaced by the unknown solid when immersed in a beaker full of water (Archimedes' Principle).

## 6 Conclusion

In this lab, we were thus able to experimentally determine the specific heat capacity of an unknown material and were able to identify this unknown material by comparing the specific heat value with tabulated values. In order to not rely on just the specific heat capacity, we also recorded another property of the material. This secondary property was the material's density and we were therefore able to use both values to determine the composition of the unknown material. Further investigation may now be conducted on other properties of the material, such as coefficient of linear expansion, emission spectrum, etc.

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