Specific Heat Capacity of Metals
PHYS 442

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Partners:	Whole class
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1 Objective

The objective of this experiment is to measure the specific heat capacity of three different samples of unknown metals and to compare those with the accepted values.

2 Definitions

Heat Heat is the measure of the internal kinetic energy of a substance.

Temperature Temperature is a measure of the kinetic energy of a particle. It is the degree or intensity of heat in a substance. Celcius is a unit of temperature. One degree Celcius represents the temperature change of one gram of water when 2.39×10^{-5}Joules of heat is added to it.

Specific Heat Capacity The specific heat capacity is the energy transferred to one kilogram of substance causing its temperature to increase by one degree Celcius. Homer (2014)

Thermal Equilibrium Thermal equilibrium is a condition where two substances in physical contact with each other exchange no net heat energy. Substances in thermal equilibrium are at the same temperature.

3 Theory

The change in the internal energy of an object or substance is equal to the product of the mass and the specific heat capacity and the change in temperature.

$$\Delta U = mC_p\Delta T$$

When water and the metal samples are in thermal equilibrium the change in heat of the water is equal in magnitude to the change in heat of the metal.

$$\Delta U_{metal} = \Delta U_{water}$$

From this relationship we may derive a formula for the specific heat capacity of the metal sample given the mass of metal, mass of water, change in temperature of the water, change in temperature of the metal and the specific heat capacity of water.

$$m_{metal}C_{metal}\Delta T_{metal} = m_{water}C_{water}\Delta T_{water}$$

$$\boxed{C_{metal} = \frac{m_{water}}{m_{metal}}\frac{\Delta T_{water}}{\Delta T_{metal}}C_{water}}$$

4 Materials

- kettle
- unknown metal samples (aluminum, zinc and copper)
- styrofoam cups
- graduated cylinder
- scale
- thermometer
- tongs
- flask of water

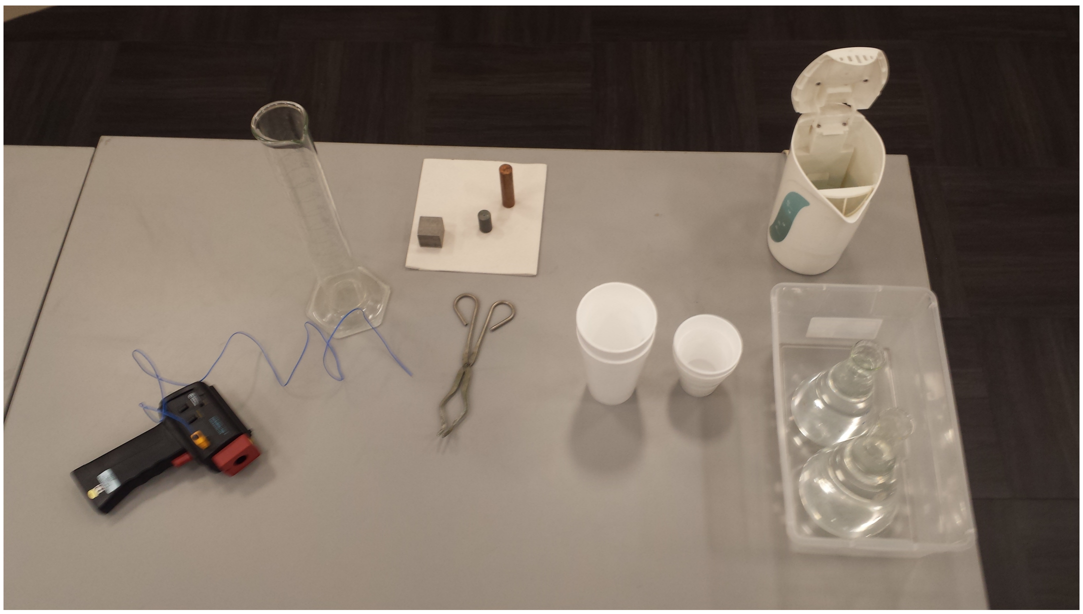

Figure 1: Experimental materials

5 Method

a. Weigh the samples and record

b. Measure 350 ml of water in graduated cylinder and transfer to styrofoam cup

c. Measure the initial temperature of the water

d. Boil water and add metal samples to kettle

e. Use tongs to transfer a sample to the cup with water

f. Place thermometer in cup, cover it, stir and record equilibrium temperature

g. Repeat steps b-f for each sample. For the last sample (64.1 g one) measure 300 ml of water.

6 Data

Metal	Mass Metal	Mass Water	Temp Water Initial	Temp Final
Cube (Al)	90.5 g	350 g	20.5 Celcius	24.5 Celcius
Long cylinder (Cu)	203.0 g	350 g	20.8 Celcius	24.8 Celcius
Short cylinder (Zn)	64.1 g	300 g	20.9 Celcius	22.5 Celcius

Table 1: Experimental data

Material	Specific Heat Capacity
Water	4180 $^{J}/_{kg \cdot {}^\circ C}$
Aluminum	900 $^{J}/_{kg \cdot {}^\circ C}$
Copper	387 $^{J}/_{kg \cdot {}^\circ C}$
Zinc	380 $^{J}/_{kg \cdot {}^\circ C}$
Iron	452 $^{J}/_{kg \cdot {}^\circ C}$
Steel	452 $^{J}/_{kg \cdot {}^\circ C}$
Lead	128 $^{J}/_{kg \cdot {}^\circ C}$
Silver	230 $^{J}/_{kg \cdot {}^\circ C}$

Table 2: Known specific heat capacities

7 Example Calculations

This is the calculation for the specific heat capacity of the long cylinder (copper).

$$C_{metal} = \frac{m_{water}}{m_{metal}} \frac{\Delta T_{water}}{\Delta T_{metal}} C_{water}$$

$$\Delta T_{water} = 24.8 - 20.8 = 4.0°\text{C}$$

$$\Delta T_{metal} = 100 - 24.8 = 75.2°\text{C}$$

$$C_{metal} = \frac{0.350\text{kg}}{0.203\text{kg}} \frac{4.0°\text{C}}{75.2°\text{C}} 4180\ {}^{\text{J}}\!/_{\text{kg}°\text{C}} = 383\ {}^{\text{J}}\!/_{\text{kg}\cdot°\text{C}}$$

The percent error is calculated as follows.

$$Error = \frac{387 - 383}{387} = 1.0\%$$

8 Results

Metal	Material	Measured C_p	Percent Error
Cube	Aluminum	856 J/kg·°C	4.8%
Long cylinder	Copper	383 J/kg·°C	1.0%
Short cylinder	Zinc	404 J/kg·°C	6.3%

Table 3: Calculated specific heat capacities

9 Discussion of Error

Possible sources of error in this lab include the following. The main source of error is heat loss, as heat was released from the thermally isolated system within the styrofoam cups when opened to measure the metals' temperature. During this brief moment heat was lost, although minimally. Also although a really thermally protected environment given by two styrofoam cups, which are of an excellent material to prevent the heat from dissipating, covered by another two cups heat could have been absorbed by the cups, resulting in a less accurate measurement (infinitesimally). Another source of error is the purity of the metals. Although they were aluminum, copper and zinc, purity plays a key point in determining their heat capacity. If one of the metals wasn't pure enough (as in containing part of another metals (being a blend to minimize costs)), its specific heat capacity varied from the real one.

10 Conclusion

During the experiment there was a crucial obstacle: determining what metal was the short cylinder (later found to be zinc), since its specific heat capacity was close to that of iron and steel, copper, and zinc. Through its color (gray), however, the possibility of it being copper was discarded. After this it was a mater of perceptual analysis resolving that it couldn't be neither steel nor iron. Moreover, its capacity was much closer to that of zinc than to these two. After determining all of the samples' specific heat capacities, they were found to be aluminum, zinc and copper. This was later confirmed by the professor. In this way, it can be seen how specific heat capacity can be used practically to determine the identity of a given material.

References

Homer, J. (2014). *Physics*. Oxford, 3rd edition.