Specific Heat Capacity of Metals

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1 Objective

The objective of this experiment is to measure the specific heat capacity of three different samples of metal and to compare those with the accepted values. The samples consist of aluminum, zinc and copper.

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
- aluminum, zinc and copper samples
- styrofoam cups
- graduated cylinder
- scale
- thermometer
- tongs
- flask of water

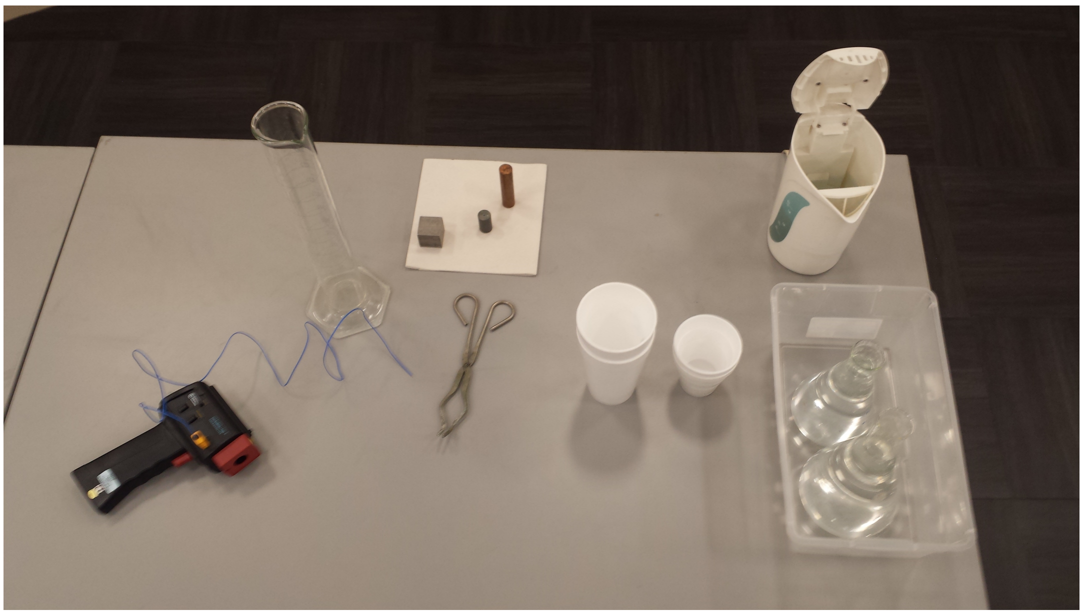

Figure 1: Experimental materials

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

6 Data

Metal	Mass Metal	Mass Water	Temp Water Initial	Temp Final
Aluminum	90.6 g	350 g	22.5 Celcius	26.3 Celcius
Zinc	64.1 g	350 g	22.9 Celcius	24.4 Celcius
Copper	203.0 g	300 g	22.5 Celcius	26.2 Celcius

Table 1: Experimental data

Material	Specific Heat Capacity
Water	4180 $^{J}/_{kg \cdot {}^{\circ}C}$
Aluminum	900 $^{J}/_{kg \cdot {}^{\circ}C}$
Zinc	380 $^{J}/_{kg \cdot {}^{\circ}C}$
Copper	387 $^{J}/_{kg \cdot {}^{\circ}C}$
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 copper.

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

$$\Delta T_{water} = 26.2 - 22.5 = 3.7°\text{C}$$

$$\Delta T_{metal} = 100 - 26.2 = 73.8°\text{C}$$

$$C_{metal} = \frac{0.350\text{kg}}{0.203\text{kg}} \frac{3.7°\text{C}}{73.8°\text{C}} 4180\ {}^{\text{J}}\!/_{\text{kg}°\text{C}} = 361\ {}^{\text{J}}\!/_{\text{kg}\cdot°\text{C}}$$

The percent error is calculated as follows.

$$Error = \frac{387 - 361}{387} = 6.7\%$$

8 Results

Material	Measured C_p	Percent Error
Aluminum	832 $^{\text{J}}\!/_{\text{kg}\cdot°\text{C}}$	7.5
Zinc	453 $^{\text{J}}\!/_{\text{kg}\cdot°\text{C}}$	18%
Copper	387 $^{\text{J}}\!/_{\text{kg}\cdot°\text{C}}$	6.7%

Table 3: Calculated specific heat capacities

9 Discussion of Error

Here is the list of possible errors that could happen during the lab:
Additional energy:Additional energy is added by stirring the metal in the water.
Human error: reading the thermometer inaccurately.
Heat loss: During the experiment there is a time gap because of gathering everything together and start measuring the temperature, therefore metals lose their heat during this gap.
temperature measurement: Not enough time spent in order to measure the temperature of metal in the hot water.

10 Conclusion

We measured the Specific heat capacity of three different metals of Aluminum, Zinc and Cooper which were measured to be 832 J/kg C, 453 J/kg and 387 J/kg respectively. The given specific heat capacities are of course not exact numbers and they have some errors. As stated above we calculated the C metal by keeping the element in contact with water, measuring the equilibrium temperature and using the concept of heat transfer to calculate the specific heat capacity of the metals.

$$C_{Metal} = \frac{M_{Water}}{M_{Metal}} \times \frac{\triangle T_{Water}}{\triangle T_{Metal}} C_{Water} \tag{1}$$

There is a digital error present in our scale which is affecting the uncertainty in the measured mass of metal, there can also be human error in recording the equilibrium temperature and the impurity of water which makes the specific heat capacity of water different than the one used to calculate C metal.
In spite of these uncertainties we have a pretty decent data, at least for cooper and zinc due to the small difference that there is between the measured C and known C. We can even use the concept of t score to know whether the number calculated with the digital uncertainty of scale is different than the known value or not.

$$t' = \frac{A - B}{\sqrt{dA^2 + dB^2}'} \quad 0 < t' < 1 \tag{2}$$

$$\leftrightarrow confidentlythesame$$

$$t' = \frac{387 - 385}{\sqrt{\frac{0.5^2}{\sqrt{3}}}} = 0.06 \tag{3}$$

Even based on the t score the cooper metal seems to be shown a cooper in reality, we can do the same on the other two metals and make sure about the identity of the metal, if the t score is not between 0 and 1 then we have to go back to our measurement and increase the level of our accuracy.

References

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