Heat Conduction of Metals

1 Objective

- Determine the thermal conductivity constant κ of a metal using the constant temperature gradient method.

2 Prelab Questions

1. Briefly state the conditions for thermodynamic equilibrium.
2. If the water and the calorimeters inner walls are your system, what thermodynamic processes take place after you remove the ice for the first time, (in Part 1)? What is the surrounding in thermodynamic terms?
3. Using the same system what thermodynamic processes take place after removing the ice the second time, (in Part 2)? What is the surrounding in thermodynamic terms?
4. Is the rod in the experiment in thermodynamic equilibrium? Explain.

3 Principles

- A metal rod, isolated from the sides, is placed in thermal contact with two heat reservoirs: one contains boiling water and the other contains iced water.
- After some time, a steady state is reached and the amount of heat flowing through the rod is constant. Ice is then removed from the cold water.

- Accounting for all the heat gained by the cold water and calorimeter walls, the thermal conductivity of the metal rod could be calculated.

4 Apparatus

- Two lidless calorimeters.
- Heating coil.
- Metal rod.
- Temperature metre with three probes.
- Magnetic stirrer with base.
- Heat coductive paste.
- Gauze bag.
- Stop watch.
- Beaker, distilled water and ice.
- Two stands and six clamps.

5 Precautions

1. Establish good thermal contact with rod and temperature probes T_2 and T_1 using the heat conductive paste.
2. Make sure that the heater is covered by water.
3. Water has to cover the uninsulated part of the rod when you remove the ice.

6 Experimental Steps

6.1 Part 1:

1. Record the mass of the empty lower calorimeter m_0.
2. Find the equivalent heat capacity C of the lower calorimeter by the mixing method.
3. Place the magnetic stirrer in the lower calorimeter and fill it half way through with water.
4. Fill the gauze with ice and place it in the lower calorimeter.
5. Place the calorimeter on the magnetic stirrer base. Switch it on and make sure that the stirrer is rotating freely.
6. Insert the tip of T_3 probe in the calorimeter then switch on the temperature metre. Press the knob $T_{(1..4)}$ until the green LED light comes on at T_3.
7. Allow the ice and water mixture to sit for 10 minutes or so. Once the temperature reaches its lowest value, and does not change significantly, remove the ice.
8. Record the temperature T, each minute t, for 30 minutes.
9. Weigh the calorimeter and record the mass of the cold water m_{f1}. Do not dispose of the cold water in the calorimeter.

6.2 Part 2:

1. Fill the top calorimeter with water up to 1 cm below the rim. Then insert the heater in the water and switch it on. Start the stopwatch.
2. Add ice in the lower calorimeter (the one that contains the cold water) and place the tip of the metal rod which is not insulated in the calorimeter. Make sure it is covered by water and the stirrer is moving freely.
3. Notice that the two probes T_1 and T_2 are touching the top most indent and the lowest indent of the metal rod, respectively.
4. Set the themperature metre to read $\Delta T(T_2 - T_1)$, by pressing the ΔT knob more than once until the red LED light comes on beside T_1 and T_2 on the monitor. Wait until ΔT does not vary.
5. Remove the ice from the cold water. Record T_3 and ΔT, every 30 seconds, for 6 minutes. (See second precaution)
6. Weigh the calorimeter to find the mass of the cold water m_{f2}.

7 Evaluation

1. Calculate the equivalent heat capacity C of the lower calorimeter.
2. Plot the temperature T vs. time t in Part 1. Use the slope to get $\frac{dQ_{surr}}{dt} = (m_w C_w + C)\frac{dT}{dt}$.
3. Plot the temperature T vs. time t in Part 2. Use the slope to get $\frac{dQ_{tot}}{dt}$.
4. Subtract the two previous quantaties to obtain $\frac{dQ_{rod}}{dt}$.
5. Measure the distance Δx between the temperature probes T_1 and T_2.
6. Use $\frac{dQ_{rod}}{dt}$ to find the thermal conductivity of the rod κ. Use an average value of ΔT for ∂T and Δx for ∂x.

8 Postlab Questions

1. Explain why you wait for ΔT to stop changing and what does it mean if it changes?
2. What is a closed system and what are the approximations you need to make when analysing the data?
3. What will happen to your results if the water does not cover the uninsulated tip of the rod
4. In what ways is your experiment different than the ideal experiment to measure κ?

9 Helpful Sites (clickable links)

- Thermal and electrical conductivity of metals.