ASEN 2012

Project 1

Calorimetry

Assigned: Monday 26th September

Individual Report Due: 21st October 11:59pm uploaded to D2L

OBJECTIVES

- *Use temperature measurements, the first- law of thermodynamics and least squares extrapolation to determine the specific heat of a sample material and assess associate errors, and determine the possible material from which the sample is made.*

REQUIRED DELIVERABLES

- *The data files required to carry out your analysis are posted on the D2L website.*
- *Report must have the following sections: 1) abstract 2) introduction 3) experimental method 4) results 5) discussion 6) conclusion 7) references and 8) appendix containing your code, a flow chart for you code (i.e. your algorithm) and any sample calculations*
- *The report must be written in the AIAA format.*

Calorimetry

a) A thermocouple with software cold-junction compensation is used to measure the calorimeter temperature.

b) Include a derivation of eq. (1) in your report using the First Law.

c) Estimate the specific heat of your sample from eq (1) and using the table provided in the excel sheet identify the material from which the sample may have been made.

d) From you analysis what is the probable material from which the sample is made? Determine this by providing an error estimate for your computed value and relate whether the accepted value of specific heat of the material you propose the sample may be made from falls within the error estimate. If the deviation were significant, where the accepted value lies outside the error bar, how would parameters used in your calculation from eq (1) have to change to account for the observed bias? Provide physical reasoning behind your assessment.

Calorimetry background

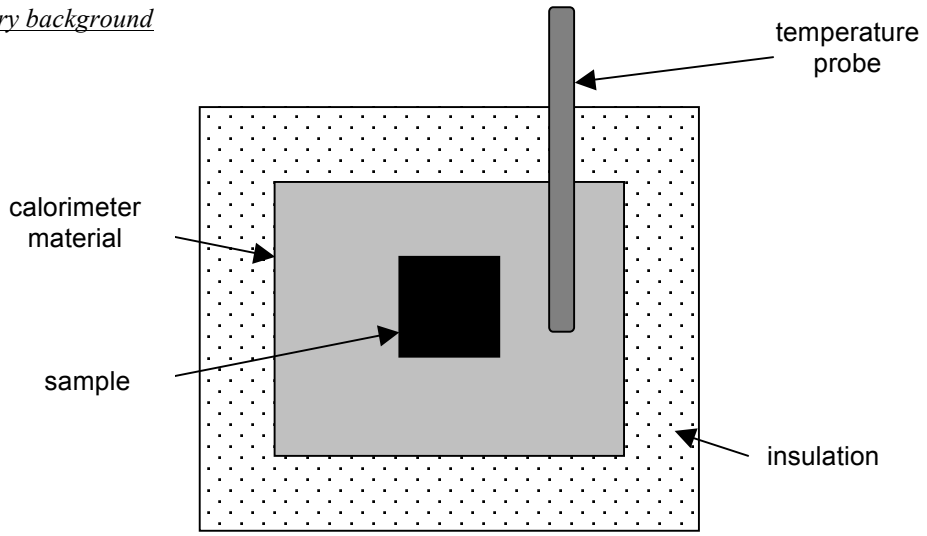

Figure 1 Schematic of the calorimeter, and adiabatic system.

Calorimetry is a basic technique for measuring thermodynamic quantities, especially those involving heat transfer, i.e., specific heats, heat of fusion, heat of vaporization, and heat of chemical reactions. It is one of the oldest experimental methods in thermodynamics. Benjamin Thompson used a calorimeter in 1798 to show that work could be converted to heat (thermal energy), and Joule conducted elegant experiments in the 1840s to measure the mechanical equivalent of heat (thermal energy). People who count "calories" can look up the energy value of various foods in their diet, e.g., three Chips Ahoy cookies (~32 grams) supply 169 Calories (kcal) of energy. We know this because someone, in this case Nabisco, Inc., conducted calorimetry experiments.

When a sample of different temperature than the calorimeter vessel is put in the calorimeter, heat transfer between the sample and the calorimeter takes place. Considering the sample combined with the calorimeter as the adiabatic system, one can show that

$$C_{s,av} = \frac{m_c C_{c,av}(T_2 - T_0)}{m_s(T_1 - T_2)} \tag{1}$$

where $C_{s,av}$ = specific heat of the sample, $C_{c,av}$ = specific heat of the calorimeter, T_0 = initial temperature of the calorimeter, T_1 = initial temperature of the sample, T_2 = final temperature of the calorimeter and sample at equilibrium, m_c = mass of the calorimeter, and m_s = mass of the sample.

Adiabatic conditions are difficult to maintain. Fig. 2 is copied from the kit manual for the calorimeter and shows a typical temperature profile from this calorimeter. As can be seen in the data from 1:00 pm to 1:20 pm, the temperature of the empty calorimeter is rising slowly in the room. The calorimeter temperature rises rapidly after a sample at 99.5°C is added at 1:21 pm. By 1:23 pm, however, the temperature rise has slowed. During this time, the calorimeter loses thermal energy to the surroundings, in spite of the insulation. That temperature loss is clear after 1:25 pm. The description following Fig. 2 describes the procedure to extrapolate values for T_0 and T_2 from a linear fit of temperature measurements before the sample was added and after heat transfer to the surroundings began to be a major factor respectively. The purpose of the extrapolation method is to account for heat loss before, during and after the experiment.

As one can see from the data in Fig. 2, the calorimeter temperature begins to rise immediately after the sample is introduced; but the rise is at first rapid (point A to point B), then slower, then the temperature started to decrease, during the time period from point C to point D, the calorimeter temperature is observed to fall from 25.5 °C to 25.2 °C in 12 minutes, which represents a change of 0.025 °C per minute. We must employ a method to compensate for this unaccounted for heat loss.

Determine the approximate temperature before addition of the sample by fitting a line to the pre-sample temperature data from 1:10pm to 1:20pm. Then extrapolate the line forward to the time the sample was added, in this case 1:21 pm (time of sample addition). Note the extrapolated temperature at T_{Low}(1:21). Fit a second line from the maximum temperature reading (i.e. 1:27pm) to the last temperature reading at 1:50pm. Extrapolate this line back to the time when the sample was added (i.e. 1:21pm) and note the extrapolated temperature T_{Hi}(1:21). In this case T_{Low}(1:21) and T_{Hi}(1:21) temperatures are 20.3 °C and 25.7 °C respectively. These are approximately correct. Next, determine the average of these two temperatures (23.0 °C); and from the graph determine the time associated with this temperature (1:22 pm approximately). Extrapolate the line from the later readings back to 1:22 pm, T_{Hi}(1:22). T_{Low}(1:21) represents the initial temperature of the calorimeter, T_0, and T_{Hi}(1:22) represents the final temperature of the calorimeter and sample at equilibrium, T_2, with a compensation for heat loss to enable the adiabatic assumption to be applied and eq 1 to be applicable.

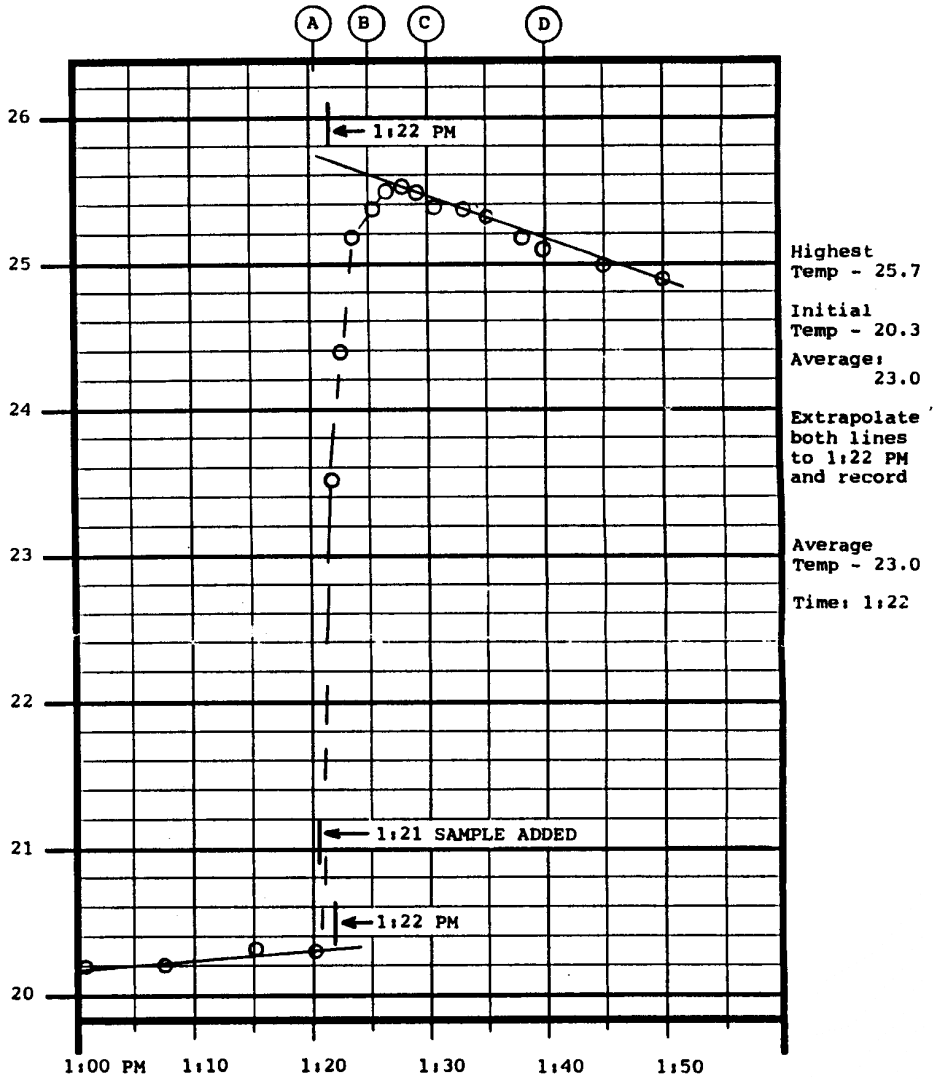

Figure 2. Typical temperature profile from calorimeter