A Portable Adiabatic Calorimeter

by B. L. Hansen and H. H. G. Jellinek
PREFACE

The work reported in this paper was carried out by Mr. Hansen, Chief, Technical Equipment Branch, and by Dr. Jellinek, physical chemist, under contract DA-21-018-ENG-500 (SIPRE Project 22.1-18, Research for the classification of ice) with Polytechnic Institute of Brooklyn.

Manuscript received 2 May 1957

Department of the Army Project 8-66-02-004
SUMMARY

An adiabatic calorimeter was constructed and tested on glacier ice. The heat of fusion thus determined was found to be within a small fraction of a percent of published values for ice. The calorimeter is considered to be suitable for the determination of water in snow.
A PORTABLE ADIABATIC CALORIMETER

by

B. Lyle Hansen and H. H. G. Jellinek

There is a need for a simple, but accurate calorimeter, which can be used either in the laboratory or in the field. Such an instrument is needed, for instance, for the determination of free water content in snow. With this purpose in mind, a calorimeter was constructed, which is described below.

The principle of the calorimeter is as follows:

The ice or snow sample is suspended in an organic liquid placed in a vacuum flask. A known amount of electrical energy is supplied via a heating wire and the amount of heat needed to melt the sample can be deduced.

An exploded view of the calorimeter is shown in Figure 1. A small vacuum flask (1) of about 13 cm height and 5.8 cm internal diameter is extended 5 cm by a Lucite cylinder of 7.6 cm inner diameter. A Lucite cup (2) can be fitted snugly into this cylinder sitting on the rim of the flask. The leads for the heater (4) are cemented into a Lucite rod (3), the heating wire being wound around the lower bent piece of the rod and covered with a thin film of Lucite. The small vacuum flask is placed into the larger one (5) and the assembly covered with a wooden lid (6). A copper-constantan thermocouple can be introduced through the center tube of the Lucite cup into the calorimeter. Initially, the Lucite rod carrying the heating wire served as stirrer; however, it was found not to be very efficient and an electrically driven stirrer was introduced through the center tube and another tube provided for the thermocouple. The whole electrical circuit is shown in Figure 2.

Figure 1. Exploded view of calorimeter (see text)
Figure 2. Electrical circuit diagram for calorimeter.

E₁ - 6-v battery (Burgess S461).
E₂ - 1.34-v mercury cell (Mallory RM-5020).
E₃ - 1.5-v (No. 6) dry cell in external galvanometer (Leeds and Northrup Cat. 2430-a, only used in special laboratory experiments).
G - Galvanometer (Rubicon 'Pointerlite', Cat. No. 3080 AL, 0.3 μ amp/mm, resistance 10 Ω).
R₁ - 25 Ω helical potentiometer (Helipot Cat. No. 25-AZ with Duodial).
R₂ - 10 Ω wire-wound resistor (IRC WW4J).
R₃ - 10KΩ helical potentiometer (Helipot Cat. No. 19KAZ with Duodial).
R₄ - 470 Ω, 1-w.
R₅ - Dummy heater (match heater resistance within 0.1%) non-inductive winding, ceramic core.
R₆ - 47 Ω, 1-w.
S₁, S₂ - DPDT Center Off Position (Cutler Hammer 8821-K5).
S₃ - Lampswitch on galvanometer.

The heating wire has a resistance of 30.96 Ω and that of the leads is 0.042 Ω. The power input was adjusted to 1 watt within 0.1%. A dummy heater of nearly the same resistance as the heater in the calorimeter was provided. A similar power input to that used for the heater in the calorimeter was employed for the dummy. The current was passed through the dummy heater for at least half an hour before the experiment was started, so that the dry battery which was used as a power source would be in a stable condition.
Figure 3. Galvanometer divisions (temperature) as a function of time for an experiment using 10 g of glacier ice.

Procedure: The calorimeter was tested with pure ice. The large vacuum flask and the Lucite cup were filled with an ice-water mixture; 150 ml of 2,2,4-trimethylpentane and 10 g of ice were placed into the small flask. The stirrer was started and the time when heating was begun was accurately noted.

Figure 3 shows the results obtained for 10 g of glacier ice, where galvanometer divisions are plotted as a function of time.

The curve was evaluated as follows:

A horizontal line was drawn at the level where the experimental curve shows the first sharp transition. The reciprocal slope of the heating curve before melting is a measure of the heat capacity of the calorimeter containing the organic liquid and the ice. Hence, the energy needed to heat the system from the starting temperature to the temperature corresponding to the horizontal line is given by the time interval from zero time to the intersection point with the horizontal line multiplied by the constant power input. Similarly, the energy needed to heat the calorimeter plus organic liquid and water from the melting temperature to a higher temperature is given by the time interval from the intersection point of the second straight-line heating curve with the horizontal line up to the time when the respective higher temperature is reached, again multiplied by the power input. The heat of fusion is then given by the total energy input to raise the system from a temperature below 0°C to a temperature above 0°C minus the energy necessary to heat the system up to 0°C (point A, Fig. 3) and from 0°C (point B) to above 0°C. In other words, the heat of fusion is equal to the time interval (55.6 min) between the two intersection points multiplied by the
constant power input in the appropriate units. Corrections for heat losses or gains or heat generated by the stirrer were not applied. The heat of fusion found for the glacier ice is 79.7 cal/g. This value compares favorably with a value of 79.71 cal/g given in the Handbook of Physics and Chemistry, 38th Ed. (1956/57, Chemical Rubber Publishing Company). One of the principal errors which arises lies in the drawing of the straight lines, as there is some ambiguity in this procedure.

Actual water-in-snow determinations will have to start at 0°C. The time interval between the start of heating and the intersection point of the horizontal line with the straight heating line will be a measure of the amount of ice in the wet snow.