A HEAT-CONDUCTING MICROCALORIMETER WITH COPPER – CONSTANTAN THERMOPILES

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The heat-conducting microcalorimeter described consists of two calorimetric elements, thermostatically controlled units, and a mirror galvanometer. The calorimetric elements each have 132 copper–constantan wire junctions. The sensitivity of the instrument is 17.6×10^{-6} W. The apparatus has been used to determine the energy exchange of isolated animal organs.

The writer has designed, built, and tested a microcalorimeter (Fig. 1) consisting of two calorimetric elements (1), a metal unit (2), two cones (3), a recording instrument (4), and a thermostatically controlled jacket (5).

The calorimetric element consists of an inner shell on the outer wall of which are secured 66 "working" copper–constantan junctions, and an outer shell to which the "zero" junctions are fixed. The inner shell consists of a turned bronze cylinder, 25 mm in diameter, 100 mm high, and with walls 0.2 mm thick.

The system of thermocouples of each of the two calorimetric elements is a detector thermopile consisting of 132 series-connected junctions of copper and constantan wire. The thermopiles of the two elements are connected to the terminals of the recording instrument.

The metal unit designed to stabilize the temperature of the inner shell of the calorimetric elements consists of two bell-shaped hoods covering these elements and a common cylindrical body. All parts of the unit are made from duralumin.

The upper and lower cones of the apparatus are designed to reduce the local effect of changes in external temperature, i.e., to reduce the horizontal thermal nonhomogeneity, and also, like the metal unit, to increase the total heat capacity of the components of the body. The side walls of the cones are made of aluminum, the end walls from laminated Bakelite. The interior of the cones is filled with fine-grain river sand.

The recording instrument is a type 3CG-47 mirror galvanometer with sensitivity of the order of 1×10^{-8} A $\cdot$ mm^{-1} when the distance from mirror to scale is 1 m. The galvanometer is fixed inside the constant-temperature space.

The thermostatic jacket consists of three metal shells (galvanized iron) of cylindrical shape, separated from each other by an air space of 3-5 cm. Several layers of strong paper are glued over the outer cylinder (6). The heating coil (tungsten wire, 0.4 mm section) is wound on the first layer of paper nearest to the metal shell (7). The electrothermometer (8), the master element for automatic control of the thermostat, is in direct contact with the outer metal cylinder.

To ensure the best thermal contact with the surface of the inner shell, each junction is mounted in an obturator, a rectangular piece of bronze foil. Electrical insulation between the thermopile and the calorimetric shell is provided by polyethylene film glued to its outer surface.

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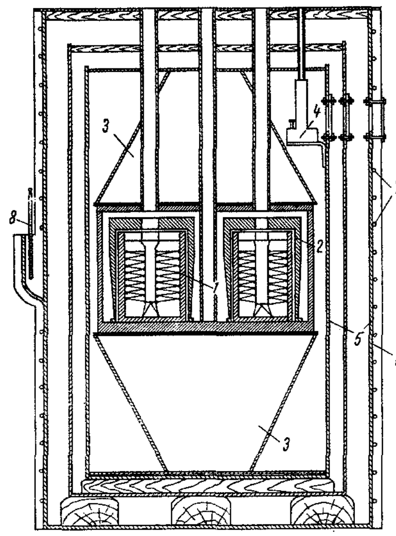

Fig. 1. Scheme of microcalorimeter. Explanation in text.

The working and zero junctions of the thermopile of each calorimetric element are arranged in eight horizontal rows and eight vertical rows. Four junctions are fixed to the floor of the inner shell. Only the mouth of the shell, amounting to about 5% of its total surface area, is not covered by them.

The optimal design of the thermopiles was calculated by the methods described by Calvier and Pratt [1], with the aid of some additional experimental data (measurement of the thermal emf of the copper–constantan thermocouples, etc.).

The instrument is analogous to the Tiana–Calvier calorimeter. Both are heat-conducting or nonadiabatic calorimeters. It works on the principle of determining the power of the heat flux from the inner shell of the calorimetric element to the outer shell, spreading mainly along the wires of the thermopile. Because of the large number of thermocouples, the readings of the instrument are independent of internal thermal nonhomogeneity, and the heat flux rapidly reaches its stationary level, i.e., the time constant of the calorimeter is reduced.

The instrument can work under isothermic conditions if the Peltier effect is used to compensate for heat loss. For this purpose, some of the junctions located on the inner shell of the working calorimetric element must be disconnected from the detector thermopile and connected to the external source of current. A differential circuit is then used for the instrument. Heat loss in the working calorimetric element is compensated by the Joule effect on the resistor placed inside the shell of the control element. The heater is made of constantan wire with a resistance of 8.9 Ω.

The constants of the instrument are determined and the heat emitted by the test objects calculated by means of Tiana's equation

$$W = W' + \frac{P}{g} l + \frac{\mu}{g} \frac{dl}{dt},$$

where W is the measurable flow of heat; W' the heat flow compensated by the Joule effect; g the sensitivity of the galvanometer; l the deflection of the spot of light; t the time; P the coefficient of heat loss, determined principally by the number of thermocouples; and μ the thermal capacity of the inner shell.

The time constants τ and τ' of the working and control calorimetric elements were obtained with the aid of calibration curves, and their values were 14.5 and 14.1 min, respectively. The difference between τ and τ' is small enough for the calorimetric elements to be regarded as completely identical as regards the constants P and μ and for the instrument to work on a differential circuit.

The value of the constants of the working calorimetric element were $P/g = 4.27 \times 10^{-6}$ cal·sec^{-1} and $\mu/g = 3.73 \times 10^{-3}$ cal·sec^{-1}. The calculated equation is thus as follows:

$$W \text{ cal}\cdot\text{sec}^{-1} = W' + 4{,}3 \cdot 10^{-6} + 3{,}7 \cdot 10^{-3} \frac{dl}{dt}.$$

The sensitivity of the microcalorimeter at 24°C is 17.6×10^{-6} W or 4.2×10^{-6} cal·sec^{-1}. The instrument has been used to study changes in energy exchange of isolated animal organs.

LITERATURE CITED

1. E. Calvier and A. Pratt, Microcalorimetry. Its Use in Physical Chemistry and Biology [Russian translation], Moscow (1963).