not entirely independent of temperature, varies but little, if at all, between 0°C. and 100°C.

METAL	VALUE OF f AT 0°C.	AT 100°C.	METAL	VALUE OF f AT 0°C.	AT 100°C.
Aluminium	1.588	1.587	Palladium	2.040	2.039
Bismuth	1.359	1.358	Platinum	2.121	2.120
Cobalt	1.568	1.568	Silver	2.203	2.204
Copper	2.257	2.255	Thallium	2.203	2.204
Gold	2.322	2.322	Tin	2.287	2.286
Iron	2.852	2.853	Tungsten	2.841	2.837
Magnesium	2.127	2.125	Zinc	2.213	2.211
Molybdenum	2.450	2.448	Constantan	2.135	2.135
Nickel	1.335	1.334	Manganin	3.136	3.135

Equation (1) as amended, in accordance with what has here been shown, becomes

$$U = f.kT^2\frac{d \ln K}{dT}. \qquad (7)$$

[1] *Theoretische Chemie,* 7th ed., p. 675.
[2] See *Proc. Nat. Acad. Sci.,* **16** (1930), p. 49, Table 1.

THE EFFECT OF LOW TEMPERATURES ON THE SENSITIVITY OF RADIOMETERS[1]

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The behavior of radiometers at low temperatures, besides being of some interest to the theoretical physicist,[2] is of considerable importance to one desiring to carry radiant energy measurements to an extreme limit. Various workers have already pushed the sensitivity of such instruments as the thermocouple, radio micrometer, and radiometer into the region in which Brownian movement begins to mask observations so that any great gain in the sensitivity of existing instruments must come from some change in technique rather than from mere refinement of our instruments. Some hope lies in reducing the effect of Brownian movement by working at greatly reduced temperatures, and for this purpose the radiometer has much in its favor. In the case of the thermocouple, not only must the couple be at a low temperature, but also the galvanometer, and this offers numerous technical difficulties. The radiomicrometer is an instrument very thoroughly insulated against heat, and the temperature is not easily controlled. The radiometer, however, working as it does at a gas pressure high enough to have a fair heat conductivity, can be depended upon to assume the temperature of the walls of its container.

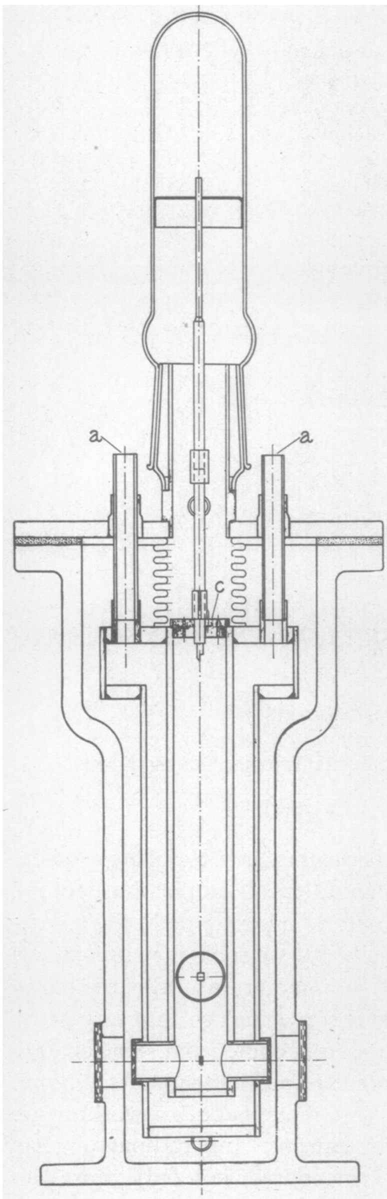

FIGURE 1

Cross-section of the radiometer chamber.

A chamber suitable for the study of radiometers at low temperature was built as shown in figure 1. The outside case consists of a vacuum-tight silicon-aluminum casting,[3] closed at the top by a brass plate seated on a rubber gasket. The inner double-walled chamber is hung from the brass cover by the two brass tubes, *a*, *a*, which serve as supports and provide a means for introducing the cooling medium (liquid air in these experiments) into the hollow walls of the inner chamber. These tubes are made as thin as possible in order to reduce heat conductivity. As the space between the inner chamber and the outer case is highly evacuated during an experiment, the only heat path from the inner chamber to the "outside" other than the two supporting tubes, is the "sylphon" bellows which gives access to the radiometer chamber proper. An extension of the radiometer chamber is carried through the cover plate, and a section including a glass ground-joint is cemented to this extension as shown in the figure. This enables one to rotate the radiometer without opening the chamber as the rod which carries the radiometer ends in a hard rubber spline which engages in a slotted piece of brass attached to the upper member of the ground joint. The hard rubber spline also enables one to remove the radiometer, for the cover (*c*) of the radiometer chamber proper, the rod, and the radiometer itself form one assembly which can be lifted out when the upper member of the ground joint is removed.

Windows are double throughout, for the inner windows which are cooled during the experiments would "frost" if exposed to the atmosphere. Some difficulty was experienced in finding a method of attaching these inner windows. Khotinsky wax, sealing wax, and beeswax and resin, in fact all common waxes, are useless at liquid air temperatures, and while

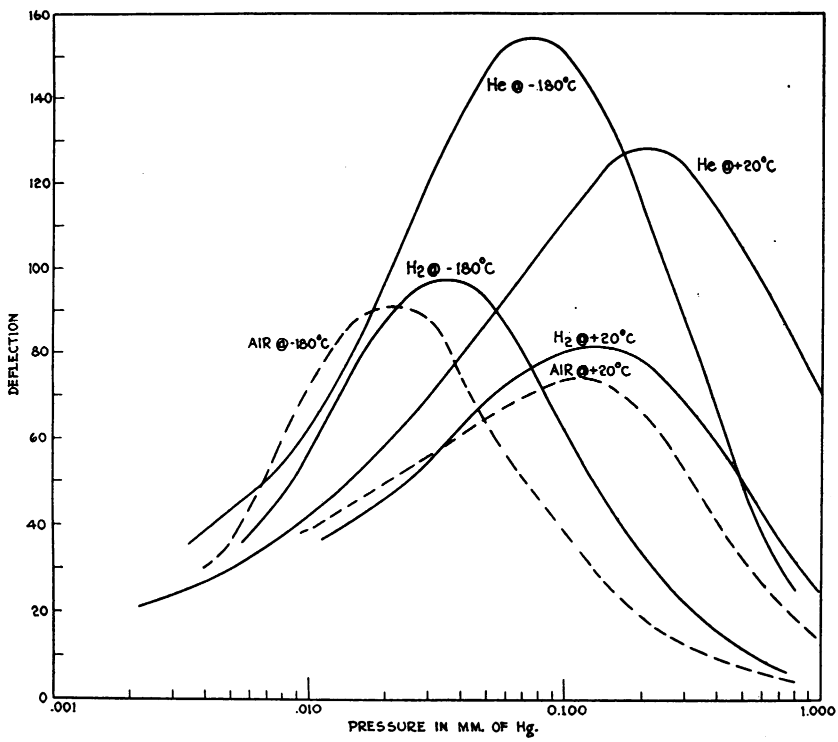

FIGURE 2

Dupont cement usually holds at low temperatures, in this apparatus it generally broke the windows by pulling fragments out of the surface. The windows were finally held in place by short lengths of rubber tubing, moistened with a few drops of castor oil. This method worked perfectly, for the radiometer chamber showed no loss of gas when the pressure in the region between the cooling chamber and the outer case was kept less than 10^{-4} mm. for a period of several hours.

The procedure was as follows. The radiometer[4] to be studied was mounted in the inner chamber, and after the chamber had been thoroughly evacuated, the desired gas was introduced, with precautions as to purity and dryness. Light from a controlled lamp was then allowed to fall on one of the radiometer vanes, and deflections were recorded for a series of different pressures. The cooling chamber was then filled with liquid air and the series repeated.

The results for a typical radiometer in H_2, He, and air are shown in figure 2. As may be seen from the curves, the maximum sensitivity in each case increases at low temperatures and shifts toward lower pressures. As to be expected, the radiometer becomes very sensitive to stray radiation at low temperatures; but stray radiation can easily be eliminated. In other respects the behavior is very good. The zero is remarkable steady, and at a meter scale distance deflections can be duplicated to about 0.1 mm.

[1] This work was undertaken as a part of a coöperative study of astrophysical instruments and methods, made in connection with the development of the Astrophysical Observatory and Laboratory of the California Institute of Technology.

[2] For a full discussion of the theory of radiometers see Epstein, *Zs. Phys.*, **54**, p. 537, 1928.

[3] Nichols, *J. O. S. A.*, **19**, p. 164.

[4] The radiometer used was a sensitive double, vane radiometer built along the lines described by Tear (*Phys. Rev.*, **23**, 641). A full description of the technique of building sensitive radiometers will appear elsewhere.