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The Electrical and Thermal Conductivity of Liquid Rubidium to 2,900°F, and the Critical Point of Rubidium.+

by

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The design and optimization of space power cycles requires the thermo-dynamic and transport properties of possible working fluids to high tempera-tures. The critical data for a fluid facilitate extrapolation of such proper-ties and completion of thermodynamic diagrams. All such results also assist extrapolation and correlation of other related properties of the fluid, and prediction and extrapolation of properties of other related fluids. There-fore, such a program on the alkali metals has been initiated in this labora-tory (1). Cesium was first studied (2, 3) because its critical point was ex-pected to be the lowest. Rubidium in a high available commercial purity (99.7 to 99.9% Rb) was next employed. Preliminary results herein reported are on a hypocritical density run; a hypercritical density run that is planned will yield greater accuracy.

Electrical conductivity of the liquid phase was determined by measuring the d.c. IR drop between voltage taps along a partially-filled vertical cylin-drical capsule of known dimensions. The capsule was of 90 Ta/10 W alloy, 1 in. O.D., 1/16 in. wall, and 12 in. long. It was surrounded by a molybdenum wire heater on an alumina core and radiation shields, all contained in a vessel rated at 2500 psi and pressurized with argon of extreme purity. Temperature was obtained by W/W-26 Re thermocouples.

The temperature was varied in increments from 1500 to 3140°F and back down. Subtracting at each temperature the previously measured conductance of the empty capsule between the pair of taps from the observed total conductance yielded that of the rubidium, from which its electrical resistivity R was com-puted after correcting for thermal expansion of the capsule. Data up to 3048°F clearly showed the presence of liquid phase. However, due to the low liquid level, the results above 2,900°F are considered inaccurate, and are not included.

+ This is a revised abstract of the paper presented at the Electrochemical Society, Washington, D.C. (October 14, 1964), Abstract No.191, and published as an Extended Abstract of that meeting in "Electrothermics and Metallurgy", Vol.D4, p.61(1964).

Smoothing the resistivity values, R, by a plot of R/T vs. T, the tabulated values are obtained. It is seen that agreement with available lower temperature data (4) for highly purified rubidium is quite close, showing a maximum discrepancy of 3.3% at 1500°F, which decreases monotonically to 0.2% at 2000°F.

From the resistivity the thermal conductivity was calculated, employing the Lorenz relation with a constant of 2.3×10^{-8} (volts/°K)^2. This is an average value for most pure metals, agrees well with that for sodium (3), and is the average of the values calculable from the cesium electrical and thermal conductivity data of Battelle Memorial Institute (5), and 2.45 used by Pratt and Whitney (5). These results are also shown in the table.

A "pseudoreduced" electrical resistivity of mercury ($R/R_{T_r} = .5$) calculated from Birch's data (2), and a "pseudoreduced" electrical resistivity of cesium calculated from Hochman's data (2), were separately plotted vs. reduced temperature T_r. By trial and error it was determined that a T_c for rubidium of approximately 3800°R (3340°F, 2111°K or 1838°C) exhibited a "pseudoreduced" curve whose semilogarithmic slope agreed fairly well with that of both the mercury and the cesium data. This is, therefore, the critical temperature of rubidium by this method and data, and is believed to be correct within some 100°F. The corresponding critical pressure, by Shulman's equation (6) is 162.3 atmospheres abs. (2386 psia). Shulman's equation, based on data up to 11 atmospheres abs., averages 0.5% higher than the prior rubidium vapor pressure equation from this laboratory (7).

Capsules were fabricated and filled by the Space Power and Propulsion Section of General Electric. Rubidium was provided by Penn Rare Metals, the pressure vessel by the Consolidated Edison Co., of N.Y., and the argon by Linde.

(1) AEC Research Division Contract AT(30-1)-2660.

(2) Hochman, J.M. with Bonilla, C.F. Eng. Sci. Dr. dissertation, Department of Chemical Engineering, Columbia University (1964).

(3) Hochman, J.M. and Bonilla, C.F. Trans.Amer.Nuclear Soc. 7, No. 1 (June, 1964); Nucl. Sci. and Eng'g. (Feb., 1965).

(4) Tepper, F. et al. M.S.A. Research Corporation. Report 63-139, Contract AF-31(657)7659 (15 October 1963).

(5) Lemmon, A.W. et al. Battelle Memorial Institute. NASA Report CR-54018, pp. 19-20 (Feb. 29, 1964).

(6) Shulman, G. with Bonilla, C.F. M.S. thesis, Department of Chemical Engineering, Columbia University (1963).

(7) Bonilla, C.F., Sawhney, D.L. and Makansi, M.M. Trans. A.S.M. 55, 887 (1962).

ELECTRICAL RESISTIVITY AND THERMAL CONDUCTIVITY OF LIQUID RUBIDIUM

Temperature (Fahrenheit)	Electrical Resistivity (micro-ohm-cm)		Thermal Conductivity (watts/cm °F)
	Present (inter-polated)	MSAR (5)	Present (calculated)
1500	123.5	119.5	0.1126
1600	136.0	132.1	0.1065
1700	149.2	146.0	0.1028
1800	163.6	161.3	0.0980
1900	179.4	177.9	0.0934
2000	196.6	196.2	0.0888
2100	215.8		0.0842
2200	239.1		0.0790
2300	265.0		0.0739
2400	294.0		0.0690
2500	325.6		0.0645
2600	359.6		0.0604
2700	396.6		0.0566
2800	439.8		0.0526
2900	500.6		0.0476