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NRL Report 6213

High Temperature Properties of Sodium, Potassium, and Cesium

Thirteenth Progress Report

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Inorganic and Nuclear Chemistry Branch
Chemistry Division

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U.S. NAVAL RESEARCH LABORATORY
Washington, D.C.

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An experimental program to measure various thermo-physical properties of sodium, potassium, cesium, and their vapors at elevated temperatures has been completed at NRL. Preliminary data for the density of liquid potassium (1099° to 2287°F) and the vapor pressure of cesium (1214° to 2345°F) are presented in this report.

INTRODUCTION

In the development of compact turboelectric systems, the National Aeronautics and Space Administration is sponsoring a property measurement program for the evaluation of several liquid metals as possible working fluids. As an integral part of this program, the Naval Research Laboratory is engaged in the measurement of various thermo-physical properties of sodium to 2500°F, potassium to 2300°F, and cesium to 2300°F.

SUMMARY OF EXPERIMENTAL PROGRAM

For the three alkali metals, the properties which are being determined experimentally include vapor pressure, specific volume of liquid, specific heat of liquid (except for cesium), surface tension of liquid (except for sodium), and specific volume of saturated and superheated vapors (PVT studies). Additional thermodynamic properties including latent heat of vaporization, enthalpy, entropy, and specific heat of the vapor will be calculated from the measured properties.

The experimental phases of the PVT studies for both sodium and potassium have been completed. The thermodynamic properties of potassium including specific volume, enthalpy, entropy, and specific heat were obtained from a comprehenisve thermodynamic treatment of the vapor and liquid properties. A preliminary reporting of this treatment and tables of the thermodynamic properties were included in the Twelfth Progress Report (1). A treatment of the sodium data similar to that described for potassium (1) is in progress, and tabular properties should be available for inclusion in the next quarterly report. PVT measurements for cesium are in progress, and preliminary saturation pressures are reported.

Densities of liquid potassium from 1099° to 2287°F have been completed, and final values are reported. Densities of sodium for the temperature range from 2100° to 2500°F were reported in the Sixth Progress Report (2). Additional sodium measurements at lower temperatures and the cesium measurements are in progress.

The surface tension measurements of liquid potassium and cesium have been delayed by the PVT work and by problems experienced in the welding of the maximum-bubble-pressure apparatus. However, measurements are expected to be made during the last quarter of this fiscal year.

DENSITY OF LIQUID POTASSIUM

The final density measurements of potassium are reported in Table 1. Pycnometers of Cb-1%Zr with 30 cc nominal volumes are used for the determinations. The method employed is as follows. The alkali metal is distilled into the pycnometer, and an overflow vessel is welded to the

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TABLE 1
Density of Liquid Potassium

Temperature (°F)	Density (lb/cu ft)
1099.0	43.973
1562.6	40.066
1747.0	38.423
1928.0	36.783
2121.7	35.047
2286.7	33.713

top with an interconnecting capillary (3). The apparatus is pressurized (1 atm overpressure at all temperatures), heated to the desired equilibrium temperature, and the weight of metal remaining in the known volume determined both by weight difference and by chemical analysis. The maximum difference of these two weight determinations in all cases has been less than 0.1%.

The recommended density equation for liquid potassium is

$$d = 52.759 - 7.4392 \times 10^{-3}t - 0.5784 \times 10^{-6}t^2 + 0.0780 \times 10^{-9}t^3 \quad (1)$$

where d is density in lb/cu ft and t is temperature in °F. Equation (1), for the temperature range from the melting point to 2300°F, was derived by fitting the best curve to the density determinations of Hagen (4) and NRL (5) at lower temperatures; Novikov (6), MSA (7), and Rinck (8) at moderate temperatures; and NRL (Table 1) at higher temperatures. For each literature investigation, the average deviation of the observed densities from those calculated using Eq. (1) is presented in Table 2. It will be noted that overlapping density determinations have been made from the melting point to 2300°F and that the bulk of these determinations are represented by Eq. (1) with deviations of less than 0.2%. This indicates a confidence limit for Eq. (1) of ±0.2 to ±0.3%.

SATURATED VAPOR PRESSURE OF CESIUM

Saturation pressures were obtained for cesium from 0.88 atm at 1214°F to 33.5 atm at 2345°F with the null-point apparatus. The data for the full temperature range from the normal boiling point to 2345°F were effectively fitted with one three-term equation.

$$\log p = 5.87303 - \frac{7040.69}{T} - \cdot 53290 \log T \quad (2)$$

where p is vapor pressure in abs atm and T is temperature in °R. The average deviation of the observed vapor pressure data from corresponding values computed using Eq. 2 is ±0.35%.

TABLE 2
Fit of General Density Equation for Potassium to Literature Data

Investigator	Temp Range (°F)	Average Deviation of All Observed Values of Each Investigator from Corresponding Values Calculated with Eq. (1) (%)
Hagen	(mp to 229.6)	−0.17
NRL	(mp to 499.1)	±0.05
Novikov	(196 to 1352)	±0.20
MSA	(257 to 1281)	+0.81
Rinck	(617 to 1104)	±0.46*
NRL	(1099 to 2287)	±0.11

*Except for two results, the data of Rinck show an average deviation of ±0.21%.

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