NRL REPORT C-3383

FR-3383

QUARTERLY PROGRESS REPORT NO. 9 ON THE MEASUREMENT OF THE PHYSICAL AND CHEMICAL PROPERTIES OF THE SODIUM-POTASSIUM ALLOYS

Joseph A. Grand
Robert E. Seebold
Curtis T. Ewing

October 1948

Distribution Unlimited

Approved for
Public Release

Approved by:

Mr. R. R. Miller, Head, Physical and Inorganic Section
Dr. P. Borgstrom, Superintendent, Chemistry Division

NAVAL RESEARCH LABORATORY

CAPTAIN H. A. SCHADE, USN, DIRECTOR
WASHINGTON, D.C.

DISTRIBUTION

ONR	
Attn: Assistant Chief for Research	1
Attn: Code N-482	2
BuAer	
Attn: Code TD-4	1
CNO	
Attn: Code OP-36	4
BuShips	
Attn: Code 432	2
Attn: Code 433	2
Attn: Code 343	1
Attn: Code 180	1
BuOrd	
Attn: Code Re9	1
Dir., USNEL	2
CO, USNOTS	
Attn: Reports Unit	2
Dir., USNEES	1
Chief of Ordnance, Dept. of the Army	
Attn: Ch. Rocket Development Div.	1
OCsigO	
Attn: Ch. Eng. & Tech. Div., SIGTM-S	1
CO, SCEL	
Attn: Dir. of Engineering	2
CG, Wright-Patterson Air Force Base	
Attn: Power Plant Lab., Engineering Div.	2
BAGR, CD, Wright-Patterson Air Force Base	
Attn: BAU-ADD	1
CG, Manhattan District Engineers, Dept. of the Army	2

General Electric Co., Schenectady, N. Y.	
Attn: Capt. Burris	6
Attn: General Engineering & Consulting Lab.	1
Griscom-Russell Co., N. Y., N. Y.	1
Babcock and Wilcox Co., Alliance, Ohio	
Attn: Research and Development Dept., Mr. M. B. Leland	2
Mine Safety Appliances Co., Pittsburgh, Pa.	
Attn: Dr. C. B. Jackson	2
Argonne National Laboratory, Chicago, Ill.	
Attn: Dr. W. H. Zinn	1
Clinton National Laboratory, Oak Ridge, Tenn.	
Attn: Mr. R. M. Lyons	2
University of Southern California, Los Angeles, Calif.	
Attn: Dr. A. B. Burg	1
Atomic Energy Commission, Schenectady, N. Y.	
Attn: Lt. Cdr. H. A. Jackson	1
Atomic Energy Commission, Wash., D. C.	
Attn: Mr. B. M. Frye, Library	3
RDB	
Attn: Library	2
Attn: Navy Secretary	1
Science and Technology Project	
Attn: Mr. J. H. Heald	2

CONTENTS

ABSTRACT

The status of active physical and chemical property measurements on sodium-potassium alloys at this Laboratory and all measured results obtained since the preceding Quarterly Report are presented. Certain studies of a long-term nature - including those on specific heat, thermal conductivity, surface tension, and contaminants (the latter by radioactive tracers) - are continuing, but there is little to report at this time.

The modified specific heat apparatus, however, was used to measure the specific heat up to 450°C of the alloy containing 46 weight percent potassium, and these results are reported. Measurements of magnetic susceptibility were made at the University of Kansas under an ONR contract and are included. The study of wetting with regard to temperature and surface conditions was recently resumed.

PROBLEM STATUS

This is an interim report on this problem; work is continuing.

AUTHORIZATION

This problem was initiated in June 1946 upon the request of Bureau of Ships. The new NRL Problem Number assigned 1 July 1948 was C11-02R (BuShips Proj. 990/46).

STATEMENT OF PROBLEM

To investigate the physical and chemical properties of liquid metals..... The investigation to date has been principally concerned with the alkali metals.

QUARTERLY PROGRESS REPORT NO. 9 ON THE MEASUREMENT OF THE PHYSICAL AND CHEMICAL PROPERTIES OF THE SODIUM-POTASSIUM ALLOYS

PHYSICAL PROPERTY MEASUREMENTS

Magnetic Susceptibility

Magnetic susceptibility measurements were made under ONR contract at the University of Kansas. Susceptibilities were determined by the Guoy method for the pure metals and two alloys at 25° C. The completed work as furnished by the University is transcribed in this report as the letter on page 2 and the table on page 3. The measured values, considering the stated accuracy, would seem to corroborate those obtained by previous investigators. They give uniform paramagnetic values over the composition range.

The sample tubes were filled and furnished by this Laboratory. Each metal sample was distilled under high-vacuum from a nickel still as prescribed previously.[1] A portion of each sample was removed for analysis by the usual method.

Mixed chlorides from the four samples were examined spectrographically for magnetic impurities. No trace of iron, nickel, manganese, cobalt, or chromium was found.

Specific Heat

The heat content of 46 weight percent potassium alloy was determined by the drop method over the range 100°C to 450°C. This data indicated the specific heat of the alloy to be 0.30 g-cal/gm from 100° to 230°C and 0.26 g-cal/gm from 270° to 450°C. These results are believed untrustworthy because of absorbed hydrogen in the electrolytic iron buckets used as containers for the alloy. The heat capacity apparatus is being redesigned, and in the future buckets freed from hydrogen by vacuum-induction heating will be used.

Surface Tension

Recent measurements of surface tension by the maximum-bubble-pressure method have verified those previously reported only in order of magnitude. By substituting a capillary with a knife-edge tip, the measurements were found to be reproducible at any time and temperature to within one or two percent, but with any change in temperature or lapse of time the results were still erratic. As with other properties, sodium and the

---

[1] Ewing, C. T., R. S. Hartman, and H. B. Atkinson, Jr., NRL Report C-3152, "Quarterly Progress Report No. 4 on the Measurement of the Physical and Chemical Properties of the Sodium-Potassium Alloys," (Unclassified), July 1947.

THE UNIVERSITY OF KANSAS
Lawrence

Department of Chemistry August 13, 1948

Mr. R. R. Miller
Chemistry Division
Naval Research Laboratory
Washington 20, D. C.

Subject: Measurement of Magnetic Susceptibilities requested by ONR.

References: ONR letter EXOS:ONR:N425:FS:ly
NR 052 036 - N6 ori-164 T. O. I
dated Jan 28, 1948
NRL letter 3230-118/48 ep dated July 14, 1948

The requested magnetic susceptibilities of the metals and alloys have been measured. The results are shown in the accompanying table.

The samples arrived in good condition. The sample tubes were well made and fit our balance all right. The slight amount of metal trapped in the top of a tube caused no trouble, for with fillings deeper than 7 cm. the surface is out of range of the effective magnetic field. Therefore slight differences in depth have no effect on the measurements.

We assumed that all the sample tubes had the same diameter and also that all had the same "blank susceptibility" as the two empty tubes.

Measurements were made with a magnetic field strength of 6800 gausses. The $\Delta\omega$ for these samples was of the order of a few milligrams, a rather small value to be detected with an analytical balance.

The values reported here agree, within experimental limits, with values reported by Böhm and Klemm (Z. anorg. allgem. Chemie, 243, 69, (1939)).

We will be glad to make further measurements on these alloys but will be unable to do so until after the 15th of September. Should you want these samples returned, let us know in your next letter.

cc Dr. L. W. Butz
Chemistry Branch
Office of Naval Research
Navy Department
Washington 25, D. C.

cc Commanding Officer
Office of Naval Research
Chicago Branch office
844 N. Rush Street
Chicago 11, Ill.

Respectfully,

Joseph Thompson

William H. Schechter

Jacob Kleinberg

Magnetic Susceptibilities of Sodium, Potassium, and Their Alloys

Tube	Contents	Density	Volume Susceptibility (cgs units)	Gram Susceptibility (cgs units)	Atomic Susceptibility (cgs units)	Mean Atomic Weight
I.	100% Na	.97	$.67 \times 10^{-6}$	$.69 \times 10^{-6}$	15.9×10^{-6}	23.0
II.	100% Na	.97	$.68 \times 10^{-6}$	$.70 \times 10^{-6}$	16.1×10^{-6}	23.0
III.	99.9% K	.86	$.48 \times 10^{-6}$	$.56 \times 10^{-6}$	21.9×10^{-6}	39.1
IV.	99.9% K	.86	$.49 \times 10^{-6}$	$.57 \times 10^{-6}$	22.3×10^{-6}	39.1
V.	45.4% K	.91	$.58 \times 10^{-6}$	$.64 \times 10^{-6}$	18.1×10^{-6}	28.3
VI.	45.4% K	.91	$.60 \times 10^{-6}$	$.66 \times 10^{-6}$	18.7×10^{-6}	28.3
VII.	78.4% K	.87	$.52 \times 10^{-6}$	$.60 \times 10^{-6}$	19.7×10^{-6}	32.9
VIII.	78.4% K	.87	$.52 \times 10^{-6}$	$.60 \times 10^{-6}$	19.7×10^{-6}	32.9

Notes:
1. Temperature = 25° C.
2. Estimated precision: $\pm$ 5%
3. Densities of the pure metals were obtained from the Chemical Rubber Handbook. Densities of the alloys were obtained from NRL charts.
4. Mean atomic weights of alloys were calculated as follows:

$$\text{Mean at. wt.} = \frac{100}{\frac{\text{wt\% K}}{39.1} + \frac{\text{wt\% Na}}{23}}$$

high-sodium alloys are more erratic. It seems pointless to report additional values until more is learned regarding the peculiar behavior of the metals. The glass capillary is to be replaced by metal to study further the possibility of wetting phenomenon at the tip. If high temperature values become useful in the correlation of other properties, an all-metal type apparatus will be assembled.

Thermal Conductivity

The thermal conductivity measurements are being delayed pending delivery of necessary instruments and materials. The final apparatus will be essentially as described in the preceding report.

Wetting Temperatures

Previous wetting tests[2] were of a nonconclusive nature and were discontinued. This situation resulted from unknowns in surface conditions and possible misinterpretation of

---

[2] Ewing, C. T., and R. R. Miller, NRL Report P-3010, "Quarterly Progress Report No. 1 - Sodium-Potassium Alloys," (Unclassified), 30 September 1946; Ewing, C. T., R. S. Hartman, and H. B. Atkinson, Jr., NRL Report C-3105, "Quarterly Progress Report No. 3 - Sodium-Potassium Alloys," (Unclassified), April 1947.

data due to the reducing action of the alkali metals (on the surface oxides of the sample piece).

The method now employed is somewhat different from that previously described. In the present experiments, several drops of the desired metal are forced from a glass ampule onto the horizontal surface of a prepared test piece. Provision is made for heating (under high vacuum or under an inert atmosphere) the test piece and for recording the temperature. The height of each drop relative to the surface of the test piece can be observed visually as the temperature is raised, and conclusions as to wetting are drawn therefrom. Exacting precautions are prescribed to insure surface conditions of the liquid metals and of the metal test piece. The apparatus is also designed for the reduction when desired of surface oxides on the test piece using hydrogen under induction heat. By varying the condition of the surface of the test piece, it is hoped that the present experiments will distinguish between wetting and reduction.

Association

The eccentric behavior of the liquid metals on the high-sodium side led to speculation in a former report[3] as to the persistence of compounds above the melting point. Such behavior is now believed to be caused by the association or aggregation of sodium atoms in the liquid state. Conceivably, a similar interpretation of data might result from the presence of impurities or from compounds, but neither seems likely. The physical properties of the metals (surface tension, viscosity, density, etc.) indicate association with apparent molecular weight for pure sodium of approximately 35 at 100°C. Disassociation to monatomic sodium possibly takes place as the temperature is raised to the boiling point. This association, if such it is, would undoubtedly be accompanied by low energy changes, and further knowledge can best be gained through the effect of the molecular sodium on physical properties. At the present time the association factor is a convenient explanation and any conclusion drawn or applications made should take this into consideration.

Recent Literature of Interest

The compressibilities of the alkali metals were measured by P. W. Bridgman[4] at pressures of 1 to 100,000 Kg/cm^2 (14.22 to 1,422,000 lbs/in^2). If one assumes compressibility to be linear between the two pressures given, then the compressibility coefficients for certain alkali metals referred to unit volume at 14.22 lbs/in^2 are: for K, $\beta = 0.3515 \times 10^{-6}$; for Na, $\beta = 0.2770 \times 10^{-6}$; and for Li, $\beta = 0.2306 \times 10^{-6}$. With these coefficients the compressed volume (V_2) at any pressure (P_2) relative to unit volume at 14.22 lbs/in^2 can be estimated from the equation

$$V_2 = V_1 \left[1 - \beta (P_2 - 14.22)\right]$$

when P_2 is the applied pressure in pounds per square inch.

* * *

[3] Ewing, C. T., R. S. Hartman, and H. B. Atkinson, Jr., NRL Report C-3152, "Quarterly Progress Report No. 4 ... Sodium-Potassium Alloys" (Restricted), July 1947

[4] Bridgman, P. W., Proc. Am. Acad. Arts, Sci., 76, 55-70, (1948)

PRNC-9088-1-27-49-200