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DENSITY OF LIQUID URANIUM<sup>1</sup>

Sir:

The density of pure liquid uranium was determined by using the Archimedean method, from its melting point (1406°K.) to about 1900°K.

Three runs were made using different type sinkers and crucibles to avoid or minimize chemical contamination effects. The sinkers and crucibles used were a ZrO<sub>2</sub>-coated molybdenum sinker and a Al<sub>2</sub>O<sub>3</sub> crucible in run 1, a pure Al<sub>2</sub>O<sub>3</sub> sinker and a Al<sub>2</sub>O<sub>3</sub> crucible in run 2, and a ZrO<sub>2</sub>-coated molybdenum sinker and a pure ThO<sub>2</sub> crucible in run 3. No noticeable chemical reaction was observed. All materials performed satisfactorily, those of run 3 being the best. All the measured values fitted the same straight line. The uranium (from Davison Chemical Co.) contained 0.220% U<sup>235</sup> and its actual uranium content was 99.9 wt.%. Impurities, in p.p.m., were: Fe and Ni, 200; O, 150; C, 90; Cu and Si, 50; N, 25; Al, 20.

liquid temperature range diagram of metals demonstrating the relationship between liquid (and saturated vapor) density vs. temperature over the whole liquid temperature range, from the melting point to the critical point, by using the theorem of corresponding states of van der Waals, the law of rectilinear diameter of Cailletet and Mathias and experimental data on heats and entropies of vaporization, vapor pressure and particularly experimental liquid density data over as wide a temperature range as possible. Density measurements have been carried out, at this Institute, on a large number of metals from their melting points to their boiling points, such metals as Pb,<sup>2</sup> Ag,<sup>6</sup> Cu, Sn, and In.

It is clear now, from a study of the temperature range diagram of liquid metals, that liquid density is a straight line function of temperature far beyond the metal's normal boiling point, because the saturated vapor density of metal, which according to the law of rectilinear diameter causes deviation from

TABLE I

°K.	D of liquid uranium in g./cm. <sup>3</sup>				Atomic volume, cm. <sup>3</sup> /g. at.	Cubical coef. of expansion for natural uranium, T <sup>-1</sup> °K. × 10 <sup>4</sup>
	Natural	U <sup>235</sup>	U <sup>238</sup>	U <sup>235</sup>		
1406 m.p.	17.898	17.905	17.678	17.528	13.301	57.60
1500	17.801	17.807	17.582	17.432	13.374	57.92
2000	17.284	17.291	17.072	16.927	13.774	59.65
2500	16.768	16.774	16.562	16.421	14.158	61.49
3000	16.252	16.258	16.052	15.916	14.649	63.44
4200 b.p.	15.01 ± 0.04	15.02	14.83	14.70	15.86 ± 0.04	69
D <sub>0</sub>	19.350	19.357	19.112	18.949		
α	-10.310 × 10 <sup>-4</sup>	-10.330 × 10 <sup>-4</sup>	-10.260 × 10 <sup>-4</sup>	-10.110 × 10 <sup>-4</sup>		

The equation of the density of liquid uranium, determined by the method of least squares, is  $D_{liq.}$  in g./cm.<sup>3</sup> = 19.356 - 10.328 · 10<sup>-4</sup> T, with a probable error of ±0.078%.

Details of our general method of density measurement, electrical heating, temperature control and surface tension correction are given in another publication.<sup>2</sup>

In recent papers<sup>3,4</sup> it was shown that the temperature range of liquid metals, *i.e.*, the range from the melting to the critical point, is far greater than for any other type of substance. It extends, in view of their elementary and atomic nature, far beyond the thermal limits of existence of any other solid or liquid; even the stablest of the latter dissociate into atoms at about 5000-6000°K. In contrast, the refractory metals such as Re, Ta and W will be liquids up to a critical temperature of about 20,000, 22,000, and 23,000°K., respectively.

It also was shown<sup>3,4</sup> that one can construct a

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(2) A. D. Kirshenbaum, J. A. Cahill and A. V. Grosse, *J. Inorg. & Nucl. Chem.*, in press (1961).

linearity, assumes significant values only substantially above the normal boiling point. Thus, we can estimate the density of liquid uranium at its normal boiling point with reasonable accuracy.

T. W. Richards in his classical work<sup>5</sup> on the atomic volumes of separated lead isotopes proved F. Soddy's concept of the equality of atomic volumes of isotopes with a high degree of precision. Thus, we can estimate from our data the liquid densities of pure U<sup>235</sup>, U<sup>238</sup> and U<sup>238</sup>. The coefficients of the density equation  $D_T = D_0 + \alpha T$  and density values for set temperatures for the three isotopes and the natural U-mixture are given in Table I.

(3) A. V. Grosse, "The Liquid Range of Metals and Some of Their Physical Properties at High Temperatures," Report of the Research Institute of Temple University, September, 1960.

(4) A. V. Grosse, *J. Inorg. & Nucl. Chem.*, in press (1961).

(5) A. D. Kirshenbaum, J. A. Cahill and A. V. Grosse, *J. Inorg. & Nucl. Chem.*, in press (1961).

(6) T. W. Richards and C. Wadsworth, *J. Am. Chem. Soc.*, 38, 221 (1916).

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