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Viscosities of Liquid Sodium and Potassium, from Their Melting Points to Their Critical Points

Abstract. *The viscosities of liquid sodium and potassium were estimated up to the critical temperatures according to the method recently described for mercury. The critical absolute viscosity of sodium is 0.072 centipoise and that of potassium 0.055 centipoise, the estimated precision being plus or minus 0.01 centipoise. The critical absolute viscosities of metals are higher than those of covalent or homopolar substances of van der Waals type.*

The liquid alkali metals are of interest as heat transfer media in reactor technology and in space applications. Their so-called transport properties, particularly viscosity, have been the subject of detailed studies both in this country (*1–3*) and in the Soviet Union (*4*). The viscosity of sodium has now been measured up to 1200°K and of potassium, up to 1400°K. To cover the full liquid range, viscosities must be measured over another 1600°K in the case of sodium and about 1000°K for potassium in order to reach their critical temperatures, estimated as 2800°K for Na and 2450°K for K (*5*). In view of the difficulties encountered in measuring properties of highly reactive liquid metals at high temperatures, and particularly at high pressures, it will probably be many more years before the entire liquid range of the alkali metals is covered experimentally and before the values for the critical viscosities can be determined directly.

On the other hand, the absolute viscosity of liquid mercury can be estimated (*6*) up to its experimentally determined critical temperature of 1733°K. It would seem ludicrous for anyone familiar with the usually rapid decrease of liquid viscosity with temperature to attempt to extrapolate the viscosity of any substance over a range of 1600° or even 1000°K. We now report, however, that in their behavior as liquids, sodium and potassium resemble mercury and represent a particularly simple case.

In a manner similar to mercury or any other thermally stable liquid, the absolute or dynamic viscosity of liquid sodium or potassium has to decrease from the end of the experimental temperature range to the critical point; on the other hand, the viscosity of the saturated vapor of the metal, in equilibrium with the liquid, increases over the entire range up to the critical point. The viscosity of saturated vapor can be calculated easily, in first approximation, from simple kinetic theory; it increases proportionally to $\sqrt{T}$ in the lower temperature range and proportionally to T in the medium range (*6*). Therefore, the estimation of the critical viscosity becomes self-bracketing; as one extrapolates the viscosity, η, of the liquid and the saturated vapor beyond the experimental into the uncertain region, the range of conceivable η-values becomes very small. This is further supported by the fact that ½ $(\eta_{liq} + \eta_{sat\ vap})$, exactly like ½ $(D_l + D_{sat\ vap})$ in the law of rectilinear diameter for liquid densities (*5, 7*), is practically a straight line function of T in the critical region.

Table 1. Absolute viscosity of sodium, from melting point (371.00°K) to critical point (2800°K).

T (°K)	η (10^{-2} poise)	v (cm^3/g)	$\eta v^{1/3}$ (10^3 poise $cm/g^{-1/3}$)	$1/Tv$ [$10^3 g/(cm^3 \cdot °K)$]
		Experimental range		
371.00	0.690	1.078,75	7.0766	2.4987
473	.450	1.106,56	4.6544	1.9106
573	.340	1.135,72	3.5482	1.5366
673	.278	1.166,86	2.9268	1.2734
773	.239	1.200,34	2.54057	1.0776
873	.212	1.236,25	2.2754	0.9266
973	.193	1.274,37	2.0925	.8065
1073	.179	1.315,79	1.9615	.7083
1173	.167	1.360,54	1.8505	.6266
1203	.164	1.373,62	1.8230	.6052
		Extrapolated range		
1400	0.147	1.4705	1.67	0.486
1600	.134	1.5898	1.57_1	.393
1800	.123	1.730_1	1.48	.321
2000	.115	1.898	1.42	.264
2200	.106	2.128	1.37	.214
2400	.099	2.421	1.33	.172
2600	.091	2.89_9	1.29	.133
2700	.086	3.30_0	1.27	.112
2800	.069	5.71_4	1.23	$.062_5$

Table 2. Absolute viscosity of potassium, from melting point (336.9°K) to critical point (2450°K).

T (°K)	η (10^{-2} poise)	v (cm^3/g)	$\eta v^{1/3}$ (10^3 poise $cm/g^{-1/3}$)	$1/Tv$ [$10^3 g/(cm^3 \cdot °K)$]
		Experimental range		
336.9	0.560	1.2062_7	5.961_2	2.4606
400	.384	1.22911	4.113_4	2.0340
500	.276	1.26711	2.986_6	1.5784
600	.221	1.3075_3	2.416_6	1.2747
700	.185	1.3506_2	2.045_0	1.0577
800	.162	1.3966_6	1.810_8	0.8949_7
900	.147	1.4459_2	1.6623	$.7684_6$
1000	.132	1.4988_0	1.5106	$.6672_0$
1100	.121	1.5556_9	1.4020	$.5843_6$
1200	.113	1.6170_7	1.3264	$.5153_3$
1300	.106	1.6835_0	1.2610	$.4569_1$
1400	.100	1.7556_1	1.2064	$.4068_7$
		Extrapolated range		
1600	0.092	1.9417	1.150	0.3219
1800	.084	2.1739	1.085	.2555
2000	.077	2.500	1.0495	.2000
2200	.071	2.94_1	1.015	.1546
2400	.062	3.92_2	0.975	.1062
2450	$.05_2$	5.88_2	0.940	.0694