

Table 3. Calculated properties according to DM theory for potassium

$V/V_0$	Temperature ( $^{\circ}$ K)	Gamma	$P(0)$ ( $mb = 10^3$ kbar)	$P(298)$ ( $mb$ )	$P(\text{HUG})$ ( $mb$ )
0.87789	$3.5856 \times 10^2$	1.1928	0.00291	0.00500	0.00535
0.80160	4.2622	1.1093	0.00790	0.01000	0.01088
0.74681	5.1265	1.0661	0.01287	0.01500	0.01659
0.70421	6.2120	1.0385	0.01782	0.02000	0.02252
0.66950	7.5286	1.0169	0.02278	0.02500	0.02870
0.64034	9.0794	0.9978	0.02774	0.03000	0.03512
0.61529	$1.0864 \times 10^3$	0.9801	0.03271	0.03500	0.04179
0.59342	1.2882	0.9635	0.03768	0.04000	0.04873
0.57404	1.5133	0.9478	0.04266	0.04500	0.05591
0.55671	1.7617	0.9331	0.04764	0.05000	0.06336
0.52679	2.3285	0.9062	0.05761	0.06000	0.07907
0.50169	2.9896	0.8824	0.06758	0.07000	0.09588
0.48017	3.7469	0.8612	0.07756	0.08000	0.11384
0.46139	4.6027	0.8422	0.08754	0.09000	0.13301
0.44480	5.5600	0.8249	0.09752	0.10000	0.15344
0.41661	7.7943	0.7946	0.11749	0.12000	0.19835
0.39334	$1.0485 \times 10^4$	0.7685	0.13746	0.14000	0.24911

Table 4. Calculated properties according to DM theory for rubidium

$V/V_0$	Temperature ( $^{\circ}$ K)	Gamma	$P(0)$ ( $bm = 10^3$ kbar)	$P(298)$ ( $mb$ )	$P(\text{HUG})$ ( $mb$ )
0.83762	$3.9226 \times 10^2$	1.2190	0.00340	0.00500	0.00544
0.75022	5.0554	1.1421	0.00835	0.01000	0.01118
0.69098	6.5794	1.1060	0.01328	0.01500	0.01728
0.64649	8.5349	1.0791	0.01822	0.02000	0.02380
0.61114	$1.0935 \times 10^3$	1.0548	0.02318	0.02500	0.03074
0.58199	1.3778	1.0321	0.02814	0.03000	0.03811
0.55733	1.7075	1.0110	0.03311	0.03500	0.04594
0.53603	2.0831	0.9916	0.03808	0.04000	0.05423
0.51735	2.5055	0.9736	0.04306	0.04500	0.06299
0.50077	2.9760	0.9571	0.04804	0.05000	0.07226
0.47241	4.0658	0.9276	0.05800	0.06000	0.09238
0.44884	5.3660	0.9019	0.06797	0.07000	0.11476
0.42878	6.8915	0.8792	0.07794	0.08000	0.13960
0.41139	8.6634	0.8589	0.08792	0.09000	0.16716
0.39610	$1.0702 \times 10^4$	0.8404	0.09790	0.10000	0.19769
0.37024	1.5682	0.8077	0.11786	0.12000	0.26890
0.34902	2.2084	0.7793	0.13784	0.14000	0.35616

merely states low-pressure results were 'adjusted' [9(c)] to agree with earlier values obtained at 10,000 kg/cm.

Results to 100,000 kg/cm<sup>2</sup> were published by Bridgman [9(d)] in 1941. In these particular experiments, measurements were made in a carbide cell immersed in isopentane which could be compressed to 25–30,000 bar. The diameter of his sample was  $\frac{3}{16}$  in., the

total length of the sample was under  $\frac{1}{2}$  in. In this apparatus, internal pressure was measured electrically by changes in resistance of a hardened steel grid, and piston displacement was obtained through remote readings with an Ames dial gage. Dilation calibrations in this apparatus was measured by assuming a compression of gold extrapolated to 100,000 atm from measurements made only

to 12,000 atm. Double values of friction of as high as 20 per cent were reported in these measurements. Bridgman reported a final accuracy for these numbers between 1 and 2 per cent. It is clear that Bridgman's pressure measurements were not good in this apparatus as he reported a transition in barium at 60 kbar which is now known to lie at 55 kbar, and reported a transition in bismuth at 90 kbar which is now known to lie at 77.5 kbar. Thus, his error in measuring pressure was 10–15 kbar at values of approximately 100 kbar. Further, all of Bridgman's measurements on the alkali metals were made with the alkalis in copper capsules which occupied two-thirds of the total volume of the system. Rigidity of copper is large and there is no evidence that a satisfactory fraction of the pressure generated inside this apparatus was actually transmitted to the alkali metal. The compressibility of copper which enters as a first-order correction to his results was extrapolated to 100 kbar from results of 12 kbar. The new data on the alkali metals obtained in this apparatus were normalized to the earlier 45 kbar data. However, the slopes of the compressibility curves are quite different and the two sets of curves meet at a rather sharp angle. Further, there is a suggestion that there is an uncertainty of at least 10 per cent in the amount of the alkali metal present. Bridgman says that "the volume of the alkali metal found (by measuring the dimensions of the charge) in this way agreed within 10 per cent with less accurate volumes given by weighing." In this apparatus Bridgman's raw measurement of the compression of potassium at 50 kbar were  $\Delta V/V_0$  of 0.462 in contrast to his earlier measurements of 0.416. The raw data from the 100 kbar set of measurements, however, were 'normalized' against his earlier 50 kbar (45 kbar) measurements.

Bridgman[9(e)] published new measurements of the alkali metals to 100 kbar. These new measurements involved a certain amount of modification of the method for measuring

displacement of the piston. However, the technique and apparatus were essentially similar to his previous 100 kbar measurements. In these new measurements on the alkali metals, aluminum sheaths were used rather than the copper sheaths of the previous determinations. Bridgman's new volume for the alkali metals at 100,000 kg/cm<sup>2</sup> contrast very markedly from his previously published values. The earliest 100,000 kg/cm<sup>2</sup> value for potassium was  $\Delta V/V_0 = 0.573$ ; whereas his newer, and presumably, better value is 0.500. Rubidium was changed from an initial value of  $\Delta V/V_0$  of 0.638 at 100 kbar to a value of 0.527, with correspondingly large changes for the other alkali metals. In general, the newer sets of measurements show a revision downward in the compressibilities of 10–20 per cent from the prior measurements. Unfortunately, from the point of view of the shock wave results, these revisions are in the wrong direction, as the first and presumably the least accurate set of compressibility measurements show closest agreement to shock wave densities computed from the model outlined in this paper.

Thus, in view of the fact that Bridgman revised earlier numbers by 20 per cent in  $\Delta V/V_0$  on a number of occasions where newer data overlapped older data at the upper end of a pressure range, disagreement between Bridgman's results and shock wave results of this magnitude should, perhaps, not be so surprising.

#### REDUCTION OF HUGONIOT DATA

The source of the differences in the reduction of the Hugoniot to the isotherm between Rice and the Russian group can be easily understood without resort to numerical calculations in terms of thermal equation of state of the metal. Where the thermal pressure of the metal is much less than its low-temperature bulk modulus at the same volume, it may be taken to be proportional to the thermal energy according to the accepted Mie-Grüneisen equation of state for solids.