TABLE III. Experimental data and calculation of V_{ql} in a CdSe crystal obtained with water column. $L=0.66446$ cm; average velocity $=3.576\times10^5$ cm/sec.

N	f_n (MHz)	Δf (MHz)	Δf_{avg} (MHz)	$f_n/\Delta f_{avg}$	n	$V=2Lf_n/n$ (10^5 cm/sec)
1	22.338510	0.268458	0.269285	82.9549	83	3.5767
2	22.070052	0.269854		81.9580	82	3.5768
3	21.800198	0.269532		80.9558	81	3.5766
4	21.530666	0.268967		79.9549	80	3.5766
5	21.261699	0.269299		78.9561	79	3.5766
6	20.992400	0.269963		77.9561	78	3.5766
7	20.722435	0.268466		76.9535	77	3.5764
8	20.453969	0.269059		75.9566	76	3.5766
9	20.184910	0.271199		74.9574	75	3.5766
10	19.913711	0.269398		73.9503	74	3.5753
11	19.644313	0.268712		72.9499	73	3.5762
12	19.375601	0.269031		71.9520	72	3.5762
13	19.106568	0.269571		70.9530	71	3.5762
14	18.836997	0.269477		69.9519	70	3.5761
15	18.567520	0.269030		68.9512	69	3.5761
16	18.298490	0.268829		67.9521	68	3.5761
17	18.029661	0.268787		66.9538	67	3.5761
18	17.760874	0.269720		65.9557	66	3.5762
19	17.491154	0.268955		64.9540	65	3.5761
20	17.222199	0.269386		63.9553	64	3.5761
21	16.952813	...		62.9549	63	3.5760

used on specimens too thin to be measured by other means. Disadvantages of using water are obvious if the materials tested are affected by humidity differences. Also, attenuation of sound in the water limits the frequency of measurements to approximately 20 MHz.

The shear-velocity measurements reported here were made by using a fused-silica buffer rod and Y-cut quartz crystals at an upper frequency of 46 MHz. No coupling corrections were applied to the data.

Table III gives the results of measurements on a CdSe crystal obtained with the water column. Note that the integer is not truly an integer but very nearly so. Since no coupling corrections were necessary, this difference was assumed to be due to the averaging in

TABLE IV. Velocities and elastic constants for BeO, ZnS, and CdSe.

Compound	Velocity (10^5 cm/sec)	C_{ij} (10^{11})[a]	S_{ij} (10^{-12})	β (10^{-12})	θ (°K)
BeO					
$\rho=3.010$ g/cc	$V_{11}=12.37$	$C_{11}=46.06$	$S_{11}=0.2397$	0.4456	1280
	$V_{33}=12.78$	$C_{33}=49.16$	$S_{33}=0.2151$		
	$V_{s66}=7.449$	$C_{66}=16.70$	$S_{66}=0.5988$		
	$V_{s44a}=7.005$	$C_{44}=14.77$	$S_{44}=0.6770$		
	$V_{s44b}=7.026$	$C_{12}=12.65$	$S_{12}=-0.05964$		
	$V_{ql}=11.93$	$C_{13}=8.848$	$S_{13}=-0.03241$		
	$V_{qs1}=8.019$				
	$V_{qs2}=7.206$				
ZnS					
$\rho=4.089$ g/cc	$V_{11}=5.512$	$C_{11}=12.42$	$S_{11}=1.103$	1.303	351
	$V_{33}=5.852$	$C_{33}=14.00$	$S_{33}=0.8507$		
	$V_{s66}=2.799$	$C_{66}=3.203$	$S_{66}=3.122$		
	$V_{s44a}=2.647$	$C_{44}=2.864$	$S_{44}=3.419$		
	$V_{s44b}=2.652$	$C_{12}=6.015$	$S_{12}=-0.4573$		
	$V_{ql}=5.362$	$C_{13}=4.554$	$S_{13}=-0.2101$		
	$V_{qs1}=3.246$				
	$V_{qs2}=2.728$				
CdSe					
$\rho=5.684$ g/cc	$V_{11}=3.630$	$C_{11}=7.490$	$S_{11}=2.327$	1.862	181
	$V_{33}=3.856$	$C_{33}=8.451$	$S_{33}=1.694$		
	$V_{s66}=1.592$	$C_{66}=1.441$	$S_{66}=6.939$		
	$V_{s44a}=1.521$	$C_{44}=1.315$	$S_{44}=7.605$		
	$V_{s44b}=1.520$	$C_{12}=4.609$	$S_{12}=-1.144$		
	$V_{ql}=3.572$	$C_{13}=3.926$	$S_{13}=-0.5498$	(3.393)	using negative C_{13}
	$V_{qs1}=1.881$				
	$V_{qs2}=1.556$				

[a] Elastic constants given in cgs units.

Δf, so it was rounded off to an integer before the velocity was calculated.

RESULTS AND DISCUSSION

Table IV is a summary of the elastic-moduli data obtained in this study. The data were programmed and computed on the IBM 7094 computer, along with the Debye-temperature calculations. The Debye temperatures were calculated by a method proposed by Anderson.[13] Debye temperatures were also calculated for ZnO,[14] CdS, and CdTe,[15] and are tabulated in Table V. The Poisson's ratio $(-S_{12}/S_{11})$ and another elastic constant C, which corresponds to a strain which changes the c/a ratio at constant volume, are also included in Table V for completeness. Figures 3–5 illustrate the values of Young's modulus $E=(1/S_{11})$ for BeO, CdSe, and ZnS as a function of orientation. The data for BeO indicate a minimum at 50° to the c axis, which agrees with the earlier data of Bentle[3] and Sjodhal and Chandler.[16]

TABLE V. Elastic properties of II–VI compounds.

Compound	Debye temperature θ (°K)	$C^a \times 10^{12}$	Poisson's ratio $(-S_{12}/S_{11})$
BeO	1280	12.16	0.249
ZnO[b]	416	3.32	0.437
ZnS	351	2.82	0.415
CdS[c]	216	0.132	0.483
CdSe	181	0.128	0.492
CdTe[d]	160	...	...

[a] $C=C_{11}+C_{12}+2C_{33}-4C_{13}$.
[b] Data from Bateman.[14]
[c] Data from Berlincourt.[5]
[d] Data from McSkimin.[15]

Tables VI and VII compare our data with the work of Bentle[3] on BeO and Berlincourt *et al.*[5] on CdSe. The greatest difference between Berlincourt's most accurate values, i.e., C_{33}, C_{44}, and C_{66}, and ours amounts to less than 0.5%. The agreement with Bentle's work on BeO is not so good. The agreement between C_{11}, C_{33}, and C_{44} falls well into the estimated error of 5% quoted by Bentle, but differences of 32% and 35% for C_{12} and C_{13}, respectively, do not fall into the 10% error bracket quoted by Bentle. This discrepancy can be partially resolved for the difference in C_{66} and C_{12} by use of a value of 1.63×10^{12} for C_{66} which Bentle reported but considered in error. Use of this value gives agreement with our value of C_{66} to 2.4% and change his value of C_{12} so that the agreement is within 12% instead of 32%, which is much more reasonable. The positive value of C_{13} was used in each case for the compressibility calculations. There is no physical reason

[13] O. L. Anderson, J. Phys. Chem. Solids **24**, 909 (1963).
[14] T. B. Bateman, J. Appl. Phys. **33**, 3309 (1962).
[15] H. J. McSkimin and D. G. Thomas, J. Appl. Phys. **33**, 56 (1962).
[16] L. H. Sjodahl and B. A. Chandler, J. Am. Ceram. Soc. **46**, 351 (1963).

TABLE VI. Results of measurements on CdSe. Density = 5.684 g/cc.

	C_{11}	C_{12}	C_{13}	C_{33}	C_{44}	C_{66}
	(in units of 10^{11} dyn/cm^2)					
Present work	7.490	4.609	3.926	8.451	1.315	1.441
Berlincourt *et al.* (Ref. 5)	7.42	4.53	3.93	8.477	1.317	1.445

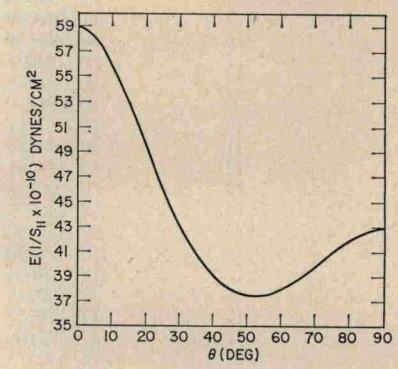

FIG. 4. Young's modulus of CdSe as a function of angle from the "c" axis.

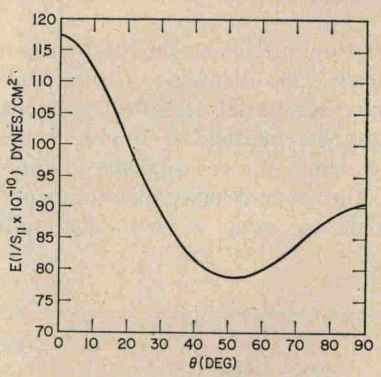

FIG. 5. Young's modulus of ZnS as a function of angle from the "c" axis.

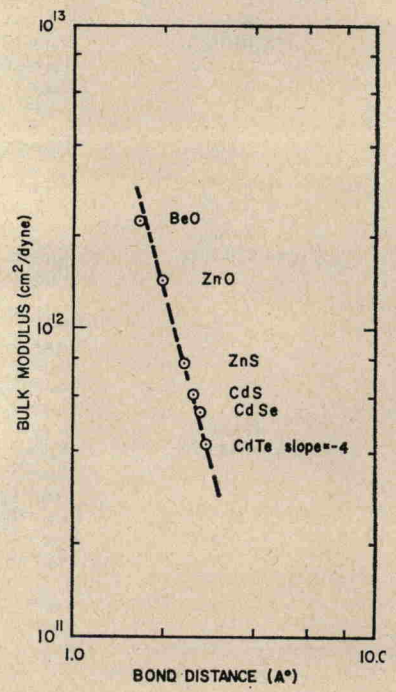

FIG. 6. Bulk modulus vs bond distance for II–VI compounds.