TABLE I. Smooth-curve values at one atmosphere of the adiabatic elastic constants c_{11}, c_{44}, and C' and calculated values of $1/\beta^S$ for NH_4Br in the cubic disordered phase, all in units of 10^{11} dyn cm^{-2}.

T(°K)	c_{11}	c_{44}	C'	$1/\beta^S$
235	...	0.7992	1.3110	...
236	...	0.7987	1.3171	...
237	3.2640	0.7977	1.3205	1.5033
238	3.2860	0.7968	1.3231	1.5219
240	3.3190	0.7948	1.3260	1.5510
245	3.3694	0.7897	1.3292	1.5971
250	3.3942	0.7842	1.3300	1.6209
260	3.4205	0.7726	1.3289	1.6486
270	3.4293	0.7605	1.3264	1.6608
280	3.4293	0.7478	1.3232	1.6650
290	3.4236	0.7349	1.3197	1.6640
300	3.4144	0.7218	1.3160	1.6597
310	3.4028	0.7083	1.3122	1.6532
320	3.3885	0.6944	1.3083	1.6441

As the temperature was lowered toward the transition temperature, an increase in attenuation was observed. For longitudinal waves in the [100] and [110] direction and for the transverse wave which yields C', the attenuation increased rapidly at the transition temperature and the echoes completely disappeared. As the temperature was lowered below 210°K, echoes slowly began to reappear. The shape of these echoes was very poor, and there was still a great deal of attenuation. Thus it was not possible to make meaningful velocity measurements for c_{11} and C' below the transition.

For the transverse waves associated with c_{44} there was only slight attenuation in the critical region, and data could be obtained over the entire temperature range 100°–320°K including the immediate vicinity of T_λ. Values of c_{44} were determined between 215° and 235°K on all three crystals (using both [100] and [110] propagation directions) and good agreement was obtained. This lends support to the idea that there are small domains with their tetragonal axes randomly oriented along the x, y, or z axes of the original cubic crystal. In that case, the measured ρU_t^2 values below the transition point correspond to an average shear constant $\bar{c}_{44}$ which is related to the single-crystal tetragonal constants by $\bar{c}_{44}=\frac{1}{3}(2c_{44}+c_{66})$. Values of $\rho U_t^2=\bar{c}_{44}$ obtained from measurements along a [100] direction (in the original cubic crystal) are given in Table II and shown in Fig. 4.

TABLE II. Smooth-curve values of the adiabatic quantity $\rho U_t^2=\bar{c}_{44}$ for NH_4Br in the tetragonal (ordered) phase at 1 atm, in units of 10^{11} dyn cm^{-2}.

T(°K)	c_{44}	T(°K)	c_{44}
110	0.7713	205	0.7273
120	0.7639	210	0.7297
130	0.7567	215	0.7331
140	0.7496	220	0.7386
150	0.7427	225	0.7481
160	0.7364	230	0.7627
170	0.7307	231	0.7680
180	0.7265	232	0.7725
190	0.7244	233	~0.778
200	0.7258	234	~0.79

Although it is not shown in Fig. 4, hysteresis was observed in the temperature behavior of c_{44}. On cooling the sample a sharp drop in c_{44} occurred at 234.2°K, whereas the most rapid jump in the c_{44} value on warming the sample occurred at 234.8°K. This temperature hysteresis of 0.6°K is quite comparable to the hysteresis of 0.9°K observed for both c_{44} and C' in ammonium chloride.[12]

The greatest sources of error in these elastic constants at 1 atm are due to uncertainties in the path lengths at 20°C (±0.1%) and ambiguities in the choice of the $n=0$ condition[12] for shear waves (especially for c_{44}). Therefore, to check the possibility that a wrong $n=0$ value had been chosen and also to check the internal consistency of our data, the velocity of the longitudinal wave in the [110] direction was measured as a function of temperature. The experimental value of $\rho U_{l'}^2$ for this wave and that calculated from Eq. (4) using the tabulated values of c_{11}, c_{44}, and C' were within 0.1 percent of each other over the entire temperature range 250°–300°K. This eliminates the possibility of a systematic error in the choice of the $n=0$ value for C'. For c_{44} there is still a possibility that the reported values may be systematically in error by ±0.9%. A propagation-of-errors treatment indicates that the random error in all three elastic constants is about ±0.2% at all temperatures.

TABLE III. The adabatic elastic constants and bulk modulus of ammonium bromide single crystals at room temperature obtained from the present measurements (P) compared with the results obtained by Haussuhl (H) and by Sundara Roa and Balakrishnan (S and B); the bulk modulus of polycrystalline ammonium bromide obtained by Bridgman (B) is included. All values are given in units of 10^{11} dyn cm^{-2}.

Obs.	T(°K)	c_{11}	c_{44}	C'	c_{12}	$1/\beta^S$
P	300	3.414	0.722	1.316	0.782	1.66
H	293	3.38	0.685	1.24	0.91	1.73
S and B	298	2.96	0.53	1.19	0.59	1.38
B	298	...	...	...	...	1.63

The independent adiabatic elastic constants of single-crystal ammonium bromide at room temperature have been measured by Sundara Roa and Balakrishnan[19] and by Haussuhl,[20] who also measured the temperature dependence down to the transition. Table III gives a comparison of the elastic constants and the bulk modulus obtained by these investigators with the results

[19] R. V. G. Sundara Rao and T. S. Balakrishnan, Proc. Ind. Acad. Sci. **28A**, 480 (1948).
[20] S. Haussuhl, Acta Cryst. **13**, 685 (1960).

of the present experiments. Also included is the adiabatic bulk modulus of a polycrystalline sample calculated from Bridgman's isothermal value.[21] The large difference between the present results and those of Sundara Roa and Balakrishnan should not be taken too seriously since the latter were reported to be accurate only to within 10%. The agreement with Haussuhl's elastic constants is not very good, although the slopes of his elastic constants versus temperature agree quite well with those of the present measurements.

Constant-Temperature Data

The experimental values of c_{11}, c_{44}, and C' as functions of pressure at various constant temperatures are shown

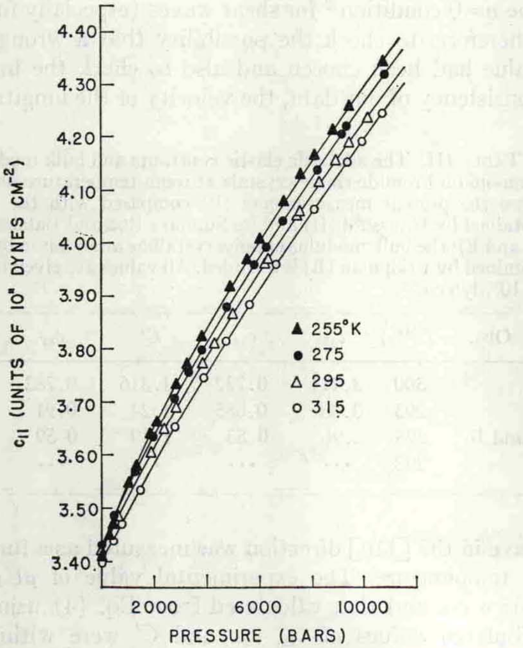

FIG 6. Dependence of c_{11} on pressure at various temperatures.

in Figs. 6–8. Data on the shear constants were obtained with 20-Mc/sec transducers, but these showed a bad tendency to break after several high-pressure runs. Measurements of c_{11} were made at 30 Mc/sec by using a 10-Mc/sec transducer, and this did not break on repeated runs at various temperatures. A tabulation of the smooth-curve values of these elastic constants as a function of pressure is given in Table IV. The limits of error in these elastic constant values at high pressures is somewhat greater than that at 1 atm due to greater uncertainty in the phase-shift correction term. (There is an appreciable increase in γ with an increase in the pressure.)

[21] P. W. Bridgman, Phys. Rev. **38**, 182 (1931).

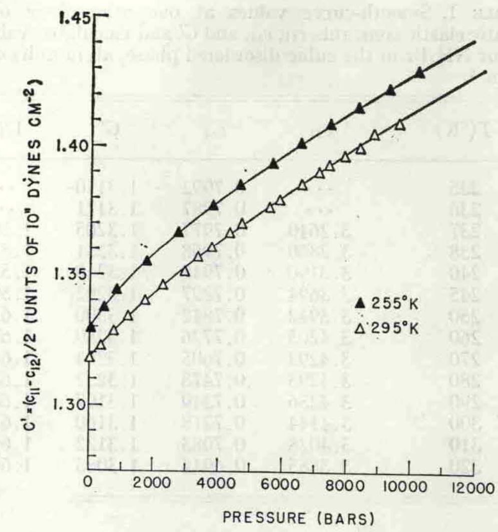

FIG. 7. Dependence of C' on pressure at two temperatures.

Bridgman[21] has measured $\Delta V/V_0$ as a function of pressure for ammonium bromide at 0° and 75°C. A comparison of his values with the values calculated from our present data shows that his values are about 6% high. Bridgman's difference between $\Delta V/V_0$ for a given pressure interval at the two temperatures is about 3 to 4 times greater than that observed in these experiments. The explanation for this difference seems to be that Bridgman's data were taken on a pressed polycrystalline sample, which one would expect to be more

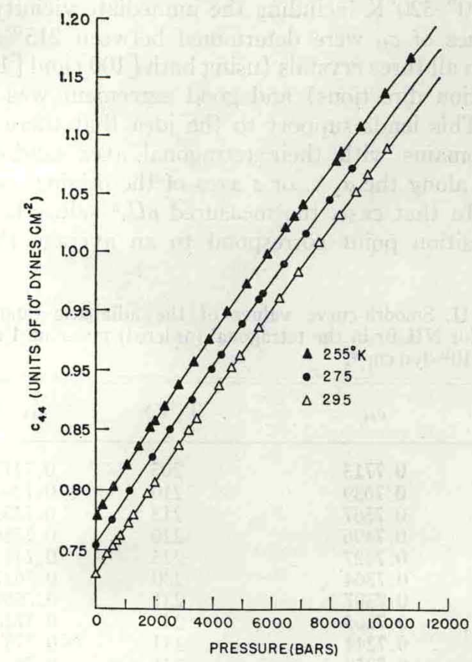

FIG. 8. Dependence of c_{44} on pressure at various temperatures.