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Brillouin scattering from D_2O at pressures up to 34 GPa

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A Brillouin scattering study of D_2O under hydrostatic pressure shows that the effective longitudinal modulus behaves the same as that of H_2O (reported earlier by the present authors). This is in contrast to the behavior found for the bulk modulus [reported by Munro *et al.*, J. Appl. Phys. 53, 6174 (1982)].

In a recent publication[1] we presented the results of a Brillouin scattering study of H_2O up to 30 GPa in which an effective longitudinal elastic modulus was determined as a function of pressure. This study was later extended to pressures up to 67 GPa and a new phase (ice X) encountered.[2] In the cubic ice VII phase (2 GPa → 44 GPa) we compared[1] our values for the effective longitudinal elastic constant (C) with values of the bulk modulus (B) determined in Ref. 3. We found that within experimental error our value of $C' = \Delta(\log_{10} C)/\Delta(\log_{10}\rho)$ was equal to the value of $B' = \Delta(\log_{10} B)/\Delta(\log_{10}\rho)$ (where ρ is the density) determined in Ref. 3. The large difference[3] in the values of B' for H_2O and D_2O and the differences[4] in the transition pressures and temperatures from liquid to ice VI and ice VI to ice VII for these two substances prompted us to investigate the elastic properties of D_2O using Brillouin scattering.

We mention here that the difference between B' in H_2O and D_2O has recently been explained using thermodynamical considerations.[5]

The experimental setup is identical to that described in Ref. 1. Although data are analyzed in the same way as in Ref. 1, for clarity, the method will be briefly described here: we measured the Brillouin frequency shift $\Delta\omega_B$ from which the product of the refractive index n times the sound velocity V can be calculated. The velocity is, in turn, related to the density (ρ) and an elastic constant (C) by

$$V = (C/\rho)^{1/2} \ . \tag{1}$$

Since the refractive index is known up to 1.1 GPa and is extrapolated[1] up to 34 GPa, and the density is known up to 36 GPa,[3] the sound velocity and an effective elastic constant can be calculated. Analysis of this elastic constant in the framework of the Murnaghan equation of state leads to a linear dependence of $\log_{10}C$ vs $\log_{10}\rho$.

Analogous to the bulk modulus results,[3] we find no difference in the values of C determined for H_2O and D_2O at a given pressure. In Fig. 1 we plot our values of $\log_{10}C$ (C in GPa) vs $\log_{10}(\rho/\rho_0)$; from these results we obtain for D_2O $C' = 4.00 \pm 0.15$ which is to be compared with the values 4.3 and 4.1 determined for H_2O in Refs. 1 and 2, respectively. The errors given for C' do not include a possible systematic error in the extrapolation of n; however, a change of 10% in the extrapolation of n only changes C' by 0.04.

The small (or zero) difference between the values of C' for D_2O and H_2O is in sharp contrast to the values found for B'. In Ref. 3 B' is found to be weakly pressure dependent but at 15 GPa, for example, B' is 4.20 ± 0.15 for H_2O and 3.55 ± 0.02 for D_2O. Recalling that for a cubic crystal

$$B = \tfrac{1}{3}(C_{11} + 2C_{12}) \ , \tag{2}$$

and assuming that our effective longitudinal elastic modulus mirrors the behavior of the constant C_{11}, we can infer that the changes in the elastic behavior of crystals of H_2O and

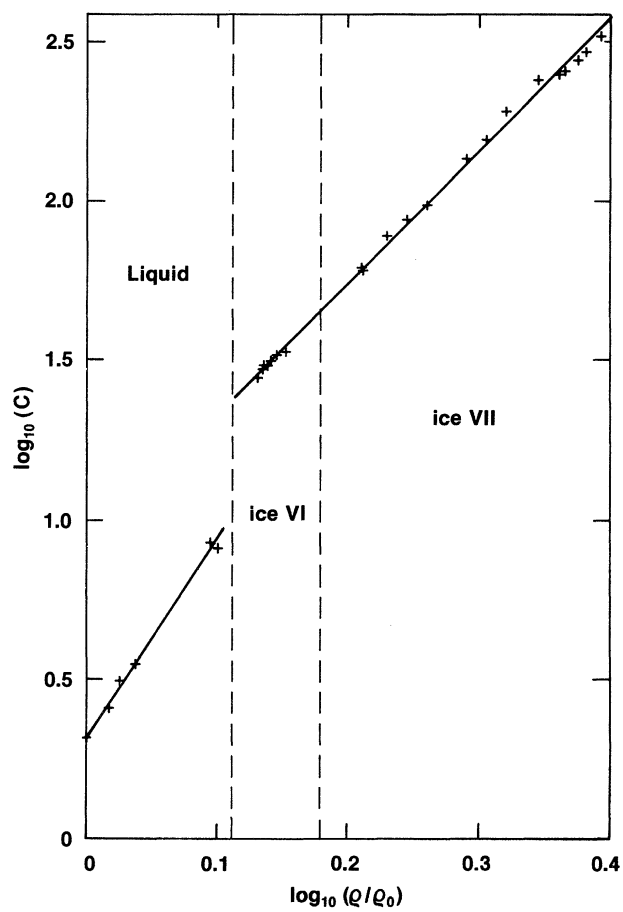

FIG. 1. Plot of $\log_{10}C$ (C in GPa) vs $\log_{10}(\rho/\rho_0)$ for D_2O at room temperature.

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D_2O are principally due to changes in the constant C_{12}. Since this constant is critical in describing the shear elastic properties of a solid, it is of great interest to obtain information on the shear elastic moduli. In order to do this by Brillouin scattering, however, a modified diamond anvil cell such as that described in Refs. 6 and 7 is required.

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