THE TWO VISCOSITIES OF WATER AND OTHER LIQUIDS UNDER HIGH PRESSURE

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SCIENTIFIC CONTEXT :

Newtonian liquids are characterized by two viscosities: the shear viscosity, which measures the resistance to flow; and the bulk viscosity, which contributes mainly to sound attenuation.

Bulk viscosity is much less studied than shear viscosity. Recently, we have measured both viscosities in water from ambient pressure to 1.6 GPa (a pressure at which the liquid is metastable with respect to ice VI) [1]. The pressure is generated in a diamond anvil cell, while the viscosities are measured by light scattering. Sub-micrometer Brownian spheres in suspension scatter light elastically; the decorrelation time of this scattered light gives access to the shear viscosity. Thermal density fluctuations in the liquid scatter light inelastically; the resulting spectrum contains blue and red-shifted peaks, which are analyzed by a spectrometer. The peak width gives the sound attenuation. The combined measurements provide both shear and bulk viscosities. Our results for water show a much more rapid increase with pressure of the shear viscosity compared to the bulk one. This is analyzed theoretically with a visco-elastic relaxation model.

MISSIONS :

In brief, the liquid response to a pressure jump is solid-like at short times, and liquid-like at long times. The relevant timescale is the structural relaxation time $\tau\alpha$, of order 1 ps. Our measurements revealed a new anomaly of water (which had already many! [2]): $\tau\alpha$ goes through a minimum around 500 MPa. We interpret this anomaly in connection with major structural changes occurring in water, involving the collapse of the hydrogen bond network. We have also performed molecular dynamics simulations that support this interpretation [3].

The proposed internship/doctoral work will investigate several directions:

· we will refine our inelastic light scattering experiment by using a second, detuned laser, for interferometer stabilization, which will allow a significant increase of the resolution on the inelastic peak width;

· we will repeat our experiments on heavy water, which exhibits slower dynamics than normal water;

· we will also extend our experiments to other liquids, to systematically investigate the ratio of bulk to shear viscosity in liquids made of different classes of molecules.

OUTLOOKS :

A motivated student could also participate in simulations related to the research program.

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