Trans. Faraday Soc, 67, 340-52 (1971)

Torsional Crystal Technique for the Measurement of Viscosities of Liquids at High Pressure

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Received 13*th July*, 1970

The damping effect of a viscous medium on a torsionally vibrating quartz crystal has been used to measure the viscosities of liquids at high pressures. Results have been obtained for benzene, cyclohexane, carbon tetrachloride, isopentane and n-pentane at temperatures of 30 or 50°C and pressures up to 7000 kg cm^{-2} in systems where the liquid did not freeze. Good agreement with existing high pressure data for these systems is obtained.

It is difficult to extend conventional techniques of high accuracy such as the capillary flow method to determine the viscosity of liquids at high pressures. Most of the effort in this field has therefore been confined to falling weight or rolling ball techniques. Even with these methods substantial problems remain in either rotating the high pressure system with the viscometer or uncoupling from it after each pressure change. It is therefore pertinent to explore alternative methods of determining the viscosity of liquids which do not present great difficulties at pressures up to about 10 000 bar and temperatures of the order of 100°C. In the present work, application of the torsional crystal technique to high pressure viscometry is examined.

Theory of Method

When a suspended quartz crystal of length l with axis parallel to its length has an alternating voltage applied to electrodes located longitudinally in the four quadrants between the Y and Z axes, mechanical torsion is produced which generates pure shear waves. In a vacuum, the crystal then resonates at a characteristic frequency f_0, which for the fundamental mode is given by

$$f_0 = (2l(\rho_Q\sigma)^{\frac{1}{2}})^{-1}, \tag{1}$$

where $\sigma = 2.42 \times 10^{-12}$ cm^2 dyn^{-1}, is the elastic modulus for torsion and ρ_Q is the density of quartz. Both f_0 and R_0, the resistance at resonance in a vacuum, vary slowly with temperature.

When the crystal is placed in a viscous medium, the propagated wave is damped according to the equation for plane waves,

$$p = p_0 \exp\left[-\left(\frac{\pi f \rho}{\eta}\right)^{\frac{1}{2}} z\right], \tag{2}$$

where z is the distance from the surface of the crystal, and η and ρ are the viscosity and density of the medium respectively. The attenuation of a wave, $(\pi f\rho/\eta)^{\frac{1}{2}}$,

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