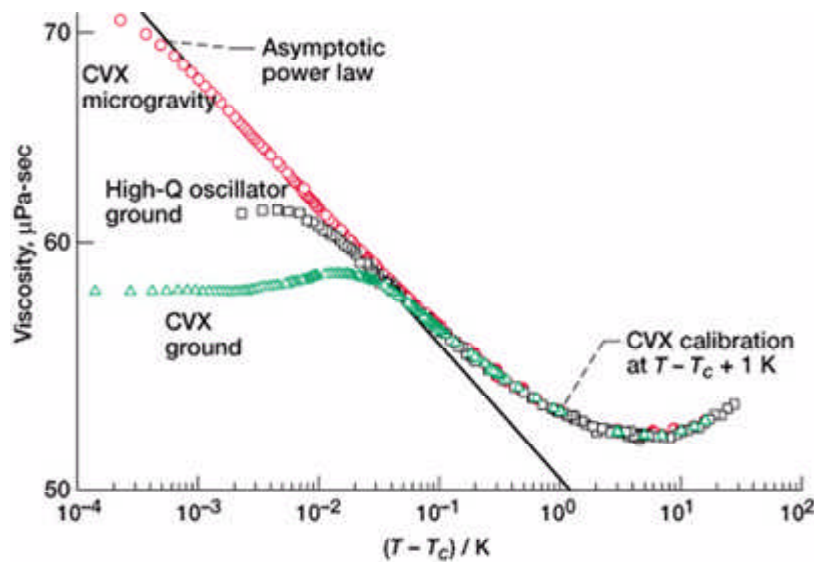


# Viscosity of Xenon Examined in Microgravity

Why does water flow faster than honey? The short answer, that honey has a greater viscosity, merely rephrases the question. The fundamental answer is that viscosity originates in the interactions between a fluid's molecules. These interactions are so complicated that, except for low-density gases, the viscosity of a fluid cannot be accurately predicted. Progress in understanding viscosity has been made by studying moderately dense gases and, more recently, fluids near the critical point. Modern theories predict a universal behavior for all pure fluids near the liquid-vapor critical point, and they relate the increase in viscosity to spontaneous fluctuations in density near this point. The Critical Viscosity of Xenon (CVX) experiment tested these theories with unprecedented precision when it flew aboard the Space Shuttle Discovery (STS-85) in August 1997.

Near the critical point, xenon is a billion times more compressible than water, yet it has about the same density. Because the fluid is so "soft," it collapses under its own weight when exposed to the force of Earth's gravity--much like a very soft spring. Because the CVX experiment is conducted in microgravity, it achieves a very uniform fluid density even very close to the critical point. The accompanying graph reveals the dramatic difference between Earth-based measurements and the data obtained in microgravity.



*Ground-based and microgravity measurements of the viscosity of xenon near the critical point. In microgravity, the increase of viscosity is measured 100 times closer to the critical temperature  $T_c$  and much more accurately than on Earth. The asymptotic power law characterizes the universal behavior of viscosity in all pure fluids near the critical point. Temperature of sample,  $T$ ; quality factor,  $Q$ . (High- $Q$  indicates weak damping.)*

At the heart of the CVX experiment is a novel viscometer built around a small nickel screen. An oscillating electric field forces the screen to oscillate between pairs of

electrodes. Viscosity, which dampens the oscillations, can be calculated by measuring the screen motion and the force applied to the screen. So that the fluid's delicate state near the critical point will not be disrupted, the screen oscillations are set to be both slow and small.

CVX is the culmination of a series of Earth-based viscosity measurements near critical points. Robert F. Berg and Michael R. Moldover of the National Institute of Standards and Technology are the principal investigators, and Gregory Zimmerli of Lewis and the National Center for Microgravity Research is the project scientist. NASA funded both the Earth-based and flight experiments through Lewis' Microgravity Science Division. NASA Lewis science contractors--NYMA, ADF, and Sverdrup--developed and built the flight instrument.

Since the flight, the principal investigators have analyzed the flight data in great detail. The data show that the viscosity increases as the critical point is approached and that it agrees with the theoretical prediction. CVX also measured low-frequency viscoelasticity in a pure fluid for the first time. Viscoelasticity is a partly elastic response to shear stress. It is common in polymers, foams, and other complex fluids, but has never been observed in a simple fluid such as xenon. A journal publication describing the scientific findings has been published (ref. 1).

As an extension to this very successful flight experiment, the principal investigators are preparing a second flight experiment, CVX-2. This experiment, which will measure the shear thinning of viscosity near the critical point of xenon, will be the first experiment of its kind to measure shear thinning in a simple fluid. A quantitative understanding of shear thinning near the critical point will lead to a better understanding of shear thinning in more complex fluids, such as polymers and emulsions, and thus may have broad applications in science and industry.

## Reference

1. Berg, R.F.; Moldover, M.R.; and Zimmerli, G.A.: Viscoelasticity of Xenon near the critical point. *Phys. Rev. Lett.*, vol. 82, Feb. 1, 1999, pp. 920-923.

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