

## Diffusion anisotropy of Helium-3 gas in ordered Al<sub>2</sub>O<sub>3</sub> aerogels

Hadi Loutfi<sup>1</sup>, Geneviève Tastevin<sup>1</sup>, Pierre-Jean Nacher<sup>1</sup>, Vyacheslav Kuzmin<sup>2</sup>, Kajum Safiullin<sup>3</sup>

<sup>1</sup>Laboratoire Kastler Brossel, ENS-PSL University, CNRS, Sorbonne Université, Collège de France, Paris, France

<sup>2</sup>Laboratory of Magnetic Resonance Spectroscopy, Institute of Physics, Kazan Federal University, Kazan, Russia

<sup>3</sup>Since Nov.2022: Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen, Germany

**Introduction:** Helium-3 was used for comparison of NMR measurement of gas diffusion along different directions within nanoporous ordered Al<sub>2</sub>O<sub>3</sub> aerogels at room temperature in Paris and low temperature in Kazan [1,2].

**Aim:** This work aimed at a test of the validity and limit of the Knudsen model of gas diffusion within native and compressed aerogel samples [2] for a wide range of gas densities and associated mean free paths.

**Methods:** At 300K, 10-30 mbar of laser-polarised <sup>3</sup>He gas mixed with 0-1 bar of N<sub>2</sub> (effective pressure P<sub>eff</sub>=10-2500 mbar) was used for multiple (CPMG or XY-16 sequences) spin-echo studies at 2.6 mT with pulsed gradients G of fixed or variable directions and strengths. At 4.2 K, diffusion was probed at 0.5 T with Boltzmann polarised <sup>3</sup>He gas (10-1000mbar), Hahn-echoes, and static gradients.

**Results:** Within aerogel, diffusion was strongly restricted at all gas densities and a “free diffusion regime” was achieved (negligible effects of sample boundaries). At 300 K, <sup>3</sup>He polarisation (~50%) typically yielded SNRs around 200. Diffusion anisotropy (changes in apparent diffusion coefficient D<sub>app</sub> with the angle between G and aerogel fibers) was highest at low P<sub>eff</sub> (up to a factor of 2). At 4.2K, we have observed that the degree of diffusion anisotropy depends significantly on the aerogel porosity, notably in the compressed samples. We have also observed a strong decrease of gas diffusion and a deviation from the expected Knudsen) behaviour, attributed to the low-T enhanced influence of the walls attractive potential on gas dynamics.

**Discussion:** Our measurements of anisotropy and pressure dependence of D<sub>app</sub> at 300 K support and complemented the 4.2 K findings. They significantly extend the range of gas densities used to probe restricted gas diffusion in such complex materials.

[1] anr.fr/Projet-ANR-19-CE30-0023; RSF project: 20-42-09023

[2] Kuzmin et al. (2023) doi.org/10.1021/acs.jpcc.2c08251