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Gas diffusion and relaxation within ordered Al₂O₃ aerogels

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Introduction: Gas diffusion in nanoporous materials correlates with key properties for applications. NMR studies of diffusion and magnetic relaxation in ordered Al₂O₃ aerogels are jointly made [1] at low temperature in Kazan and room temperature in Paris.

Aim: Strongly reduced ³He gas diffusion and diffusion anisotropy (Fig. a) were found in ordered aerogels at 4.2 K [1]. Data deviate from expectations within Knudsen models. This behaviour was attributed to the action of the aerogel wall attractive potential on gas atom dynamics. The hereby reported room temperature studies may confirm this scenario.

Methods: ³He gas is laser-polarised (at ~1 mbar) for high sensitivity, then compressed into a low- or medium-density [2] aerogel sample (Fig. b). Each measurement uses a few mbar of ³He mixed with 0-1 bar of buffer gas. NMR is performed at 1.3 mT, using pulsed gradients and CPMG sequences or small flip angles for T₂ or T₁ measurements, respectively. Experimental details for low temperature studies are given in [2].

Results: Polarisation of ~50% typically yield SNRs of ~1000. Very long relaxation times (minutes) are achieved with no applied gradients. Changes in T₂ with gradients and timings are investigated and effective diffusion coefficients D_{eff} are inferred (Fig. c). Results on the pressure and orientation dependence of D_{eff} will be presented and discussed, as well as data for gradient-induced T₁s.

Discussion: Hyperpolarisation provides excellent sensitivity for ³He NMR, even at low gas pressure and weak magnetic field. Polarisation is well preserved in Al₂O₃ aerogel samples thanks to slow wall relaxation on this material. Final conclusions on actual processes restricting gas diffusion are expected to be derived from data obtained with aerogels of different densities and comparison with low-temperature results and with suitable numerical models.

[1] MARGIN project: anr.fr/Projet-ANR-19-CE30-0023

[2] Kuzmin et al., doi.org/10.1021/acs.jpcb.2c08251

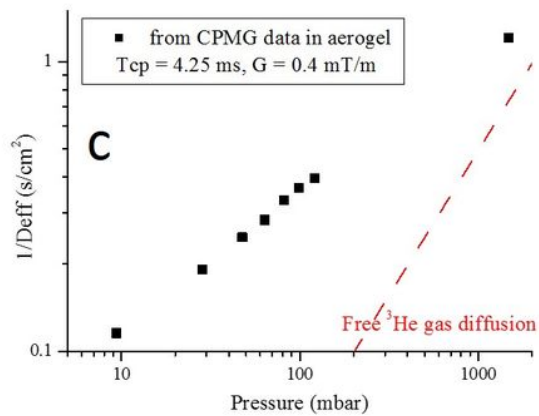
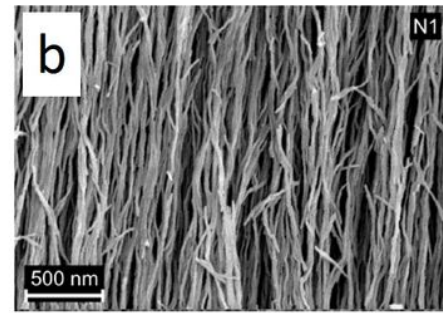
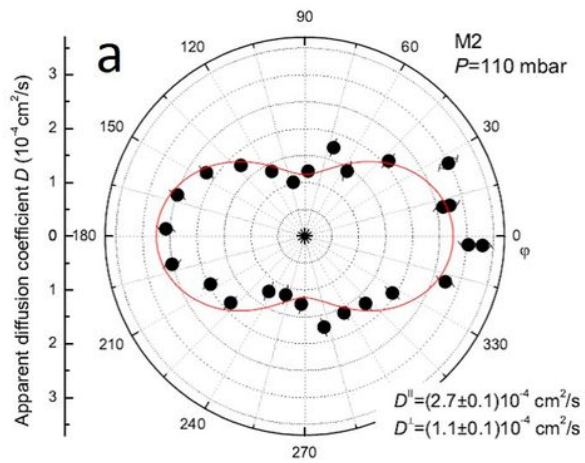


Fig. 1 a: Diffusion anisotropy of ^3He gas in compressed Al_2O_3 aerogel at 4.2 K [1].

b: SEM images of uncompressed aerogel [1].

c: Example of pressure dependence of diffusion coefficients in aerogel at room temperature.