3He gas diffusion in anisotropic porous media (ordered Al2O3 aerogels)

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Nuclear magnetic resonance (NMR) is an established non-invasive technique used to characterize diffusion of fluids in porous materials. Here, we report on NMR studies of gas diffusion and magnetic relaxation in ordered nanoporous Al_2O_3 aerogels with porosities of 76.5-98%. These studies are jointly made [1] at low temperature in Kazan and room temperature in Paris. At low temperature (4.2K), a strong reduction of ^{3}He apparent diffusion due to presence of the immobile adsorbed phase on aerogel walls was observed in Al_2O_3 aerogels [2]. Application of two-phase model apparent diffusion revealed a strong deviation of gas-phase diffusion and its anisotropy from Knudsen model as well. This behaviour is attributed to the action of the aerogel wall attractive potential on gas atom dynamics.

At room temperature, ^{3}He gas is laser-polarised for high sensitivity (polarisation of ~50%, at ~ 1 mbar) then compressed into Al_2O_3 aerogels. Each measurement uses a few mbar of ^{3}He mixed with 0 to 1 bar of ^{4}He gas. Litz wire PU coils were designed to optimize signal-to-noise ratio while achieving uniform sensitivity maps. Two coils with the same bore and different outer dimensions were made and tuned near 42 and 84 kHz (Q~100) for operation in different NMR systems equipped with 1D and 3D gradient coils. CPMG sequences were used to investigate the dependency of T_2 on inter-echo time T_{cp}, pulsed gradient strength G, and gas pressure P. Gas diffusion regimes in ordered aerogels and other cells containing bulk gas or stacks of thin gas slabs are compared for a wide range of values of G, T_{cp}, and P. Effective diffusion coefficients within aerogel D_{eff} are inferred. Moreover, T_1 measurements are made using repeated small-angle flips. Long relaxation times (several minutes) with no applied gradients show that gas polarisation is well preserved in Al_2O_3 aerogel samples thanks to slow wall relaxation on this material.

First results on anisotropy of gas diffusion in low-density ordered aerogels and initial measurements of gradient-induced T_1 relaxation will be reported. Short-term prospects of these experiments will be discussed and compared with low temperature results.

[1] MARGIN project: anr.fr/Projet-ANR-19-CE30-0023
[2] Kuzmin et al., doi.org/10.1021/acs.jpcb.2c08251