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Probing Hydrogen Diffusion in Coal for Geological Storage via Quasielastic Neutron Scattering

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Underground hydrogen storage (UHS) in coal seams presents a compelling opportunity for scalable, low-carbon energy storage, yet the fundamental understanding of hydrogen transport in such complex porous media remains limited. In this study, we explore hydrogen diffusion in coal using quasielastic neutron scattering (QENS), a technique uniquely suited to capturing molecular-scale dynamics of hydrogen due to its large incoherent scattering cross-section. Our focus lies in characterizing how temperature, pressure, and coal heterogeneity affect hydrogen mobility and retention at the microscopic level. Through prior neutron spin echo (NSE) experiments on methane and macroscopic sorption studies in anthracite coal, we observed strong temperature dependence and time-dependent diffusivity indicative of heterogeneous transport pathways. Early-stage findings also suggest that hydrogen diffuses more rapidly than CH_4 and CO_2 due to its smaller size and weaker interaction with the coal matrix, a trend accompanied by slight coal matrix shrinkage upon hydrogen uptake. These preliminary insights highlight the need for multi-scale, high-resolution characterization of gas transport in coal. QENS offers the potential to resolve localized hopping and longer-range diffusion regimes, thereby advancing our understanding of hydrogen mobility in nanoporous carbonaceous systems and informing strategies for safe and efficient subsurface hydrogen storage.

Primary author: HE, Xinxin (Pennsylvania State University)

Co-authors: Prof. ELSWORTH, Derek (Pennsylvania State University); Prof. LIU, Shimin (Pennsylvania State University)

Presenter: HE, Xinxin (Pennsylvania State University)

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