M2 internship proposal (6 months)

Hydrogen storage in clay materials

Hydrogen is the ultimate carbon-free fuel, as its combustion emits only water. At present, the point limiting the massive deployment of technologies using hydrogen for energy purposes is its storage. Sorption-based technologies are among the most widely explored. But little research has been done on clays for hydrogen storage, even though the recent discovery of high levels of hydrogen in clay-rich rocks shows their potential in this area [1].

Swelling clay minerals are lamellar compounds that are largely used for industrial and health applications. These layered compounds are typically formed from two Si tetrahedral sheets encompassing an octahedral (Al, Mg) sheet. Isomorphic substitutions often occur in both layers, inducing a negative charge deficit compensated for by exchangeable cations located in the interlayer space [2]. A high-charge smectite has already been identified as potentially interesting for hydrogen storage. In this internship, we propose to modulate the width of the interlayer space by various cation exchanges, in order to enable strong yield of hydrogen storage. The structure of the cation-exchanged samples will be studied mainly by X-ray scattering experiments at Laboratoire de Physique des Solides. This part of the work is quite substantial, as the relative organization of the layers can be modified depending on the cations used. It will also be important to understand the structuring of the cations in the interlayer space. The hydrogen adsorption experiments will be carried out with an external collaboration.

The internship could be followed by a thesis, to study the absorption of hydrogen on a microscopic scale in order to understand how to maximize the amount of adsorbed H_2. This study will be based on elastic and inelastic neutron scattering experiments [3] coupled to numerical simulations, which makes it possible to differentiate energetically between different adsorption sites or to study the structuring of hydrogen. It will be performed both at low temperature and pressure but also at room temperature and under pressure, in most interesting conditions for H_2 storage.

References:

[1] L. Truche et al., Science 383, 6683 (2024)
[2] F. Bergaya et al., 2006. Handbook of Clay Science (2006)
[3] L. R. Terry et al., Nanoscale 14, 7250 (2022)

Place of internship:

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