



5–6 Month Master's Internship (2025) with Potential Extension to PhD Starting in October 2025

Zeolite – Gas hydrate composite systems for gas storage

CONTEXT :

In the frame of the CaeSAR project coordinated by the University of Caen Normandy (France), we plan to hire several PhD students in various areas of materials science. Prior to starting this PhD program, we are seeking highly motivated students to undertake a 5- or 6-months internship as part of their master's studies. **The project could be pursued by a PhD funded for 3 years.**

SCIENTIFIC PROJECT :

Clathrates, or gas hydrates, are crystalline compounds in which gas molecules, typically methane, nitrogen, or carbon dioxide, are trapped inside water molecule networks. These unique structures, resembling cages, form under specific temperature and pressure conditions, often in deep ocean floors or permafrost regions. Clathrates have garnered significant interest due to their potential role in the carbon cycle and energy production, as they contain substantial amounts of gas in solid form.

This project aims to combine two types of microporous materials: zeolites, which are widely used in industry as molecular sieves and heterogeneous catalysts, and gas hydrates (GHs), which have significant potential as a storage medium but face challenges in industrial applications due to their slow crystal formation rate. By integrating these environmentally friendly materials—zeolites, natural aluminosilicate minerals, and GHs, which are crystalline structures formed by water molecules encapsulating gas molecules—the project seeks to develop a novel storage medium.

A major focus of the project is to gain a deeper understanding of the gas hydrate crystal growth mechanism, with zeolites acting as heterogeneous surfaces that promote the nucleation process. Zeolites with varying surface chemistries and pore characteristics will be investigated. Gas hydrate formation will be studied using both in situ and post-synthesis techniques. Key methods, including X-ray and neutron diffraction, will be used to observe the formation of hydrates in real-time.

The project will involve the LCS (Laboratoire Catalyse et Spectrochimie) for sample synthesis and characterization of absorption properties, and CRISMAT (Laboratoire de Cristallographie et Sciences des Matériaux) for studying crystal structures and conducting X-ray diffraction analyses.

During the internship, the student will synthesize zeolite materials and monitor the formation of gas hydrates within these zeolites using various techniques, including SEM/EDX, XRD, NMR, and ICP-AES. Part of the internship will also be dedicated to developing procedures and setting up equipment for X-ray diffraction characterization of gas hydrates.



CANDIDATE PROFILE :

The candidate must be currently enrolled in the second year of a Master's degree in Chemistry with a solid knowledge of solid-state chemistry, synthesis methods, crystallography and material characterization techniques: spectroscopy (IR, ICP, NMR, EDX), X-ray diffraction, thermal analysis, Scanning Electron Microscopy.

HOW TO APPLY :

Prospective candidates should send their CV and a cover letter by email **before the** January 31, 2025 to nicolas.barrier@ensicaen.fr

Internship gratification: 1000 euros/month. The project could be pursued by a PhD funded for 3 years.

Location: Laboratoires LCS & CRISMAT , UNICAEN/CNRS/ENSICAEN, Campus 2, 6 Bd Maréchal Juin, 14000 Caen, France

Dates/duration: Starting in February-March 2025, 5 to 6 months

Framework: Caesar Excellence project Supported by University of Caen Normandy (<https://anr.fr/ProjetIA-23-EXES-0001>)

Supervisors :

- Dr Valentin VALTCHEV (DR CNRS / LCS) : valentin.valtchev@ensicaen.fr
- Dr Nicolas BARRIER (MCF-HDR / CRISMAT) : nicolas.barrier@ensicaen.fr