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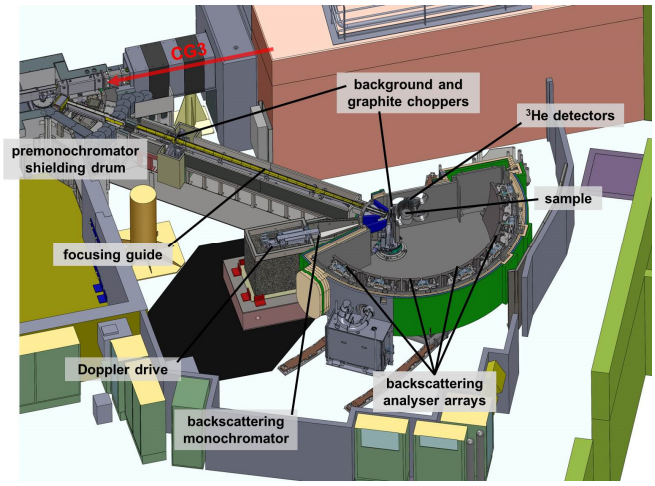
Australian Centre for Neutron Scattering (ACNS)

Emu

Cold-Neutron Backscattering Spectrometer

Emu is a high-resolution spectrometer used to measure neutron inelastic scattering, which is highly sensitive to atomic and molecular motion at the nanoscale.



Backscattering

Backscattering means the reflection of waves, particles, or signals back to the direction of there origin. Using a Bragg angle close to 90° for the selection and for the analysis of neutrons in a spectrometer causes the reflected wavelength band Δλ to become very narrow.

What makes Emu special?

Emu allows measurements at high energy-transfer resolution, $\Delta E/E \sim \Delta\lambda/\lambda$. The pre-monochromator selects neutrons with a wavelength λ of 6.3Å, a Doppler-driven monochromator shifts the incident neutron energy within a range of +/- 31μeV. The silicon crystals on the monochromator and analyser arrays are set up in backscattering to provide 1μeV FWHM energy resolution, the highest amongst the neutron spectrometers at the ACNS.

Applications

The backscattering technique allows both quasi-elastic neutron scattering and inelastic neutron scattering studies with slow sample relaxation times of up to several nanoseconds. Relevant fields include soft-matter, biology, chemistry, materials science, solid-state physics, and geoscience.

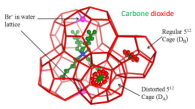
The energy range and resolution of EMU is ideally to study:

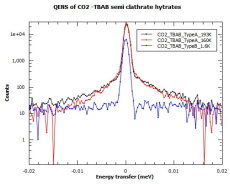
- quasi-elastic scattering from relaxation processes, diffusion of atoms/molecules (e.g. water in confined space, ionic diffusion in conductor materials).
- protein dynamics in biological samples and local motions of complex materials like polymers and membranes.
- quantum rotational tunnelling of functional groups (e.g. $-CH_3$, $-NH_4^+$).
- hyperfine splitting of nuclear energy levels.

CASE STUDIES

Confined structures

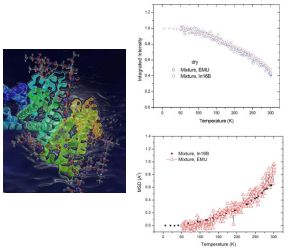
Carbon capture technology using clathrate hydrates is a concept that utilizes the physical interaction of gas molecules with water to selectively capture CO_2 gas in a water-based solid structure. The addition of quaternary ammonium salt (TBAB) to the water gas system and the consequent formation of semi-clathrates hydrates has led to improved gas selectivity. Emu is useful to examine the dynamics of the carbohydrate chains of the quaternary ammonium salt cation, which are trapped, like the CO_2 molecules, in the water cages of the clathrate structure. The gained knowledge about the dynamic processes and the associated interaction potentials will support the optimization of the CO_2 capture technology. The figure shows the quasi-elastic neutron spectrum (QENS) of CO_2-TBAB semi-clathrate hydrates at different temperatures measured by Emu.





Protein dynamics

Emu is suited to investigate the relaxation dynamics of protein–polymer conjugates. To understand to which extent the coating of a protein by a polymer can replace water in promoting thermal structural fluctuations, the dynamics of protein–polymer mixtures to that of conjugates with a variable number of polymers covalently attached were studied. Upon hydration, both the native protein and the conjugate show equivalent dynamics, suggesting that the polymer grafted on the protein surface adsorbs all water molecules. The figure shows the proton mean-square displacements from elastic fixed-window scans measured by Emu (Langmuir 2019, 35, 7, 2674-2679).



SPECIFICATIONS

EMU is located on the cold guide CG3 in the neutron guide hall.

Beam size:

30 x 30 mm (maximum)

Angular ranges:

- Q-range: 0.1 - 1.96Å^{-1}
- 2 θ-angle: 5.6 - 156°

Monochromators:

- Pyrolytic Graphite (002) with λ = 6.3 Å (2.08 meV)
- Graphite Chopper: Pyrolytic Graphite (002) with λ = 6.3 Å (2.08 meV)
- Doppler drive: Silicon (111) with λ = 6.271 Å, speed v_{max} = 4.7ms^{-1} provides an energy transfer range of -/+31μeV

Sample:

- Flux at sample position ~ 1.5 x 10^5 n cm^{-2}s^{-1}

Analyser:

- Analysers: 7 Silicon (111) arrays with λ = 6.271 Å (2.08 meV)

Detector:

- 35 vertical ^{3}He detectors, Ø12.7 mm x 300 mm, p=10 mbar
- 16 horizontal ^{3}He detectors, Ø12.7 mm x 260 mm, p=10 mbar

Sample Environment:

- Top and bottom loading cryogenic-furnace: 1.5K – 750K
- ^{3}He/^{4}He Dilution Insert: 25mK – 1K
- Gas and vapour delivery systems

INSTRUMENT SCIENTISTS

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