CFEL SCIENCE

SEMINAR

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Spin Isomers and Long-lived Nuclear Spin States

The phenomenon of spin isomerism is one of the most remarkable consequences of quantum mechanics: the Pauli principle sets strong constraints on the exchange symmetry of the complete quantum state, and hence strongly entangles the nuclear spin states with the spatial quantum states. For example, in a system like dihydrogen with two nuclear spins-1/2, the singlet nuclear spin state is associated with even rotational states (para hydrogen), while the triplet nuclear spin states are associated with odd rotational states (ortho hydrogen). Similar phenomena exist in molecules such as water, and for quantum rotors such as freely rotating methyl groups in the cryogenic solid state.

Results demonstrating a novel spin-isomer phenomenon will be shown: namely the slowly change in dielectric constant of a material containing encapsulated water, as ortho water converts to para water over the timescale of hours. The principles of this cryogenic solid-state effect are closely related to the behaviour of isolated water molecules in beams or molecular traps.

As will be discussed, some aspects of spin isomerism persist even for asymmetrical “ordinary” molecules in solution. The exchange symmetries which lead to spin isomerism may also give rise to the phenomenon of long-lived spin states, in which certain non-magnetic configurations of nuclear spin clusters persist for a long time. In some cases the lifetime of such long-lived states is more than 50 times longer than the relaxation time of ordinary nuclear magnetization. We have recently demonstrated a long-lived nuclear spin state which has a decay time constant exceeding 1 hour in room temperature solution. Such long-lived states may find applications in hyperpolarized NMR and magnetic resonance imaging.

Host: Terry Mullins / CFEL Molecular Physics Seminar