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Measurement of the Liquid Hydrogen Ortho/Para Conversion Rate at the Manuel Lujan Jr. Neutron Scattering Center

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Abstract

Molecular hydrogen (H_2) exists in two states, ortho and para-H_2. In the case of orthohydrogen, the proton spins are aligned (up-up), and in the case of para-hydrogen the spins are anti-parallel resulting in molecules with spins of 1 and 0, respectively. The energy difference between these two states is only 14.7 meV; para-hydrogen is the ground state and, therefore, lower in energy. At temperature of the liquid hydrogen para-hydrogen predominates (~99.8%) at equilibrium. On the other hand, hydrogen gas at room temperature has a para-hydrogen concentration of only about 25%. Once the hydrogen is liquefied, ortho-hydrogen naturally converts to para-hydrogen converging to the above mentioned equilibrium. This process is well known for non-radiation environment but it is not fully understood in high-radiation environment. Since the total neutron scattering cross section for these two molecular hydrogen states differs significantly below approximately 20–30 meV, the neutronic performance of a liquid hydrogen moderator depends strongly on the ortho/para hydrogen fraction. The differences in performance of a supercritical partially coupled hydrogen moderator caused by changing the ortho/para ratio were studied previously at the Lujan Center [1], albeit over very limited operational time period (~week). Since the 2010 run cycle we have operated a new target-moderator-reflector assembly utilizing a cold beryllium reflector-filter coupled with a supercritical partially coupled liquid hydrogen moderator. During the 2011 run cycle we have been recording the cold neutron spectra produced by the partially coupled liquid hydrogen moderator equipped with a cold beryllium reflector-filter using two permanently-installed neutron flux monitors. In the process we have gathered an unprecendented amount of data that can be used to assess the ortho/para conversion rate over extended periods of time. We will present the experimentally measured changes to the cold neutron spectra coupled with MCNPX neutron transport calculations gauging the ortho/para conversion rate.

References:

[1] M. Ooi, et al., Nuclear Instruments and Methods A **566** (2006), 699-705