THERMODYNAMIC PROPERTIES OF HYDROGEN-HELIUM AND METHANE-HELIUM SUSPENSIONS: NMR STUDIES

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Introduction

The quantum solids formed by the different molecular species of hydrogen have unique thermodynamic properties associated with the extreme quantum mechanical nature of the rotational degrees of freedom. There are two molecular species, ortho- and para-hydrogen, whose properties at low temperatures are those of almost pure quantum mechanical states with angular momentum J=1 and J=0, respectively. Quantum tunneling between rotational states and quantum diffusion play the key roles in determining the thermodynamic properties of the solid hydrogens, and unusual orientational glass states have been observed for ortho-para solid mixtures in addition to well-ordered states for pure ortho-hydrogen [1]. While these properties are well documented for bulk systems, very little is known about the behaviors for small particles for which size effects become important. Of especial interest is the case of fine granules of hydrogen formed as a "slush" with liquid helium. Understanding the diffusion and internal relaxation modes of these finely dispersed mixtures of solid hydrogen in liquid helium are important for considerations of atomic propellant designs for future spacecraft [2], using the hydrogen or methane particles as cryogenic matrices to store atomic species.

Results and Discussion

In order to determine the thermal relaxation processes in finely divided quantum solid mixtures we have measured the nuclear spin-lattice and nuclear spin-spin relaxation times for small grains of hydrogen and small grains of methane suspended in liquid helium. Pulsed NMR studies, using different pulse sequences, allow one to obtain information about spatial diffusion, quantum diffusion between rotational states, and the surface interactions between the cryogenic fluid and the solid particulate. We find that for hydrogen particulates the NMR relaxation rate is consistent with scattering at surface boundaries due to the large electric quadrupole moment of ortho-hydrogen [3]. On the other hand, for methane, the results are consistent with internal diffusion as opposed to surface scattering.

Conclusions

We conclude that for atomic propellants, methane is a superior host because the grains of methane are better isolated from the helium bath.

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References

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