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Hydrogen refrigeration via kinetic para-ortho manipulation in a vortex tube

Hydrogen has two separable nuclear-spin isomers, denoted by ortho and para, with potentially significant differences in thermophysical properties. The entropy change with ortho-para conversion is the largest of any material phase change known to occur at cryogenic temperatures. A prior experimental study demonstrated that the endothermic reaction of para-ortho conversion can be utilized to increase the effective cooling capacity of liquid parahydrogen boil-off vapors below 100 K. This work expands the concept of endothermic para-ortho conversion to primary refrigeration below 77 K via kinetic manipulation in a vortex tube. Vortex tubes are non-moving devices that utilize a kinetic energy differential to partition a fluid into hot and cold streams. The vortex tube could use a hydrogen stream pre-cooled in a liquid nitrogen bath and catalyzed to the 50-50 equilibrium composition at 77 K. By catalyzing the hot fluid on the outer wall of the vortex, endothermic para-ortho conversion will cause bulk cooling after which the orthohydrogen is separated and recycled to the liquid nitrogen bath. The statistical partition function is utilized to establish performance limits of the concept. Initial experimental results in bare and catalyzed vortex tubes are presented. Based on the theoretical analysis and initial experiments, the potential for para-ortho conversion as a new approach to hydrogen refrigeration is assessed.