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BEHAVIOR OF ATOMIC H IN SOLID H_2 FROM 0.2 TO 0.8 K

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ABSTRACT

A mixture of hydrogen with 0.03 percent tritium was liquefied and then solidified to produce H radicals in a crystalline solid H_2 matrix below 1.0 K. Temperature dependent stored energy releases were "triggered" at various temperatures below 0.8 K with and without a 3-tesla field. From sample susceptibility measurements near 0.33 K and other considerations we surmize that there exists cooperative interactions and that localized regions of higher H concentrations may behave as ferromagnetic domains.

The potential superior performance of atomic H radicals as a rocket propellant has stimulated renewed interest in the formation and properties of H and other radicals at lower temperatures and in higher effective magnetic fields than were used in previous investigations.[1,2,3]

In this investigation the H radicals were produced in a crystalline solid H_2 matrix below 1.0 K. A 0.25-gram hydrogen sample with 0.03 percent tritium by weight was liquefied and then slowly solidified near its triple point. Then 4 days later, cooled to liquid He temperatures. The sample system consisted of two nearly identical 3cc Epibond chambers which were in thermal contact with each other, sample thermometers, a sample heater, and the cold terminal of a He-3 dilution refrigerator. (See fig. 1). The upper chamber contained the hydrogen sample while the lower chamber contained a paramagnetic salt (CMN). The susceptibility coil system was immersed in the inner dewar He bath and consisted of a primary coil producing

2.5 Gauss at 17 Hz and two secondary coils.[4] The two secondary coils were wound in opposition with one secondary surrounding the hydrogen sample and the other secondary surrounding the CMN chamber.

Beta particles from the tritium decay produce for the most part H_2^+ ions which in turn, produce in part, localized regions of varying $\dot{H}$ radical concentrations along primary and secondary electron tracks.[5,6] In gas experiments an average beta particle (5.6 keV) produces as many as 750 H radicals.[7] In our sample there are $\sim 3\times 10^{10}$ beta emissions per second. Sample storage periods as long as 32 hours would be expected to yield bulk concentrations less than 0.01 percent H by weight but localized concentrations are expected to be several orders of magnitude higher.

An experimental run consisted of cooling the sample system, with or without a 3-tesla applied field, to a given storage temperature (T_{st}) below 0.8 K. This temperature, T_{st}, was maintained until a rapid energy release occurred spontaneously or until the sample was deliberately heated to cause a stimulated energy release at a higher temperature. The energy releases are believed to result, in part, from recombination of some fraction of the H radicals stored in the sample, producing about 4.4 eV per ion pair. There appears to exist a "trigger" temperature (T_R) for any given H concentration at which the sample becomes unstable and either a spontaneous or a stimulated energy release occurs. Spontaneous releases then have a T_R approximately equal to T_{st}, while stimulated releases have T_R greater than T_{st}. T_R decreases with increasing storage time or increasing H content and increases with application of a 3-tesla field. No observable releases took place above about 0.7 K.

Figure 2 indicates that the elapsed sample storage time as a function of T_R for both spontaneous and stimulated releases abruptly increases for T_R

below about 0.33 K. Counting of elapsed storage time began as the sample was cooled below 0.8 K to reach T_{st} and terminated at the energy release, which was either spontaneous or stimulated. The largest releases increased the sample thermometer temperature from 0.3 to about 3.0 K within 0.2 second while other releases had peak temperatures below 2.0 K. For either case it was concluded that some fraction of the H radicals did not recombine. Solid symbols in figure 2 represent runs which were preceded by sample temperatures of 1.8 to 3.3 K, from either an initial 2.5 K cooldown or from a preceding energy release peak. Open symbols indicate that the run followed a previous run without warming above 1.8 K. The cleanout of sample H is presumed to be more thorough at higher temperatures but this is not evident in this data. Runs which had most of their elapsed storage time below 0.35 K are shown as circular symbols. All other runs had T_{st} greater than 0.35 K. A circular symbol with T_R greater than 0.35 K represents a run terminating in a stimulated release. Runs made in a 3-tesla field are designated by M; runs made in the magnet's remnant field (<200 Gauss) are denoted with r. All other runs were in "zero" magnetic field (2.5 Gauss, 17 Hz).

The rate of energy storage was higher in the 3-tesla field and remained higher even after the field was reduced to the magnet's remnant field. This was indicated by a lower steady state refrigerator temperature, which is load dependent. A study of the energy releases indicated a smaller fraction of the H radicals appeared to recombine during releases with an applied 3-tesla field than in "zero" field. Susceptibility measurements were taken only in "zero" field (2.5 Gauss, 17 Hz). Measured susceptibility values above about 0.40 K were indistinguishable from the susceptibility contribution of the CMN salt alone. However from 0.37 to 0.299 K, the lowest T achieved in "zero" field, the sample susceptibility was too large to be explained by paramagnetic behavior of the maximum number of H atoms that are energetically possible, even if we assume 100 percent conversion of the beta energy into dissociations. From this and other considerations we surmize that cooperative interactions exist and that localized regions of higher H concentrations may behave as ferromagnetic domains.

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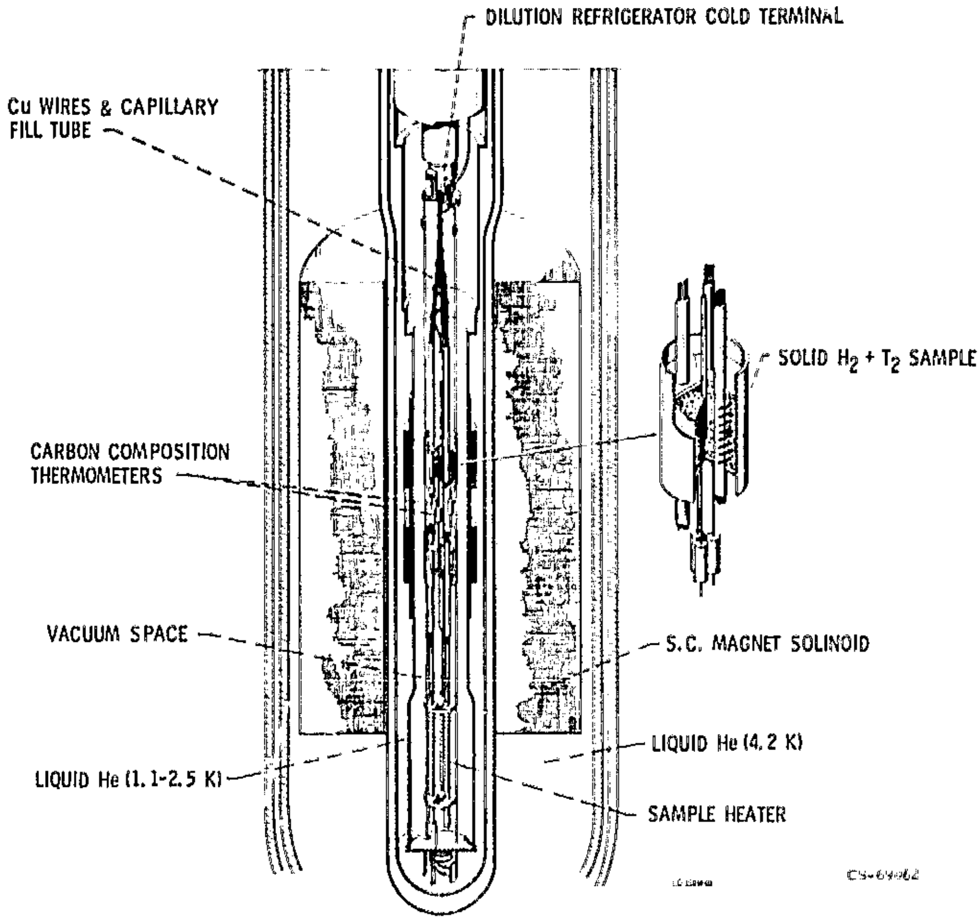

Figure 1. - Sample system for solid hydrogen-tritium experiment near 0.1 K.

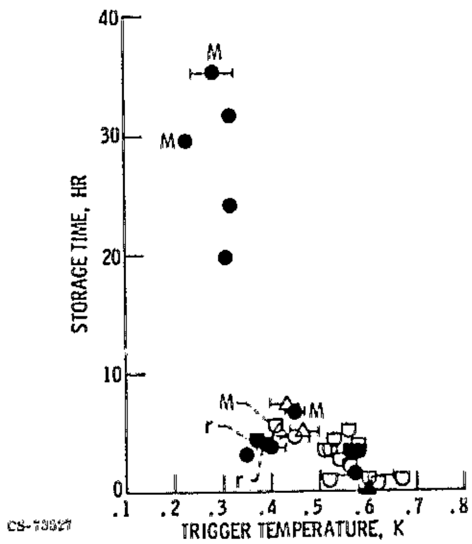

Figure 2. - Storage time versus "trigger" temperature.

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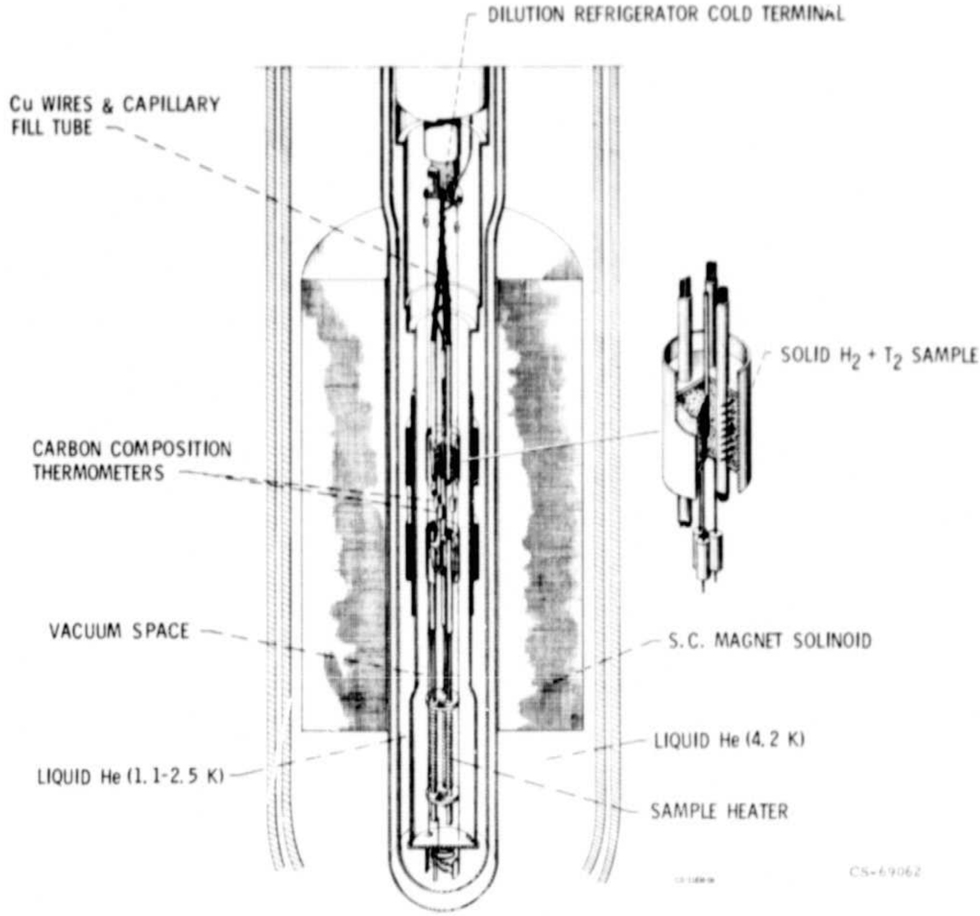

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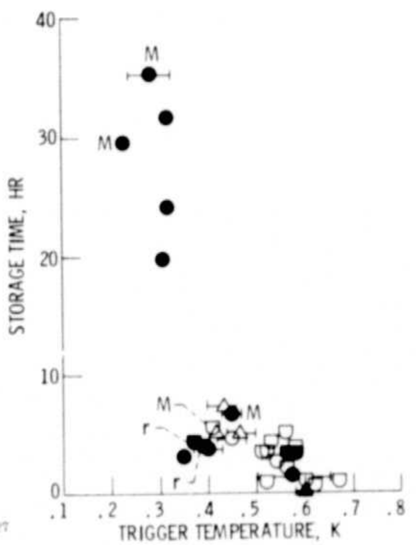

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