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On the Accumulation of
He-H Molecular Complexes

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**On the Accumulation of
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by

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ON THE ACCUMULATION OF He-H MOLECULAR COMPLEXES

P. T. Sikora[†], David Depatie[‡], and A. F. Schuch

ABSTRACT

Liquid tritium is proposed as an agent for producing and stabilizing macroscopic quantities of He-H molecular complexes. Information on their existence could be inferred from simple pressure measurements.

Several recent theoretical studies^{1,2} of the helium-hydrogen molecular system have shown that He-H and (He-H)⁺ can form bound states. The purpose of this note is to point out a situation in which these substances might be observed in quantity and to note certain consequences of their appearance.

Consider the β -decay of H-H³ where H³ is tritium and H stands for any one of the isotopes of hydrogen. The nondissociative β -decay process

results in the creation of the molecular ion. Because the molecular ion is formed with the nuclei at roughly the equilibrium internuclear separation and because the decay process ejects only light particles, the probability of molecular dissociation during β -decay should be quite small. Indeed measurements have shown that the probability of dissociation during β -decay is $\approx 7\%$ for free H¹-H³.³ This probability would presumably be even smaller in a dense low temperature system.

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Any He-H complex formed may be expected to be more stable in a low temperature liquid than in a gas phase because of the reduced mobility in the liquid and the virtual absence of high energy collisions. Furthermore, charged complexes are expected to have a still lower mobility because of electrostrictive effects⁴ which will have a dominant influence on ionic recombination. Liquid tritium, H₂³, is unique in that it maximizes the production of He-H complexes in an environment which would favor their survival. A simple measurement that could indicate the accumulation of the He-H complexes in liquid H₂³ would be to monitor the pressure over the liquid tritium sample. This possibility is facilitated by the small (≤ 0.1 mole % at 1 atm and 21 K)^{5,6} solubility of He³ in liquid H₂. Moreover, since the vapor-volume to liquid-volume ratio can be made small, certain pressure effects can be magnified.

Consider the behavior of the pressure as a function of the lifetime of the He-H complex. If this lifetime is microscopic, then free He³ will be formed and will appear in the vapor, adding to the H₂³ vapor pressure. This pressure would increase in time according to

$$\Delta P \propto N = N_0(1 - e^{-\alpha t}) \quad (1)$$

where N_0 is the initial number of H^3 atoms, and α is the decay constant (for β -decay).

If the lifetime of any complex formed is macroscopic, then the pressure rise would be expected to deviate from the behavior given by Eq. (1). The He^3 atom which would otherwise have passed into the vapor immediately after its creation will now remain in solution as a component of the complex. The increase in total pressure above the liquid will be less than that predicted by Eq. (1), regardless of the kind of molecular species produced.

It is, in fact, possible to calculate the resulting pressure behavior explicitly provided that certain simplifying assumptions are made. If it is assumed that the complex is completely stable in liquid tritium, that two He^3 atoms are liberated whenever both nuclei of a given molecule have undergone β -decay, and that the solubility of atomic He^3 in liquid tritium is negligible, one finds

$$\Delta P \propto N = N_0 (1 - e^{-\alpha t})^2 \quad (2)$$

which predicts a much smaller initial pressure rise than does Eq. (1).

In the above assessment several complications have been neglected. Among these are the existence of more complicated molecular species, the influence of the finite solubility of He^3 in the liquid, the influence of dissolved ions, and molecular dissociation due to the β -activity of the tritium. None of the above situations would lead to a pressure increase which would be greater than that calculated for simple decay [Eq. (1)].

In summary, we have noted the unique capabilities of liquid tritium with regard to the production and stabilization of helium-tritium molecular complexes. These properties of liquid tritium should make it possible to obtain experimental amounts of these species and to maintain them for macroscopic time durations. The presence of significant amounts of such substances would be indicated by simple pressure measurements.

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