Reports

Helium Difluoride: Possible Preparative Techniques Based on Nuclear Transmutations

Abstract. *It might be possible to prepare difluoride by beta decay of tritium, lithium-6 transmutation, or alpha-particle bombardment. In the first method, which may be the most feasible, tritiated potassium bifluoride could be used as a host lattice. The beta-decay recoil energy would not dislodge the daughter helium atom from the host site, thus helium difluoride could perhaps be formed in an ideally shaped lattice site.*

The possibility that halogen compounds of helium might exist was noted previously (1). If a compound such as HeF_2 could be prepared, the implications would, perhaps, have as much impact upon traditional views of chemical bonding as was furnished by the discovery of XeF_4. Because of the dramatic implications, all possible modes of preparation of helium compounds ought to be explored. If such a compound exists, but with marginal stability, relatively unconventional preparative techniques may be needed. In particular, methods which permit synthesis and detection at extremely low temperatures have special appeal. We offer here three rather uncommon but promising possibilities, hoping to bring them to the attention of other research workers who possess the special experimental facilities needed.

1) The beta decay of a tritium atom held in an appropriate solid lattice might provide unique conditions for the formation of HeF_2 or other compounds of helium. The nuclear reaction $_1T^3 \rightarrow _2He^3 + \beta^-$ occurs with a half-life of 12.46 years and it is exothermic by 0.0176 mev (2). The maximum and the average recoil energies imparted to the nucleus when an isolated tritium atom decays are about 74 and 24 kcal, respectively (3). If the tritium atom is chemically bound, its effective mass is increased and the recoil energy received by the product nucleus is appropriately reduced. With the usual energy spectrum of beta decay, many of the beta particles are emitted with less than average recoil energy. Conditions are favorable for the retention of the helium product nucleus in the chemical environment of the parent nucleus. That this conclusion is reasonable is supported by the experiments of Snell et al. (4) and of Wexler (5). These workers found that beta decay of gaseous TH and of T_2 produce, respectively, HeH^+ and HeT^+ in at least 90 percent of the decay events.

It would seem that the optimum chemical environment in which to attempt the formation of HeF_2 by tritium decay might be in a solid KHF_2 lattice. The tritium decay would occur in the TF_2^- ion, converting it to neutral HeF_2 placed in a lattice site of ideal shape. Other chemical environments also deserve consideration, such as condensed TF or mixed fluoride salts, depending upon the advantages that might be gained in preparation and detection.

Among the techniques that might be used for detection, infrared and ultraviolet spectroscopy seem to be most promising. The sample could be prepared and stored in a suitable optical cell and, if desired, kept at a low temperature continuously during the growth period of beta decay and subsequent optical study. Infrared detection would require the larger accumulation of product. About 20 curies of tritium might yield 10 μmole of product in a period of 4 or 5 months, an amount that would probably be ample for detection. Because of the low energy of the beta decay and absence of gamma rays, radioactive shielding is not burdensome. Far less HeF_2 would probably suffice if electronic, spectroscopic detection were attempted but, unfortunately, recognition would be more difficult. Furthermore, the electronic absorptions of the hypothetical HeF_2 might be found in the vacuum ultraviolet region, as are those of XeF_2 (6). In that case, the transparency of the host lattice would have to be considered.

2) Lithium-6 transmutation offers another opportunity. The $_2He^4$ nucleus can be obtained by neutron bombardment of $_3Li^6$ without the production of gamma rays: $_3Li^6 + _0n^1 \rightarrow _2He^4 + _1T^3$. Thus, thermal neutron irradiation of a few grams of lithium fluoride would produce about 10 μmole of $_2He^4$ in a period of 1 day in a neutron flux of 10^{12} neutrons per square centimeter per second.

The $_3Li^6(n, \alpha)$ reaction is exothermic by 4.78 mev. (7). Hence the helium and tritium nuclei will receive, respectively, recoil energy of 2.05 and 2.73 mev. Each nucleus will be significantly displaced from the site of formation and initially may be stripped of electrons. If a LiF host lattice is in use, the tritium nucleus will presumably become chemically bound as TF at the end of its track. Conceivably, the alpha particle ejected into a network of F^- ions might form HeF_2 if the compound is stable.

3) An alternative to the $_3Li^6(n,\alpha)$ reaction is alpha bombardment. For example, alpha bombardment of solid fluorine would surely rupture many fluorine bonds. Thus the alpha particle would initially come to rest in a chemically reactive site and with a net positive charge, encouraging the formation of helium compounds. As charge neutrality is restored, again there is a possibility that a helium compound such as HeF_2 might be stabilized.

Of these three proposals, all based upon nuclear reactions, the first seems to be the most favorable. Experimental work based on this technique is now being considered.

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References

1. G. C. Pimentel, *J. Chem. Phys.* **19**, 446 (1951); ——— and R. D. Spratley, *J. Am. Chem. Soc.* **85**, 826 (1963).
2. G. Friedlander and J. W. Kennedy, *Nuclear and Radiochemistry* (Wiley, New York, 1955), p. 415.
3. E. P. Cooper and F. T. Rogers, *Phys. Rev.* **77**, 402 (1950).
4. A. H. Snell, F. Pleasonten, H. E. Leming, *J. Inorg. Nucl. Chem.* **5**, 112 (1957).
5. S. Wexler, *ibid.* **10**, 8 (1959).
6. E. G. Wilson, J. Jortner, S. A. Rice, *J. Am. Chem. Soc.* **85**, 813 (1963).
7. D. J. Hughes, *Pile Neutron Research* (Addison-Wesley, Cambridge, Mass., 1953), p. 118.

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