K−-Meson Capture by Helium (*).

T. B. DAY

Physics Department, University of Maryland - College Park, Md.

(riccìvuto il 22 Luglio 1960)

Summary. — Some atomic and molecular processes which occur when K−-mesons stop and are captured in liquid helium are investigated. It is shown that while the K−-meson is in its initially highly-excited atomic states, S-state capture is predominant.

1. - Introduction.

Some understanding of the atomic and molecular processes which occur when K−-mesons stop in liquid bubble chambers is preliminary to any discussion of the direct nuclear capture which finally results. Not only do these atomic and molecular processes have intrinsic interest, but, in particular, a knowledge of the atomic orbital from which the meson is captured has a direct bearing on the interpretation of the nuclear capture processes.

Fairly recently, DAY, SNOW and SUCHER considered the case of K−-mesons being captured in liquid hydrogen (1,2). They showed that for the excited states of the (K−, p) atom through which the K−-meson must pass, the electric field of a neighboring proton will mix degenerate levels of the atom in such a way that the very strong S-state nuclear capture will completely dominate (3).

(*) This research was supported in part by the United States Air Force through the Air Force Office of Scientific Research of the Air Research and Development Command.


(3) The arguments in references (1) and (2) were semi-classical. A quantum mechanical calculation of the effect for a very closely related model has been performed by F. GÜRSEY and C. N. YANG with results which agree with references (1) and (2). F. GÜRSEY: private communication.
Experimental difficulties have, as yet, prevented the direct verification of this effect (by observing the lack of $K^-$-mesic X-rays, for example). Still, the theoretical arguments are sufficiently convincing that one can, with fair confidence, assume that the interaction of $K^-$-mesons with the protons of liquid hydrogen occurs only in $S$-states. This has many important consequences, and in particular, has been used recently in a measurement of the spin of the $\Sigma^+$ hyperon.

In the case of liquid helium bubble chambers, the problem is completely different. For, the simplicity of the considerations for hydrogen relied on the fact that the $(K^-, p)$ atom was a small, neutral object which could wander within another hydrogen atom’s electronic orbit and thus feel the intense electric field of the proton. The object which results when a $K^-$-meson is stopped by a helium atom very quickly becomes a small, charged ion. Thus it will not experience the simple Stark effect considered for hydrogen.

This, then, leads to a consideration of the various atomic and molecular processes which the resulting ion undergoes in liquid helium, and which are dealt with in turn in the succeeding sections. Finally, we conclude by pointing out that, at least in the initial stages of the de-excitation of the $K^-$-meson the most likely process leads again to $S$-state capture, and we discuss the usefulness of this fact in establishing the relative $K^-$-$\Lambda^0$ parity.

2. Initial atomic capture and Auger.

When the $K^-$-meson is first captured by a helium atom, it tends to occupy an excited state whose wave function best overlaps that of the electron which is replaced. Since the reduced mass $\mu_k$ of the $K^-$-meson in a helium atom is 856 $m_e$, the principal quantum number, $n$, of the initially occupied state is

$$n_1 = \sqrt{856} \sim 30.$$ 

In such a neutral atom, where the meson very closely overlaps the second electron, the Auger process is highly likely, and occurs in times of the order $10^{-15}$ s. The principal quantum number of the state about the unshielded $\alpha$-particle to which the $K^-$-meson must fall in order to release the 24.56 eV

---

