Muon Capture in Nuclei.

L. L. Foldy (*) and J. D. Walecka (**)

CERN - Geneva

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Summary. — Theoretical calculations of the total capture rate for muons in certain light nuclei ($^{40}\text{Ca}$, $^{126}\text{C}$, $^{4}\text{He}$) have been carried out with cognizance taken of the important role played by giant dipole resonances in the capture process. The calculation involves the following steps: 1) Relating the dipole contribution of the vector interaction to its un-retarded value by the use of the ground-state elastic form factor. 2) Relating the un-retarded dipole part of the vector interaction to an integral over the photo-disintegration cross-section (by the use of isotope-spin invariance) and using empirical photo-disintegration data to evaluate this contribution. 3) Using the Wigner supermultiplet theory to relate the matrix elements of the axial vector and induced pseudoscalar interaction to those of the vector interaction. 4) Using the shell model (with and without the closure approximation) to evaluate other multipolar contributions and recoil correction terms. The assumptions implicit in the above steps have been examined in as much detail as present knowledge permits. In particular, arguments are given on the basis of several models to justify step 1). The basic assumption involved in the supermultiplet theory used in step 3) is that of weak spin-dependence of the forces. This theory predicts that the giant electric dipole resonance is one of a family (vector supermultiplet) of giant resonances involving spins and isospins. Evidence for the existence of at least one other such resonance is shown to exist in inelastic electron scattering data on $^{16}\text{O}$. The effect of spin-dependence of the forces in splitting this giant resonance supermultiplet is investigated by examining the $0^-$, $1^-$, and $2^-$ particle-hole states calculated by Lewis for $^{16}\text{O}$; its effect in our calculations is relatively small. Agreement between theory and experiment is within the uncertainties of both (but with the possibility of a real discrepancy in $^{4}\text{He}$) thus exhibiting general consistency of muon capture with the universality of weak interactions. Inelastic electron scattering data can be a rich source of information to serve as the basis for better calculations and for exploring the giant resonance supermultiplet.

(*) National Science Foundation Senior Post doctoral Fellow, on leave from Case Institute of Technology, Cleveland 6, Ohio.

(**) A.P. Sloan Foundation Fellow, on leave from Stanford University, Stanford, Cal.
1. Introduction.

The problem of fitting the phenomenon of muon capture into the general framework of a universal theory of weak interactions is an important and challenging one and has therefore been the subject of considerable theoretical and experimental work. The primary aim of such investigations is the determination of the nature of the fundamental muon-capture interaction and its consistency with some appropriately formulated universal Fermi interaction theory (U.F.I.), although one can also hope eventually to turn the picture around and use muon capture as a tool for studying nuclear structure. To achieve these aims, one must determine from experimentally observed capture rates the basic parameters entering into the fundamental interaction. Here one is faced with two problems. First there are questions of an atomic or molecular nature since the rate is determined in part by the atomic or molecular wave function of the muon before capture. This part of the problem presents no real difficulties except in the case of capture in hydrogen where the formation of ~-molecules plays an important role. Secondly, however, there is the necessity of evaluating nuclear matrix elements of appropriate operators. Except in the case of hydrogen, this is a complicated problem since one must generally depend on the use of some kind of nuclear model and the question of its suitability for the calculations required becomes a critical one. As always in such cases, it is helpful to be able to correlate the required nuclear structure information with information which can be obtained from other experiments.

Leaving aside the case of capture in hydrogen with its own special problems there are, generally speaking, three experimental approaches to the muon capture problem and for each an associated theoretical problem concerning nuclear matrix elements: one may observe muon capture to a definite final state of the daughter nucleus in which case one requires specific information on the initial and final state nuclear wave functions. Or one may study the systematics of total capture rates in heavy nuclei with the aim of determining the «capture properties» of extended «nuclear matter» in the hope of thus freeing oneself from the details of individual wave functions for nuclear states. Such an approach was initiated by Primakoff (1) and considered further by Tolhoek and his collaborators (2), Klein and Wolfenstein (3), and Bell and Lovseth (4). Finally, one can consider total capture rates of selected nuclei, usually