Muon Capture in Certain Light Nuclei (*).

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Summary. — The rates of the muon capture reactions: \( \mu^- + ^2\text{He} \rightarrow ^3\text{He} + \nu \), \( \mu^- + ^6\text{Li} \rightarrow ^6\text{He} + \nu \), \( \mu^- + ^{12}\text{C} \rightarrow ^{12}\text{B} + \nu \), with the daughter nuclei formed in their ground states, are calculated assuming universality between muon-bare nucleon and electron-bare nucleon coupling constants. The induced pseudoscalar interaction and the additional terms arising from the assumption of a conserved vector current are included in the muon-nucleon effective Hamiltonian. The ratios of the nuclear matrix elements for the muon captures and for the corresponding \( \beta \)-decays are first estimated in an approximately model independent fashion using appropriate nuclear proton density distribution functions and then evaluated in more detail on the basis of variational trial wave functions for \(^3\text{He}, ^3\text{H}\), and of LS coupling and \(jj\) coupling shell model wave functions (with configuration mixing) for \(^6\text{Li}, ^6\text{He}\), and \(^{12}\text{C}, ^{12}\text{B}\), respectively. The calculated capture rate for \( \mu^- + ^{12}\text{C} \rightarrow ^{12}\text{B} + \nu \) is in agreement with experiment — experiments however are not yet available in the other two cases.

1. — Introduction.

The transition rate for nuclear capture of orbitally bound negative muons has been studied both theoretically and experimentally by several authors (\(^1\)).

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The most significant results of these investigations are well known: i) the approximate equality of the effective coupling constants for the reaction \( \mu^- + p \rightarrow n + \nu \) and the reaction \( n \rightarrow p + e^- + \bar{\nu} \); ii) the comparatively low mean excitation energy of the daughter nuclei formed in the capture process ((10–20) MeV). However nearly all of the studies in question are concerned with the total muon capture rate, i.e. with the sum of the partial muon capture rates to all energetically accessible bound and unbound levels of the daughter nucleus.

The first investigation in which a partial muon capture rate was determined is due to Godfrey (2). Godfrey studied experimentally the rate of that muon capture reaction

\[
\mu^- + ^{12}_6C \rightarrow ^{12}_5B + \nu ,
\]

which was followed by the \( \beta \) decay of \(^{12}_5B\)

\[
^{12}_5B \rightarrow ^{12}_6C + e^- + \bar{\nu}
\]

and accordingly obtained the partial rate of muon capture to all the bound states of \(^{12}_5B\). He further gave a qualitative argument in favour of the view that most of the muon capture transitions to the bound states of \(^{12}_5B\) actually go to the ground state of \(^{12}_5B\); as a result he identified his observed partial muon capture rate with the rate from \(^{12}_6C\) to the \(^{12}_5B\) ground state. Godfrey then established an approximate theoretical relation between the nuclear matrix elements for muon capture and \( \beta \) decay between the ground states of \(^{12}_6C\) and \(^{12}_5B\); using this relation and comparing his observed muon capture rate with the known \(^{12}_5B\) \( \beta \) decay rate he concluded that the Gamow-Teller coupling constants in muon capture and in \( \beta \) decay are approximately equal.

In the present paper we reexamine and refine the relation between the nuclear matrix elements for muon capture and for \( \beta \) decay between the ground states of \(^{12}_6C\) and \(^{12}_5B\), and also extend the argument to the calculation of the ground state to ground state partial muon capture rates in the reactions

\[
\mu^- + ^{6}_3Li \rightarrow ^{4}_2He + \nu ,
\]

\[
\mu^- + ^{4}_2He \rightarrow ^{3}_2H + \nu .
\]

For this purpose we use a muon-nucleon effective Hamiltonian developed in the next section.