Test of the Pauli Exclusion Principle for Atomic Electrons

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The Pauli exclusion principle has been tested for atomic electrons giving a lifetime for such a violation, per iodine atom, of $>2\times10^{27}$ sec. This result is compared to a normal electromagnetic dipole transition, and a limit is set on a possible symmetric wave-function admixture to a K-shell electron wave function.

As pointed out by Goldhaber,[1] the same experimental data which were used to set a limit on the lifetime of the electron can be used to test the validity of the Pauli exclusion principle for atomic electrons. Moe and Reines[2] looked for the disappearance of a K-shell electron in an iodine atom of a well-shielded NaI crystal (1278 g). This occurrence would be characterized by an electron cascade to fill the resultant vacancy with a net photon emission of 33.2 keV. In the present interpretation, if an L-shell electron violated the exclusion principle and went to the "filled" K shell, the resultant x-ray emission would be identical to that searched for in the electron lifetime experiment.

In this interpretation we attribute the unexplained NaI detector rate of 8×10^4 yr^{-1} in the 17-keV region centered on 33.2 keV to violation of the exclusion principle. This gives a lifetime against such violation, per iodine atom, of $>2\times10^{27}$ sec. To obtain a measure of the maximum relative strength of a Pauli violating (Pv) transition, we compare this lifetime with that of the normal electromagnetic dipole transition to the K shell ($\sim6\times10^{-17}$ sec). The result is

$$(g_{\mathrm{Pv}}/g_{\mathrm{em}})^2<3\times10^{-44}.$$

A more fundamental way of describing this result is to cast it in terms of a limit imposed on the admixture of a symmetric wave function, Ψ_s, which is predominantly antisymmetric, Ψ_a. The wave function appropriate to the K-shell electron may be written

$$\Psi=\Psi_a+\beta\Psi_s,$$

where β represents the admixture of the two parts.[3] In these terms, $\beta=g_{\mathrm{Pv}}/g_{\mathrm{em}}$.

On a more primitive level, we can use the experimental results to place an upper limit on the fraction of iodine atoms which have an altered chemistry due to violation of the exclusion principle since the origin of a big-bang universe $\sim10^{10}$ yr ago. The fraction, $<10^{-9}$, is probably too small to have been detected by chemical or other means. The limiting fraction for elements with higher and lower Z are, respectively, greater and lesser than for iodine.[4]

The experimental limits can be improved with the use of recently developed high resolution solid state detectors.

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[1] M. Goldhaber, unpublished.

[2] M. K. Moe and F. Reines, Phys. Rev. 140, B992 (1965).

[3] M. Dresden discusses parastatistics and the equivalence of an admixture of symmetric and antisymmetic states in *Brandeis Summer Institute 1962 Lectures in Theoretical Physics*, edited by K. W. Ford (Benjamin, New York, 1963), Vol. 2, *Astrophysics and Weak Interactions*, p. 378 *et seq.*

[4] In arriving at this fraction we counted all electrons in the iodine atom in addition to those in the L shell as candidates for violation of the exclusion principle.