Erratum: The Cross Section for Photo-Disintegration of the Deuteron at Low Energies

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In Table IX the designations in the first, second, and fifth rows of the first column should be, respectively, $\sigma_{2.757}(\mathrm{cm}^2)\times 10^{28}$, $\sigma_{2.618}(\mathrm{cm}^2)\times 10^{28}$, and $\sigma_{2.504}(\mathrm{cm}^2)\times 10^{28}$.

The Excitation Energy Difference in $\mathrm{Li}^7-\mathrm{Be}^7$

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It has been observed that the $\mathrm{Be}^7-\mathrm{Li}^7$ Coulomb energy difference falls below the smooth empirical curve determined by the other $4n+3$ mirror systems.[1] The discrepancy is just about 10 percent. A related discrepancy occurs in the location of the low excited states. In Li^7 the excitation energy is 0.478 Mev; in Be^7 the recently discovered excited state occurs at 0.429 Mev, again smaller by about 10 percent.[2-5] These large differences can be correlated in a consistent manner with the small binding energy of Be^7 relative to He^4 and He^3 components. Denoting energies relative to the three and four particle components by script symbols and using subscripts g and e to distinguish ground and excited states and the subscript c for Coulomb energies, one may write

$$\begin{aligned}\mathcal{E}_g(\mathrm{Be}^7)&\equiv M(\mathrm{Be}^7)-M(\mathrm{He}^4)-M(\mathrm{He}^3)=-1.62\text{ Mev},\\ \mathcal{E}_g(\mathrm{Li}^7)&\equiv M(\mathrm{Li}^7)-M(\mathrm{He}^4)-M(\mathrm{H}^3)=-2.51\text{ Mev};\end{aligned}\tag{1}$$

$$\begin{aligned}\mathcal{E}_c(\mathrm{Be}^7)&\equiv E_c(\mathrm{Be}^7)-E_c(\mathrm{He}^4)-E_c(\mathrm{He}^3)\sim 2.08\text{ Mev},\\ \mathcal{E}_c(\mathrm{Li}^7)&\equiv E_c(\mathrm{Li}^7)-E_c(\mathrm{He}^4)\sim 1.04\text{ Mev}.\end{aligned}\tag{2}$$

The estimated Coulomb energies appearing in Eq. (2) are not the actual values in the seven particle systems, but are rather the values which would obtain if these systems were not expanded by the Coulomb repulsion of the three and four particle systems.

The formula

$$\begin{aligned}\mathcal{E}_g(\lambda)&=\lambda^2K-U(\lambda)+\lambda\mathcal{E}_c\\ &=\mathcal{E}_{g0}(\lambda)+\lambda\mathcal{E}_c\end{aligned}\tag{3}$$

expresses the energy as a function of a scale parameter λ, the kinetic and Coulomb terms depending on λ in the manner shown because the corresponding operators are homogeneous functions of degree -2 and -1, respectively, in the space coordinates. Nothing is required of the potential energy $U(\lambda)$ beyond the possibility of an expansion in powers of $\lambda-1$. In the absence of the Coulomb repulsion between the three and four particle components, minimum energy, associated with $\lambda=1$, requires $2K=U'(1)$. Including the Coulomb repulsion, minimum energy occurs at

$$\lambda_g=1-\mathcal{E}_c/\mathcal{E}_{g0}''(1)\tag{4}$$

and has the value

$$\mathcal{E}_g(\lambda_g)=\mathcal{E}_{g0}(1)+\mathcal{E}_c-\mathcal{E}_c^2/2\mathcal{E}_{g0}''(1).\tag{5}$$

Low excited states may be characterized by a reduction in the magnitude of the potential energy:

$$\mathcal{E}_e(\lambda)=\lambda^2K-(1-\delta)U(\lambda)+\lambda\mathcal{E}_c.\tag{6}$$

Then minimum energy occurs at

$$\lambda_e=1-(\mathcal{E}_c+2K\delta)/[\mathcal{E}_{g0}''(1)+U''(1)]\tag{7}$$

and has the value

$$\begin{aligned}\mathcal{E}_e(\lambda_e)=\mathcal{E}_{g0}(1)+U(1)\delta+\mathcal{E}_c&\\ -(\mathcal{E}_c+2K\delta)^2/2[\mathcal{E}_{g0}''(1)+U''(1)\delta].&\end{aligned}\tag{8}$$

Introducing numbers, it is found that the 10 percent discrepancy in Coulomb energy requires $\mathcal{E}_{g0}''(1)\sim 11$ Mev. The radius of Be^7 is approximately 10 percent greater than that of Li^7. The parameter δ is determined as a function of K/U by the condition $\mathcal{E}_e(\mathrm{Li}^7)-\mathcal{E}_g(\mathrm{Li}^7)=0.478$ Mev. In the range $0.2\leqq K/U\leqq 0.8$, δ varies between 0.139 and 0.034, and the difference in the excitation energies of Li^7 and Be^7 varies linearly with K/U from 24 kev (50 percent of the experimental difference) at the lower end to 79 kev (161 percent of the experimental difference) at the upper end of the range. Agreement with the experimental energy difference is found at $K/U\sim 0.4$.

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Experimental Search for the Beta-Decay of the π^+ Meson*

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The possibility that nuclear beta-decay is associated with the beta-decay of the meson, formed during an intermediate step, has long been of interest in the development of meson theories. The μ-meson does decay into an electron, but its coupling with nucleons is too weak for this purpose. To explain nuclear beta-decay, the beta-decay rate for the π-meson should be comparable to its μ-decay rate. We report the results of an investigation to detect other than $(\pi-\mu)$ events for π^+ mesons which stop in Ilford G-5 (beta-sensitive) 400- and 600-micron emulsions. The result to date is zero $(\pi-e)$ events compared to 829 $(\pi-\mu)$ events for mesons satisfying certain criteria discussed below.

A collimating exposure chamber was used in the fringing magnetic field inside the vacuum chamber of the Columbia 164-in. cyclotron. The mesons were produced by 385-Mev protons on copper. Plots of the expected meson orbits led to an expected total energy spread for any point X along the plate of about 0.5 Mev.

The meson energy distribution, calculated from the observed ranges, shows that 90 percent of the mesons were within 1 Mev of the mean energy for each X, which varied from 11 to 14 Mev. A comparison with the variation of the ranges of the (supposedly monoenergetic) μ-mesons from the $(\pi-\mu)$ decays suggests that a sizable fraction of the observed spread for the π-mesons is due to straggling rather than a true energy spread.

We consider only meson tracks entering the top surface of the emulsion which stop in the emulsion. Let A represent those associated with a $(\pi-\mu)$ event, B those with no $(\pi-\mu)$ event but with a meson-electron event, and C those with no $(\pi-\mu)$ event or observable meson-electron event. We investigate the ratio of events B and C to A. The following two factors are most apt to lead to false results for the $(\pi-e)$ occurrence rate. (a) Since the $(\pi-\mu)$ event is particularly striking, there is danger that mesons will tend to be recognized mainly because of the $(\pi-\mu)$ event. Thus, in the scanning there is greater relative probability of overlooking events B or C than A. (b) There will be some energetic μ-mesons entering the emulsion due to $(\pi-\mu)$ decays in flight. These will give meson-electron events which might be misinterpreted as π-electron events. We feel that both of these problems have been successfully solved in these studies.

Several scanning procedures were tried to test for, and avoid, effect (a). Techniques were gradually evolved by which mesons were always identified without reference to the $(\pi-\mu)$ event. The present method is to scan just the top surface of the plate. All tracks entering the emulsion in the field of view at about the proper angle are recorded, followed, and identified. Mesons are always identified well before their endings. In the 600μ plates, about 40 percent of the entering tracks are mesons, of which about 40 percent stop in the emulsion.

Factor (b) is met by the collimating system which defines conditions such that 90 percent of the stopped mesons have their entrance directions and ranges well defined for each X. Mesons falling outside these limits are not counted. A few μ-mesons, formed in flight, gave tracks of type B and C, but, as expected, had considerably different ranges than the π-mesons. These investigations are being continued.

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Paramagnetic Resonance at Very Low Fields

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We have observed a very strong and narrow paramagnetic resonance absorption line at fields from 7.0 to 10.3 gauss (i.e., at frequencies of about 19.5 to 29.5 Mc) in a one-gram sample of the free radical α, α-diphenyl β-picryl hydrazyl, $(C_6H_5)_2N-NC_6H_2(NO_2)_3$, using a Bloembergen-Purcell-Pound type of apparatus designed for nuclear magnetic resonance experiments.[1] The modulation frequency used was 30 cycles/sec. The signal was sufficiently strong to be very easily observable on an oscilloscope, although the line width was obtained by means of slope measurements using a one-cycle wide amplifier. A solenoid operating from storage batteries supplied a steady field of sufficient homogeneity.

To our knowledge this is the lowest field strength at which paramagnetic resonance has been observed. Indications are that the line can be detected readily at even lower fields, thus providing a means of extending the range of precision magnetic field measurements provided by the nuclear resonance technique down to such fields. The nuclear resonance signal becomes too weak at low fields to be easily detectable. By inserting a paramagnetic material in place of one involving the use of nuclear magnetism, an enormous increase of signal to noise is obtained.

The observed line width at 29.5 Mc, as measured by the separation between the points of extreme slope of the absorption signal, was 1.4±0.1 gauss. This is not necessarily the same as the width measured at the half-maximum absorption points, since the strong exchange narrowing occurring in the material tends to raise the extreme slope points above the half-maximum points. At microwave frequencies using the latter points a line width roughly double this has been reported.[2, 3]

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The Qualitative Similarity of Origin of the Main Cosmic Radiation and of Showers

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In a recent communication Cocconi[1] raises the question whether or not the total continuous cosmic radiation and the extensive atmospheric showers occurring in it are produced by entirely equivalent processes.

This problem has occupied our attention for many years, and, from different measurements, we have concluded that when a meson comes down there is a chance of from 40 to 100 percent that a coherent meson will be found in the neighborhood.[2] This was found by measuring the coincidences of a penetrating particle passing through a surface of size 6×6 cm, with another particle passing through another surface of 6×6 cm at three different distances from the first, of 9, 14, and 21 cm. From the exponential decrease in the coincidence rate with distance, we were able to find the total flux of soft and of penetrating particles around the direction of the primary particles. The ratio of the soft (which we take to be decay electrons) to the penetrating particles was found to lie between 0.09 and 0.12. In two independent sets of measurements the occurrence of coherent penetrating particles was found to be 40 to 100 percent, respectively, so that we concluded that generally at least one coherent meson, or an electron resulting from the decay of one, comes down with every meson.

In another experiment we took two sets of 3 counter boxes, with a sensitive surface of 140 cm^2 per set. The number of coherent particles registered at three distances enabled us to conclude that the distribution of the particles around each of the sets decreased exponentially with the distance to that set. We were able to compute the total number of particles coming down simultaneously with the particle in the first set. This was 202 per minute, while the number of particles counted in the first set was 260, so that we found that in 80 percent of the cases there must have been a coherent meson in the neighborhood.[3]

We must realize that in most cases the energy of the incident proton is not very large, so that the multiplicity of production is small. Moreover, since this production occurs at high altitudes, the number of coherent mesons which can be found in the lower parts of the atmosphere will be small, in general, and the number of secondaries accompanying the penetrating meson will be small also in the very extensive showers. But if two conditions are realized, (1) that the proton producing the mesons (which in their turn produce secondaries) has a high energy, and (2) that the position of the primary collision happens to lie in the lower atmosphere, the mesons and their secondaries will then be observed as a high concentration of particles, that is, as a shower. That the large showers are produced at low levels is confirmed by the fact that the barometric coefficient[3] is about 14 percent per cm Hg. Qualitatively, the original process will be the same in the case of the continuous radiation and of the showers.

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