The Energy of the Gamma-Ray from Se^{77m}

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A METASTABLE state of Se^{77} of 17.5-sec half-life has been produced by neutron excitation of Se by Arnold and Sugarman,[1] and by Goldhaber and Muehlhause.[2] This isomer has also been produced by x-ray excitation by Gideon, Miller, and Waldman[3]. The isomer, Se^{77m}, decays to the ground state of Se^{77} with the emission of a highly internally converted gamma-ray. The absorption in aluminum of the internal conversion electrons has been measured by Gideon, Miller, and Waldman, who give the energy of the gamma-ray as approximately 150 kev. Flammersfeld and Ythier[4] have made similar measurements and give the value 165 kev for the energy of the gamma-ray. Der Mateosian and Goldhaber[5] have measured the energy of the gamma-ray using a scintillation counter and find an energy of 150 kev.

The present experiments stem from an investigation of Br^{77} (57 hr) which is in progress in this laboratory. Br^{77} was made by the reaction $As^{75}(\alpha, 2n)Br^{77}$ in the Indiana cyclotron. The spectrum of the photoelectrons ejected from a lead radiator and also the particle spectrum (internal conversion electrons and positrons) were measured in a magnetic lens spectrometer. Among other things a very weak gamma-ray of 160 kev was found in the photoelectric spectrum, and a very strong internal conversion line corresponding to the same gamma-ray was found in the particle spectrum.

Experiments were performed to see whether a Se activity was growing from the Br^{77}. To a solution containing activated Br^{77} ion there was added a small amount of $SeO_3^{=}$. The $SeO_3^{=}$ was reduced to Se metal by the addition of stannous chloride. The solution was filtered, washed, and transferred to a counter for measurement. The whole procedure took about one minute. The decay curve of the resulting Se^{77m} yields a half-life of 17.5 sec, with a probable error of about 10 percent. The energy of the gamma-ray associated with this transition is 159.9 ± 1.0 kev.

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Nuclear Magnetic Moment of Rb^{85}, Rb^{87}, and I^{127}

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WE have recently completed a series of measurements of the nuclear magnetic moment of Rb^{85}, Rb^{87}, and I^{127} using the nuclear resonance absorption method of Purcell *et al.*[1] The apparatus described elsewhere[2] had been modified to permit the precise determination of the deuteron[3] by a side band modulation technique, and it was considered profitable to exploit the technique used in the latter measurement for the more accurate determinations of other isotopes. The side band modulation technique requires use of a master oscillator of frequency f_0, a harmonic amplifier and mixer, and a modulation oscillator of frequency f to generate the required side band. The ratio of proton to unknown Larmor precession frequency is given by

$$f_H/f_x = (af_0 \pm f)/bf_0,$$

where a and b are integers chosen to have the lowest value consistent with a low value for f. The imprecision in the frequency ratio is reduced by the factor f/f_H from that obtained with direct techniques. The samples and the coils were arranged[3] so that simultaneous measurement of proton and unknown resonance was possible.

Because of the theoretical interest in the nuclear moments of isotopic pairs,[4] the rubidium isotopes were investigated in the form of saturated solutions of RbCl. The operating conditions for the Rb^{85} were roughly $f_0 = 3.0 \times 10^6$ cycles/sec, $f = (+)1.071 \times 10^6$ cycles/sec, $a = 10$, $b = 1$, and a line width of 0.32 gauss. In all cases the field inhomogeneity limited the proton line width to about 0.02 gauss. The ratio of resonant frequencies (uncorrected for diamagnetic effects) was

$$f_H/f_{Rb^{85}} = 10.357105 \pm 0.000030,$$

where, as in all cases, the indicated error is three times the probable error. This value is to be compared with the previous value of Chambers and Williams[5] of 10.351 ± 0.004.

For the Rb^{87} isotope, the conditions were $f_0 = 1.0 \times 10^7$ cycles/sec, $f = (+)5.61 \times 10^5$ cycles/sec, $a = 3$, $b = 1$, and a line width of 0.20 gauss. The resultant frequency ratio

$$f_H/f_{Rb^{87}} = 3.0561097 \pm 0.0000055$$

is in good agreement with the value of Zimmerman and Williams[6] of 3.0564 ± 0.0015.

Using the assigned spin values of 5/2 and 3/2 for the Rb^{85} and Rb^{87} isotopes, respectively, we find the ratio of the moments to be

$$\mu_{Rb^{87}}/\mu_{Rb^{85}} = 2.0333905 \pm 0.0000075,$$

in good agreement with the value of Adams *et al.*[7] of 2.033380 ± 0.000028.

The I^{127} isotope in a saturated solution of KI was investigated under conditions of $f_0 = 6.17 \times 10^6$ cycles/sec, $f = (-)1.3 \times 10^4$ cycles/sec, $a = 5$, $b = 1$, and where the line width was broadened, presumably by the large quadrupole moment, to 2.5 gauss. The precision was severely limited by this width and yielded

$$f_H/f_I = 4.99763 \pm 0.00015,$$

in good agreement with the value of Zimmerman and Williams[6] of 4.9993 ± 0.0020.

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On the Low States of He^5 and Li^5

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AN examination of the experimental material available on the low states of He^5 and Li^5 might be expected to provide information on the charge independence of nuclear forces and the strength of spin orbit forces in nuclei. The available material consists of measurements of the $p-\alpha$ differential scattering cross section[1] and the $n-\alpha$ total cross section[2] as well as more qualitative measurements of the $n-\alpha$ angular distribution[3] and back scattering.[4]

Though a $P_{3/2}-P_{1/2}$ doublet may be involved, their associated scattering phase shifts will be independent of one another, since states with different values of spin, j, or parity will not interact. These phase shifts, $\delta(l, j)$, may then be approximated by the single level formula of nuclear dispersion theory and written as:[5]

$$\delta(l, j) = \tan^{-1}\frac{k\gamma^2[F_l^2(a)+G_l^2(a)]^{-1}}{E_\lambda+\Delta-E} - \tan^{-1}\left\{\frac{F_l(a)}{G_l(a)}\right\}, \quad (1)$$

where F and G are the regular and irregular free particle wave functions,[6] a is the reaction radius, and γ^2 is the energy independent reduced width. E_λ is a characteristic energy of the state, the energy at which the logarithmic derivative of the wave function becomes

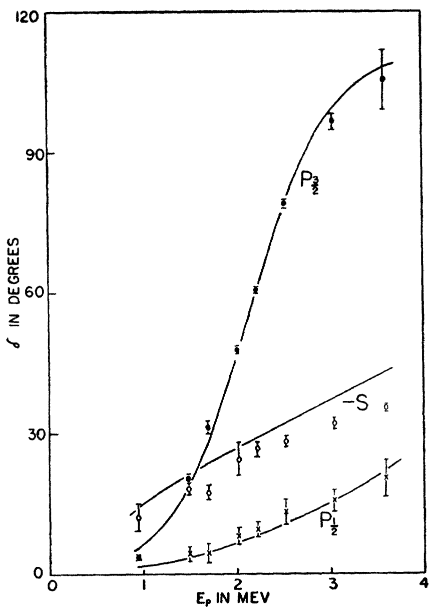

FIG. 1. Phase shifts for $p-\alpha$ scattering as a function of proton bombardment energy.

equal to $-l$ at the nuclear surface. The level shift, Δ, is equal[7] to

$$-\frac{\gamma^2}{a}\left(d\frac{\ln(F_l^2(a)+G_l^2(a))^{\frac{1}{2}}}{d\ln ka}+l\right).$$

Critchfield and Dodder[8] have shown that the $p-\alpha$ differential cross section is consistent with either of two sets of phase shifts, one representing an inverted doublet with an undetermined large splitting, the other corresponding to a regular doublet with a splitting of about one Mev. The points on Fig. 1 represent their values for the phase shifts in the former case, together with their estimate of the probable error. The curves represent the best fit, obtained by trial and error, of Eq. (1) to the points. Corresponding values of the parameters were $a=2.9\times10^{-13}$ cm, $\gamma^2(P_{3/2})=\gamma^2(P_{1/2})=17.6\times10^{-13}$ Mev cm, $E_\lambda(P_{3/2})=3.65$ Mev, and the doublet splitting $E_\lambda(P_{1/2})-E_\lambda(P_{3/2})=5$ Mev. The S-wave curve was calculated using only the potential scattering part of the resonance formula, $\delta_0=-\tan^{-1}[F_0(a)/G_0(a)]$. Effects of high lying levels would be expected to reduce this phase shift in agreement with the experimental results.

The total $n-\alpha$ cross section will equal

$$\sigma_t=2\pi k^{-2}\textstyle\sum_{l,j}(2j+1)\sin^2\delta(l,j), \tag{2}$$

where $\delta(P_{3/2})$ and $\delta(P_{1/2})$ are calculated from Eq. (1). The points on Fig. 2 are the experimental values of reference 2, while the curve represents the fit of Eq. (2) to the data, using the same values of the parameters, a, γ^2, and the splitting $E_\lambda(P_{1/2})-E_\lambda(P_{3/2})$, as for the $p-\alpha$ analysis. The discrepancy between the data and the curve at 1.2 Mev can be accounted for by an experimental effect discussed in reference 2. The $n-\alpha$ levels are 1.25 Mev lower than the $p-\alpha$ levels, a shift attributable to the difference in coulomb energy. The $n-\alpha$ S-wave phase shifts were calculated by requiring the wave function to have the same logarithmic derivative at the nuclear surface as the $p-\alpha$ S-wave. This leads to a value of about 0.8 barn for the low energy cross section, consistent with reference 2, but in disagreement with the value of 1.45 barns reported by Harris.[9] The sign of the S-wave phase shift is negative,[10] as is the proton phase shift. It seems reasonable to assume that the higher angular momenta phase shifts are negligible. Goldstein[11] has pointed out that this assignment of levels is consistent with the $n-\alpha$ angular distribution and back scattering experiments. For both Li[5] and He[5] the parameters for the $P_{1/2}$ level are somewhat arbitrary.

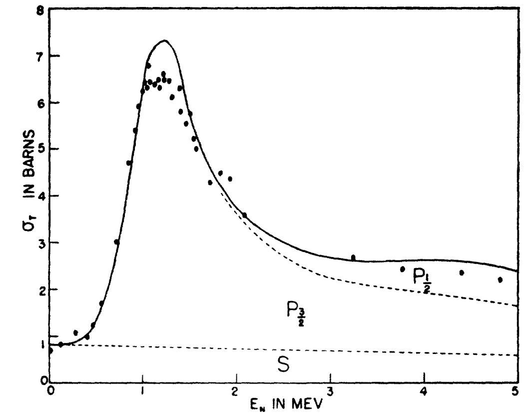

FIG. 2. $n-\alpha$ total cross section as a function of neutron bombardment energy. The dashed lines separate the contributions of the various partial waves.

The value obtained for the reduced width, γ^2, is about equal to $\hbar^2/ma$, where m is the reduced mass of the system. With this value of γ^2 and $|E_\lambda-E|\lesssim\gamma^2/a$, Eq. (1) takes the same form as the result for scattering by a square well of depth E', where $(E'+E_\lambda)^{\frac{1}{2}}(2ma/\hbar^2)^{\frac{1}{2}}=\pi(l+1)$, indicating that the interaction may be represented adequately as a one-body interaction. E' should provide an estimate of the average interaction energy. $E'+E_\lambda$ is equal to 38 Mev for a radius a of 2.9×10^{-13} cm.

In summary, it appears that the data are consistent with the thesis of charge independent forces and the formation of a widely spaced inverted $P_{3/2}-P_{1/2}$ doublet. The doublet splitting of the order of five Mev is much larger than Dancoff's[12] estimate of the effect of tensor forces and may be evidence for the importance of velocity dependent forces,[13] or some other large spin orbit coupling as is postulated for one of the nuclear shell models.[14]

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Emission of the Forbidden Oxygen Lines by Molecular Dissociation

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THE process which occurs in a gas when it is excited by an electrical discharge is often quite complicated. It is not easy to distinguish in the emission spectrum the parts coming from the direct electronic excitation, from the recombination of ions and electrons, and from secondary reactions such as atomic recombination or molecular decomposition.