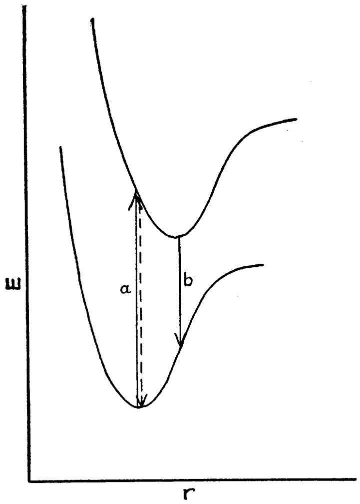

FIG. 2. Typical potential curve relationship. a = energy required to excite molecule; b = energy available after loss of upper state vibrational energy; dotted line = energy available for transfer before vibrational energy is lost.

for which such self-transfer occurs should be in the class of inefficient scintillators, whereas those showing no self-transfer should be efficient scintillators. This is in general the case. Efficient self-transferring substances such as anthracene are relatively inefficient as solution scintillators when compared with, say, terphenyl or diphenyl hexatriene, which show no sign of self-transfer phenomena in low temperature glasses. Whereas this relationship holds for most of the substances examined, there are a few cases for which its validity is doubtful. For example, fluoranthene and pyrene do not show self-transfer but are only moderately good scintillators. Such apparent exceptions are probably explained by the comparatively low quantum yields of fluorescence shown by these substances in the pure state as a result of radiationless internal conversion to the ground state within the molecule. This process was not considered in the above arguments.

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The Reaction $Li^7(\alpha,\gamma)B^{11}$ and States of B^{11}

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WE have used NaI(Tl) crystals to study gamma-ray transitions from states in B^{11} at 8.93, 9.19, and 9.28 Mev formed by bombarding Li^7 with alpha-particles.[1] Figure 1 shows the gamma-rays which we have detected, together with the previously known[2] locations of the energy levels.

Table I lists the labeled gamma-rays, the probability of the mode of de-excitation of which they form a part (normalized to unity for each initial state), their energy as expected from the known[2] levels, and their energy as measured in the present investigation.

TABLE I. Gamma-rays from B^{11}.

Gamma-ray	Probability	Expected energy (Mev)	Measured energy (Mev)
γ_1	0.89	8.926 ± 0.012	8.91 ± 0.03
γ_2	0.07	3.892 ± 0.018	3.90 ± 0.12
γ_3	0.07	5.034 ± 0.014	5.05 ± 0.08
γ_4	0.04	6.788 ± 0.018	6.80 ± 0.10
γ_5	0.97	4.731 ± 0.018	4.728 ± 0.023
γ_6	0.97	4.459 ± 0.014	4.470 ± 0.023
γ_7	0.03	6.808 ± 0.013	6.80 ± 0.03
γ_8	0.10	9.276 ± 0.012	9.27 ± 0.03
γ_9	0.83	4.817 ± 0.018	4.806 ± 0.013
γ_{10}	0.83	4.459 ± 0.014	4.464 ± 0.013
γ_{11}	0.07	2.468 ± 0.018	2.53 ± 0.06
γ_{12}	0.07	6.808 ± 0.013	6.83 ± 0.03

The status of γ_4 is a little uncertain; it is possible that the doublet around 6.8 Mev is involved rather than the 2.14-Mev level. The lifetime of the 4.46-Mev level is less than a few times 10^{-14} sec—it displays a Doppler shift.[3] The radiative widths of the 8.93-, 9.19-, and 9.28-Mev levels are, very roughly, 0.1, 1, and 10 ev, respectively.

We have also carried out the following angular distribution and correlation measurements:[4] $\alpha-\gamma_1$, $\alpha-\gamma_5$, $\alpha-\gamma_6$, $\gamma_5-\gamma_6$ (in two planes), $\alpha-\gamma_7$, $\alpha-\gamma_8$, $\alpha-\gamma_9$, $\alpha-\gamma_{10}$, $\gamma_9-\gamma_{10}$ (in two planes), $\alpha-\gamma_{12}$; coincidences between γ_{11} and γ_{12} have been detected. If we take the ground states of both Li^7 and B^{11} to be $3/2-$ we are able to assign, with fair certainty, spins and parities to the levels in B^{11} at 4.46, 6.81, 8.93, 9.19, and 9.28 Mev; under reasonable assumptions these assignments lead to spin assignments for the levels at 2.14 and 5.03 Mev. These results are shown in Fig. 1 and in Table II.

TABLE II. Experimental characteristics of levels of B^{11} and shell model assignments.

Level	0	2.14	4.46	5.03	6.76	6.81	7.30	8.57	8.93	9.19	9.28
Exptl.	$3/2-$	$\frac{1}{2}\pm$	$5/2+$	$\frac{1}{2}\pm$		$3/2+$			$3/2+$	$7/2+$	$5/2-$
Shell	$1p_{3/2}$	$1p_{\frac{1}{2}}$	$1d_{5/2}$	$2s_{\frac{1}{2}}$	$M(3/2-)$	$1d_{3/2}$	$1f_{7/2}$	$2p_{3/2}$	M	M	$1f_{5/2}$

We have been tempted to apply the shell model to B^{11} even at high excitation; the resulting identifications appear in Fig. 1 and in Table II where M stands for a state of multiple excitation; the first, at 6.76 Mev, is probably $3/2-$, i.e., $(1p_{\frac{1}{2}})^2(1p_{\frac{3}{2}})^{-1}$.

In defense of this rather speculative shell scheme, it must be said that it agrees with all our experimental findings and contradicts none; that it may not be completely sophistical is further suggested by three remarks:

(a) All transitions from the 9.28-Mev level, assigned by the scheme to a single-particle state, agree with the predictions of

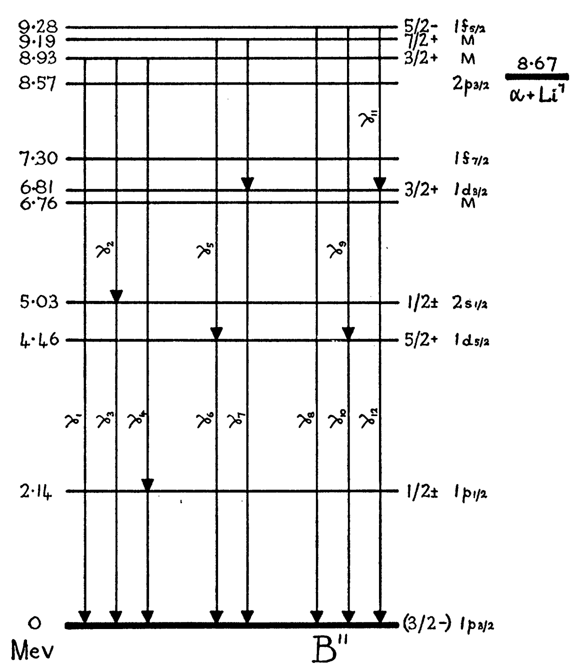

FIG. 1. Decay scheme of 8.93-, 9.19-, and 9.28-Mev levels of B^{11}. Arrows indicate the observed modes of de-excitation; the labeled gamma-rays are those whose energy has been measured. To the right of the levels are their experimental assignments with their description by the shell model. (M stands for a state of multiple excitation.)

the single-particle model;[5] those from the 8.93- and 9.19-Mev levels, supposed by the scheme to be of multiple excitation, show preferred $E2$ transitions[6] to be expected from such states of more general excitation.

(b) The splittings of the supposed p, d, and f doublets are 2.1, 2.4, and 2.0 Mev, respectively, all of the correct order.

(c) The separation of the supposed $1d_{5/2}-2s_{\frac{1}{2}}$ levels is 0.57 Mev, in good accord with the nearest known examples of this separation in O^{17} and F^{17} of 0.55 and 0.87 Mev, respectively.[7]

We would like to point out the considerable interest that attaches to the parity assignments which would be available from a study of $B^{10}(d,p)B^{11}$ stripping.

A full account of this work is in preparation.

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The Quenching of *Ortho*-Positronium Decay by a Magnetic Field*

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We have measured the quenching of three-quantum annihilation from positronium by a magnetic field.[1] This effect has been detected by Deutsch and Dulit[2] and by Pond and Dicke[3] using different methods. Positronium was formed in SF_6 gas in a chamber placed between the poles of a magnet. The positron source was ~0.01 mC Na^{22} on a Zapon film. The decay of the $^3S_1$ positronium was detected by three NaI scintillation counters placed with their axes 120° apart in the plane perpendicular to the magnetic field.[4] The background triple coincidence rate was found by letting nitric oxide into the gas chamber. Generally, the background was about ten percent of the total triple coincidence rate. The magnet was specially designed and the 5819 photomultipliers magnetically shielded to eliminate magnetic field effects on the counters. At a given pressure we measured the ratio $n(H)$ of the true triple coincidence rate at the field H to that at $H=0$.

If one plots $n(H)$, against $(1-n)/H^2$, one should obtain—at low enough gas densities—a straight line whose intercept is the fraction of the rate contributed by the $^3S_1$, $m_J=\pm1$ states. A typical experimental curve is shown in Fig. 1 for a density of 0.052 g/cm³. It is clear that the $m_J=\pm1$ states supply less than two-thirds of the zero field rate. This is in agreement with calculations by Drisko[5] who finds that the probability for annihilation from any

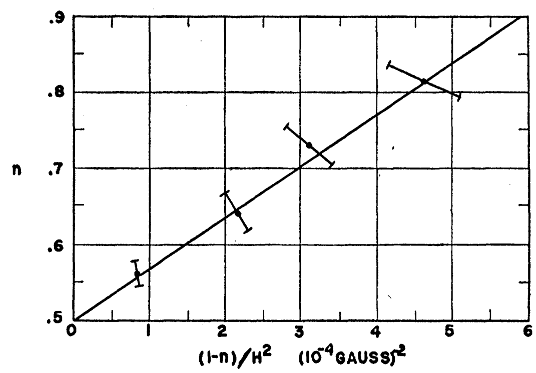

FIG. 1. A quenching plot for an SF_6 density of 0.052 g/cm².

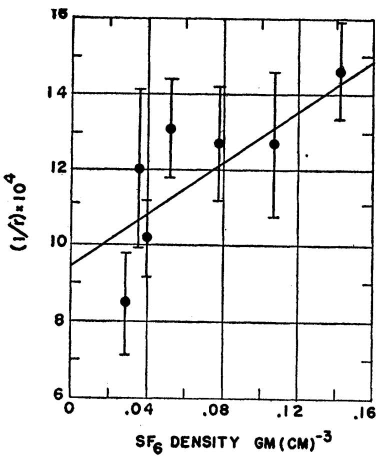

FIG. 2. A least squares line whose intercept gives r_0 and whose slope gives σ.

particular m_J substate of the $^3S_1$ state depends on the angle of the plane of the annihilation with the external field. In the special case corresponding to our geometry, Drisko finds that the $m_J=0$ state contributes one-half of the zero field rate. All our data are in agreement with this result.

If collisions are ignored, the theoretical expression for $n(H)$ for our geometry is

$$n(H)=(2+a^2r_0)/(2+2a^2r_0),$$

where $r_0=\tau_3/\tau_1=1120$ as given theoretically by Ore and Powell,[6] and $a=2\mu_0H/\Delta E$ with ΔE the ground state splitting as determined recently by Deutsch and Brown.[7] If one includes the possibility that collisions with gas atoms can cause transitions from $J=1$ to $J=0$ (probability per unit time $\lambda=Nv\sigma$) and transitions in which m_J changes with $\Delta J=0$ (probability per unit time $\lambda'=Nv\sigma'$), the situation is more complicated.[8] Transitions of the latter type cause $n(H)$ to approach a high field limit of less than $\frac{1}{2}$.

At high fields the quenching is relatively more sensitive to λ' than to λ. We found by measuring $n(H)$ as a function of gas density at $H=7100$ gauss that $\sigma'<\frac{1}{4}\sigma$. This conclusion depends on making use of a value of σ reported by Siegel and De Benedetti[9] for SF_6 ($\sigma\cong10^{-21}$ cm²). Using this approximate limit for σ', we find that for $H<3000$ gauss and for gas densities less than 0.15 g/cm³ the effect of the λ' transitions on the quenching is negligible and that, in fact, the quenching is given by Eq. (1) with r_0 replaced by $r=r_0/(1+\tau_3\lambda)$.

In order to obtain an experimental value for r_0 and to check σ, we make the definite assumption that λ' transitions are negligible. For each density we then determine the best value for r, using only data with $H<3000$ gauss. Consequently, the plot shown in Fig. 2 should be linear. The probable errors are large because $1/r$ is relatively sensitive to n; a one percent change in n produces at least a six percent change in $1/r$. The intercept and slope of the least squares line fitted to the data give the values of r_0 and σ. Our procedure requires only that Siegel and De Benedetti's value of σ be correct as to order to magnitude, justifying neglect of the λ' transitions; in this sense only is our value of σ independent. In computing σ from λ, we have assumed the dominance of single collisions. We find $r_0=1050\pm140$ compared with Ore and Powell's theoretical result of $r_0=1120$, and we find $\sigma=8\times10^{-22}$ cm² compared with $\sigma=10^{-21}$ cm² obtained by Siegel and De Benedetti.[9]

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