SHORT COMMUNICATIONS

SPINS AND PARITIES OF LEVELS OF ^{9}Be BELOW 15 MeV*

By H. H. Thies† and B. M. Spicer†

In a recent study of the cross section of the reaction ^{9}Be(γ,n) (Thies, Spicer, and Baglin 1959), distinct maxima were observed at 11·25 and 13·25 MeV. The maximum at 11·25 MeV was identified with the known level at 11·3 MeV and the 13·25 MeV maximum was attributed to absorption by one level at that energy. The nearly equal widths of the 11·25 and 13·25 MeV peaks justify this assumption. These peaks were attributed to $M1$ or $E1$ absorption by Thies, Spicer, and Baglin (1959).

A recent experiment on the electro-disintegration of ^{9}Be (Barber 1958) shows that, for excitations from 6 to 17 MeV, this nucleus is excited predominantly by $E1$ transitions and not $M1$ transitions. As the 11·25 and 13·25 MeV maxima are the only significant contributions to the (γ,n) cross section in the energy region 10–15 MeV, it is concluded that they are due to $E1$ transitions. In this case, the corresponding levels can have only the following assignments: J=1/2, 3/2, 5/2$^+$ (since the ground state of ^{9}Be is J=3/2$^-$).

The parameters of the 1·7 MeV level in ^{9}Be have been given by the photo-disintegration experiment of Connors and Miller (1956). From their results, the integrated cross section for absorption into this level is of the same order as that into the 11·25 and 13·25 MeV levels. Therefore, it may be tentatively inferred that this level is also excited by an $E1$ transition and is thus of even parity. This level was also observed (B. M. Spicer, unpublished data) in a betatron experiment on the ^{9}Be(γ,n) reaction, in which the yield curve was measured in steps of 30 keV from threshold to 4·5 MeV. However, this experiment did not detect any effect due to the known levels at 2·43 or 3·05 MeV. Therefore, these levels either have odd parity (and are therefore excited by weaker $M1$ or $E2$ transitions) or even parity and $J \geqslant 7/2$.

The known levels of ^{9}Be will be considered below and spin and parity assignments made on the basis of present knowledge from charged particle reactions and the above considerations.

1·7 MeV level.—D. W. Miller (1958) has established beyond doubt the existence of an excited state at 1·7 MeV. In the charged particle reactions a spectrum edge from three-body break-up makes observation of this level difficult. Miller gives several independent arguments supporting the assignment of J=1/2$^+$ for this state, but leaves open the possibility J=1/2$^-$ as this contention seemed to be supported by the interpretation of the (γ,n) experiment of Connors

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† Physics Department, University of Melbourne.

and W. C. Miller (1956). These authors referred to unpublished work of Mast, in which it was stated that a shell model calculation had shown the 1·7 MeV level to be excited by an $M1$ transition. However, an abstract of a report by Mast and Mullin (1956) shows that this γ-transition takes place to a state having $J=1/2^+$. This work is stated to be an intermediate coupling shell model calculation.

Thus, considering all available evidence, the assignment for the 1·7 MeV state is $J=1/2^+$.

2·43 MeV level.—The work of Summers-Gill (1958) on the inelastic scattering of protons, deuterons, and α-particles from ^{9}Be gives $J=5/2^-$ as the only possible assignment. The interpretation of the angular distributions for scattering used the theory of Austern, Butler, and McManus (1953). His assignment is in agreement with the non-appearance of the level in the (γ,n) study referred to above. This evidence indicates the weakness of $M1$ transitions in this nucleus.

3·05 MeV level.—Bockelman, Leveque, and Buechner (1956) placed the lower limit of 280 keV on the width of this level. Using the Wigner sum rule on reduced widths of levels, they state that $J\leqslant 3/2$. This being so, the (γ,n) result of Spicer (unpublished data) requires that the parity be odd. This is consistent with a $J=1/2^-$ assignment for a level near 3 MeV from intermediate coupling shell model calculations of Kurath (1956).

4·8 MeV level.—This level has width 1·2 MeV (Almqvist, Allen, and Bigham 1955). The intermediate coupling prediction is for three levels near this energy, having $J=3/2^-$, $5/2^-$, $7/2^-$ respectively. This may explain the large observed width (see Fig. 1).

6·8 MeV and 7·9 MeV levels.—Benveniste, Finke, and Martinelli (1956) measured the angular distribution of inelastically scattered protons which leave ^{9}Be in these levels. Bombardment was with 31 MeV protons, and the distributions were analysed using the direct interaction theory of Austern, Butler, and McManus (1953). Benveniste, Finke, and Martinelli's interpretation has been criticized by Summers-Gill (1958) on the ground that the interaction radius they use is unrealistically small. In his own work, Summers-Gill established the radius to be used from elastic scattering data, and obtained good fits to his data with values of the radius between 4·5 and 5·5 fermis. Benveniste's results have been re-examined, using this larger radius. It was found that the angular distribution from the " 6·8 MeV level " could not be fitted with the assumption of one level, but requires two levels of opposite parity. This is in line with the findings of Benveniste, Finke, and Martinelli (1956) and is insensitive to the value of nuclear radius chosen. Thus we find that we need one level having $1/2\leqslant J\leqslant 11/2^+$ and another of lower energy having $J=1/2$, $5/2$, $7/2$, $9/2^-$, to explain the position of the peak in the angular distribution.

The 7·94 MeV level is fitted uniquely in this manner, the fit being for angular momentum transfer of 5 units in the scattering. This is consistent with the small cross section for inelastic scattering to this level. These data suggest a spin of $5/2\leqslant J\leqslant 15/2$ and even parity. In the (γ,n) experiment of Thies, Spicer, and Baglin (1959) there is substantial cross section between 6 and 8 MeV.

This, taken with Barber's (1958) electro-disintegration experiment, indicates $E1$ transitions to levels in this region. Thus the γ-absorbing levels must have $J=1/2,\ 3/2,\ 5/2^+$.

Taking these two pieces of evidence together, the spin and parity of the $7 \cdot 94$ MeV level is fixed at $5/2^+$. The even parity level near $6 \cdot 8$ MeV has $J=1/2,\ 3/2,\ 5/2^+$.

9·2 MeV level.—The existence of this level is not certain. Evidence for it was found by Almqvist, Allen, and Bigham (1955) on the basis of a study of the proton groups from the reaction $^7Li(^3He,p)^9Be$. Thies, Spicer, and Baglin

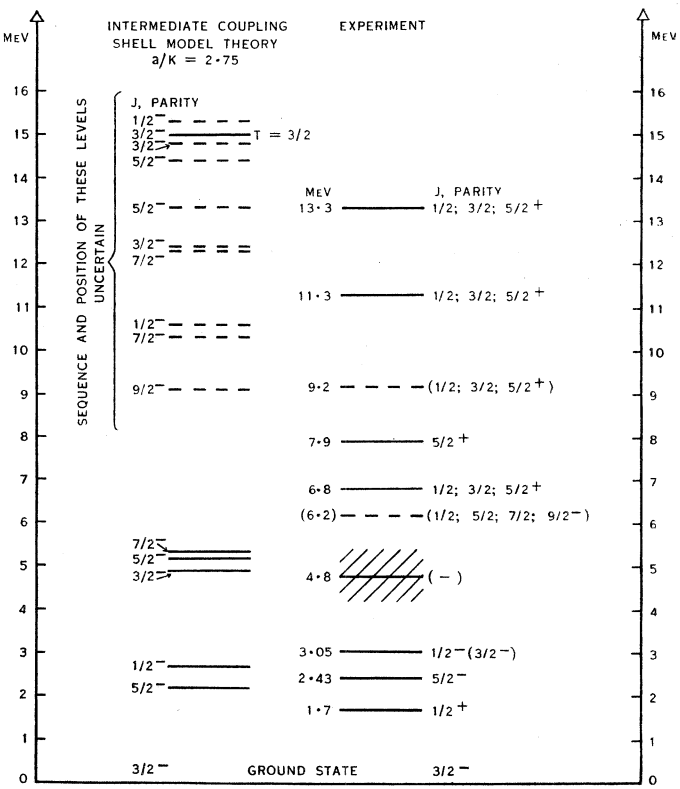

Fig. 1.—Spin and parity of levels of ^9Be. Assignments in parentheses are tentative.

(1959) note that there must be a substantial contribution to the (γ,n) cross section due to a level near 9 MeV, which is expected, on the basis of the electro-disintegration data, to have $1/2,\ 3/2,\ 5/2^+$.

11·3 and 13·3 MeV levels.—It has previously been noted that the spins and parities of these levels must be one of $J=1/2,\ 3/2,\ 5/2^+$.

Both French, Halbert, and Pandya (1955) and Kurath (1956) have calculated the energies of odd parity levels of ^9Be, for various values of the intermediate coupling parameter a/K. The spectrum of odd parity levels, as far as they are known, is consistent with an a/K value of about $2 \cdot 75$. This, as D. W. Miller

(1958) points out, is in line with the coupling strength required for neighbouring nuclei. The assignments indicated by the above discussion are shown in Figure 1, along with the intermediate coupling predictions of odd parity states for $a/K=2\cdot75$.

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