1.7-Mev State in Be^9

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Evidence is presented concerning the 1.7-Mev state in Be^9 and its characteristics, which are currently in doubt because of the extreme weakness of the anomaly observed in charged-particle reactions. On the basis of this evidence, the state now appears to be well established, and its spin and parity are probably $\frac{1}{2}^+$ or $\frac{1}{2}^-$. The evidence in favor of the $\frac{1}{2}^+$ assignment, corresponding to an intermediate-coupling parameter a/K of $\sim$2.75 for Be^9, comes from the final-state-interaction analysis in the present paper of the results of three different charged-particle reactions at Indiana University and the Massachusetts Institute of Technology, from the agreement between the scattering length for neutrons on Be^8 resulting from this analysis and the predictions of Ford and Bohm, and from the continuity of a/K with mass number. In addition, experiments on the mirror nucleus B^9 by Marion *et al.* seem to be in disagreement with the existence of a $\frac{1}{2}^-$ state in this region. The evidence in favor of the $\frac{1}{2}^-$ assignment, corresponding to $a/K\sim1.5$, comes from the static magnetic moment of Be^9 and the photodisintegration data of Connors and Miller.

I. INTRODUCTION

MANY of the features of light nuclei appear to be explained theoretically by the use of a nuclear model intermediate between the *jj* coupling and *LS* coupling shell models.[1,2] Quantitative intermediate-coupling calculations of this type[3] give rather good agreement to the energy-level schemes and ground-state magnetic moments of the *p*-shell nuclei from $A=5$ to $A=16$. These calculations contain the so-called intermediate-coupling parameter a/K, which measures the relative spin-orbit to central-energy contributions, and therefore varies from 0 (pure *LS* coupling) to ∞ (pure *jj* coupling). This parameter is normally adjusted for each mass number to yield the best fit to the experimental level scheme and the static electromagnetic moments. From an examination of the light *p*-shell nuclei, Kurath[2] has pointed out that a rather sharp discontinuity seems to occur at $A=9$ in the trend of these "best" a/K values as a function of mass number. It becomes especially important then to establish the energy-level scheme of Be^9, particularly the low-lying states. There is currently some question about the existence and nature of the lowest excited state reported in Be^9, usually quoted at about 1.8-Mev excitation. This paper discusses evidence in favor of the existence of a $\frac{1}{2}^+$ state in this region of Be^9.

The first suggestion of the existence of a state in Be^9 around 1.6 Mev was made by Guth and Mullin[4] from a theoretical analysis of the $Be^9(\gamma,n)$ reaction. In their interpretation, this state was represented by the interaction of a neutron with a Be^8 core in an $S_{\frac{1}{2}}$ configuration. However, Van Patter *et al.*[5] and Arthur *et al.*,[6] studying the $B^{11}(d,\alpha)Be^9$ and $Be^9(p,p')Be^9$ reactions, respectively, did not find any evidence for an excited state in Be^9 below 2.43 Mev. Attention was refocused on the problem by Moak *et al.*[7] and by Almqvist *et al.*,[8] who again found evidence for a 1.8-Mev state by using the $Li^7(He^3,p)Be^9$, and $B^{10}(t,\alpha)Be^9$ reactions. Other investigators studied a variety of charged-particle reactions[9–13] and verified the existence of a weak anomaly in the data in all cases around 1.7-Mev excitation in Be^9. Because of the proximity of this anomaly to the binding energy of the neutron in Be^9, Gossett *et al.*[10] suggested that it might be related to the three-body breakup of the compound nucleus. Rasmussen *et al.*[11] succeeded in making a rough fit to the unusual shape of the inelastic deuteron distribution from Be^9 by assuming that the reaction proceeded via the process $Be^9(d,d'n)Be^8$ and taking into account the alteration of the observed deuteron spectrum produced by the final-state interaction[14] between the outgoing Be^8 and neutron. This analysis was also applied to the $Be^9(p,p')$ and $B^{11}(d,\alpha)$ reactions by Bockelman *et al.*[12] who were also able to fit the shape of the observed charged-particle distributions. These preliminary analyses both suggested that the data could be satisfactorily (although not uniquely) explained by assuming a final-state potential-scattering interaction between the Be^8 and neutron, which presumably did not require an excited state in Be^9 near the neutron binding energy. The present paper concerns itself largely with a more detailed consideration of this question.

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[1] D. R. Inglis, Revs. Modern Phys. **25**, 353 (1953).
[2] D. Kurath, Phys. Rev. **101**, 216 (1956).
[3] See reference 2 for a list of references to these calculations.
[4] E. Guth and C. J. Mullin, Phys. Rev. **76**, 234 (1949).
[5] Van Patter, Sperduto, Huang, Strait, and Buechner, Phys. Rev. **81**, 233 (1951).
[6] Arthur, Allen, Bender, Hausman, and McDole, Phys. Rev. **88**, 1291 (1952).
[7] Moak, Good, and Kunz, Phys. Rev. **96**, 1363 (1954).
[8] Almqvist, Allen, and Bigham, Phys. Rev. **99**, 631(A) (1955).
[9] L. L. Lee and D. R. Inglis, Phys. Rev. **99**, 96 (1955).
[10] Gossett, Phillips, Schiffer, and Windham, Phys. Rev. **100**, 203 (1955).
[11] Rasmussen, Sampson, Miller, and Gupta, Phys. Rev. **100**, 851 (1951).
[12] Bockelman, Leveque, and Buechner, Phys. Rev. **104**, 456 (1956).
[13] R. G. Summers-Gill, Bull. Am. Phys. Soc. Ser. II, **1**, 253 (1956).
[14] K. M. Watson, Phys. Rev. **88**, 1163 (1952).

II. ANALYSIS OF DATA

If one assumes an uncorrelated three-body breakup of the compound system C^* in a reaction of the type $A+a\rightarrow C^*\rightarrow b+n+\mathrm{Be}^8$, the spectrum of the charged particle b is governed purely by phase space considerations.[15] This statistical spectrum rises smoothly and monotonically, beginning at the energy of the particle b corresponding to the threshold for the $\mathrm{Be}^9\rightarrow\mathrm{Be}^8+n$ breakup, as is shown, for example, in Figs. 2 and 3 by the dashed line. If correlations exist between the outgoing particles, however, the spectrum will be modified from this simple shape. Just above threshold the Be^8 and neutron are moving in nearly the same direction with small relative velocity, so that the theory of S-wave final-state interactions (fsi) as discussed by Watson[14] may be applied. For example, an attractive fsi between the outgoing neutron and Be^8 results in a peaking of the spectrum of the particle b near the energy corresponding to the three-body threshold. The mathematical expressions derived by Watson for the shape of the expected particle spectra are given in reference 11 for three cases; (a) no fsi, (b) S-wave potential-scattering fsi, characterized by the scattering length a, and (c) S-wave resonance-scattering fsi, characterized by the resonance energy E_0 and width Γ.

In the original application of this type of analysis to the Be^9 problem[11] only a rough fit was attempted since no resolution correction was included. More recently, the $\mathrm{Be}^9(d,d')$ reaction in this particular energy region has been reinvestigated at Indiana at a more favorable laboratory angle (25°) with better statistics. These data have been analyzed more carefully, with the inclusion of a resolution correction in obtaining the best fit. At the same time, the high-resolution data of Bockelman *et al.*[12] on the $\mathrm{Be}^9(p,p')$ and $\mathrm{B}^{11}(d,\alpha)$ reactions were reanalyzed independently to see if a fit using the same parameters could be made to these three sets of data taken at two different laboratories under different experimental conditions.

Figure 1 shows the new Indiana data for the $\mathrm{Be}^9(d,d')$ reaction, taken under the same experimental conditions described in reference 11, except that the bombarding deuteron energy in the present case was 10.93 Mev and the observation angle 25° lab. The energy available for the breakup of the compound nucleus B^{11*} was 7.27 Mev. The data are plotted against Be^8+neutron relative energy on the axis of abscissas, since for each observed inelastic deuteron energy there corresponds a definite relative energy of the Be^8+neutron, assuming that the three-body breakup occurs. This method of presentation of the data allows for ready comparison of the results of various reactions at various laboratories. The solid curve represents the best fit obtained by assuming a potential-scattering fsi between the neutron and Be^8 using a scattering length of 20×10^{-13} cm. Corrections for resolution were included in this curve by folding in the experimental resolution function with the theoretical fsi-analysis curve, upon which the sharp 2.43-Mev state in Be^9 had been represented by a spike of appropriate height and zero width. This explains the sharp rise in the theoretical curve at the right of the figure.

It should be remarked at this point that Summers-Gill[13] has proposed a three-body breakup interpretation to explain his data on the $\mathrm{Be}^9(p,p')$ reaction based on what he calls "heavy-particle stripping." This interpretation predicts a strong angular dependence of the peak of the anomaly when applied to the $\mathrm{Be}^9(d,d')$ reaction at 10.8-Mev bombarding energy, so strong that at back angles the peak should have shifted some 700 kev and appear superimposed on the 2.43-Mev state.[13] Data similar to that shown in Fig. 1 have since been taken at Indiana at laboratory angles of 71°, 105°, and 140°. Within the experimental errors, no shift in the peak relative to the ground state was observed. If such a shift exists, it must be less than 150 kev. This result is in agreement with the three-body-breakup-with-fsi interpretation of the present paper, which predicts no dependence of the peak location (relative to the ground state) on angle for a given reaction and only a very slight dependence of peak location on the type of reaction.

Figure 2 shows the data of Bockelman *et al.*[12] for the $\mathrm{Be}^9(p,p')$ reaction, taken at a bombarding proton energy of 7.080 Mev and a laboratory observation angle of 130°. The energy available for the breakup of the compound nucleus B^{10*} in this case was 4.702 Mev.

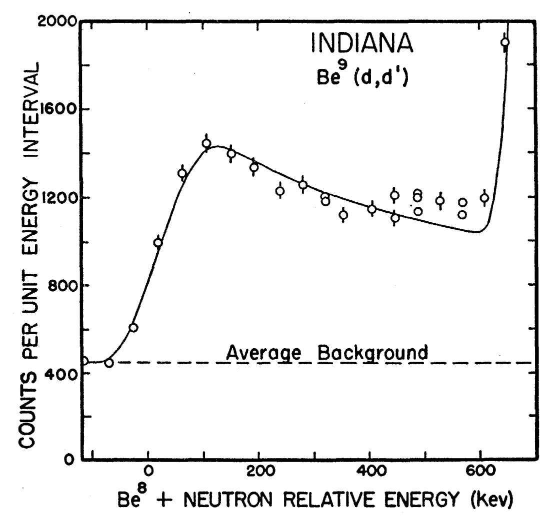

FIG. 1. The 1.7-Mev anomaly observed by means of the $\mathrm{Be}^9(d,d')$ reaction at a bombarding energy of 10.93 Mev and laboratory observation angle of 25°. The data are plotted against the relative energy of the Be^8 and neutron, assuming a three-body breakup of the compound nucleus B^{11*}. The solid curve represents a theoretical fit (corrected for resolution) assuming a potential-scattering final-state interaction between the neutron and Be^8 with a scattering length of 20×10^{-13} cm.

[15] E. Fermi, *Elementary Particles* (Yale University Press, New Haven, 1951), p. 56.

Again the data[16] are presented as a function of Be^8+neutron relative energy. The dashed line represents the spectrum to be expected for an uncorrelated three-body breakup, and the solid line the spectrum expected for a potential-scattering fsi with a scattering length of 20×10^{-13} cm. This result checks exactly with that quoted by Bockelman *et al.*, but is presented in Fig. 2 in a different fashion for comparison purposes, as mentioned above. These high-resolution results from M.I.T. suffer a bit in statistical accuracy, but clearly no resolution correction was required to the theoretical curve.

The results of Bockelman *et al.* for the $B^{11}(d,\alpha)$ reaction taken at an incident deuteron energy of 7.007 Mev and a laboratory observation angle of 60° are plotted in Fig. 3. In this case the energy available for the breakup of the compound nucleus C^{13*} was 12.273 Mev. The dashed and solid lines have the same significance as in Fig. 2. Again the same scattering length is required for the fit, in agreement with the earlier analysis.[12] Figures 1 through 3 illustrate that within the errors associated with the three experiments a satisfactory fit can be obtained in each case assuming a potential-scattering fsi between the outgoing Be^8 and neutron, with the unusually large scattering length of 20×10^{-13} cm. Too much credence cannot be placed in this exact number, however, because a constant scattering length was assumed in the analyses. A more realistic approach should allow for some variation of the scattering length with energy, particularly since its large value suggests the presence of a nearby resonance in the Be^9 system, as will be discussed later. Furthermore, a potential-scattering fit is not the only one possible, and it can only be said that the experimental results are in agreement with the analysis discussed above. To illustrate this point, Fig. 4 shows an equally good theoretical fit to the $B^{11}(d,\alpha)$ data using a resonance-scattering fsi between the outgoing neutron and Be^8 (*no* potential scattering included), using the resonance parameters $E_0=-700$ kev and the single-particle reduced width[17] $\gamma^2=\hbar^2/\mu R$. Another equally good resonant fit with E_0 at positive energy is also possible.[18]

III. INTERPRETATION OF RESULTS

A. Evidence for *S* State

The conclusion to be drawn from the analyses described above is that the data can be fitted theoretically either by assuming an *S*-wave potential-scattering fsi with a very large scattering length or a resonance-scattering fsi. To consider these two cases, it is useful to think in terms of the (hypothetical) inverse reaction represented by the scattering of neutrons by Be^8. In the first case, a large scattering length for neutrons on a

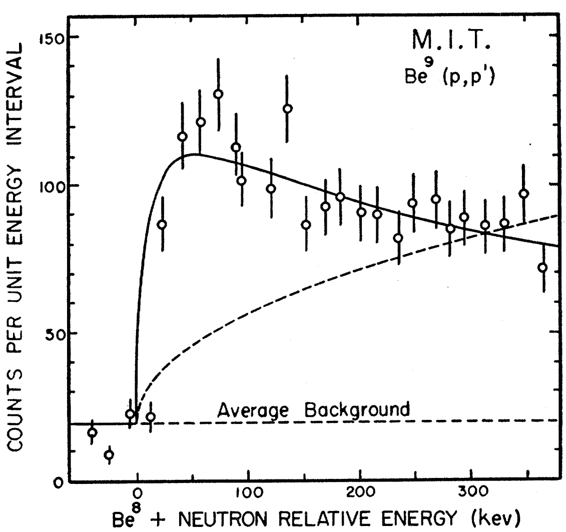

FIG. 2. The 1.7-Mev anomaly observed by Bockelman *et al.*[12] using the $Be^9(p,p')$ reaction at a bombarding energy of 7.080 Mev and laboratory observation angle of 130°. The data are plotted in the same fashion as in Fig. 1 for comparison. The dashed curve represents the spectrum expected for an uncorrelated three-body breakup of the compound nucleus B^{10*}, and the solid curve the theoretical fit assuming a potential-scattering final-state interaction between the neutron and Be^8 with a scattering length of 20×10^{-13} cm.

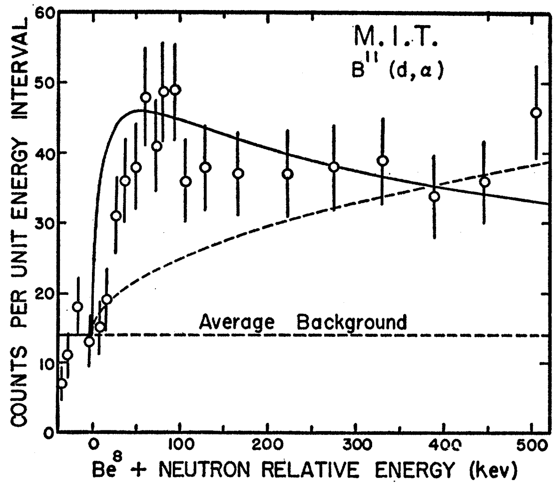

FIG. 3. The 1.7-Mev anomaly observed by Bockelman *et al.*[12] using the $B^{11}(d,\alpha)$ reaction at a bombarding energy of 7.007 Mev and laboratory observation angle of 130°. The data are plotted in the same fashion as in Figs. 1 and 2 for comparison. The dashed curve represents the spectrum expected for an uncorrelated three-body breakup of the compound nucleus C^{13*}, and the solid curve the theoretical fit assuming a potential-scattering final-state interaction between the neutron and Be^8 with a scattering length of 20×10^{-13} cm.

[16] It should be remarked that the experimental points here plotted are taken from the lower part of Fig. 1 of reference 12, except that protons per mm instead of per ½ mm were used as the raw data. The data of Fig. 3(b) in reference 12 are taken from the upper part of Fig. 1 of that reference [C. K. Bockelman (private communication)].

[17] E. Wigner, Am. J. Phys. **17**, 99 (1949).

[18] These resonant fits actually represent a way of allowing for the energy dependence of the "generalized scattering length" as just mentioned. See, for example, H. Bethe and P. Morrison, *Elementary Nuclear Theory* (John Wiley and Sons, Inc., New York, 1956), second edition, pp. 55 and 179.

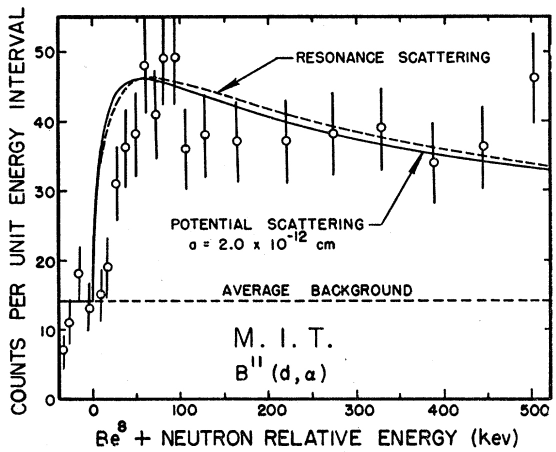

FIG. 4. The data of Fig. 3 replotted to illustrate the equally good fit which may be obtained by assuming a three-body breakup of the compound nucleus C^{13*} with a resonance-scattering final-state interaction between the neutron and Be^8 with resonance parameters $E_0=-700$ kev and the single-particle reduced width. The dashed line represents the two-parameter resonance-scattering fit and the solid line the one-parameter potential-scattering fit shown in Fig. 3.

nucleus normally implies the existence of an S state in the compound nucleus (here Be^9) near the neutron binding energy. This same interpretation (except with the resonance energy further removed from the binding energy) results by choosing the resonance scattering fit, since an S resonance in the scattering of neutrons by Be^8 again represents an S state in the compound nucleus, Be^9. Therefore, regardless of which particular fit one chooses, they both suggest the existence of an S state in Be^9 somewhere in the vicinity of the neutron binding energy.[19]

If one chooses for simplicity to accept the one-parameter potential-scattering fit, it is very interesting to compare the large scattering length obtained with theoretical expectations. In 1950, Ford and Bohm[20] recognized a simple theoretical explanation for the observed variation of neutron scattering lengths as a function of mass number. By letting the neutron-nucleus interaction be represented by a square well of depth 45.6 Mev and radius $1.40A^{\frac{1}{3}}\times 10^{-13}$ cm, they showed that for mass numbers $A\sim 12$, 55, and 151 the slope of the wave function near the nuclear surface would be expected to vanish. This in turn implied that near these mass numbers the neutron-nucleus system should be close to resonance, and a large experimental scattering length should be observed which would change sign right at resonance. The experimental data on thermal scattering lengths available at that time showed rather good agreement with these predictions. However, the experimental points exhibited considerable scatter, as would be expected due to the presence of random sharp resonances near zero energy due to multiple-particle excitation, as well as the effects of different isotopes with different spins. The $A\sim 12$ resonance appeared experimentally to come between target nucleus mass numbers of $A=7$ and $A=9$, suggesting a different form for the radial parameter in this region, but the "nuclear size resonances" at $A\sim 55$ and $A\sim 151$ were in agreement with the existing data. Measurement on fast-neutron total cross sections (averaged over sharp resonances) as a function of mass number[21–23] subsequently revealed similar gross features, i.e., unusually large low-energy cross sections near $A\sim 55$ and possibly near $A\sim 150$. Extrapolating these *average* cross sections to zero energy, Adair[24] obtained values for the *average* scattering length as a function of mass number. When these were plotted on a Ford and Bohm type of graph, the scatter in experimental points was considerably reduced, but Adair's conclusion concerning the square well parameters was essentially the same as that of Ford and Bohm.

The results of the present investigation suggest a scattering length for neutrons on Be^8 of $\sim 20\times 10^{-13}$ cm. Since Li^7 has a negative scattering length and Be^9 a positive one, on the Ford and Bohm model it is reasonable to expect Be^8 to be very near resonance and to present a very large scattering length. An analysis has been carried out to determine the radial dependence on mass number of a square well of suitable depth which would satisfy this requirement. Figure 5 shows the

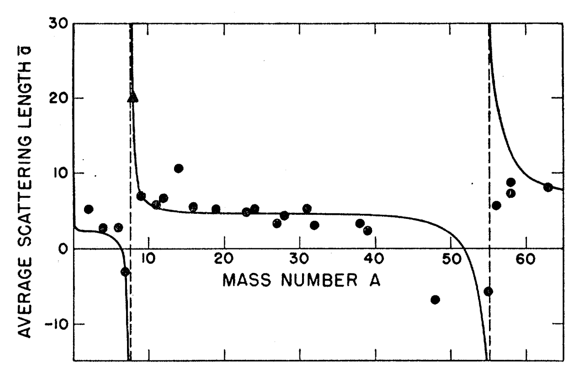

FIG. 5. Variation of the scattering-length (in units of 10^{-13} cm) for neutrons as a function of the mass number of the target nucleus, based on a Ford and Bohm type of analysis.[20] The solid curve represents the theoretical variation assuming a neutron-nucleus interaction characterized by a square well of depth 44.5 Mev and radius $R=(1.24A^{\frac{1}{3}}+0.96)\times 10^{-13}$ cm. The dots represent the experimental average scattering lengths taken from the paper by Adair,[24] and the triangle the scattering length for neutrons on Be^8 suggested by the analysis shown in Figs. 1 through 3.

[19] Strictly speaking, to assign the best value of the excitation energy to this state from these data, it would presumably be necessary to generalize the expressions in the analysis (quoted in reference 11) to include the effects of interference between resonance and potential scattering. Because the anomaly is so very weak, it is not felt that the accuracy of the present data is sufficient to warrant this procedure.

[20] K. W. Ford and D. Bohm, Phys. Rev. **79**, 745 (1950).

[21] Miller, Adair, Bockelman, and Darden, Phys. Rev. **88**, 83 (1952).

[22] Walt, Becker, Okazaki, and Fields, Phys. Rev. **89**, 1271 (1953).

[23] Okazaki, Darden, and Walton, Phys. Rev. **93**, 461 (1954).

[24] R. K. Adair, Phys. Rev. **94**, 737 (1954).

Ford and Bohm type curve obtained for a square well of depth 44.5 Mev and radius $R=(1.24A^{\frac{1}{3}}+0.96)\times10^{-13}$ cm, which gives a predicted scattering length of 20×10^{-13} cm for $A=8$ and also a resonance at $A\sim55$.[25] The experimental points plotted are the "average scattering lengths" as a function of mass number, taken from the paper by Adair. It is interesting to note that the radial dependence on mass number chosen above is similar to that used in some cloudy-crystal ball calculations at higher neutron energies.[26] However, the radial dependence chosen in Fig. 5 actually forces the next higher S resonance in the Ford and Bohm model to too high a mass number ($A\sim179$), suggesting that the Ford and Bohm value of $R=1.40A^{\frac{1}{3}}\times10^{-13}$ cm should be used above $A\sim55$.

B. Comparison with Intermediate-Coupling Predictions

A set of detailed calculations of the energy level schemes and static electromagnetic moments of nuclei between helium and oxygen has been made by Kurath using the configuration $(1p)^n$ in intermediate coupling.[2] As is customary in this type of calculation, his results are expressed primarily in terms of the intermediate-coupling parameter a/K. In the case of Be^9, the static electric quadrupole moment does not appear to be very sensitive to a/K, so that one must depend upon comparisons with the energy level scheme and magnetic moment. It must be emphasized that the configuration $(1p)^5$ for Be^9 yields only odd-parity states. This is a crucial point to the present paper, for if the 1.7-Mev state is indeed represented by the interaction of an S neutron with a Be^8 core, it will have spin $\frac{1}{2}$ and *even* parity and cannot be included in a comparison with Kurath's intermediate-coupling predictions.

It is apparent from the experimental energy level scheme and Kurath's corresponding predictions that two values of a/K are suggested. The 2.43-Mev level clearly seems to correspond to the theoretical $5/2^-$ prediction, which is consistent with experimental results.[27–29] If the 1.7-Mev state is $\frac{1}{2}^-$, then an a/K value of ~1.5 is indicated and the 3.1-Mev state must have even parity. If the 1.7-Mev state has even parity, then the 3.1-Mev state must be $\frac{1}{2}^-$, corresponding to an a/K value of ~2.75.

One argument in favor of the $\frac{1}{2}^-$ assignment to the 1.7-Mev level comes from the observed ground-state magnetic moment of Be^9. The theoretical dependence of the magnetic moment on a/K seems to favor an a/K value of ~1.5, since an $a/K\sim2.75$ would predict a magnetic moment about 20% smaller than observed.

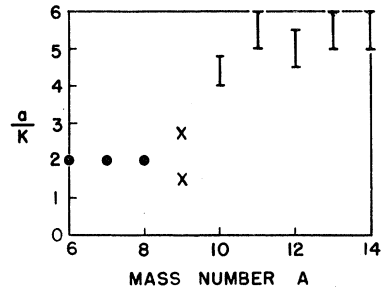

FIG. 6. Qualitative plot of the intermediate-coupling parameter a/K as a function of mass number, indicated by the results of Kurath.[2] The vertical bars do *not* represent errors; the ends of the bars represent a/K values suggested by Kurath, so that presumably any value in between would also be satisfactory. The circles also represent values suggested by Kurath as reasonable. The ×'s roughly represent the two possible values of a/K for Be^9, depending on whether the 1.7-Mev state is $\frac{1}{2}^+$ (upper ×) or $\frac{1}{2}^-$ (lower ×).

However, this discrepancy does not appear to be sufficient to rule out the larger value altogether. The $\frac{1}{2}^-$ assignment is also favored by the recent photodisintegration results of Connors and Miller.[30] These authors have carefully measured the $Be^9(\gamma,n)$ cross section and find a large peak near threshold which drops rapidly as the energy is increased. A theoretical analysis of these data seems to suggest a magnetic-dipole transition to a P state near threshold plus some transition directly into the continuum.[31] However, if this interpretation is correct, it is not easy to understand why all of the charged-particle reaction results are so weak.[31] It appears that the existing charged-particle and photodisintegration data are therefore incompatible, since in each case the interpretation fitting the one experiment predicts a different result for the other.

On the other hand, it has already been pointed out that the analysis of the present paper shows agreement with existing charged-particle reaction data if a $\frac{1}{2}^+$ state is assumed near 1.7-Mev excitation in Be^9. Although this interpretation is not unique, it appears to fit in well with the expectations of the theory of Ford and Bohm, as illustrated in Fig. 5. Further, an a/K value of ~2.75 seems to be somewhat more consistent with the trend of a/K values as a function of mass number A in this region. Figure 6 illustrates this trend roughly, as indicated in the paper by Kurath.[2] It will be noted that the "best" value of a/K seems to suffer a sharp increase for either choice of a/K for Be^9 (indicated by ×'s), but that the discontinuity appears to be smaller for $a/K\sim2.75$. Although Kurath explains the discontinuity in terms of the unusually large structure of Be^9, it may be that the smaller discontinuity suggested in the present work will be less difficult to account for in this manner.

[25] The analysis of the experimental data described in II does not reveal the *sign* of the zero-energy scattering length, so it was arbitrarily chosen to be positive in Fig. 5.
[26] W. S. Emmerich, Phys. Rev. **98**, 1148(A) (1955).
[27] F. L. Ribe and J. D. Seagrave, Phys. Rev. **94**, 934 (1954).
[28] S. Rasmussen, Phys. Rev. **103**, 186 (1956).
[29] J. B. Marion (private communication).
[30] D. R. Connors and W. C. Miller, Bull. Am. Phys. Soc. Ser. II, **1**, 340 (1956).
[31] C. J. Mullin (private communication).

In order to help distinguish between the two assignments discussed above, one might expect to look to the mirror nucleus B^9. By observing slow-neutron thresholds in the $Be^9(p,n)B^9$ reaction using the counter-ratio technique, Marion *et al.*[32] report an anomaly which can be accounted for either by assuming a broad S state near 1.4-Mev excitation in B^9 or a slow variation of the yield of the three-body breakup $Be^9(p,pn)$. The former interpretation would be in agreement with the suggestions of the present paper. At the time of this writing, an experiment by Marion and Levin[29] is in progress at Los Alamos using time-of-flight techniques to measure the neutron spectrum from Be^9+p. Preliminary results as yet do not prove or disprove the existence of a state in this region of B^9. However, if a weak state exists it is not likely to be of $\frac{1}{2}^-$ character, or it would probably have been seen as a sharp state in both experiments.[29]

Two other pieces of evidence should be mentioned for completeness, though they do not appear to distinguish between the two possibilities for a/K. The experimental width of the 3.1-Mev state reported by Bockelman *et al.*[12] limits the spin of this state to $\leq\frac{3}{2}$. If this level decays primarily by neutron emission to the ground state of Be^8, these authors point out that the orbital angular momentum of the emitted neutron is limited to 0 or 1. Thus, the 3.1-Mev state can be $\frac{1}{2}^-$, as intermediate coupling predicts it should be if the 1.7-Mev state has even parity, or it can have even parity which it should if the 1.7-Mev state is $\frac{1}{2}^-$. Although this evidence shows no preference between the choices, it is consistent with the explanation that either the 1.7- or the 3.1-Mev state has even parity, and is therefore not predicted by intermediate-coupling calculations using the configuration $(p)^5$ for Be^9. Finally, it should be mentioned that French *et al.*[33] have pointed out that an a/K value of $\sim$1.7 is consistent with the pickup results of Ribe and Seagrave[27] for the $B^{10}(n,d)Be^9$ reaction to the 2.43-Mev state of Be^9. However, they point out that the pickup results in this case are not very sensitive to a/K, so that presumably an a/K value of $\sim$2.75 might work almost as well.

[32] Marion, Bonner, and Cook, Phys. Rev. **100**, 91 (1955).

[33] French, Halbert, and Pandya, Phys. Rev. **99**, 1387 (1955).

IV. CONCLUSIONS

Because of the extreme weakness of the anomaly observed in charged-particle reactions, the exact character of the 1.7-Mev state in Be^9 remains in some doubt. However, it now appears well established that the state does exist, and that its spin and parity are probably either $\frac{1}{2}^+$ or $\frac{1}{2}^-$. The former choice, in agreement with an intermediate coupling parameter $a/K\sim2.75$ for Be^9, seems to be favored by the analysis of three different charged-particle reactions in the present paper, by the predictions of the Ford and Bohm model for neutron scattering lengths, and by the continuity of a/K as a function of mass number A. The latter choice, in agreement with $a/K\sim1.5$, seems to be favored by the static magnetic moment of Be^9 and the photodisintegration results of Connors and Miller. The results of Marion *et al.* do not rule out a corresponding state in B^9, but are inconsistent with a $\frac{1}{2}^-$ assignment to the state if it exists.

V. ACKNOWLEDGMENTS

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