Note on the Spins of Nuclei of Mass Number Ten

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THREE nuclei of mass number ten are known: Be^{10}, B^{10}, and C^{10}. B^{10} is stable and is assumed to have a nuclear spin $I=1$, like the other stable nuclei (D^2, Li^6, and N^{14}) which are "self-conjugate" (having an odd number of protons and an equal number of neutrons). Be^{10} decays to B^{10} with the emission of β-rays with a maximum energy $E=0.56$ Mev and a half-life $T=(2.5-2.9)\times 10^6$ years.[1] This lifetime is approximately 10^9–10^{10} times longer than would be expected for an allowed transition. The apparently similar transition $He^6 \xrightarrow{\beta} Li^6$ ($E=3.7$ Mev, $T=0.8$ sec.) is allowed. Many attempts have been made to explain the long life of Be^{10}, which has proved to be an outstanding difficulty for β-ray theory. The following alternative assumptions have usually been made: Assumption (a)—Though even-even nuclei have as a rule the spin $I=0$, Be^{10} is an exception and has the spin $I=4$. The transition from Be^{10} to B^{10} would then involve a spin change $\Delta I=3$ which would make the long lifetime reasonable. Assumption (b)—The spin of Be^{10}, like that of other even-even nuclei, is $I=0$, but the β-transition, $I=0 \rightarrow I=1$, is forbidden because of a selection rule which does not operate in the case of the transition $He^6 \rightarrow Li^6$.

Both assumptions are not very satisfactory. Following the discovery by Davis[2] that Na^{22} (a "self-conjugate" nucleus) has the spin $I=3$ and a magnetic moment $\mu=1.746$, it seems worth while to discuss the following assumption: Assumption (c)—The spin of B^{10} is not $I=1$, as hitherto assumed, but $I=3$.

Some of the consequences of assumption (c) are the following:

(1) From the g-value 0.598, measured by Millman, Kusch, and Rabi,[3] a value for the magnetic moment of B^{10} $\mu=1.794$ would follow.

(2) From a formula due to Sachs[4] it can be shown that the measured g-value is compatible with a $^3D_3$ state for B^{10}, with only a slight admixture of higher states. According to Feenberg and Phillips,[5] a system of five protons and five neutrons is rather unique in having in the Hartree approximation two degenerate ^3D states, as well as a ^3F and a ^3G state near the ground state, which might all contribute to an $I=3$ state.

(3) The spin of Be^{10} could be assumed to be $I=0$, as for other even-even nuclei, and the β-transition would be highly forbidden because $\Delta I=3$.

(4) Similarly, C^{10} could be assumed to have $I=0$. Sherr, Muether, and White[6] have shown that this nucleus decays to an excited state of B^{10}. The transition to the ground state of B^{10} would be highly forbidden because $\Delta I=3$.

(5) In the reaction $B^{10}+D^2 \rightarrow Be^8+He^4$, Be^8 is usually found in its excited state of $\sim$3 Mev,[7] which has on good grounds been identified as a D-state.[8] This would be difficult to understand if the spin of B^{10} were $I=1$ rather than $I=3$.

Many other nuclear reactions involving B^{10} might be worth discussing in the light of the assumption made about its spin, but such a discussion might better await a direct measurement of this quantity, which is now being attempted in the Nuclear Moments Laboratory here.

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Microwave Absorption Line Frequencies of Methyl Alcohol and their Stark Effect

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THE CH_3OH molecule presents an interesting problem for analysis because of the internal rotation of the OH bond around the axis of the OCH_3 group. Hershberger and Turkevitch[1] and Dailey[2] have reported altogether about twenty-five microwave absorption lines for methyl alcohol, including eight lines which appear to form a converging series.

The first "line" of this series has now been resolved into three distinct lines, and more accurate frequency measurements have been made on the first nine members of the series. The first-order Stark effect of these lines, observed first by Dailey, has now been studied in detail. The absorption lines were split with low electric fields (0.5 to 50 volts per cm), observations being made with the electric field of the microwave parallel to the static electric field, so that the Stark quantum number M does not change during a microwave-induced transition.

For modulation purposes a much smaller electric field (0.1 to 1.0 volts per cm) was superimposed on the static electric field. Different frequencies of alternation were used, from 50 kc to 400 kc, and the crystal current amplifier was usually tuned to the frequency of the alternating field. It is worth remarking that a non-zero value of the static electric field must be used with this method of tuning. Otherwise, the Stark pattern for the second half of the cycle will be identical with that for the first half of the cycle, and no modulation will be observed.

The Stark components of each line were spaced almost uniformly, and the outer components were most intense. This means that the quantum number J does not change during a transition, and that the number of components on each side of the pattern is equal to J. The values of J thus determined and the line frequencies are listed below.