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 ~ 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.

TABLE I.

J	Frequency (megacycles)	Stark coefficient A (mc per e.s.u.)
2	24,934.38	145
3	24,928.70	155
4	24,933.47	168
5	24,959.08	185
6	25,018.14	207
7	25,124.88	230
8	25,294.41	257
9	25,541.43	291
10	25,878.18	324

The frequency shifts of the Stark components from the center of the pattern were found to be rather accurately proportional to the electric field E and the Stark component quantum number M. The Stark coefficient tabulated in Table I is the coefficient A in the equation

$$\nu_{JM}=A(ME/J^2+J). \tag{1}$$

Although the coefficient A depended only slightly on M and E, it was found to depend greatly on J.

Recent calculations by Dennison and Burkhard[3] provide a series of lines starting with $J=2$, which can be closely fitted to the observed frequencies. Their preliminary calculations were based on a special model of an asymmetric-top with hindered internal rotation. Such a model, however, seems inadequate to explain the observed dependence of the Stark coefficients on J.

The Stark effect measurements are rather well represented by the formula

$$\Delta\nu(\text{sec.}^{-1})=\frac{E(\text{e.s.u.})}{h}\left[\frac{M}{(J^2+J)^{\frac{1}{2}}}\times\frac{0.895\times10^{-18}}{(J^2+J)^{\frac{1}{2}}}+0.0113\times10^{-18}(J^2+J)^{\frac{1}{2}}\right]. \tag{2}$$

In Eq. (2) the quantity 0.895×10^{-18} is presumably the value in e.s.u. of the electric dipole moment parallel to the axis of symmetry. From this and a generally accepted value for the total dipole moment, we find the value 1.41×10^{-18} e.s.u. for the component of the dipole moment perpendicular to the symmetry axis.

From Eq. (2) one may deduce a value for the change (during a transition) of the internal direction cosine to be associated with this component of the dipole moment. This value is aproimately $0.0080(J^2+J)^{\frac{1}{2}}$.

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Alpha-Ray Spectra of RaC and RaC′

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BEFORE the cyclotron magnet of the alpha-ray spectrograph* was returned to the cyclotron group, a few plates were exposed to the alpha-particles from several natural radioactive sources, still using the track method of detection. Examination of the plates has been mostly done during the past few months. The following is a summary of the results obtained for RaC and RaC′. The results for RdTh, ThC, and ThC′ will be presented in the following note. We must say that several cases, especially those concerned with the weak lines, need further study with stronger sources.

TABLE I. Alpha-ray sprecta of RaC and RaC′.

Element	Alpha-energy Mev	Relative integral intensity
RaC		
RaC′α_0	7.683 (ref.)	10^6
α_0	5.517 ±0.02	160
α_1	5.466 ±0.02	200
α_2	5.333 ±0.02	70
RaC′		
α_0	7.683 (ref.)	10^6
α_3	9.080 ±0.015	30

Sources of radon deposit were prepared in the following usual manner. Radon gas of about 150 m.c. was introduced by means of a mercury pump into the vacuum of a glass tube, which contained a nickel cylinder with a platinum wire at the center. The radon gas was condensed onto the wire with liquid air outside. The wire was negatively charged at about 250 v relative to the cylinder. After about five hours the wire was removed, washed with alcohol, and heated in vacuum to about 400°C. When exposure of the plates was started in the spectrograph, RaA had practically died out, leaving mainly RaC and RaC′ as the alpha-ray sources on the wire.

To study the region on the high energy side of the RaC′ line, the magnetic field was increased so that the RaC′ line was near to the low energy end of the plate (about 19 cm long) but still on the plate. Examination of the plate was extended up to a region of about 11.5 Mev. Only one line at 9.080 Mev has been found. The intensity and energy of this line can nicely be identified with the third long-range line as found by Rutherford and his co-workers. The other lines do not show up on the plate, presumably because the source was too weak; the peak value of this line as found in the present case is not more than 20 times the general background. We feel that, in order to study these extremely weak long-range lines, the general background must be reduced to less than 1 in 10^6 of the main line. This background was presumably due to such scattering that the scattered particles produced tracks on the plate parallel to the true tracks of the particles which had come directly from the source.

For the study of the region on the low energy side of the RaC′ line, the magnetic field was adjusted so that the RaC′ line was near to the high energy end of the plate. A region covering approximately 4.8–6.0 Mev was examined. Three or four lines have been found in an interval of about 0.5 Mev (see the curve). The energies of the first two lines are in good agreement with the α_1 and α_2 of RaC as found by Rutherford and his co-workers. The third one is weaker, and the fourth one (if true) is still weaker and very broad. The intensity of each line is roughly 1 in 10^4 of the intensity of the RaC′ line (for better values see