## Internal Conversion Electrons from $Br^{80}$

Segrè, Halford and Seaborg[1] have recently reported that the 18 min. $Br^{80}$ isomer is formed by the decay of the 4.4-hr. activity. They have concluded that the 4.4-hr. isomer has the greater energy. This is in agreement with the proton threshold measurements reported by Buck.[2] They also conclude that the 4.4-hr. radiation is probably composed entirely of low energy internal conversion electrons.

We have produced $Br^{78,\,80,\,82}$ by proton bombardment of thin selenium films mounted on $2.5\mu$ Al foil. The negative electron spectra were examined in the region 13 kev to 150 kev with a $\beta$-ray spectrograph. We find two strong lines of electrons at $44\pm1$ and $33.5\pm1$ kev, respectively. These are accompanied by a third much weaker line at $21.5\pm2$ kev. We have shown definitely that the 44 and 33.5 kev lines belong to the 4.4-hr. $Br^{80}$ period. The 21.5 kev line belongs either to the 4.4-hr. $Br^{80}$ or to the 33-hr. $Br^{82}$ with a much greater probability in favor of its belonging to $Br^{80}$.

We exposed four plates to different relative intensities of the various activities of $Br^{78,\,80,\,82}$ as follows:

| Exposure | Plate No. 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 6.3 min. $Br^{78}$ | 70 | 130 | 0 | 0 |
| 18 min. $Br^{80}$ | 330 | 1140 | 0 | 0 |
| 4.4 hr. $Br^{80}$ | 52 | 450 | 455 | 0 |
| 33 hr. | 2.5 | 48 | 250 | 300 |

The exposure figures given refer to measurements of the total radiation emitted by each isotope as measured with a $N_2$-filled ionization chamber. Plates 2 and 3 are reproduced in Fig. 1 and microphotometer measurements of these plates are shown in Fig. 2. It should be noted that (1) Plates 2 and 3 were exposed to the same intensity of 4.4-hr. activity and show the 44 and 33.5 kev lines at the same intensity, (2) Plate 2 was exposed to only 20 percent as much $Br^{82}$ radiation as was Plate 3, yet shows the 21.5 kev line equally strong. Plate 1 was blank. Plate 4 was exposed the most intensely of all the Plates to $Br^{82}$ radiation, yet shows only a small and questionable maximum around 20 kev.

The 44 kev and 33.5 kev lines agree within the experimental error with the expected values for $L$ and $K$ conversion in bromine of a gamma-ray of about 45 kev. The 21.5 kev line is either the result of $L$ conversion of a 23 kev gamma or $K$ conversion of a 34 kev gamma-ray. Since the existence of this 21.5 kev line is important to the theory of isomers we shall complete its examination shortly.

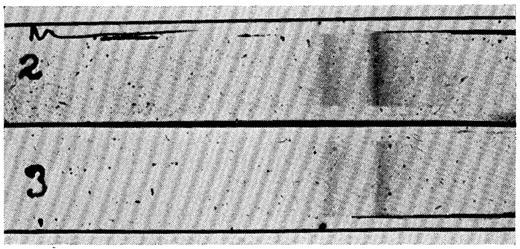

FIG. 1.

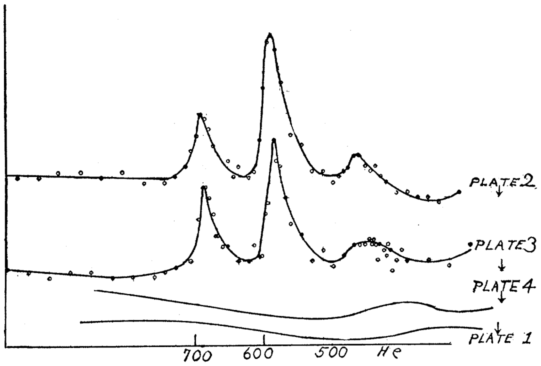

FIG. 2. Microphotometric measurements of the plates.

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## On the Nuclear Magnetic Moment of Beryllium*

The molecular-beam magnetic-resonance method, discussed in the preceding issue of the *Physical Review*,[1] measures $g$, the ratio of the magnetic moment to the angular momentum of a nucleus. For the nuclei therein reported the spins are known, and the magnetic moments were obtained directly from the product of the spins and the measured $g$ values. Elsewhere in this issue a method of measuring the sign of the nuclear moment is described.[2] We have applied these methods to the study of the gyromagnetic properties of the beryllium nucleus, ${}_4Be^9$.

The molecules used in our experiments were sodium beryllium fluoride ($NaF\cdot BeF_2$) and potassium beryllium fluoride ($KF\cdot BeF_2$). The resonance minima we obtain yield values of $\mu/hI=f/H$ for the constituent nuclei of the molecules. There were two different values of $f/H$ common to both molecules. One of these values agreed closely with that previously found for $F^{19}$. The other value must therefore be ascribed to $Be^9$. The value of $f/H$ for $Be^9$ was found to be constant to 0.2 percent for frequencies ranging from $0.9\times10^6$ to $3.0\times10^6$ cycles per second. The value of $g$ of $Be^9$ is $0.783\pm0.003$ when referred to that of $Li^7$ ($g=2.167$).[1]

The sign of the moment of $Be^9$, as determined from the systematic shifts of the positions of the resonance minima when the direction of the homogeneous field is reversed[2] is found to be negative. This is the first nucleus investigated by molecular-beam magnetic-resonance methods for which a negative magnetic moment has been found.

Since our experiment does not measure spin and since no reliable value of the spin exists in the literature we cannot ascribe a definite value to the moment of this nucleus. However, it is highly improbable that the spin is $\frac{1}{2}$. If the nuclear state were $P_{\frac{1}{2}}$ the neutron spin would be directed oppositely to the orbital angular momentum and since the neutron moment is negative[3] the resultant would be positive. If the state were $S_{\frac{1}{2}}$ the resultant moment would indeed be negative but equal to $-0.783\times\frac{1}{3}=-0.392$ which is to be compared with the expected value of the neutron moment of $-1.9$.[4] A value of $\frac{3}{2}$ for the spin would be much more plausible. In this case the nuclear moment would be $-1.175$ nuclear magnetons. This is to be compared with the theoretical prediction of Rose and Bethe[5] which is $-1.65$. The lack of agreement may arise from the value of the neutron moment which these authors assumed as equal to $-2.0$. Recent work on the H and D nuclei shows that the deuteron possesses a quadrupole moment,[6] which indicates that there is an orbital contribution to the moment of the D nucleus. Such an orbital contribution would decrease the absolute value of the moment of the neutron which is obtained by comparing the moments of H and D.[7] Our present results are in agreement with this view. The research has been aided by a grant from the Research Corporation.

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## New Periods of Radioactive Tin

We have found in the tin precipitate, prepared by bombardment of tin with five-Mev deuterons, radioactivities with half-lives 9 minutes (−), 40 minutes (−), 26 hours (−), 10 days (−), about 70 days (−) and at least 400 days (sign unknown). All but the very longest period have also been obtained with slow neutrons on tin. One of the deuteron activated samples is over two years old and is still measurably active.

Previous reports on tin activities have been made: Naidu[1] found 8 and 18 minutes while Nahmias[2] gives 6 minutes, both after slow neutron activation of tin; we have quoted[3] half-lives of 12 minutes, 45 minutes, 28 hours and several months, obtained with deuterons on tin; Pool, Cork and Thornton have found[4] a 47-minute period with fast neutrons on tin; Barnes obtains[5] radioactive tin with half-lives 20 minutes (+) and 50 days (−) from protons on indium. All of these activities, except the 20-minute positron emitter, are probably to be identified with the periods quoted in the first paragraph.

The unstable tin isotopes to which these activities could be assigned are $Sn^{113}$, $Sn^{121}$, $Sn^{123}$ and $Sn^{125}$. One must of course also consider the possibility that some of them may be due to excited forms of stable tin, similar to that of indium recently described.[6, 7] A few identifications can be made reasonably.

Inasmuch as neither we nor Pool, Cork and Thornton observe the 9-minute period when fast neutrons from Li+D are used, it is plausible to assign this period to $Sn^{125}$, obtained as the result of neutron capture by the heaviest stable isotope. Barnes' two activities should both belong to $Sn^{113}$ (provided the longer period decays by $K$-electron capture) and our 70-day activity may perhaps be the same as that given by him as a 50-day period. We will give further evidence for this below. (The fact that the 20-minute activity is not obtained after deuteron or slow neutron bombardment of tin is probably explained by the low abundance of $Sn^{112}$ and the high intensity of the observed short lived products.) We have reason to believe that an early report[8] by one of us of a 24-hour tin formed by $Sb^{123}(d, \alpha)Sn^{121}$ is in error, so that the 26-hour tin isotope from tin plus deuterons or neutrons is not necessarily associated with $Sn^{121}$, although it may be.

The isotopic constitution of the neighboring elements is such that little additional aid in assignment is obtained by studying the transmutations of elements close to tin. The only unstable tin isotope common to the reactions $(Sn, dp)Sn$ and $Cd(\alpha, n)Sn$ is $Sn^{113}$. A chemical separation for tin after activation of cadmium with 16-Mev helium ions does in fact give a precipitate which contains an activity with a half-life of about 70 days (sign unknown). This is additional evidence that $Sn^{113}$ has this period, and perhaps decays by $K$-electron capture to stable $In^{113}$. This tin fraction also contains activities with half-lives of 25 minutes (−), 3 hours (−) and 13 days (−). The question as to whether this 25-minute activity is to be identified with Barnes' 20-minute period cannot be decided from the present data since our magnetic deflection experiments show the predominant sign of the 25-minute period to be negative, while Barnes reports that positrons were observed. No assignment can be attempted for the 3-hour and 13-day activities. They may be formed from the rare isotopes $Cd^{108}$ or $Cd^{106}$ (abundance about one percent, compared to the 12.8 percent of $Cd^{110}$ which gives rise to the 70-day $Sn^{113}$) and hence would be involved in multiple decays leading back to stable $Cd^{111}$ or $Ag^{109}$.

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