Lindner.[3] The $Mg^{28}$ for this work has been prepared by spallation of Si and of $K_2SO_4$. Previous to the measurements in the beta-ray spectrometer, the isotope was studied and it was confirmed radiochemically that it is a Mg isotope and the activity of its daughter $Al^{28}$ was separated and counted; so it was checked that the assignment as $Mg^{28}$ was correct. The value of 20.8±0.5 hr was determined for its half-life.

The samples for the beta-ray spectrometer were made by irradiating a few grams of the chemicals Si or $K_2SO_4$ in a copper vial at 420 Mev in the University of Chicago synchrocyclotron for about one hour. The targets with about 1 or 2 mg of Mg carrier were dissolved, hold-back carriers of likely active impurities added, and the $Mg^{28}$ activity cleaned by precipitating impurities as sulfides in acid and basic solutions and by precipitating ferric hydroxide with ammonia. Finally, the magnesium was precipitated as the hydroxide with NaOH or was precipitated as the magnesium ammonium phosphate.

The samples for the beta-ray spectrometer were mounted in a thin Zapon backing; for that the magnesium was converted to the chloride or mounted directly as magnesium ammonium phosphate. The thinnest samples had thickness of about 0.2 mg/cm².

For the low energy part of the spectrum a Geiger counter with a window of Formvar *E* and a thickness of 0.2 mg/cm² was used. It was supported by a grid and filled *in situ* to 10 cm of Hg pressure with a mixture of 20 percent ethyl alcohol and 80 percent argon. For the high energy part of the spectrum a Geiger counter with a mica window of 1.3 mg/cm² was used.

A typical example of the results obtained is shown in Fig. 1. The high energy beta of $Al^{28}$ shows an allowed shape from its end

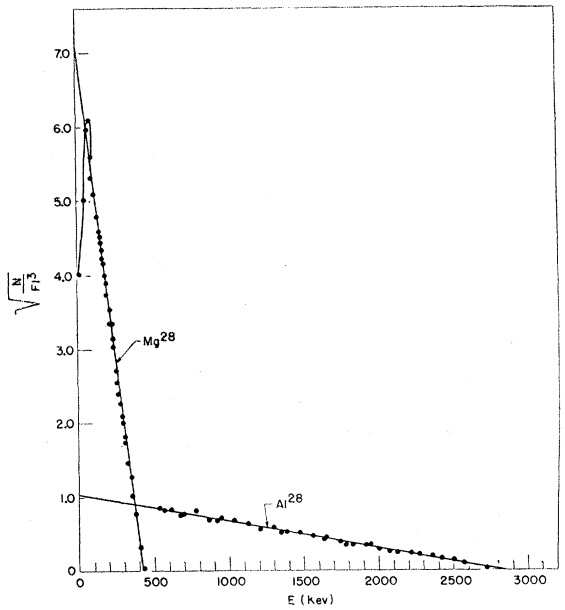


FIG. 1. The Fermi plot for the beta-spectra of $Mg^{28}$ and $Al^{28}$.

point up to where the activity of $Mg^{28}$ begins to appear. The extrapolated activity of $Al^{28}$ for a given momentum was subtracted from the observed activity to obtain the activity of $Mg^{28}$. The Fermi plot of $Mg^{28}$ obtained this way is shown also in Fig. 1, and it has an allowed shape for energies greater than 100 kev. Below 100 kev the usual experimental difficulties distort it. Most of the measurements gave similar results, and it can be concluded that both $Mg^{28}$ and $Al^{28}$ have allowed spectra. The most probable values for the maximum energies obtained are 418±10 kev for $Mg^{28}$ and 2850±50 kev for $Al^{28}$. The value of log*ft* for the decay of $Mg^{28}$ comes out then to be 4.25. No other group of beta-activity could be detected, and it can be estimated that no less than 90 percent of the decay of $Mg^{28}$ goes through the 418-kev beta.

I am indebted to H. L. Anderson for making available to me the beta-ray spectrometer and the facilities of the University of Chicago synchrocyclotron, and to R. K. Sheline for letting me know the results of his experiments before publication. Thanks are due L. Kornblith, Jr., C. Bordeaux, and the crew of the synchrocyclotron for their cooperation during the irradiations.

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## Nuclear Magnetic Resonance Measurements of Selenium*

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MEASUREMENTS to determine the nuclear magnetic resonance of selenium 77 have been performed using a nuclear induction system. Frequencies were determined with a BC-221 frequency meter calibrated against standard frequency signals from WWV and an externally controlled crystal oscillator. The resonances occurred at a magnetic field of approximately 9500 gauss which was produced by an electronically regulated electromagnet.

The sample consisted of approximately 3 ml of $H_2Se$, and determinations were made relative to the resonance of deuterium in a 1-ml sample of $D_2O$ containing 0.1 molar $MnSO_4$. The ratio of the resonance frequency of selenium to that of deuterium was determined to be

$$\nu(Se^{77})/\nu(D)=1.24211\pm0.00010.$$

The stated uncertainty is the estimated experimental error. The probable error as usually defined is ±0.000025 and the 95 percent confidence interval is ±0.000091.

This value for $H_2Se$ is not in agreement with the value for $H_2SeO_3$ as determined by Dharmatti and Weaver,[1] and further investigations were carried out to ascertain whether or not the difference was real.

Using samples of $H_2SeO_3$ (aqueous), $H_2SeO_4$ (aqueous), and $H_2Se$, the following direct frequency ratios were found:

$$\nu(Se^{77}(H_2SeO_3))/\nu(Se^{77}(H_2Se))=1.001504\pm0.000040,$$
$$\nu(Se^{77}(H_2SeO_4))/\nu(Se^{77}(H_2Se))=1.001560\pm0.000080.$$

Since the resonance of $H_2Se$ appears at the highest value of applied magnetic field, it appears to exhibit the least paramagnetic shielding. Measurements were also attempted on a sample of $SeOCl_3$, but conditions of the experiment were not suitable for satisfactory measurements.

Combining our measured ratios with Lindström's value for the deuteron to proton ratio[2] of 0.15350668, the selenium-to-proton frequency is calculated to be

$$\frac{\nu(Se^{77}(H_2SeO_3))}{\nu(H)}=\frac{\nu(H_2SeO_3)}{\nu(H_2Se)}\times\frac{\nu(H_2Se)}{\nu(D)}\times\frac{\nu(D)}{\nu(H)}$$
$$=0.190959\pm0.000017.$$

Using the results of Dharmatti and Weaver[1] (0.72193) and Lindström's[2] sodium-to-proton frequency ratio of 0.2645182, we find their ratio to be

$$\frac{\nu(Se^{77}(H_2SeO_3))}{\nu(H)}=\frac{\nu(H_2SeO_3)}{\nu(Na)}\times\frac{\nu(Na)}{\nu(H)}=0.190964\pm0.000005.$$

It is concluded that our measurements are in substantial agreement with those of Dharmatti and Weaver and that a chemical

shift of 0.15 percent exists between the $H_2Se$ and $H_2SeO_3$ selenium resonance fields. Additional measurements of higher precision are planned after modification of the present equipment to increase sensitivity and stability.

Appreciation is expressed to H. E. Weaver, Jr., for suggestions to be incorporated in the improved equipment design and also to J. R. McNally, Jr., of this laboratory for his continued interest in this work.

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## The Decay Scheme of Natural Lutetium 176

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THE nuclide lutetium 176 is of particular interest for two related reasons; first, that it is the central member of one of the four known triads of naturally occurring adjacent isobars, and second, that its spin of at least 7 units[1] is the highest known. Flammersfeld has reported a decay scheme for this nuclide,[2] in which both $K$ capture and $\beta$-decay appear, the ratio of the branches being $K/\beta^-=2$. The observed gamma-ray was placed in the $K$ branch, and its energy fixed at 0.260 Mev.

Suttle has recently redetermined the absolute beta-decay rate of this species.[3] The availability of a sample of 0.18 gram of lutetium (as the oxalate) led us to undertake a study of its gamma- and x-radiation with our low level spectrometer, with a view to redetermining its decay scheme.

We first determined roughly its absolute emission rate for electromagnetic radiation, and found $12.0\pm1.8$ disintegrations per minute per mg lutetium, or about twice the value of 5.5 disintegrations per minute per mg found for $\beta$-emission by Suttle.

Using two NaI crystals in coincidence, we have shown that there are two gamma-rays of about 0.25 Mev in cascade, and that these comprise the great bulk of the radiation observed.

Using one crystal in coincidence with an end-window counter, we find that these gamma-rays are in coincidence with the 0.4-Mev $\beta$-ray (verified by absorption).

An energy scan of the electromagnetic radiation, using a 1-inch aluminum canned NaI crystal, and RCA 5819 phototube cooled to $-20$°C, and calibrating by means of the 0.28-Mev gamma-ray of $Hg^{203}$, showed to peaks at $200\pm20$ kev and $320\pm20$ kev of approximately equal intensity. A peak at $50\pm10$ kev, presumably the $K$ x-ray of hafnium, was $0.35\pm0.15$ as intense as the two large peaks. No other peak of intensity above 10 percent was seen, and in particular no crossover at 520 kev.

The isomeric state of $Lu^{176}$ decays by way of an 89-kev excited state of $Hf^{176}$.[4] No $K$ capture branch or decay to the ground state of $Lu^{176}$ has been seen. Goldhaber and Hill,[5] on the basis of unpublished work of Scharff-Goldhaber, have constructed a new decay scheme for $Lu^{176}$. This scheme agrees with our work as to the absence of a $K$ capture branch, although our energies are higher than theirs. We fail to find the 90-kev gamma-ray, but because of its high $L$ and $M$ conversion we might well have missed it, and all other radiations below 100 kev.

The x-ray peak is well accounted for by the conversion of the 200- and 320-kev lines; the $K$ conversion of the 90-kev line might be included, assuming as we must that all are $E2$. $L$ x-rays would not have been seen in our arrangement.

We thus generally confirm Goldhaber and Hill's decay scheme, as far as our evidence extends, although we have not seen the 90-kev transition.

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