

An enriched  $B^{10}F_3$  proportional counter, surrounded with 2 inches of paraffin was placed immediately behind the water container. The delayed neutrons from the reaction were counted by this counter, the pulses from which were amplified by an Atomic Instrument Company linear amplifier and recorded as a function of time by a Brush pen recorder connected through the scaling elements of a Tracerlab auto scaler. Selection of the scaling factor provided either fast or slow recording. The water was bombarded by neutrons from the LiF or the C source for about 20 sec., after which the cyclotron was shut off. The delayed neutron intensity was recorded. A half-life of  $4.5 \pm 1.0$  sec. was found, indicating the existence of  $N^{17}$ .

The delayed neutron count without the water target was about one-third of that observed when the water target was in position. This high background is probably due to the cooling water in the cyclotron itself. However, when neutrons of lower maximum energy from C were used to bombard the water, the number of delayed neutrons was reduced by a factor of about 15 because of the smaller number of high energy neutrons from the C source. It should be noted that the reaction energy of the  $O^{17}(n,p)N^{17}$  process is 8 Mev.

The reaction  $O^{18}(\gamma,p)N^{17}$  is unlikely, even though the isotopic content of  $O^{18}$  is five times that of  $O^{17}$  in normal water, because the cross section for a  $(\gamma,p)$  process is, in general, much smaller than that for an  $(n,p)$  process. However, to test the possibility of the formation of  $N^{17}$  by an  $O^{18}(\gamma,p)N^{17}$  process in our experimental conditions, a four-inch lead shield was placed between the LiF and the water target. The reduction of about 35 percent in the number of delayed neutrons from the water target due to the absorption of primary neutrons in the lead was the same as the measured absorption of the primary neutron beam itself. This indicates that the number of atoms of  $N^{17}$  formed is proportional to that of the incident neutrons and that neutrons rather than  $\gamma$ -rays are responsible for the production of  $N^{17}$ .

The average cross section for the process has been roughly estimated to be  $10^{-26}$  cm<sup>2</sup>. This figure may be off by a factor of 10, but it does serve to illustrate that the order of magnitude of the cross section of the process is comparable with other  $(n,p)$  reactions.

It is suggested that the reaction  $O^{18}(\gamma,p)N^{17}$  may be induced in a similar fashion where strong  $\gamma$ -ray sources of over 16 Mev are available.

- \* Partially assisted by the Joint Program of ONR and AEC.  
<sup>1</sup> Knable, Lawrence, Leith, Moyer, and Thornton, Phys. Rev. **74**, 1217A (1948).  
<sup>2</sup> L. W. Alvarez, Phys. Rev. **74**, 1217A (1948).  
<sup>3</sup> L. W. Alvarez, Phys. Rev. **75**, 1127 (1949).  
<sup>4</sup> E. Hayward, Phys. Rev. **75**, 917 (1949).  
<sup>5</sup> W. E. Chupp and E. M. McMillan, Phys. Rev. **74**, 1217A (1948).  
<sup>6</sup> Sun, Jennings, Shoupp, and Allen, Phys. Rev. **75**, 1302A (1949).  
<sup>7</sup> H. A. Bethe, *Elementary Nuclear Theory* (John Wiley and Sons, Inc., New York, 1947), except that the mass of neutron is taken as 1.00899.

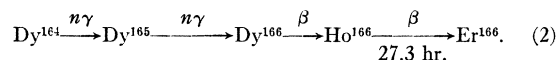
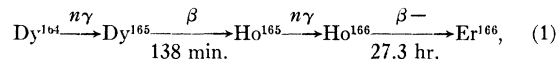
### New Radioactive Isotopes of Dysprosium\*

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ALTHOUGH two isomers of  $Dy^{165}$  have been established by the studies of several investigators,<sup>1</sup> no activities have been assigned definitely to other dysprosium isotopes.

A sample of dysprosium oxide,<sup>2</sup> highly purified by ion exchange techniques, was irradiated with slow neutrons in the Oak Ridge National Laboratory reactor. The decay curve of the induced activity was resolved into three components with periods of 138 min., 81 hr., and 146 days. The 138-min. activity is known to belong to  $Dy^{165}$ . Feather analysis of aluminum absorption curves showed that there were two beta-groups with maximum energies of 0.4 Mev and 1.8 Mev associated with the decay of the 81-hr. activity. The 146-day activity appeared to decay largely by orbital electron capture.

Because of the difficulty of preparing pure rare earths and the prevalence of high activation cross sections among these elements, it is essential to make chemical separations before assigning activities. Therefore an ion exchange column separation<sup>3</sup> was performed on another sample of the dysprosium oxide which had been irradiated for five months. The conditions were such that holmium, dysprosium, and terbium would be separated. The presence of the 27.3-hr. activity of  $Ho^{166}$  was demonstrated. Since the dysprosium which was irradiated was known to be extremely pure, it was suspected that the holmium activity was produced by double neutron capture as represented by either or both of the following two series of reactions:



The dysprosium fraction from which the holmium had been removed showed growth rather than decay. Therefore it appears certain that at least part of the holmium activity observed had been formed according to Eq. (2). In order to verify this hypothesis a second chemical separation of holmium from the dysprosium was made. Again  $Ho^{166}$  was identified. The analysis of the growth curve of the holmium deficient dysprosium sample showed that an activity with an 80-hr. half-life was decaying to a daughter whose half-life was 27 hr. Furthermore, it was possible to obtain an aluminum absorption curve on the freshly purified dysprosium. Feather analysis of this curve showed that the 80-hr. activity emits a beta whose maximum energy is 0.4 Mev. After equilibrium had been established between the 80-hr. parent and the 27-hr. daughter, an aluminum absorption curve indicated the presence of the 0.4-Mev beta and also a 1.8-Mev beta. Since both the half-life and the energy of the daughter activity agree with those of  $Ho^{166}$ , we conclude that the 80-hr. parent is  $Dy^{166}$ .

After the 80-hr. activity had decayed out of these dysprosium samples, there was a residual activity with a half-life of  $140 \pm 10$  days. Since absorption curves in copper and tantalum show that this activity decays by orbital electron capture, it must belong to  $Dy^{167}$  or  $Dy^{169}$ . The decay has not been followed sufficiently long to ascertain whether there is a longer lived activity of  $Tb^{167}$  present.

From the ratio of 80-hr. activity to 140-min. activity in a sample of dysprosium which had undergone no chemical separation after irradiation, an approximate value of the neutron activation cross section of  $Dy^{166}$  was computed to be 5000 barns.

A detailed discussion of these studies is being prepared for publication in the near future.

\* This document is based on work performed under Contract Number W-7404 eng 26 for the Atomic Energy Project at Oak Ridge National Laboratory.

<sup>1</sup> Summarized by G. T. Seaborg and I. Perlman, Phys. Rev. **20**, 585 (1948).

<sup>2</sup> The author wishes to thank Mr. D. H. Harris who kindly supplied this extremely pure material.

<sup>3</sup> B. H. Ketelle and G. E. Boyd, J. Am. Chem. Soc. **69**, 2800 (1947).

### Detection of Antiferromagnetism by Neutron Diffraction\*

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TWO necessary conditions for the existence of ferromagnetism are: (1) the atoms must have a net magnetic moment due to an unfilled electron shell, and (2) the exchange integral  $J$  relating to the exchange of electrons between neighboring atoms