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±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 (γ,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 γ-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^2. 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 γ-ray sources of over 16 Mev are available.

* Partially assisted by the Joint Program of ONR and AEC.
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New Radioactive Isotopes of Dysprosium*

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September 6, 1949

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

A sample of dysprosium oxide,[2] 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[3] 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:

$$Dy^{164} \xrightarrow{n\gamma} Dy^{165} \xrightarrow[138\ \text{min.}]{\beta} Ho^{165} \xrightarrow{n\gamma} Ho^{166} \xrightarrow[27.3\ \text{hr.}]{\beta-} Er^{166}, \quad (1)$$

$$Dy^{164} \xrightarrow{n\gamma} Dy^{165} \xrightarrow{n\gamma} Dy^{166} \xrightarrow{\beta} Ho^{166} \xrightarrow[27.3\ \text{hr.}]{\beta} Er^{166}. \quad (2)$$

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±10 days. Since absorption curves in copper and tantalum show that this activity decays by orbital electron capture, it must belong to Dy^{157} or Dy^{159}. The decay has not been followed sufficiently long to ascertain whether there is a longer lived activity of Tb^{157} 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^{165} 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.
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Detection of Antiferromagnetism by Neutron Diffraction*

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August 29, 1949

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

must be positive. This last condition is required in order that spin states of high multiplicity, which favor ferromagnetism, have the lowest energy. It seems certain that for many of the non-ferromagnetic substances containing a high concentration of magnetic atoms the exchange integrals are negative. In such cases the lowest energy state is the one in which the maximum number of antiparallel pairs occur. An approximate theory of such substances has been developed by Néel,[1] Bitter,[2] and Van Vleck[3] for one specific case and the results are briefly described below.

Consider a crystalline structure which can be divided into two interpenetrating lattices such that atoms on one lattice have nearest neighbors only on the other lattice. Examples are simple cubic and body-centered cubic structures. Let the exchange integral for nearest neighbors be negative and consider only nearest neighbor interactions. Theory then predicts that the structure will exhibit a Curie temperature. Below the Curie temperature the spontaneous magnetization *vs.* temperature curve for one of the sub-lattices is that for an ordinary ferromagnetic material. However, the magnetization directions for the two lattices are antiparallel so that no net spontaneous magnetization exists. At absolute zero all of the atoms on one lattice have their electronic magnetic moments aligned in the same direction and all of the atoms on the other lattice have their moments antiparallel to the first. Above the Curie temperature the thermal energy is sufficient to overcome the tendency of the atoms to lock antiparallel and the behavior is that of a normal paramagnetic substance.

Materials exhibiting the characteristics described above have been designated "antiferromagnetic." Up to the present time the only methods of detecting antiferromagnetism experimentally have been indirect, e.g., determination of Curie points by susceptibility and specific heat anomalies. It has occurred to one of us (J.S.S.) that neutron diffraction experiments might provide a direct means of detecting antiferromagnetism. In an antiferromagnetic material below the Curie temperature a rigid lattice of magnetic ions is formed and the interaction of the neutron magnetic moment with this lattice should result in measurable coherent scattering. Halpern and Johnson[4] have shown that the magnetic and nuclear scattering amplitudes of a paramagnetic atom should be of the same order of magnitude and this result has been qualitatively verified by experimental investigators.[5] At the time of the above suggestion, an experimental program on the determination of the magnetic scattering patterns for various paramagnetic substances (MnO, MnF_2, $MnSO_4$ and Fe_2O_3) was underway at Oak Ridge National Laboratory and room temperature examination had shown (1) a form factor type of diffusion magnetic scattering (no coupling of the atomic moments) to exist for MnF_2 and $MnSO_4$, (2) a liquid type of magnetic scattering (short-range order coupling of oppositely directed magnetic moments) to exist for MnO and (3) the presence of strong coherent magnetic diffraction peaks at forbidden reflection positions for the α-Fe_2O_3 lattice. The latter two observations are in complete accord with the antiferromagnetic notion since the Curie points for MnO and α-Fe_2O_3 are respectively[6] 122°K and 950°K.

Figure 1 shows the neutron diffraction patterns obtained for powdered MnO at room temperature and at 80°K. The room temperature pattern shows coherent nuclear diffraction peaks at the regular face-centered cubic reflection positions and the liquid type of diffuse magnetic scattering in the background. It should be pointed out that the coherent nuclear scattering amplitudes for Mn and O are of opposite sign so that the diffraction pattern is a reversed NaCl type of pattern. The low temperature pattern also shows the same nuclear diffraction peaks, since there is no crystallographic transition in this temperature region,[7] and in addition shows the presence of strong magnetic reflections at positions not allowed on the basis of the chemical unit cell. The magnetic reflections can be indexed, however, making use of a magnetic unit cell twice as large as the chemical unit cell. A complete description of the magnetic structure will be given at a later date.

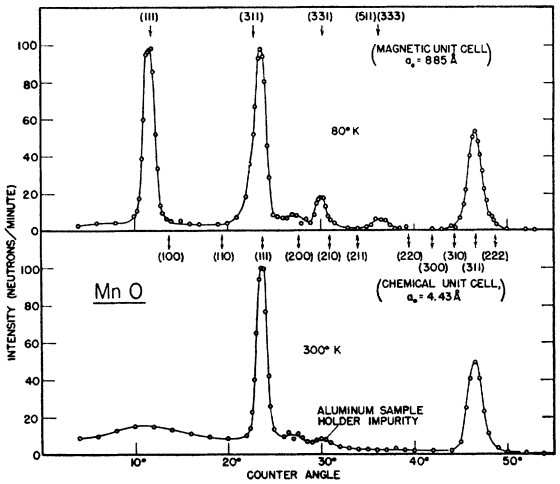

FIG. 1. Neutron diffraction patterns for MnO at room temperature and at 80°K.

In conclusion it appears that neutron diffraction studies of antiferromagnetic materials should provide a new and important method of investigating the exchange coupling of magnetic ions.

* This work was supported in part by the ONR.

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Imprisonment of Resonance Radiation in Mercury Vapor

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August 29, 1949

THE term "imprisonment of resonance radiation" describes the situation wherein resonance radiation emitted in the interior of a gas-filled enclosure is strongly absorbed by normal gas atoms before it can get out; the eventual escape of a quantum of radiation then takes place only after a number of successive atomic absorptions and emissions. The phenomenon was first observed by Zemansky[1] who measured the time of decay, T, of diffuse resonance radiation from an enclosure of optically excited mercury vapor, after the exciting beam of 2537A light was cut off. T was found to depend upon gas density and enclosure geometry; at densities around 10^{15}/cc, T attained values of the order of 10^{-4} sec., a thousand times greater than the natural lifetime of an excited 6^3P_1 atom.

On the theoretical side, a number of treatments[2–6] have been presented. The early work[2–4] is reviewed in reference 6. In the latter paper (as well as in that of Bieberman[5]), the transport of resonance quanta is described by a Boltzmann-type integro-differential equation for the density of excited 6^3P_1 atoms; the solution of this equation by the Ritz variational method gives accurate values for the decay time, T. It was found that T depends not only on vapor density and enclosure geometry, but also on the spectral line shape of the resonance radiation, as pointed out earlier by Kenty;[4] explicit results were obtained for the case of Doppler broadening and plane-parallel enclosure geometry. Most recently, unpublished calculations have extended the analysis to enclosures of the form of infinite circular cylinders and to a variety of line shapes.