Now $B(x)$ occurs in $H(x)$ as a scalar meson vector-interaction. If we perform the transformation[7]

$$\Psi = e^{-iS}\Psi', \tag{4}$$

where

$$S = (1/\hbar c\kappa)\int j_\mu(x)B(x)d\sigma_\mu, \tag{5}$$

on the generalized Schrödinger equation in the Schrödinger representation,[8] the total Hamiltonian is unaltered except for the removal of the last two terms in (3). In this form the free field Hamiltonians can be removed by a transformation to the interaction representation to give the Hamiltonian

$$H(x) = (1/c)j_\mu(x)A_\mu(x) = ig\psi(x)\gamma_\mu\psi(x)A_\mu(x) \tag{6}$$

from which differentials of Δ_F-functions will not arise in the S-matrix. Since (5) commutes with the operator in (2), the subsidiary condition will not be altered by the transformation. Just as in electrodynamics, the suffix μ can take all four values in virtual effects but for real mesons it is restricted by the supplementary condition. This restriction will be automatically satisfied if the free meson lines are made to correspond to factors $\phi_\mu(x)$ in the integrals. Thus the Hamiltonian can be taken to be

$$H_1(x) = (1/c)j_\mu(x)\phi_\mu(x) - \hbar c\delta\kappa_0\psi(x)\psi(x) - \tfrac{1}{2}\delta\kappa^2\phi_\mu{}^2(x) \tag{7}$$

in the calculation of the S-matrix provided internal meson lines correspond to factors

$$\langle P(A_\mu(x), A_\nu(y))\rangle_0 = \tfrac{1}{2}\hbar c\delta_{\mu\nu}\Delta_F(x-y). \tag{8}$$

The extra terms in $H_1(x)$ allow for the renormalisation of both nucleon and meson masses. The possible primitive divergents are the same as in electrodynamics. The integrals from square parts are also the same and thus introduce no new divergences. Hence a finite S-matrix can be obtained. If the mesons are charged there is an extra term in (6)[7] which cannot be treated by these methods.

A similar treatment is not possible for the pseudo-vector meson because the corresponding transformation does not remove the subsidiary pseudo-scalar field, but introduces a complicated interaction involving the subsidiary field in the power of an exponential.[7]

It is hoped to publish elsewhere a more detailed discussion of the derivation of (7) and the failure of Dyson's method in the other cases.

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Electric Quadrupole Moments of Nuclei

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THE rule, given by Gordy[1] in order to estimate the electric quadrupole moments Q for isotopic pairs having the same spin may be extended to isotopic pairs having different spin and to nuclei with Z values nearly equal.

The magnetic moment is a function of atomic number, spin, and quadrupole electric moment, other things being equal: (1) the spin decreases with a decrease of the magnetic moment; (2) the magnetic moment increases with Z; (3) if the quadrupole moment becomes more positive (or less negative for flattened nuclei), the magnetic moment appears to decrease.

With these rules, we can obtain further Q-values, absolute or relative. All the quadrupole electric moments as estimated by Gordy are in good agreement with these rules, which are cumulative. For instance, going from Ga^{71} to As^{75}, Z grows by two units, the spins remain the same, and the magnetic moment gets smaller.

Therefore, we expect the nuclear quadrupole moment of As^{75} to be more positive, which turns out to be true.

According to these rules, the following Q-values can be expected:

Zn^{67} nucleus is less flattened than Cu^{65} and $Q(Zn^{67})\sim=0$,
Co^{59} nucleus is less flattened than Mn^{55} and $Q(Co)>Q(Mn)$,
Rb^{85} nucleus is less flattened than Rb^{87} and $Q(Rb^{85})\sim=+30\times10^{-26}$ cm^2,
Sb^{123} nucleus is less flattened than Sb^{121} and $Q(Sb^{123})\sim=-60\times10^{-26}$ cm^2.

[1] W. Gordy, Phys. Rev. **76**, 139 (1949).

On the Delayed Neutron Emitter $_7N^{17}$ *

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IT has been found by E. O. Lawrence and his associates[1] at California that when O and the elements immediately above it in atomic number are bombarded with 195-Mev deuterons, a delayed neutron emitter with a 4.14±0.04 sec. half-life is formed. Alvarez[2] identified this delayed neutron emitter as N^{17} and Alvarez[3] and Hayward[4] determined the energy relationships in the $\beta-n$ decay process. The production of N^{17} by bombarding elements of higher atomic number than fluorine with 195-Mev deuterons probably takes place by a spallation process. It is known that the yield of the delayed neutron emitter decreases with increasing atomic number of the target material.[5] The same nuclide was also produced by the $C^{14}(\alpha,p)N^{17}$ process by Sun, Jennings, Shoupp, and Allen[6] who found an upper limit of the (α,p) threshold of 16 Mev in agreement with Alvarez's measurements.

We may calculate the Q-values of the possible simple nuclear reactions by which N^{17} may be formed. Using Bethe's[7] value for the mass of O^{17} and Alvarez's value[3] for the $(N^{17}-O^{17})$ mass difference one obtains the mass of N^{17} to be 17.01385 a.m.u. Using Bethe's values for the other atomic masses, the Q-values for these reactions are given in Table I.

Because of the short half-lives of N^{16} and F^{20}, it is reasonable to consider the stable, although rare, nuclides O^{17} and O^{18} as the starting elements for the production of N^{17}. The following experiment was performed to determine whether N^{17} can be made by the $O^{17}(n,p)N^{17}$ process. Neutrons of known maximum energy were produced by bombarding a thick LiF or C target with a 14-Mev 2μa external deuteron beam from the University of Pittsburgh cyclotron. (Q-values are 15.0 Mev for Li^7, 10.7 Mev for F and -0.28 Mev for C.) Our previous measurements of neutron fluxes from various targets in this cyclotron indicate that the total number of neutrons produced per μa by the LiF and C targets is about the same and that only the energy of the neutrons, as inferred from the Q-values, is different. Thus it follows that the number of neutrons with energy above 8 Mev is greater for LiF than C targets. Neutrons from these sources were used to bombard 500 g of water containing O^{17} in its natural isotopic proportion.

TABLE I. Q-values of various reactions by which N^{17} is formed.

Reaction	Q-value
$N^{16}(n,\gamma)N^{17}$	5.9 Mev^a
$O^{17}(n,p)N^{17}$	-7.9 Mev
$O^{18}(n,d)N^{17}$	-13.7 Mev
$N^{16}(d,p)N^{17}$	3.7 Mev
$O^{18}(\gamma,p)N^{17}$	-15.9 Mev
$F^{20}(n,d)N^{17}$	>-4.3 Mev and <0.4 Mev

^{a} The mass of N^{16} is taken as 16.01121 after L. D. Wyly, Phys. Rev. **76**, 462 (1949).

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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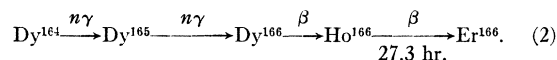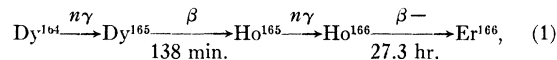
New Radioactive Isotopes of Dysprosium*

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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:

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

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

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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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