and Nechaj[5] and Sher, Halpern, and Stephens[6] have found new reactions for its production.

The excitation function of the reaction $C^{14}(\alpha, p)N^{17}$ was measured by monitoring the delayed neutrons, emitted by the product nuclide N^{17}, at various alpha-energies. The variation in alpha-energies was achieved by inserting 0.0005-in. aluminum foils in the cyclotron beam. The energy values were obtained by measuring the ranges in air. The experimental setup is shown in Fig. 1. The neutron counts determined as a function of time exhibited a half-life of 4.6 ± 1 sec. The counts in 20 seconds immediately after the bombardment (0.02 μamp and 30 sec), which included practically all the available counts, were recorded and plotted against the energy of the bombarding alphas. The result is shown in Fig. 2.

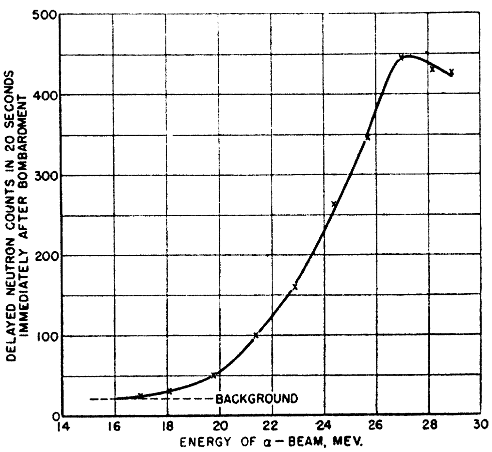

FIG. 2. Relative excitation function of $C^{14}(\alpha, p)N^{17}$.

The threshold of the reaction, based on data from Alvarez's work,[3] should be 12.4 Mev. It was not possible for us to determine this threshold experimentally because of the slow increase in the yield due to the potential barrier for the outgoing protons, and because of the presence of a moderate neutron background. The decrease in yield after 27 Mev is probably due to the competing reaction $C^{14}(\alpha, 3n)O^{16}$ which sets in at an alpha-threshold of about 27.6 Mev. The cross section of the $C^{14}(\alpha, p)N^{17}$ for 27-Mev alpha-particles was estimated to be about 6×10^{-26} cm^2.

* Assisted by the joint program of the ONR and AEC.

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Nuclear Magnetic Moments and Similarity between Neutron and Proton States in the Nucleus*

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THE single particle model of nuclear moments assumes that all nucleons except the last odd particle are paired and that the spin and magnetic moment are due to this particle only. Actual nuclei have magnetic moments lying between the Schmidt limits given by the extreme single particle model, but usually near enough to one limit so that the state of the odd particle can be assigned.

It is well known that for light atoms the nth proton usually occupies the same angular momentum state in the nucleus as the nth neutron. In fact, the spin of the nucleus having n odd protons (and an even number of neutrons) is the same as that of the nucleus with n odd neutrons in every case up to $n=41$ with the sole exception of the O^{17}, F^{19} pair.[1] The values of the magnetic moments of the odd proton and odd neutron nuclei indicate a still closer similarity between neutron and proton wave functions. If the deviation from the Schmidt limits is caused by an admixture of the two states with the same I ($I=l+\frac{1}{2}$, $I=l-\frac{1}{2}$) and if the proton and neutron wave functions are very similar, the mixture should be the same for the two cases. Then, the moments may be expected to lie at the same fractional distance between the appropriate $I=l+\frac{1}{2}$ and $I=l-\frac{1}{2}$ Schmidt limits. Thus, if the value of the moment of a certain odd proton nucleus places it 10 percent of the distance from its $l+\frac{1}{2}$ limit, the corresponding odd neutron nucleus will have a moment lying about 10 percent of the distance from its $l+\frac{1}{2}$ limit to the $l-\frac{1}{2}$ limit. Some other[2] explanations of deviations from the Schmidt limits should give essentially the same behavior as long as neutron and proton wave functions are very similar.

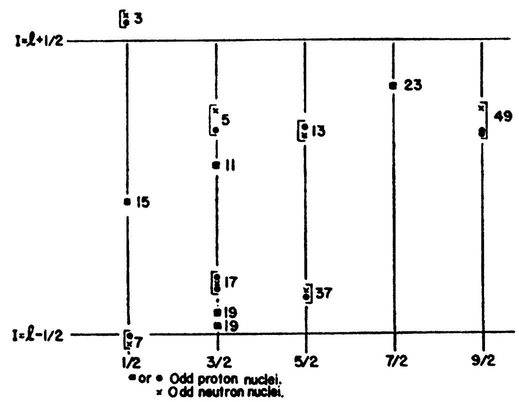

FIG. 1. Comparison of magnetic moments of odd-proton and odd-neutron nuclei. The upper line represents the Schmidt limit $I=l+\frac{1}{2}$ for either neutrons or protons, and the lower line the Schmidt limit for $I=l-\frac{1}{2}$. Ordinate for a nucleus of spin I and magnetic moment μ is $(\mu-\mu_{l-\frac{1}{2}})(\mu_{l+\frac{1}{2}}-\mu_{l-\frac{1}{2}})$, where $\mu_{l+\frac{1}{2}}$ and $\mu_{l-\frac{1}{2}}$ are the magnetic moments for the two Schmidt limits and for the appropriate spin I. Ordinates are therefore the fractional distance from the $I=l-\frac{1}{2}$ Schmidt limit. Numbers beside points are the number of odd particles in the nuclei. Cases with equal numbers of odd protons or odd neutrons are bracketed.

Figure 1 shows the extent of agreement with these expectations. The upper horizontal line represents the Schmidt limit for the magnetic moment of an odd proton or odd neutron nucleus for $I=l+\frac{1}{2}$, and the lower one for $I=l-\frac{1}{2}$. The ordinate is the fractional distance from the $l-\frac{1}{2}$ Schmidt limit. It may be seen that odd neutron and odd proton nuclei of a given number of odd particles fall very close together on this diagram, as expected, indicating a close similarity of wave functions. The worst deviations are for $n=5$, which corresponds to Be^9 and B^{11} and hence to a rather large fractional difference in nuclear size, and for $n=49$,

TABLE I. Predicted nuclear magnetic moments. Nuclear spins which have not been definitely established are in parentheses.

Number of odd particles	Odd-proton nuclei Element	Spin	μ observed (nuclear magnetons)	Odd-neutron nuclei Element	Spin	μ predicted (nuclear magnetons)
11	$_{11}Na^{23}$	3/2	+2.21711	$_{10}Ne^{21}$	3/2	−0.60
15	$_{15}P^{31}$	1/2	+1.13165	$_{14}Si^{29}$	(1/2)	−0.53
19	$_{19}K^{39}$	3/2	+0.391	$_{16}S^{35}$	3/2	+1.00
	$_{19}K^{41}$	3/2	+0.215			
23	$_{23}V^{51}$	7/2	+5.1478	$_{20}Ca^{43}$	(7/2)	−1.38
25	$_{25}Mn^{55}$	5/2	+3.4681	$_{22}Ti^{47}$	(5/2)	−1.79
27	$_{27}Co^{59}$	7/2	+4.6484	$_{22}Ti^{49}$	(7/2)	−0.96
29	$_{29}Cu^{63}$	3/2	+2.22617	$_{24}Cr^{53}$	(3/2)	−0.67
	$_{29}Cu^{65}$	3/2	+2.3845			
31	$_{31}Ga^{69}$	3/2	+2.0167	$_{26}Fe^{57}$	(3/2)	−0.66
	$_{31}Ga^{71}$	3/2	+2.5614			
33	$_{33}As^{75}$	3/2	+1.4	$_{28}Ni^{61}$	(3/2)	+0.10
41	$_{41}Cb^{93}$	9/2	+6.1659	$_{32}Ge^{73}$	9/2	−1.39
51	$_{51}Sl^{121}$	5/2	+3.7	$_{40}Zr^{91}$	5/2	−0.99

where coulomb forces probably are of importance. Other points in Fig. 1 represent odd proton nuclei for which the corresponding odd neutron nuclei have not yet been measured. The moments of these odd neutron nuclei may then be predicted with some assurance to lie near those for the corresponding odd proton nuclei.

On this basis predictions of magnetic moments of odd neutron nuclei are given in Table I. Judging from the deviations in Fig. 1, the accuracy of these predictions should be approximately ±0.1 nuclear magneton.

All nuclear moments used in Fig. 1 and Table I are taken from Mack's review article,[3] except S^{33} and Mg^{25} which are from more recent publications.[4,5]

Considerations of this general type are probably not new, but it seems worthwhile to examine the agreement with experiment now that some odd neutron nuclei moments are being measured. The predicted values may be of use in searching for unknown moments by the nuclear induction method.

* Work supported by the AEC.

[1] The O^{17} spin is 5/2 according to F. Alder and F. C. Yu, Phys. Rev. 81, 1066 (1951). A spin of 5/2 is also indicated by recent work at Columbia University.

[2] A. Bohr, Phys. Rev. 81, 134 (1951).

[3] J. E. Mack, Revs. Modern Phys. 22, 64 (1950).

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[5] We are grateful to F. Alder and F. C. Yu for communicating their value of the Mg^{5} moment to us before publication. This value is consistent with, but more precise than, the spectroscopic value quoted by Mack.

The Magnetization Process in Ferrites

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It is known how the initial permeability μ_0 of ferrites[1] changes with frequency:[2] μ_0 is constant at relatively low frequencies and drops to very low values in a frequency range where resonance phenomena take place. Snoek ascribes this drop to the resonance of the magnetic spins caused by the rf magnetic field in the constant internal anisotropy fields. A close relationship between the value of this resonance frequency and the expected strength of the internal anisotropy fields, as deduced from the value of the initial permeability, has been well proven.[3] In Snoek's theory, it is assumed that the magnetization of ferrites in a small external field is caused by the simultaneous rotation of the electron spins, and not by the reversible Bloch-wall displacements, which are believed to be the cause of the magnetization of ferromagnetic metals in small fields.[4] Therefore, we wish to draw attention to some experiments we performed which shed some light on the magnetization process of ferrites, also at higher inductions.

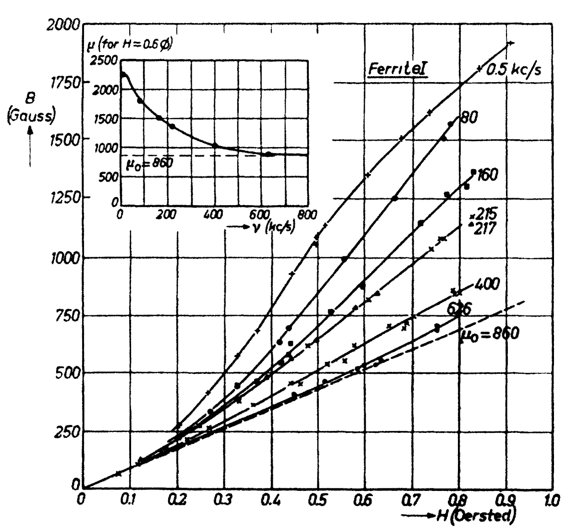

Fig. 1. Initial magnetization curve of ferrite I as a function of frequency.

Table I. Composition of ferrites.

Ferrite No.	Composition in mol. % (balance Fe_2O_3) MnO	NiO	ZnO	Density	Gyromagnetic resonance frequency* in Mc/sec
I	43.5	—		4.70	1
IIA	—	25	25	4.55	14
IIB	—	27	23	5.21	10

* The frequency for which μ'' has a maximum ($\mu_0 = \mu' - j\mu''$).

The initial magnetization curve of some ferrites has been measured as a function of frequency by applying a sinusoidal magnetic field of amplitude H_{max} to a toroidal ferrite core with a rectangular cross section. The maximum of the nonsinusoidal induction B_{max} in the core has been determined from the emf induced in a second winding on the core and rectified by a Gratz circuit. Precautions were taken to avoid partial short-circuiting of the primary and the secondary of the transformer.

For the manganese-ferrous-ferrite I (see Table I), Fig. 1 shows the behavior of the initial magnetization curve as a function of frequency. All ferrites with a high permeability have similar frequency-dependent magnetization curves. From Fig. 1 it is clear that here we have two different magnetization processes. The first, which is independent of frequency below the gyromagnetic resonance frequency, determines μ_0, while for field strengths approximately equal to the coercive force the other gives an additional magnetization which already disappears for a frequency below the gyromagnetic resonance frequency of the ferrite (see the straight line $B = \mu_0 H$ for the magnetization curve of ferrite I at 626 kc/sec). The frequency-dependence of the latter process can be described with a single relaxation time.

Another fact seems to give an indication of the kind of magnetization process involved. When two ferrites of about the same composition (IIA and IIB, see Table I) are fired at 1200°C and 1400°C, respectively, the magnetization curves are very different

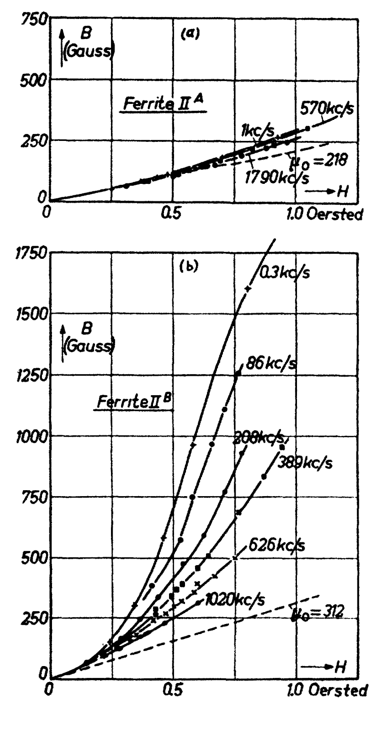

Fig. 2. Initial magnetization curves of ferrites IIA and IIB as functions of frequency.