to calculate the equilibrium temperature. They are all consistently lower than the 5 Mev needed to fit the curve for the lighter elements as a whole. There are two alternative interpretations of this: (a) the less abundant isotopes were actually formed later when the temperature had dropped below the initial 5 Mev, (b) the lower temperature is fictitious, the abundances actually departing from equilibrium for some special reason. For example the abundance of O^{17} is markedly lower than would be given by (37) at 5 Mev, and this could be due to the anomalously small binding energy of the extra neutron. While from the present point of view one might equally well assert that the small binding energy is due to an anomalously large (positive) surface energy above that given by (38), this would have the effect of raising the low temperature found in Table I. Just how much of the anomaly is due to the surface energy is simply not known. The opposite anomaly, not shown in the table, occurs with the chlorine isotopes 35 and 37 where the abundance of the heavier isotope is so large that a negative temperature would be needed to fit (35). But here the binding energy of the extra neutron is anomalously high, and one may again suppose that an unknown part of this is accountable as due to anomalously small surface energy in Cl^{37}; if this anomaly is great enough to reverse the sign of the difference $S(35)-S(37)$, formula (35) would yield a reasonable value for T.

The writer is happy to thank Dr. Maria Mayer for her helpful comments on the first draft of this paper.

PHYSICAL REVIEW VOLUME 80, NUMBER 5 DECEMBER 1, 1950

Interaction of Fast Neutrons with Nitrogen*

C. H. JOHNSON AND H. H. BARSCHALL
University of Wisconsin, Madison, Wisconsin
(Received August 1, 1950)

Using neutrons from the $Li^7(p,n)Be^7$ reaction, the cross sections for the reactions $N^{14}(n,p)C^{14}$ and $N^{14}(n,\alpha)B^{11}$ were measured for neutron energies from 150 to 2100 kev. Resonances for the (n,p) reaction were found at 499, 640, 993, and 1415 kev; for the (n,α) reaction at 1415 and 1800 kev. Information was obtained about the excited state of Be^7. It was found to lie 431 ± 5 kev above the ground state, and probabilities for its formation in the $Li(p,n)$ reaction were determined.

I. INTRODUCTION

PRELIMINARY results on the variation with energy of the cross section for the disintegration of nitrogen by fast neutrons were reported previously.[1] More careful measurements of this cross section appeared to be desirable for the following reasons: (1) measurements of the cross section of the $C^{14}(p,n)N^{14}$ reaction show a discrepancy when compared with the cross section of the $N^{14}(n,p)C^{14}$ reaction on the basis of the principle of detailed balancing;[2] (2) an attempt to find the levels in N^{15} which appear in measurements of the $N^{14}(n,p)$ reaction by measuring the total cross section of nitrogen had been unsuccessful;[3] (3) information concerning the recently discovered low energy neutron group from the $Li(p,n)$ reaction[4] might be obtained from such measurements.

II. EXPERIMENTAL PROCEDURE

The procedure followed in the present experiments was very similar to that described previously. Neutrons were produced by bombarding a Li target by protons from the electrostatic generator. The protons had an energy spread of 5 kev; the Li target had a stopping power of 12 kev for 2-Mev protons.

Protons and α-particles from the disintegration of nitrogen were observed in a cylindrical ionization chamber similar to that described by Koontz and Hall.[5] The chamber was filled with nitrogen to a pressure of 10 atmospheres. 5000 volts applied to the chamber gave saturation without gas multiplication. The center of the active volume of the chamber was placed at a distance of 16 cm from the Li target in such a direction that the axis of the chamber made an angle of 30° with respect to the incident protons.

For most of the measurements ionization pulses larger than a predetermined size were counted. In order to select the proper bias for counting the desired pulses, pulse height distributions were taken at neutron energy intervals of about 100 kev by means of a differential discriminator. As a further check on the bias settings, the pulses were presented on a cathode-ray oscilloscope and photographed on moving film. Such photographic records were made at those neutron energies at which, in preliminary experiments, especially interesting features had been observed.

* Work supported by the AEC and the Wisconsin Alumni Research Foundation.
[1] H. H. Barschall and M. E. Battat, Phys. Rev. 70, 245 (1946).
[2] Shoupp, Jennings, and Sun, Phys. Rev. 75, 1 (1949).
[3] Bockelman, Adair, Barschall, and Sala, Phys. Rev. 75, 336 (1949).
[4] Johnson, Laubenstein, and Richards, Phys. Rev. 77, 413 (1950).
[5] P. G. Koontz and T. A. Hall, Rev. Sci. Inst. 18, 643 (1947).

The neutron flux incident upon the nitrogen-filled chamber was measured by means of a "long counter",[6] the detecting efficiency of which depends very little on neutron energy. The efficiency of this counter was determined by placing a calibrated Ra—Be source at the position normally occupied by the Li target.

In Fig. 1 some typical pulse-height distribution curves are presented. Each curve shows a rapid rise at low ionization energies because of the effect of γ-rays and nitrogen recoils. Peaks in the pulse height distribution will be produced by the $N(n,p)C$ reaction and by the $N(n,\alpha)B$ reaction. Above a neutron energy of 610 kev for the main group of neutrons from the $Li^7(p,n)Be^7$ reaction, lower energy maxima in the pulse height distribution for both nitrogen reactions may be produced by neutrons from the $Li^7(p,n)Be^{7*}$ reaction, where the Be^7 nucleus is left in an excited state at about 430 kev.[7] The energies for which distributions are given in Fig. 1 were chosen to show examples of the various observed combinations of particle groups. It may be noted that the peak at the largest pulse height becomes less sharp as the neutron energy is increased. This effect arises from the fact that at the higher energies the range of the disintegration protons becomes comparable with the radius of the counter. Other factors which will contribute to a broadening of the peaks are amplifier noise, effects of the radial position of the ionization event, channel width, and neutron energy spread; however, in the present experiment it is only of importance that the peaks in the distribution curves be resolved.

In Fig. 2 the pulse heights at the various peaks in the distribution curves are plotted as a function of neutron energy. The peaks are attributed to three processes as indicated. Since the (n,p) and (n,α) pulse heights vary linearly with neutron energy, an extrapolation to zero pulse height should intercept the energy axis at the negative values of the reaction energies, and a check on the assignment of the peaks to the proper reactions may be made from the known Q-values. The intercepts are subject to considerable uncertainty as a result of the broadness of the distribution peaks and the long extrapolation; hence, these measurements are not accurate determinations of the Q-values. Intercepts (times -1) as found from Fig. 2 are 630±50 kev for the (n,p) curve in agreement with the Q-value of 630±6 as measured by Franzen *et al.*,[8] and -260 ± 80 kev for the (n,α) curve in agreement with the Q-value of -240 ± 80 kev determined by Stebler and Huber.[9] Since neither B^{11} nor C^{14} have any known energy levels[10] below 2 Mev and since no distribution peaks corresponding to any such levels were found, these nuclei are presumed to be left in their ground states.

It is of interest that the slope of the (n,α) curve is less than that of the (n,p) curve in Fig. 2. With the approximation that the energy is concentrated on the lighter particle, each slope is proportional to the ratio of the total ionization to the energy of the corresponding particle. According to observations by Jesse and Sadauskis[11] on ionization by α-particles in air, this ratio increases slightly with the velocity of the particle. Since the proton has a much larger velocity than the α-particle, there is a noticeable difference in slope. The difference is in qualitative agreement with the measurements of Jesse and Sadauskis. No significance is attached to the slope and intercept of the center curve in Fig. 2 since the points are not plotted at the energy of the neutrons causing the disintegrations.

By setting the bias between the several peaks formed in the pulse-height distributions, the number of disintegrations of each kind was counted at those energies at which complete distribution curves were not determined. A correction for wall effect was applied according

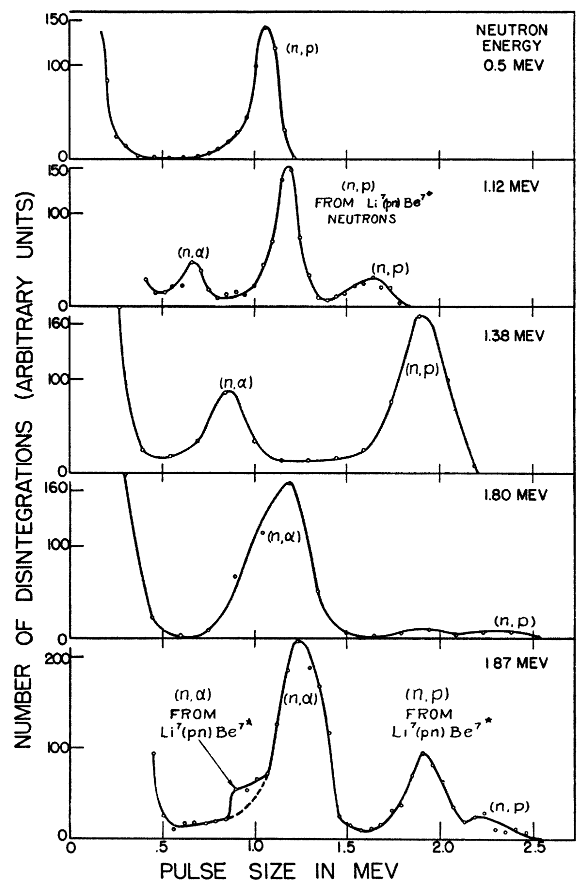

FIG. 1. Pulse-height distributions for disintegrations caused by $Li(p,n)$ neutrons entering the nitrogen-filled ionization chamber are shown for five energies of the main group of neutrons. Peaks are indicated as resulting from the $N(n,p)$ and $N(n,\alpha)$ reactions for both the main group and low energy group of neutrons.

[6] A. O. Hanson and J. L. McKibben, Phys. Rev. **72**, 673 (1947).
[7] T. Lauritsen and R. G. Thomas, Phys. Rev. **78**, 88 (1950).
[8] Franzen, Halpern, and Stephens, Phys. Rev. **77**, 641 (1950).
[9] A. Stebler and P. Huber, Helv. Phys. Acta **21**, 59 (1948).
[10] W. F. Hornyak and T. Lauritsen, Rev. Mod. Phys. **20**, 191 (1948).

[11] W. P. Jesse and J. Sadauskis, Phys. Rev. **78**, 1 (1950).

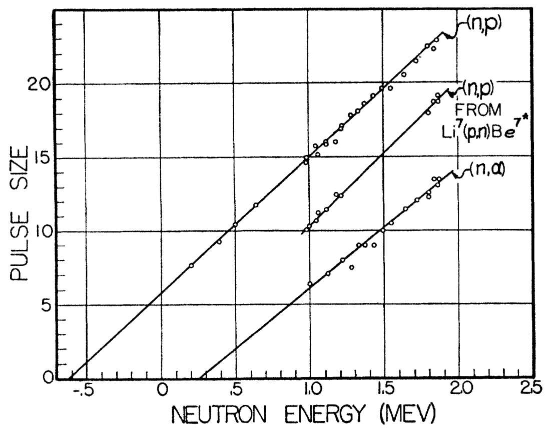

FIG. 2. Pulse heights at the various peaks in the distribution curves are plotted against the energy of the main group of Li(p,n) neutrons. The reactions causing peaks are indicated. Energy intercepts of the two curves which could be extrapolated linearly agree with the Q-values of the assigned reactions.

to the method described by Rossi and Staub.[12] Corrections were applied for both the loss of pulses by the wall effect and the gain of pulses to a low energy group as a result of counting fast particles intercepted by the wall.

III. RESULTS

The lower part of Fig. 3 shows the cross sections for the N(n,p) and the N(n,α) reactions plotted against the energy of the major neutron group in the Li(p,n) reaction. Resonances for the (n,p) reaction appear at neutron energies of 499 ± 5, 640 ± 7, 993 ± 12, and 1415 ± 15 kev; and for the (n,α) reaction at 1415 ± 50 and 1800 ± 15 kev. All the resonances are appreciably wider than the experimental neutron energy spread of about 15 kev. The height of the symbols used is equal to, or larger than, the statistical accuracy of the measurements. For the (n,α) reaction, the statistical accuracy is less than for the (n,p) reaction because the proton count has to be subtracted from the total count. Figure 3 includes results obtained both from direct counting and from the photographic records.

When the energy of the bombarding protons is such that the lower energy neutron group from the Li(p,n) reaction has an energy corresponding to a resonance in the nitrogen reactions whereas the main group has an energy corresponding to a low cross section, the effect of the neutrons of lower energy becomes particularly noticeable. In the upper part of Fig. 3 the number of disintegration protons produced by the low energy neutron group is plotted using as ordinate the apparent cross section calculated as if all the monitor counts were due to this group. The curves are plotted directly above the energy of the major neutron group at which data were taken, and at each resonance the actual energy of neutrons causing resonance is indicated as obtained from the corresponding resonance in the lower part of the figure.

In Table I the positions of the resonances expressed in terms of neutron energies are compared with values observed by others for the same reactions and for the inverse (p,n) and (α,n) reactions. Agreement within experimental error exists for all resonances that were prominent in every experiment. The resonance energy determined from the B(α,n) reaction[13] was found only to two significant figures and the corresponding Q-value used in Table I has an 80-kev uncertainty; hence, the resonance energy of 1700 kev is considered to agree within experimental error with the 1800-kev level. Preliminary measurements,[1] which were obtained without the large electrostatic analyzer available for the present work, show an energy shift of 50 kev compared to the values reported here; this shift is presumably caused by an error in the energy calibration of the accelerator in the earlier work.

As is shown in Table I, the small peak at 993 kev has not been observed by others, and three resonances observed in the inverse (p,n) reaction were not found in the present measurements. Of these three, one at 800 kev was reported to be doubtful and another one at 1540 kev may correspond to a small variation in cross section at 1610 kev in Fig. 3. A resonance corresponding to the one in the (n,α) reaction at 1415 kev was not observed in the B(α,n) reaction; failure to observe this small resonance might be expected since the spread in energy of the alpha-particles was about five times the observed level width.

The previously reported cross sections, which were obtained with a fission monitor, show agreement at the resonances with the present measurements prior to correction for wall effect except for the narrow 499-kev resonance. For this resonance the previously reported cross section was about 25 percent low, presumably because the neutron energy spread was comparable with the resonance width. The increased cross section reported here for this level does not remove the discrepancy mentioned in the introduction concerning the comparison with the inverse (p,n) reaction on the basis of the principle of detailed balance. Since the neutron energy spread used here was about half the width of the level, the observed cross section should be nearly the true value, whereas a value at least four times as large is required to secure agreement with the cross section reported for the inverse reaction. Part of this discrepancy might be resolved if the C(p,n) reaction has a relatively high yield of neutrons in the forward direction in the center of mass system since the cross section for the C(p,n) reaction was found by counting neutrons in the forward direction and assuming an isotropic center of mass distribution.

An exact comparison of the N(n,α) and B(α,n) cross sections on the principle of detailed balancing was not

[12] B. B. Rossi and H. H. Staub, *Ionization Chambers and Counters* (McGraw-Hill Book Company, Inc., New York), p. 236.

[13] R. L. Walker, Phys. Rev. **76**, 244 (1949).

possible since the energy resolution used in the two experiments was quite different. A check was obtained by assuming that the 1800-kev resonance may be fairly well represented as a Gaussian curve having the width of the observed peak and by assuming that the energy spectrum of the α-particles used by Walker was a Gaussian distribution with a 400-kev width. Using these approximations and using the principle of detailed balancing (which indicates $\sigma_{n,\alpha}=1.8\sigma_{\alpha,n}$ for this level), one finds the experimentally observed $B(\alpha,n)$ cross section at resonance should be 28 millibarns in order to be consistent with the present measurements. This value for the cross section is in agreement with the curves reported by Walker.

The energy of the excited state in Be^7 was found from the proton bombarding energies at a resonance and at the second appearance of the resonance caused by the low energy neutron group. Systematic errors in this measurement, such as might be introduced by the finite target thickness or improper alignment of the chamber, have little effect since the calculation depends mostly on the difference in proton energies. Energy values obtained from the 499- and 640-kev resonances differ by 2 kev and average 431 ± 5 kev for the excited state in Be^7. A determination using the 1415-kev resonance was less accurate, but the results are consistent within experimental error. Comparison with other work is given in the second column of Table II.

The intensity of the second neutron group relative to the main group was found from the ratio of the apparent cross section to the actual cross section at each resonance. In Table II the resulting intensities are shown with the corresponding proton energies and angles of observation for the present as well as other experiments.

Neutrons resulting from other Be^7 levels at 205 and 745 kev have been reported to be present to 58.5 and 32 percent of the main group when 5-Mev protons were used.[14] The present measurements give an upper limit for the intensity of the first one of these groups for the proton energies used here. In the regions of low (n,p) cross section, bias settings were low enough to detect neutrons of energies corresponding to preceding resonances so that any other neutron group could be detected just as the group already discussed. From such measurements the upper limit for the intensity of other groups corresponding to excited states in Be^7 between 100 and 680 kev was determined to be two percent of the major neutron group for proton energies from 2.53 to 3.03 Mev and three percent for proton energies from 3.3 to 3.91 Mev. For excited states between 810 to 1100 kev, a limit of five percent was determined for proton energies from 3.3 to 3.48 Mev. Measurements were not possible for the intermediate range of excited states between 680 and 810 kev because of the presence of the 1.4 Mev resonance for the main group of neutrons.

The nitrogen cross sections shown in the lower part of Fig. 3 have been corrected for the effect of the second neutron group on the monitor count using the three observed intensities reported in Table II. No correction

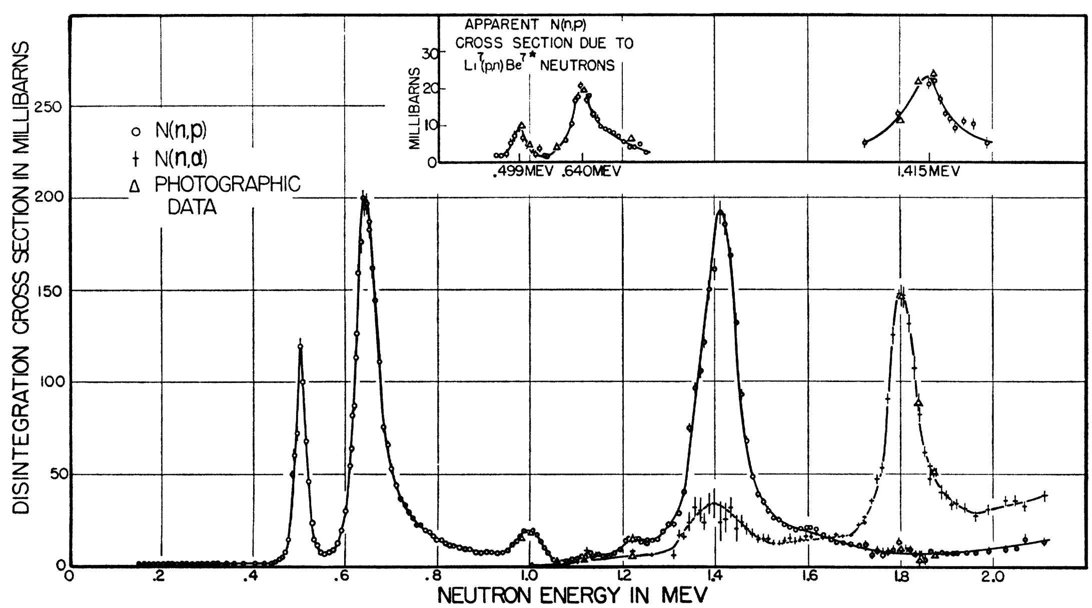

FIG. 3. In the lower part of the figure the $N(n,p)$ and $N(n,\alpha)$ cross sections are plotted against the energy of the major group of $Li(p,n)$ neutrons. On all curves triangles are used for photographic data, which were obtained by photographing the pulses presented on a cathode ray oscilloscope. The apparent cross section resulting from the low energy neutron group is plotted in the upper part of the figure directly above the energy of the major group at which data were taken, and the actual neutron energies causing resonances are indicated.

[14] J. C. Grosskreutz and K. B. Mather, Phys. Rev. 77, 580 (1950).

TABLE I. Positions of (n,p) and (n,α) resonances[a] in nitrogen expressed in terms of neutron energies in kev.

Shoupp, *et al.*[b] (n,p)[c] calculated from $C^{14}(p,n)N^{14}$	This paper (n,p)	This paper (n,α)	A. Stebler and P. Huber[d] (n,p)	A. Stebler and P. Huber[d] (n,α)	R. L. Walker[e] (n,α)[c] calculated from $B^{11}(\alpha,n)N^{14}$
470±20	499±5		480±50		
630±20	640±7		640±40		
(800±50)					
	(993±12)				
1380±20	1415±15	1415±50	1410±90	1410±90	
1540±50					
		1800±15	1770±110	1770±110	1700
1980±50					

[a] Resonances observed weakly in this work or reported as doubtful by others are indicated by parentheses.
[b] See reference 2.
[c] Q-values used for the conversion to neutron energies were $Q_{np}=625$ kev and $Q_{n\alpha}=-260$ kev.
[d] See reference 9.
[e] See reference 13.

TABLE II. Energy of excited state in Be^7 and intensity of neutrons arising from this state in the $Li(p,n)$ reaction.

Reference	Excited state (kev)	Reaction	Proton energy (Mev)	Angle of observation	Intensity in % relative to main neutron group
This paper	431±5	$Li(p,n)$	2.75	30°	9±1.5
			2.89	30°	10.5±1
			3.66	30°	12±1
a	470±70	$Li(p,n)$	5.0	20° and 90°	52.5
b	435±15	$Li(p,n)$	3.31	0°	17±10
			3.91	0°	9±4
			3.91	60°	16±6
c	428±20	$Li(p,n)$	3.12	0°	8±2
			2.70	0°	8±2
d	428±15	$Li(p,n)$	3.49	0°	11±3
e	434±5	$B(p,\alpha)$			
f	429±5	$Be^{7*}\rightarrow Be^7+\gamma$			

[a] See reference 14.
[b] See reference 4.
[c] B. Hammermesh and V. Hummel, Phys. Rev. 78, 73 (1950).
[d] Freier, Rosen, and Stratton, Phys. Rev. 79, 239 (1950).
[e] Brown, Chao, Fowler, and Lauritsen, Phys. Rev. 78, 88 (1950).
[f] See reference 7.

was applied below 900 kev, and above this energy the intensity was assumed to vary smoothly.

IV. DISCUSSION

A nuclear reaction may be described as a transition occurring through an intermediate compound nucleus. In the present experiment the neutron combines with the N^{14} nucleus to form an excited state of N^{15} which subsequently disintegrates with the emission of a proton, an α-particle, or a neutron. Inelastic scattering is assumed not to occur with the neutron energies used here because the lowest known excited state in N^{14} is 2.3 Mev above the ground state.[15] Radiative capture will be neglected since radiation widths are usually of the order of 10^{-3} times the neutron widths for light nuclei.[16]

When the incident neutron has an energy corresponding to an energy level in N^{15}, a resonance is expected in the cross section for each reaction. Isolated resonances in the (n,p) and (n,α) cross sections can be described by the single-level Breit-Wigner formula, which becomes at resonance:

$$\sigma_{np}+\sigma_{n\alpha}=\frac{2J+1}{6}\frac{4\pi}{k^2}\frac{\Gamma_n(\Gamma_p+\Gamma_\alpha)}{(\Gamma_n+\Gamma_p+\Gamma_\alpha)^2}, \tag{1}$$

where J is the spin of the compound nucleus; k is the neutron wave number; and Γ_n, Γ_p, and Γ_α are the neutron, proton, and α-particle widths. A particle-width, which is a measure of the probability for the emission of the particle from the compound nucleus, may be resolved into various contributing factors according to the relation;[16]

$$\Gamma_s=2\gamma_s^2 k_s T_{ls}, \tag{2}$$

where s refers to the particle considered; k is its wave number; T_l is the Coulomb and centrifugal barrier penetration factor for a particle with orbital angular momentum l; and γ_s^2 is called the reduced width. For a given nucleus reduced widths are not expected to differ greatly for the various particles and for levels having a given spacing; however, the effect of the wave number and penetration factor may be such that Γ_s differs appreciably between particles and between levels. This effect will cause variations in the heights and widths of resonances. A resonance observed in one process may not even be observable in another.

Any discussion of possible quantum numbers associated with the (n,p) and (n,α) resonances must be consistent with the neutron scattering cross section. For a given (n,p) and (n,α) cross section at resonance, Eq. (1) yields two solutions for the ratio of Γ_n to $\Gamma_p+\Gamma_\alpha$, of which one solution is the reciprocal of the other. If the neutron width is the larger, a resonance in total cross section should be observable and the value of J may be established. If the neutron width is the smaller, the total cross section should be approximately the reaction cross section and thus a resonance may not be observable in a transmission experiment.

At the present time measurements of the total cross section are of a preliminary nature and extend only to 900 kev.[3] These measurements indicate no resonance at 499 kev, whereas, if $\Gamma_n>\Gamma_p$, the magnitude of the (n,p) cross section leads one to expect a resonance of at least 1.7 barns. It is concluded, therefore, that $\Gamma_n<\Gamma_p$ for the 499-kev resonance. A resonance in the total cross section corresponding to the one at 640 kev in the (n,p) reaction was observed which has a maximum at 660 kev preceded by a minimum at 620 kev. The presence of a minimum indicates that the resonance is produced by s-neutrons. The difference in cross section observed between the minimum and maximum was about 1 barn. According to the Breit-Wigner formula using values of Γ_n/Γ_p obtained from the observed height of the (n,p) resonance, this difference should be 1.3 barns for $J=\frac{1}{2}$

[15] Lauritsen, Hornyak, Morrison, and Fowler, Rev. Mod. Phys. 22, 291 (1950).
[16] E. P. Wigner, Am. J. Phys. 17, 99 (1949).

and 2.9 barns for $J=\frac{3}{2}$. Thus, these preliminary scattering measurements are consistent only with $J=\frac{1}{2}$ for the 640-kev level.

An attempt was made to fit the observed resonance cross sections using the Breit-Wigner theory with reasonable reduced widths. In particular, it appeared to be of interest to try to account for the fact that at 499 kev no resonance scattering of neutrons was observed, and at 1800 kev no resonance in the proton emission was found. For these calculations reasonable limits for the reduced widths were taken to be in the range between 0.05 and 5×10^{-13} Mev-cm. Values thus far observed[16,17] for neutrons and protons lie well within these limits for nuclei with atomic number and level spacing comparable to that of N^{15}. It must be emphasized, however, that no strict limits can be assigned except that a reduced width cannot exceed $3\hbar^2/2ma$, where m is the mass of the particle and a is the radius of the compound nucleus.[16]

In the consideration of each resonance, particle widths were found from Eq. (1) for each possible value of J using the observed total width and the cross section at resonance, and reduced widths were found from Eq. (2) for l-values appropriate to each J. For a given J both the lowest possible even l-value and the lowest possible odd l-value are considered in order to include states of both parities; contributions to the cross section from higher l-values are negligible because of the higher centrifugal barrier. Nuclear spins of N^{14}, C^{14}, and B^{11} are 1, 0, and $\frac{3}{2}$, respectively, so that l-values considered are $J-\frac{3}{2}$ and $J-\frac{1}{2}$ for the neutron and α-particle (excepting $J=\frac{1}{2}$) and $J\pm\frac{1}{2}$ for the proton. Thus, except for $J=\frac{1}{2}$, the proton must have l-values equal to or larger than those of the neutron and α-particle. Penetration factors used in the calculation may be found explicitly for neutrons[18] and have been calculated for protons by Christy and Latter.[19] The factor for the α-particles was obtained by the WKB method using as the radius of nuclear interaction a value (5.35×10^{-13} cm) which is consistent with that assumed by Christy and Latter to obtain the proton penetration factor.

[17] C. K. Bockelman, (to be published).
[18] Feshbach, Peaslee, and Weisskopf, Phys. Rev. **71**, 145 (1947).
[19] R. F. Christy and R. Latter, Rev. Mod. Phys. **20**, 185 (1948).

TABLE III. Examples of quantum numbers for which reasonable reduced widths are found for the observed resonances in nitrogen.

Energy (kev)	$\Gamma_n/(\Gamma_p+\Gamma_\alpha)$	Quantum numbers J	l_p	l_n	l_α	Reduced widths (in 10^{-13} Mev-cm) γ_p^2	γ_n^2	γ_α^2
499	<1	1/2	0	1		0.2	0.03	
	<1	5/2	2	2		6.9	0.3	
640	>1	1/2	0	0		0.055	0.15	
	>1	1/2	1	0		0.17	0.15	
993	<1	5/2	2	2		4.8	0.052	
	>1	5/2	3	1		0.4	0.55	
1415	<1	3/2	1	1	0	0.43	0.1	1.2
	>1	3/2	1	1	0	0.1	0.4	0.28
1800	<1	5/2	3	2	1	0.8	0.16	1.9
	>1	5/2	3	1	1	0.08	0.25	0.18
	>1	5/2	3	1	2	0.08	0.25	1.0

Examples are given in Table III indicating that combinations of quantum numbers can be found which give fairly reasonable reduced widths for all resonances. No definite assignment of quantum numbers is possible from this analysis except perhaps for the 640-kev level. Both s- and p-protons are considered for this level in order to allow for both parities of C^{14} and N^{14}. For the resonances beyond the region where the total cross section has been measured, examples are given for both large and small $\Gamma_n/(\Gamma_p+\Gamma_\alpha)$. While no peak in the (n,p) cross section is shown at 1800 kev in Fig. 3, a cross section of 5 millibarns (as used for computations in Table III) is consistent with the observations. Table III indicates that the measurements beyond 900 kev may be fitted whether a resonance in scattering is observable or not.

It is of interest that the resonance shown in Fig. 3 at 640 kev does not have the symmetric character predicted by the single-level Breit-Wigner formula. The asymmetry cannot be explained as caused by a variation in wave number and barrier factors since these variations are very small. Such an asymmetry may be caused by an interference with an adjacent level, but the exact reason for it is not understood.

One of us (CHJ) wishes to express his gratitude to the Kimberly Clark Paper Company for the grant of a fellowship.