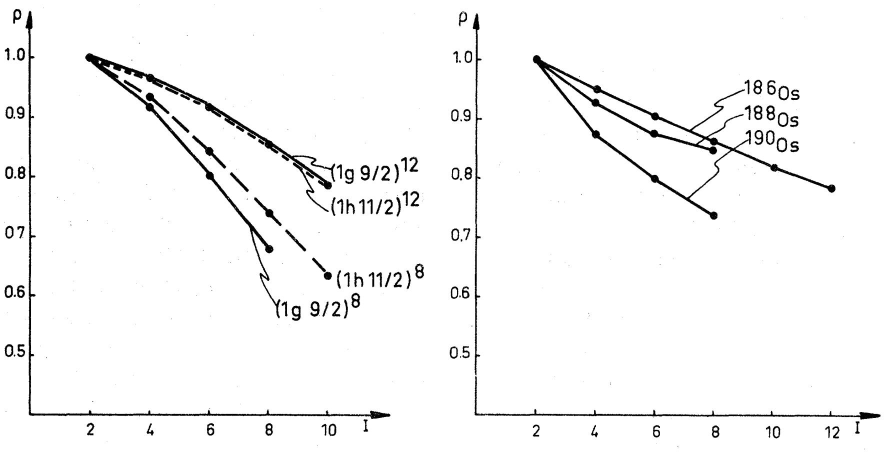

$$\rho_I = \frac{E_I / I(I+1)}{E_2 / 6}$$

FIG. 2. Departures from a purely rotational spectrum. Left part, stretch; right part, experiments. The theoretical and experimental curves are qualitatively very similar, in spite of the restriction to a single configuration in the calculation.

projected aligned-scheme wave functions, and stretch wave functions built up with holes correspond to positive intrinsic deformations while those built up with particles correspond to negative intrinsic deformations. Therefore we have used the experimental data of hole nuclei in Fig. 2.

The intrinsic excitations, i.e., those states which result from breaking a single chain, are not unique for a given total angular momentum I. A description of the intrinsic excited states thus requires a treatment of the configuration mixing between these excitations. The calculations for this case have not yet been completed.

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MASSES OF N^{12}, Al^{24}, P^{28}, Cl^{32}, AND Sc^{40}

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The masses of N^{12}, Al^{24}, P^{28}, Cl^{32}, and Sc^{40} have been determined by measuring the threshold energies for the reaction $C^{12}(p,n)N^{12}$, $Mg^{24}(p,n)Al^{24}$, $Si^{28}(p,n)P^{28}$, $S^{32}(p,n)Cl^{32}$, and $Ca^{40}(p,n)Sc^{40}$.

Protons from the Yale model MP tandem Van de Graaff accelerator were momemtum analyzed by a 90° double-focusing magnet with a nominal radius of curvature of 52 in. The beam trajectories in the magnet were limited by entrance and exit slits each set with a total separation of 0.030 in. Under these conditions the energy spread in the beam was $\leq 0.03\%$ [as measured at the $Li^7(p,n)Be^7$ threshold] and the energy stability over a two-hour interval was ≤ 200 eV (as measured at a proton energy of 6 MeV).

The analyzing magnet was calibrated[1,2] using various charge states of O^{16} in the reaction $D(O^{16},n)F^{17}$ and the well-known (p,n) thresholds for targets of Li^7, Cu^{65}, C^{13}, F^{19}, Al^{27}, Ni^{60}, Fe^{54}, and Ni^{58}. Neutrons above the Li^7, Cu^{65}, C^{13}, F^{19}, Al^{27}, and Ni^{60} (p,n) thresholds and the $D(O^{16},n)F^{17}$ thresholds were detected with either a BF_3 long counter or an NE-401[3] plastic scintillator. For all the other threshold measurements the beam was interupted by a rotating graphite chopper located just beyond the image slits of the analyzing magnet, and delayed positrons were counted during the beam-off part of the cycle using an NE-102 plastic scintillator 3 in. long and 2 in. in diameter. The chopper was driven at 1800 rpm so that the beam-on and beam-off parts of the cycle were each approximately 8 msec long. During the beam-on portion of the cycle the proton beam was stopped in a graphite slab placed immediately behind the target. Backgrounds were reduced by setting a discriminator so that only positrons with energies greater than 5 MeV were counted. Timing and scaler gating signals were derived from a photodiode activated by a light beam which was also intercepted by the mechanical chopper.

Results of the analyzing magnet calibration measurements are shown in Fig. 1 where K is the magnet constant defined by

$$K = (ME/Q^2f^2)(1+E/2Mc^2),$$

where M, E, and Q are the mass (in unified nuclidic mass units), the energy (in keV), and the charge (in units of the electron charge) of the incident particle; and f is the nmr frequency (in MHz) of the proton sample in the field of the analyzing magnet. A comparison of the $D(O^{16},n)F^{17}$ threshold measurements for the 2^+, 3^+, 4^+, and 5^+ charge states of O^{16} indicates that K is a constant in the proton nmr frequency range from 14 to 36 MHz. By averaging the magnet constants obtained from the F^{19}, Al^{27}, Fe^{54}, and Ni^{58} (p,n) thresholds with the average $D(O^{16},n)F^{17}$ calibration, a value $K = 44.230 \pm 0.020$ keV u/MHz^2 was obtained. The $Ni^{60}(p,n)Cu^{60}$ calibration point was excluded from the average because of the relatively large uncertainty in previous threshold energy measurements. At lower frequencies, the Li^7, Cu^{65}, and C^{13} (p,n) thresholds indicate that the calibration is no longer constant but increases with decreasing flux density.

The results of the C^{12}, Mg^{24}, Si^{28}, and Ca^{40} (p,n) threshold measurements are presented in Fig. 2, which shows for each reaction both the positron yield and the $\frac{2}{3}$ power of the net positron yield, assuming a background contribution independent of the incident proton energy. Results are summarized below and in Table I, which also presents a summary of previous measurements, and the mass excesses as given in contemporary mass tables,[4] and as predicted by mass formulas of Goldanskii[5] and of Garvey and Kelson.[6]

$\underline{N^{12}}$.–The graphite beam-stop was used as a target for these measurements which indicated

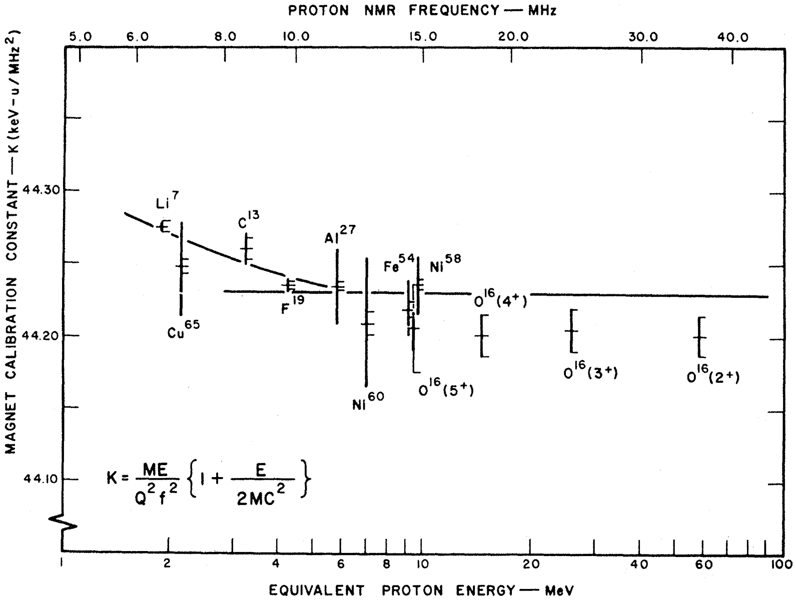

FIG. 1. The calibration constant in (keV u/MHz^2) as a function of equivalent proton energy in MeV for the Yale MP 90° analyzing magnet. The heavy vertical bars are derived from uncertainties in previously measured threshold energies, while the short horizontal error bars indicate the uncertainties in the present measurements.

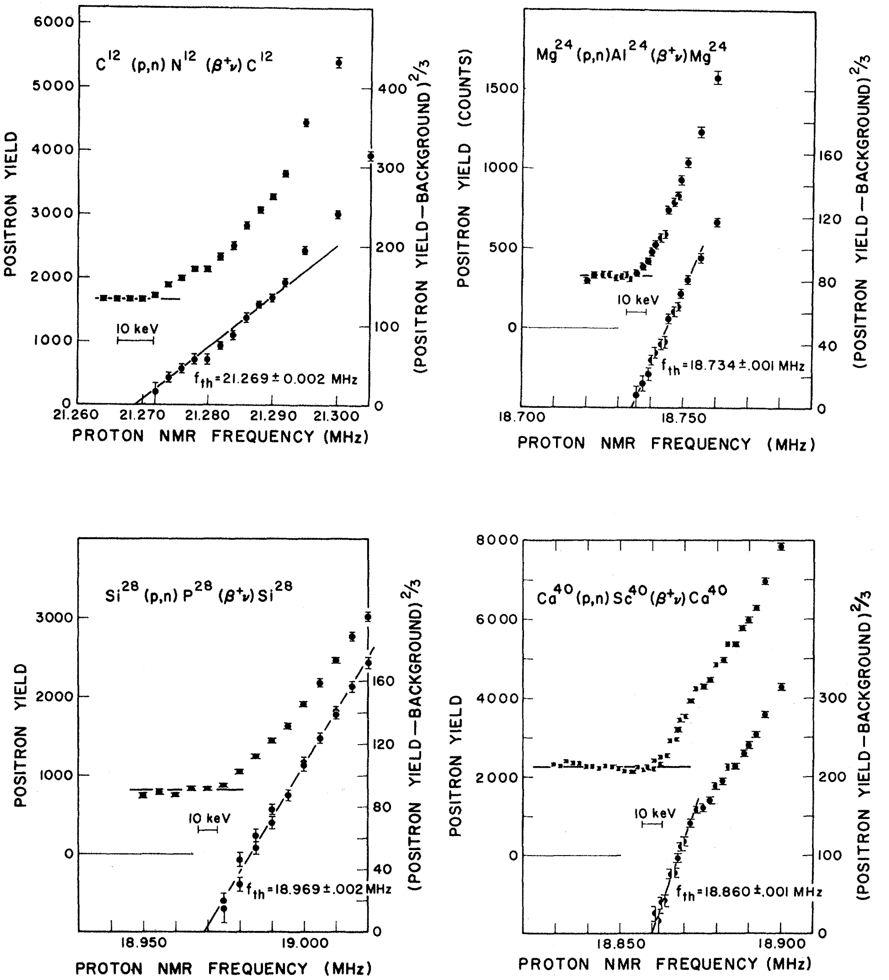

FIG. 2. Data from the threshold measurements for the reactions $C^{12}(p,n)N^{12}$, $Mg^{24}(p,n)Al^{24}$, $Si^{28}(p,n)P^{28}$, and $Ca^{40}(p,n)Sc^{40}$ as observed by detecting the delayed positrons. For discussions of the specific reactions see the text.

a $C^{12}(p,n)N^{12}$ threshold energy of 19.658 ± 0.010 MeV ($Q = -18.122 \pm 0.009$ MeV) for a N^{12} mass excess of 17.340 ± 0.009 MeV. This is in good agreement with the value of 17.351 ± 0.009 MeV obtained by Kavanagh[7] from the reaction $B^{10}(He^3, n)N^{12}$ and the mean value of 17.349 ± 0.008 MeV quoted by Lauritsen and Ajzenberg-Selove.[8]

$\underline{Al^{24}}$.—These measurements utilized a rolled foil target of 99% Mg^{24} approximately 0.75 mg/cm² thick. The threshold was observed at 15.286 ± 0.007 MeV ($Q = -14.665 \pm 0.007$ MeV) for an Al^{24} mass excess of −0.051 ± 0.007 MeV. Using the Mg^{24}, Na^{24}, and Ne^{24} ground-state masses[4] and the locations of the first $T = 1$ and $T = 2$ states of Mg^{24}, the quadratic isobaric mass formula[9] predicts an Al^{24} mass excess of 0.070 ± 0.120 MeV. The bulk of the uncertainty in the mass-formula prediction lies in the uncertainty in the locations of the first $T = 1$ and $T = 2$ states in Mg^{24}, and hence there would be considerable interest in an improvement in the measurement of these excitation energies.

$\underline{P^{28}}$.—These measurements, using a thick quartz target, indicate a $Si^{28}(p,n)P^{28}$ threshold energy of 15.699 ± 0.008 MeV ($Q = -15.120 \pm 0.008$ MeV) for a P^{28} mass excess of −7.152 ± 0.008 MeV.

$\underline{Cl^{32}}$.—A natural CdS target, 0.85 mg/cm² thick, evaporated onto gold foil was used for these measurements. The threshold was observed at an energy of 13.967 ± 0.013 MeV ($Q = -13.537 \pm 0.013$ MeV) for a Cl^{32} mass excess of −13.258 ± 0.013 MeV. The uncertainty in this result is larger than in the other cases studied because of a relatively lower reaction yield. This is caused at least in part by the

Table I. Determinations of mass excesses (in keV) for N^{12}, Al^{24}, P^{28}, Cl^{32}, and Sc^{40}.

Isotope	Goldanskii[a]	Garvey and Kelson[b]	Mass tables[c]	Previous measurements	This work
N^{12}	17 583	17 578 ± 2	17 364 ± 7	17 351 ± 9[d]	17 340 ± 9
Al^{24}	−60	−103 ± 8	+100 ± 90	−50 ± 60[e]	−51 ± 7
P^{28}	−7080	−7097 ± 9	−7660 ± 280	−7170 ± 60[e]	−7152 ± 8
Cl^{32}	−13 660	−13 289 ± 17	−12 810 ± 380		−13 258 ± 13
Sc^{40}	−21 070	−20 535 ± 26	−20 900 ± 200	−20 380 ± 60[e]	−20 523 ± 7

[a] Ref. 5.

[b] Ref. 6.

[c] Ref. 4.

[d] Ref. 7.

[e] M. E. Rickey, P. D. Kunz, J. J. Kraushaar, and W. G. Anderson, Phys. Letters 17, 296 (1965); M. E. Rickey, private communication.

relatively higher stopping cross section per sulfur atom in the target compound. Work is underway to improve this measurement with an elemental sulfur target.

Sc^{40}.—These measurements involved used of a 99.8% enriched Ca^{40} self-supporting foil target, approximately 0.85 mg/cm^2 thick. The threshold energy was determined to be 15.491 ± 0.007 MeV, leading to a Q value of −15.107 ± 0.007 MeV and a Sc^{40} mass excess of −20.523 ± 0.007 MeV. The break in the yield curve at 18.876 MHz is probably due to target thickness effects; however, the influence of an excited state corresponding to the analog of the 30-keV state of K^{40} may also affect the yield in this frequency range.

The measurements reported herein were carried out as part of the initial series of experimental studies with the Yale MP tandem accelerator. The accelerator has been found to operate in stable and reproducible fashion in the proton energy range from 1.8 to 23 MeV; no attempt has been made as yet to operate outside this energy range. Although not required in the present measurements, proton-beam currents of 25 μA at 15 MeV and of 12 μA at 20 MeV have been obtained without difficulty.

In view of current interest in precise location of isobaric multiplet members, the present studies are being extended to other nuclear species hitherto inaccessible with available tandem accelerator beams.

It is a pleasure to acknowledge Professor H. H. Barschall's participation in the early phases of these measurements. The efforts of the staff of the Nuclear Structure Laboratory, particularly the operating crew under the direction of K. Sato, have been indispensible in assembling and operating the accelerator. The aid and advice of R. Fernald and W. Scheer of The High Voltage Engineering Corporation were also invaluable during the preliminary stages of this study as was the aid of M. LeVine in taking data.

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