Section II

ABSTRACTS OF TALKS AT MEETINGS

July 1971-June 1972

American Phys. Soc. Tucson Meeting, Nov. 1971

The $^{14}N(p,p')^{14}N$ Reaction at 29.8, 36.6, and 40.0 MeV and the Tensor Part of the Two-Body Force.* S.H. FOX, S.M. AUSTIN, and D. LARSON, Mich. State Univ.—Protons from the MSU Sector-Focussed Cyclotron were scattered from gas and evaporated melamine ^{14}N targets and detected with position sensitive detectors in an Enge split-pole spectrograph. Angular distributions for elastic scattering, and the excitation of the 2.31(0^+,T=1) and 3.95(1^+,T=0) states were obtained at all energies. Data at 29.8 MeV were taken with a silicon detector telescope and states up to 8 MeV in excitation were observed. Optical model fits to the available elastic scattering data were made. Microscopic model DWBA calculations with exchange were made for the 2.31 reaction including central, L·S, and (most importantly) tensor forces in the two-body force. A T=1 tensor force with r^2 weighted integral equal to that for the OPEP tensor force is consistent with the data.

*Supported by the NSF.

American Phys. Soc. Tucson Meeting, Nov. 1971

(p,n) Quasi-Elastic Scattering.* R.K. JOLLY, T.M. AMOS, A. GALONSKY, and R. St.ONGE,** Mich. State Univ.—Angular distributions for analogue-state excitation by the (p,n) reaction have been measured from 10° to 103° with protons of 22, 30, and 40 MeV and for targets of ^{27}Al, ^{51}V, and ^{90}Zr. Neutrons were detected with a time-of-flight spectrometer using liquid scintillator. Differential cross sections vary from as much as 3 mb/ster at backward angles. For all 3 targets at 22 MeV and at 30 MeV a derivative surface interaction fits the angular distribution better than a volume interaction, but at 40 MeV the volume interaction is better for ^{51}V and for ^{90}Zr while the surface interaction is better for ^{27}Al. Interaction strengths will be presented.

*Supported in part by the NSF and the Office of Naval Research.
**Now at the University of New Hampshire.

American Phys. Soc. Tucson Meeting, Nov. 1971

$\vec{L}\cdot\vec{S}$ Inelastic Proton Scattering from ^{16}O and the $\vec{L}\cdot\vec{S}$ Part of the Two-Body Force.* Sam M. AUSTIN, W. BENENSON, D. LARSON, and R. SCHAEFFER, Mich. State Univ.—At energies below 30 MeV inelastic proton scattering from ^{16}O leaving this nucleus in its 8.88 MeV, $J^\pi=2^-$,T=0 state is fairly well described by microscopic DWBA calculations using scalar two-body forces. As the energy increases the experimental angular distributions assume an L=3 character while the central force DWBA calculations continue to predict on L=1 shape. We have made DWBA calculations for scalar, tensor, and $\vec{L}\cdot\vec{S}$ forces including the contributions of exchange. Tensor forces of T=1 type such as those from the one-pion-exchange potential have little effect on the shape of the cross-section. However, an LS force slightly larger than that recently used by Love[1] yields an L=3 shape which reproduces the cross-section and asymmetry data forward of 90°.

*Supported by the NSF.
[1]W.G. Love, Phys. Letters 35B, 37(1971).

American Phys. Soc. Tucson Meeting, Nov. 1971

The Two-Pion Exchange Contribution to the Nucleon-Nucleon Potential.* Bruce H.J. MCKELLAR** and Geoffery N. EPSTEIN, Univ. of Sydney—We present a calculation of the 2π exchange contribution to the nucleon-nucleon potential using the method of Cottingham and Vinh Mau, but using as πN amplitude consistent with recent data and the soft pion theorems and making the continuation to the $N\bar{N}\to\pi\pi$ amplitude taking into account the S wave $\pi\pi$ phase shifts as well as the ρ meson pole in the P wave. The potential obtained, which contains no arbitrary parameters, is in reasonable agreement with the phenomological potentials of the Yale Group and Hamada and Johnston.

*Supported in part by the NSF.
**Visitor Spring 1972.

American Phys. Soc. Tucson Meeting, Nov. 1971

Isospin Mixing of the Lowest T=2 State in ^{56}Ni.* R. SHERR, Princeton University, W. BENENSON, E. KASHY, D. BAYER, and I. PROCTOR, Mich. State Univ. Dzubay et al.[1] found that in ^{56}Co the T=2 0^+ analog of ^{56}Fe is strongly mixed with a nearby T=1 state. To obtain further information on this doublet we have looked for the analogs of this doublet in ^{56}Ni via the $^{58}Ni(p,t)$ reaction. With a 34 MeV proton beam from the MSU Cyclotron on an 80 $\mu g/cm^2$ target, we obtained triton spectra with 11 keV resolution using the split-pole spectrograph and a position-sensitive detector. In the expected region of excitation for the T=2 state (9.7-10.1 MeV), we found a triplet of 0^+ states at 9.915, 9.991, and 10.021 MeV, with relative strengths 1, 0.2, and 0.3 respectively. It appears that a T=0 state is excited as well as the sought-for T=1, T=2 doublet. From this experiment alone one cannot identify which of the levels comprise the doublet nor can one tell whether the third state is mixing with the doublet. Other experiments will be required to resolve these questions.

*Supported in part by the USAEC and the NSF.
[1]T.G. Dzubay, R. Sherr, F.D. Becchetti, Jr., and D. Dehnhard, Nucl. Phys. A142, 488(1970).

American Phys. Soc. Tucson Meeting, Nov. 1971

Renormalized Operators and Collective Particle-Hole Excitations in ^{40}Ca and ^{48}Ca.* H. MCMANUS and M. DWORZECKA, Mich. State Univ.—Collective particle-hole excitations in ^{40}Ca and ^{48}Ca are calculated with Sussex matrix elements in Tamm-Dancoff approximation. Calculations are done both with bare and renormalized operators. Renormalization is accomplished by including core polarization effects by perturbation in both the two-body interaction and transition moments. The results are similar to those obtained in random-phase approximation using realistic forces with core polarization screening.

*Supported by the NSF.

American Phys. Soc. Tucson Meeting, Nov. 1971

A Study of ^{43}Sc via the (p,α) Reaction.* Jerry A. NOLEN, Jr. and Paul ZEMANY, Mich. State Univ.—The direct (p,α) reaction has been measured with 30 MeV protons from the MSU Cyclotron. The alpha spectra were recorded on nuclear emulsions in a split-pole magnetic spectrograph with an overall energy resolution of 15 keV. The states of ^{43}Sc which are strongly populated by this reaction are $(f_{7/2})^3$ configurations, such as the ground state ($7/2^-$) and the state at 1.83 MeV ($11/2^-$) or proton-hole states, as in the cases of the 0.151 MeV ($3/2^+$) and 0.856 MeV ($1/2^+$) levels. There are several states of significant strength around 3 MeV excitation; one or more of these may be high spin states of $(f_{7/2})^3$ configuration. The $3/2^-$ state at 1.18 MeV which has large strength in stripping reactions is weakly populated in this reaction as are many other previously known levels of ^{43}Sc. Spectroscopic strengths extracted from DWBA calculations are compared with predictions based on shell-model wave functions. The effects of coherence in the (p,α) reaction will be discussed.

*Supported by the NSF.

American Phys. Soc. Tucson Meeting, Nov. 1971

Fine Structure in Neutron-Gamma Ray Pulse Shape Discrimination.* R. St.ONGE,** T.M. AMOS, A. GALONSKY, and R.K. JOLLY, Mich. State Univ.—With a zero-crossover pulse-shape discrimination system we have examined pulses from an NE-213 liquid scintillator irradiated with neutrons and γ rays produced by bombardment of a thin ^{7}Li target with 40-MeV protons. The 2-dimensional display of crossover time vs. pulse height shows the usual separation into neutron and γ-ray bands but with with three additional bands. By measuring the time-of-flight spectrum of each band separately we see that each additional band has a time spectrum of the neutrons. In order of decreasing separation from the γ-ray band the other bands are assigned: 1) carbon recoils, 2) alpha particles from carbon breakup, 3) the usual neutron band consisting of protons from ^{12}C(n,p), and 4) high energy protons escaping from the liquid. The monotonic relation of the pulse shape effect to dE/dx is apparent.

*Supported by the NSF and ONR.
**Now at the University of New Hampshire.

American Phys. Soc. Tucson Meeting, Nov. 1971

Interpretation of ^{170}Yb Levels Observed in the Decay of ^{170}Lu.* F.M. BERNTHAL, Mich. State Univ. and D.C. CAMP, Lawrence Livermore Lab.—Analysis of Ge(Li) γ-ray and Si(Li) conversion electron data from decay of ^{170}Lu has allowed spin and parity assignments to be proposed for 48 of the 70 excited states observed in ^{170}Yb. Significant differences exist between our proposed level scheme and that reported elsewhere. The ^{170}Lu β-decay displays essentially uniform feeding to the numerous low-spin states in ^{170}Yb. Log(ft)'s derived from γ-ray intensity balances are generally ≥7.0 for beta feeding to all levels. Four 0^+ excitations are observed within the pairing energy gap 2Δ. Of the four 2+0' states observed, only the $2+0_2$ (β-vibration?) band member has γ-ray branching to the ground band consistent with a single value of the z_0 mixing parameter. Other features of the ^{170}Yb level scheme include (1) two low-lying 1-0 states at 1364.6 and 1512.4 keV, the expected 1-1 member of the "octupole" multiplet apparently being absent below 2 MeV; (2) the absence of a state 1+0 previously thought to be identified[1] at 2533.1 keV; (3) an apparent dearth of states near the energy 2Δ.

*Work supported in part by the USAEC and the NSF.
[1]N. Bonch-Osmolovskaya, et al., Nucl. Phys A162, 305(1971).

American Phys. Soc. Tucson Meeting, Nov. 1971

Rotational Bands in ^{179}W Excited in the ^{177}Hf (α,2n) Reaction.* F.M. BERNTHAL and R.A. WARNER, Mich. State Univ.—The technique of in-beam γ-ray spectroscopy has been used to obtain γ-ray singles and γ-γ coincidence data on the rotational band structure of ^{179}W. A metallic target of 92% enriched ^{177}Hf was bombarded with 27-MeV α-particles from the MSU sector-focused cyclotron. On the basis of energy, intensity, and coincidence relationships, and earlier published decay scheme work,[1] the structure of the $7/2^-$[514] ground and $9/2^+$[624] and $1/2^-$[521] excited rotational bands have been detailed to spins at least as high as 21/2. Analysis of the highly perturbed "parity unique" $9/2^+$ band in terms of Coriolis coupling will be discussed.

*Supported in part by the USAEC and the NSF.
[1]R. Arlt, et al., Baull Acad. Sci. USSR (Phys. Ser.), 34, 619(1970).

American Phys. Soc. Tucson Meeting, Nov. 1971

The Decay of ^{40}Sc.* J.N. BLACK, Wm.C. McHARRIS, and W.H. KELLY, Mich. State Univ.—The decay of 0.18-sec. ^{40}Sc to levels in ^{40}Ca has been investigated with large, high-resolution Ge(Li) γ-ray detectors using pulsed-beam methods. The activity was produced by bombarding a 2-mg/cm^2 99.97% enriched ^{40}Ca foil with 24-MeV protons from the MSU Cyclotron. Various beam-off ray spectra, together with a beam-on spectrum, were routed into the laboratory's Sigma-7 computer and accumulated for periods of up to 32 hr. Seven γ rays were identified and placed in a consistent decay scheme for ^{40}Sc. Although the intensities of these γ rays are in agreement with the results of Armini, et al.,[1] the energies are not. However the energies are generally in agreement with those reported by Kashy, et al.[1]

*Supported by the USAEC and the NSF.
[1]Armini, Sunier, and Richardson, Phys. Rev. 165, (1968); Kashy and Snelgrove, Phys. Rev. 172, (1968).

American Phys. Soc. Tucson Meeting, Nov. 1971

The Angular Distribution Study of the ^{159}Tb(p,t) Reaction.* R.W. GOLES, R.A. WARNER, Wm.C. McHARRIS, and W.H. KELLY, Mich. State Univ.—30 MeV protons accelerated by the Michigan State University Sector-Focused Cyclotron were used to study this (p,t) reaction. Triton spectra taken between 10° and 75° at 5° intervals were momentum analyzed using an Enge split-pole magnetic spectrometer. Below the pairing gap, these spectra were dominated by β- and γ-vibrational and ground state rotational band members. The band members observed in our spectra are: ground band—GS($3/2^+$), 61($5/2^+$), 144($7/2^+$), 254($9/2^+$), 379($11/2^+$), 527($13/2^+$), and possibly 927 keV ($17/2^+$); γ band—598($1/2^+$), 640($3/2^+$), 699($5/2^+$), 795($7/2^+$), and 896 keV ($9/2^+$); β band—994($3/2^+$), 1048($5/2^+$), and 1120 keV ($7/2^+$). Angular distributions of the above listed states will be presented and compared with DWBA predictions.

*Work supported in part by the USAEC and the NSF.

American Phys. Soc. Tucson Meeting, Nov. 1971

The Half-Life of the 628.6-keV State in ^{141}Pm.* R.A. WARNER, R.R. TODD, R.E. EPPLEY, W.H. KELLY, and Wm.C. McHARRIS, Mich. State Univ.——A 2-parameter (time vs. E) delayed-coincidence experiment using Ge(Li) and NaI(Tl) detectors has been performed to measure the half-life of the $11/2^-$ state at 628.6 keV in ^{141}Pm. The result, $T_{1/2}=0.70\pm0.02$ μsec, leads to partial half-lives of 0.75 and 10.6 μsec for the 432-keV M2 and the 628.6-keV E3 transitions, respectively. The Moszkowski single-particle estimates for these transitions are 13 nsec and 17 μsec, respectively. The hindered M2 is typical and the slightly enhanced E3 is consistent with other E3 rates in this region.

*Supported by the USAEC and the NSF.

Amer. Phys. Soc. San Francisco Meeting, Jan. 1972

The Effective Two Nucleon Force in Nuclei.* Sam M. AUSTIN, Mich. State Univ.—Many recent experiments on charge exchange and inelastic scattering initiated by nucleons in the 20-60 MeV range have been analyzed by their authors to yield a value of the effective two nucleon interaction, V_{eff}. We have reviewed these analyses and selected cases where a single term in V_{eff} is dominant (see Equation) and where collective effects are fairly well understood. Where necessary corrections were made for contributions of exchange processes. Tensor forces were neglected. With a Yukawan radial dependence (r in Fermis)

$$V_{eff}=[V_o+V_\sigma\vec{\sigma}_1\cdot\vec{\sigma}_2+V_\tau\vec{\tau}_1\cdot\vec{\tau}_2+V_{\sigma\tau}(\vec{\sigma}_1\cdot\vec{\sigma}_2)(\vec{\tau}_1\cdot\vec{\tau}_2)]\frac{e^{-r}}{r}$$

we obtain $V_o=30\pm5$, $V_{\sigma\tau}=12\pm3$ MeV in reasonable agreement with estimates based on the free two-body force. There is very little available data on V_σ and V_τ in this energy range.

*Supported by the NSF.

Amer. Phys. Soc. San Francisco Meeting, Jan. 1972

The (^{3}He,t) Reaction at 70 MeV to Isobaric Analog States of ^{50}Cr, ^{62}Ni, and ^{90}Zr.* R.A. HINRICHS and D.L. SHOW, Mich. State Univ.—The study of the energy dependence of the (^{3}He,t) reaction to isobaric analog states has been extended to an incident ^{3}He energy of 70 MeV. Using the MSU Cyclotron and a stack of Si detectors, the analog state transition for the targets ^{50}Cr, ^{62}Ni, and ^{90}Zr was studied with an overall resolution of 130 keV. Both microscopic and macroscopic DWBA calculations for these transitions yielded interaction strengths significantly less than those observed at 37 MeV, but consistent with the trend found at the lower energies.[1] Most fits were quite sensitive to the optical model parameter sets used, especially the microscopic calculations. The macroscopic form factors required different shapes for each nucleus for good fits, and were themselves different than the shapes found at lower energies.

*Supported by the NSF.
[1]W.L. Fadner, J.J. Kraushaar, and S.I. Hayakawa, to be published.

Amer. Phys. Soc. San Francisco Meeting, Jan. 1972

Inelastic Proton Scattering from ^{138}Ba and ^{144}Sm.* Duane LARSON, Sam M. AUSTIN, B.H. WILDENTHAL, and S.H. Fox, Mich. State Univ.—We have studied states of ^{138}Ba and ^{144}Sm via inelastic scattering of 30 MeV protons. The data was taken on plates using the technique of dispersion matching with the Enge spectrograph. Typical resolution of less than 10 keV has allowed us to make the following energy assignments in ^{138}Ba (in keV); 1436(2), 1898(4), 2091(6), 2201, 2218(2), 2309(4), 2416, 2446, 2582, 2640(2), 2779(4), 2880(3), 3042, 3150, 3243, 3278, 3333(2), and 3363(2). In ^{144}Sm we find levels at 1659(2), 1809(3), 2191(4), 2324(6), 2426(2), 2591(4), 2806, 2831, 2889(4), 3025, 3130, 3203, 3231, 3279, and 3317. The L transfers to the strong states are shown in parenthesis. Angular distributions have been obtained for all of the above states. Spin and parity predictions have been made based on the L transfers and are in agreement both with existing data and calculations. Microscopic DWA calculations including exchange will be shown.

*Supported by the NSF.

Amer. Phys. Soc. San Francisco Meeting, Jan. 1972

The (^{3}He,^{6}He) Reaction on Some Even-Even $f_{7/2}$ Shell-Nuclei.* I.D. PROCTOR, J. DREISBACH, W. BENENSON, E. KASHY, Mich. State. Univ., G.F. TRENTELMAN, Northern Mich. Univ., and B.M. PREEDOM, Univ. of S. Carolina—A 74 MeV ^{3}He beam has been used to investigate proton-rich nuclei via the (^{3}He,^{6}He) reaction on enriched targets of ^{46}Ti, ^{48}Ti, ^{50}Cr, ^{54}Fe, and ^{58}Ni. The ^{6}He particles were analyzed in a split-pole magnetic spectrograph and detected with photographic emulsions. Masses have been determined for the $T_z=-1/2$ nuclei ^{47}Cr, ^{51}Fe, and ^{55}Ni by measurements relative to the known ^{43}Ti and ^{45}Ti masses. For ^{46}Ti, the (^{3}He,^{6}He) reaction appears similar to the (p,α) reaction on the same target.[1] The first hole state ($d_{3/2}$) in ^{43}Ti was observed at 0.40 MeV and indicates the expected strong Coulomb shift relative to its analog in ^{43}Sc at 0.15 MeV.[1] This data is currently being analyzed and the results will be presented.

*Supported by the NSF.
[1]J.A. Nolen, Jr. and Paul Zemany, BAPS 16, 1183(1971).

Amer. Phys. Soc. San Francisco Meeting, Jan. 1972

High Resolution Study of ^{59}Co(p,d)^{58}Co.* R.G.H ROBERTSON and J.A. NOLEN, Mich. State Univ.—The odd-odd nucleus ^{58}Co has been studied experimentally via the (p,d) reaction at $E_p=30$ MeV. Outgoing deuterons were analyzed in an Enge split-pole spectrograph and detected on photographic plates. By optimizing beam quality using the system of Blosser et al.,[1] peak widths of 0.25 mm, corresponding to about 5 keV FWHM, were obtained. The 374 keV level was clearly resolved from the one at 366 keV and was shown to have a substantially higher $\ell_n=3$ component than had been assumed in a previous (d,t) study.[2] Many weak states above 1100 keV were seen for the first time in neutron pickup. Several stronger states, probably arising from $(\pi f_{7/2}^{-1})(\nu f_{7/2}^{-1})$, were seen at excitation energies around 2.7 MeV. Spectroscopic factors extracted via DWBA analysis will be presented.

*Supported by the NSF.
[1]Blosser, et al., Nucl. Instr. & Methods 91, 61(1971).
[2]Robertson, et al., Can. J. Phys. 49, 1186(1971).

Amer. Phys. Soc. San Francisco Meeting, Jan. 1972

Decay of ^{202m}Pb.* Jean GUILE, R.E. DOEBLER, Wm.C. MCHARRIS, and W.H. KELLY, Mich. State Univ. and Lawrence Berkeley Laboratory—The decay of the 3.62-h 9- isomer, ^{202m}Pb, has been investigated using Ge(Li) detectors in a variety of configurations. Combined with existing electron data,[1] unambiguous multipolarity assignments were made for 16 of its 18 transitions, and all were placed in a decay scheme including seven states in ^{202}Tl (following the 9.5% ε branch) and seven states in ^{202}Pb itself (following the IT branch). Specific J^{π} assignments were made for most of these states, and their structures are discussed in shell-model terms. We also discuss the rising 2^+ state in the e-e Pb isotopes as one moves away from N=126 as coming from an increase in the pairing force.

*Supported by the USAEC and the NSF.
[1]J.A. McDonell, R. Stockendal, C.J. Herrlander, and I. Bergström, Nucl. Phys. 3, 513(1957).

Amer. Phys. Soc. San Francisco Meeting, Jan. 1972

In-Beam Study of the γ-rays Emitted in the ^{48}Ti(p,nγ)^{48}V Reaction.* L.E. SAMUELSON, R.A. WARNER, and W.H. KELLY, Mich. State Univ., E.M. BERNSTEIN and R. SHAMU, Western Mich. Univ.—The level structure of ^{48}V up to 1530 keV in excitation has been studied via the ^{48}Ti(p,nγ)^{48}V reaction. Excitation functions of the decay γ rays and γγ-coincidence measurements have allowed the determination of the ^{48}V γ-ray decay scheme. Angular distributions of ^{48}V deexcitation γ rays were also measured at five proton bombarding energies. Comparisons of relative cross-sections for the population of each level, and of the γ-ray angular distributions with the predictions of the compound nuclear statistical model has led to possible level spin assignments and γ-ray multipole-mixing ratios. Tentative level energies (in keV) and spins (in parentheses) for excitations below 1 MeV are as follows: 308.4(2), 420.9(1), 423.5?(?), 427.9(5), 519.0(1), 613.4(4?), 745.4(2), and 765.6(3). A mixing ratio of $-0.11 \leq \delta \leq -0.03$ is indicated for the 112.5 keV γ-ray transition from the 420.9 keV level.

*Work supported in part by the NSF and the AEC and a grant from the Research Corporation (WMU).

Amer. Phys. Soc. South Carolina Meeting, Mar. 1972

Shell Model Calculations for ^{22}Na and ^{22}Ne.* B.H. WILDENTHAL, Mich. State Univ. and B.M. PREEDOM, Univ. of South Carolina—Shell model calculations have been performed for the nuclei ^{22}Na and ^{22}Ne. These calculations include all Pauli-allowed combinations of six particles in the basis states $0d_{5/2}$-$1s_{1/2}$-$0d_{3/2}$ outside of an inert ^{16}O core. The two-body interaction is an empirically modified version of one calculated by Kuo from the Hamada-Johnston n-n potential. Excitation energies, E.M. transition rates, and spectroscopic factors for single-nucleon transfer are presented and compared with existing data. Properties which are characteristic of rotations of deformed nuclei are predicted in these shell model calculations. These predictions agree well for transitions and energy levels for which data exists.

*Supported in part by the NSF.

Amer. Phys. Soc. Washington Meeting, Apr. 1972

Separation of "Direct" Neutrons from Compound-Nucleus Neutrons Produced by Protons with Energies up to 40 MeV.* T.A. AMOS, A. GALONSKY, and R.K. JOLLY,** Mich. State Univ.—With the time-of-flight technique absolute neutron spectra were measured for protons of 22, 30, and 40 MeV bombarding thick targets of Cu, Ag, Ta, and Pb at 0°, 30°, 60°, 90°, 120°, and 150°. Starting with a peak at ∿1 MeV each spectrum falls exponentially for at least a few MeV before a lower decay rate sets in. At the forward angles the change is quite distinct. In the 0° Ta and Pb spectra at 40 MeV the decay rate between 8 and 20 MeV is 1/10 its value between 1 and 5 MeV, the entire change occurring between 5 and 8 MeV. Energy and angular dependences of what are apparently 2 groups of neutrons would indicate that one is of compound-nucleus (CN) origin, the other of non-CN, or "direct", origin. We have extracted the ratios.

*Supported by the NSF and ONR.
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Amer. Phys. Soc. Washington Meeting, Apr. 1972

Energy Levels of ^{25}Si.* W. BENENSON, J. DREISBACH, I.D. PROCTOR, F. TRENTELMAN,** and B.M. PREEDOM,*** Mich. State Univ.—The (^{3}He,^{6}He) reaction at 70.4 MeV has been used to study the level structure of ^{25}Si up to 6.7 MeV excitation. The ^{6}He's were detected in low sensitivity photographic emulsions on the focal plane of a split-pole spectrograph. A resolution of 28 keV permitted resolving the ground and first-excited state doublet. Levels of ^{25}Si were found at 40, 815, 1963, 2373, 2606, 3285, 3818, 4993, 5417, and 5734 keV. The observation of the 40 keV state leads to a new mass excess for the ground state of ^{25}Si of 3.824±0.010 MeV. A mass quartet based on the first-excited state is fit well without a cubic dependence of T_z as is the ground state multiplet. Some of the other states line-up well with other known T=3/2,A=25 levels. Comparisons to shell model calculations will be presented.

*Supported by the NSF.
**Present Address: Northern Mich. Univ.
***Visitor from Univ. of South Carolina

Amer. Phys. Soc. Washington Meeting, Apr. 1972

The ^{48}Ca(p,t)^{46}Ca Reaction at E_p=39 MeV.* G.M. CRAWLEY, P.S. MILLER, Mich. State Univ. and G. IGO, J. KULLECK, Univ. of Calif.—A number of 0^+ states have been observed around 5.5 MeV in ^{46}Ca by the ^{44}Ca(t,p) reaction.[1,2] Because the previous results are not completely consistent, and also since the observation of the same states by both (t,p) and (p,t) is valuable in removing ambigities in the nuclear wave functions, the reaction ^{48}Ca(p,t) was carried out using the MSU Cyclotron to examine these same states. A total resolution of 11 keV FWHM was obtained. Further interesting features of this experiment were the strong excitation of the high spin states associated with the $f_{7/2}^2$ configuration and the observation of close doublets below 5 MeV.

*Supported by the NSF.
[1]D.C. Williams, et al., Phys. Rev. 164, 1419(1969).
[2]J.H. Bjerregaard, et al., Nucl. Phys. A103, 33 (1967).

Amer. Phys. Soc. Washington Meeting, Apr. 1972

Shell-Model Predictions for ^{27}Mg, ^{28}Al, ^{29}Mg, and ^{29}Al.* M.J.A. deVOIGT, and P.W.M. GLAUDEMANS, Rijksuniv., Utrecht, and B.H. WILDENTHAL, Mich. State Univ.—A surface-delta type Hamiltonian has been obtained in a fit to some of the level energies of ^{27}Al, ^{28}Si, and ^{29}Si. A truncated model space, which allowed active particles in each of the three sd-shell orbits, was used. The resulting wave functions contained explanations for most of the observed features of the nuclear structure of these systems. We have used this identical Hamiltonian and model space, to predict energy levels and wave functions for the nuclei mentioned in the title, and have calculated the related single-nucleon S-factors, and beta-decay, and electromagnetic transition rates. The overall results might be termed surprisingly good.

*Supported in part by the NSF.

Amer. Phys. Soc. Washington Meeting, Apr. 1972

Energy Calibration of a Split-pole Magnetic Spectrograph.* E. KASHY, I.D. PROCTOR, J.A. NOLEN, and S. EWALD, Mich. State Univ.—The (p,p') and (p,d) momentum matching technique[1] is used with photographic emulsions for an accurate determination of the proton beam energy. The location of well known levels, such as the lowest 2^+ and 3^- levels of ^{12}C and ^{16}O, then gives a precise momentum calibration of the two dimensional space required to focus different reaction products. The resulting calibration allows measurements of excitation energies of 3 MeV to an accuracy of 1 keV at E_p=34 MeV. In this way we have found a significant error in the mass excess of the lowest $3/2^-$ state of ^{15}O consistent with the results of Hensley.[2] Both the method and results will be discussed.

*Supported by the NSF.
[1]G.F. Trentelman and E. Kashy, NIM 82, 304(1970).
[2]D.C. Hensley, Ph.D. Thesis-Calif. Inst. Techn., 1969 (unpublished).

Amer. Phys. Soc. Washington Meeting, Apr. 1972

The Numerical Accuracy of Optical Model Calculations for 70 MeV ^{3}He Elastic Scattering.* R.R. DOERING,** Mich. State Univ.—Differential cross sections for 70 MeV ^{3}He elastic scattering from ^{60}Ni calculated with the optical Model codes GENOA, SNOOPY3, and GIBELUMP and the DWBA code DWUCK, using identical parameters, differed by as much as 2-1/2 orders of magnitude at back angles. Angular distributions measured for 70 MeV He elastic scattering from several $f_{7/2}$ shell nuclei span over 9 orders of magnitude between 5° and 150°. Thus, calculations of the small back angle cross sections require an extraordinary degree of cancellation in the partial wave sum. This necessitates unusually accurate individual amplitudes. Specifically, it was found necessary to employ a smaller integration step size, a larger matching radius, and more partial waves than suggested by criteria often used for calculations involving other projectiles and energies.

* Supported by the NSF.
** Submitted by A. Galonsky.

Amer. Phys. Soc. Washington Meeting, Apr. 1972

A High Resolution Study of the ^{209}Bi(p,d)^{208}Bi Reaction.* W.A. LANFORD, G.M. CRAWLEY, H.G. BLOSSER, and E. KASHY, Mich. State Univ.—The ^{209}Bi(p,d)^{208}Bi reaction has been studied using the 35 MeV proton beam from the MSU Cyclotron. Using dispersion matching techniques[1] a resolution of 5 keV (FWHM) has been obtained. Exposures were taken from 6° to 46° in 4° steps for excitation in ^{208}Bi of 0-6 MeV. The present experiment examines the interaction of the $h_{9/2}$ proton (in the ^{209}Bi g.s.) with the neutron holes up to $h_{9/2}$, thus extending the previous (d,t) work[2] to higher excitation and checks the previous spin assignments for lower lying states.

*Supported by the NSF.
[1]H.G. Blosser, et al., Nucl. Inst. & Methods 91, 61(1971).
[2]W.P. Alford, et al., Phys. Rev. C3, 860(1971).

Amer. Phys. Soc. Washington Meeting, Apr. 1972

Study of Inelastic Proton Scattering from ^{90}Zr at 40 MeV.* R.A. HINRICHS, D. LARSON, Mich. State Univ. and B.M. PREEDOM, Univ. of South Carolina—Angular distributions for inelastic proton scattering from ^{90}Zr between 15° and 115° have been taken at 40 MeV using the MSU Cyclotron. Plates in an Enge split-pole spectrograph were used, which made it possible to observe the weakly excited (≤1 μb/sr) 0^+ first excited state. Simple microscopic DWBA calculations including core polarization, with emphasis upon the $(g_{9/2})^2$ configuration, yielded good fits to the 2^+, 4^+, 6^+, 8^+ states. With the inclusion of other data at 18 and 61 MeV, no energy dependence in the core polarization parameters was seen. The 0^+(1.75 MeV) state was not fit with these calculations.

*Supported by the NSF.

Amer. Phys. Soc. Washington Meeting, Apr. 1972

Calculation of Allowed β-decay in the (0d-1s) Shell.* W.A. LANFORD and B.H. WILDENTHAL, Mich. State Univ.—Allowed β-decay transition rates and half-lives have been calculated for (0d-1s)-shell nuclei with A=17-23, 27-29, 30-35, and 35-39, using previously reported wave functions calculated with mass-independent Hamiltonians. For nuclei with A=17-22 and 34-39, for which complete (0d-1s) shell model calculations were available, the calculated and experimental log(ft)'s have a rms. deviation from experiment of about 5%. There are some serious discrepancies for the nuclei nearer the middle of the shell, for which only truncated shell model calculations were available. Predicted half-lives for several unobserved nuclei have been obtained. Relevance of the ^{37}Ca decay to the solar neutrino experiment[1] will be discussed.

*Supported by the NSF.
[1]R. Davis, et al., Phys. Rev. Letters 20, 1205 (1968).

Amer. Phys. Soc. Washington Meeting, Apr. 1972

Shell-Model Predictions for Electromagnetic Transitions in ^{138}Ba and ^{139}La.* Duane LARSON and B.H. WILDENTHAL, Mich. State Univ.—Electromagnetic transition rates and ground state moments have been calculated for the N=82 nuclei ^{138}Ba and ^{139}La. Using shell model wave functions calculated in a four shell basis with a modified surface delta interaction and bare-nucleon charges and moments, we obtain a magnetic moment of 1.84 nm and a quadrupole moment of +13 efm^2 for the ground state of ^{139}La. For ^{138}Ba we obtain B(E2) values of 2_1^+-0_1^+(174 e^{2}fm^4), 4_1^+-2_1^+(2.32 e^{2}fm^4), and 6_1^+-4_1^+(7.61 e^{2}fm^4). Using an effective charge of E_p=1.5 and a suggested[1] effective proton g_ℓ of 1.1 brings the calculations into good agreement with existing data.

*Supported by the NSF.
[1]Nagamiya and Yamazaki, Phys. Rev. C4, 1961(1971).

Amer. Phys. Soc. Washington Meeting, Apr. 1972

A Comparison of ^{17}O and ^{17}F with Some Charged Particle Reactions.* I.D. PROCTOR, W. BENENSON, and D.L. BAYER,** Mich. State Univ.—Angular distributions for resolved states below 6 MeV were obtained for the reactions ^{16}O(d,p)^{17}O at 20.9 MeV, ^{16}O(h,d)^{17}F at 34.6 MeV, ^{16}O(α,h)^{17}O and ^{16}O(α,t)^{17}F at 46.2 MeV, ^{19}F(p,h)^{17}O and ^{19}F(p,t)^{17}F at 39.9 MeV. A level which has not been previously reported was observed in ^{17}F at 5.215±.012 MeV. The FRNL DWA formalism is used to analyze these reactions. The DWA prediction for the mirror reactions (α,t), (α,h) and (p,t), (p,h) will be compared to the cross section ratios obatined for the 5/2$^+$ G.S. and 1/2$^+$ first excited state. Spectroscopic factors will be presented for the single nucleon transfer reactions.

*Supported by the NSF.
**Presented Address: Rutgers University.

Amer. Phys. Soc. Washington Meeting, Apr. 1972

Effects of Operator Renormalization on (e,e') and (p,p') Scattering in ^{40}Ca.* H. MCMANUS, M. DWORZECKA, and R. HAMMERSTEIN, Mich. State Univ. Wave functions and transition densities have been calculated for the lowest 3$^-$ and 5$^-$ states in ^{40}Ca using renormalized operators. Renormalization was accomplished by taking into account all second order perturbation corrections to the two-body interaction and the transition operator. Electron inelastic scattering form factors and proton inelastic scattering angular distributions were calculated using these transition densities and were compared with experiment.

*Supported by the NSF.

Amer. Phys. Soc. Washington Meeting, Apr. 1972

Structure of ^{34}Cl from Neutron Pickup.* J.A. RICE, B.H. WILDENTHAL, and B.M. PREEDOM,** Mich. State Univ.—The states of ^{34}Cl have been studied by neutron pickup, via the (p,d) reaction, from targets of Li^{35}Cl and Na^{35}Cl at E_p=35 MeV. Data were recorded in photographic emulsions with energy resolutions of 6 to 14 keV FWHM. Angular distributions were measured between 3° and 48°. The small angle data yield a very sensitive test for ℓ=0 components in the distributions and the factor of 40 between 4° and 40° cross sections for ℓ=0 shapes allow an accurate measure of relative ℓ=0 to ℓ=2 spectroscopic factors. Many previously unknown levels in ^{34}Cl are identified above 4 MeV excitation. The implications of the spectroscopic factors of the low-lying levels for nuclear structure studies in this region will be discussed.

*Supported by the NSF.
**Present Address: Univ. of South Carolina

Amer. Phys. Soc. Washington Meeting, Apr. 1972

Production Cross Sections of Masses 6 and 7 in Proton Spallation of ^{22}Ne Between 30 and 42 MeV.* L.M. PANGGABEAN, H. LAUMER,** and Sam M. AUSTIN, Mich. State Univ.—Protons from the MSU sector focussed cyclotron bombarded an enriched (99.66%) ^{20}Ne target contained in a gas cell with a total exit areal density of 110 to 200 μg/cm^2. Particles were detected in a Si surface barrier detector and their masses were measured using a time-of-flight technique. The angular distributions σ(θ) obtained for each mass were forward peaked. Total cross sections were obtained by integrating σ(θ) and were found to be a factor of 10 smaller than the spallation cross sections for ^{14}N in this energy range, but comparable with those for ^{16}O.[1] Available spallation cross sections were used to estimate the production rate of Li, Be, and B in the solar system.

*Supported by the NSF.
**Presented Address: Kansas State University.
[1] H. Laumer, MSU, Thesis (1971).

Amer. Phys. Soc. Washington Meeting, Apr. 1972

A Study of ^{26}Al via the ^{27}Al(p,d) Reaction.* D.L. SHOW, J.A. NOLEN, E. KASHY, and B.H. WILDENTHAL, Mich. State Univ.—Angular distributions have been measured for states in ^{26}Al up through 5.5 MeV excitation energy in the angular range 4° to 52°, with energy resolutions of approximately 6 keV, FWHM. Proton bombarding energies were 29 and 35 MeV. These data provide definitive ℓ=0/ℓ=2 relative spectroscopic factors for 2$^+$ and 3$^+$ levels, accurate excitation energies for the 4-6 MeV region of the spectrum and several new levels in the high excitation region. The magnitudes and distributions of the ℓ=0 and ℓ=2 spectroscopic factor strength will be discussed in comparison to the results of new $d_{5/2}$-$s_{1/2}$-$d_{3/2}$ shell model calculations for A=26.

*Supported by the NSF.

Amer. Phys. Soc. Washington Meeting, Apr. 1972

Study of the $^{39}K(p,d)^{38}K$ Reaction with High Resolution.* B.H. WILDENTHAL and J.A. RICE, Mich. State Univ.—This experiment was undertaken with the aim of studying the levels of ^{38}K with good energy resolution in a mode which permitted good discrimination between ℓ=0 and ℓ=2 angular distribution patterns. Particle groups corresponding to levels up through 6 MeV excitation have been recorded with 8 keV resolution in emulsion plates at angles from 4° to 30°. Precise excitation energies are obtained for this region and several strong groups above 5.5 MeV excitation are resolved for the first time. States with T=1 are identified by comparison to previous $^{39}K(d,^3He)^{38}Ar$ studies. The mixing between sd-shell states and core-excited states, first identified in the (d,^{3}He) work, will be examined in the light of new sd-fp shell model calculations.

*Supported by the NSF.

Amer. Phys. Soc. Washington Meeting, Apr. 1972

The β Decay of ^{63}Ga.* G.C. GIESLER,** Wm.C. McHARRIS, R.A. WARNER, and W.H. KELLY, Mich. State Univ.—The decay of 32.4 sec ^{63}Ga to ^{63}Zn has been studied with high resolution Ge(Li) spectrometers from sources produced by the $^{64}Zn(p,2n)^{63}Ga$ reaction with natural Zn foils. A total of 16 γ transitions have been placed in a level scheme with levels (spin, parity) at 0(3/2$^-$), 193.0(5/2$^-$), 248.0(1/2$^-$), 627.1(1/2$^-$,3/2$^-$), 637.0(1/2$^-$,3/2$^-$), 650.1(3/2$^-$), 1065.2(3/2$^-$), 1395.4(3/2$^-$,1/2$^-$), and 1691.7(5/2$^-$) keV. The spins were determined from log(ft's) and γ transition intensities and are in agreement with results from various scattering reactions.

*Supported in part by the USAEC and the NSF.
**Now at Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

Amer. Phys. Soc. Washington Meeting, Apr. 1972

Levels in ^{171}Hf from ^{171}Ta Decay.* I. REZANKA, I.-M. LADENBAUER-BELLIS, F.M. BERNTHAL,** and J.O. RASMUSSEN, Yale University—The decay of ^{171}Ta ($T_{1/2}$=25 min.) produced in $^{165}Ho(^{12}C,6n)$ and $^{159}Tb(^{16}O,4n)$ reactions on Yale HILAC was studied by means of γ-ray spectroscopy. Three low-lying bands were identified in ^{171}Hf: 7/2$^+$[633] (ground state), 5/2$^-$[512] (49.6 band head), and 1/2[521] (band head position uncertain). These results are in good agreement with parallel in-beam studies. In addition to these lowest rotational levels, a number of higher-lying states were observed.

*Supported in part by the USAEC and the NSF.
**Present Address: Michigan State University.

Amer. Phys. Soc. Washington Meeting, Apr. 1972

Levels in ^{62}Cu Populated by the Decay of ^{62}Zn.* G.C. GIESLER,** Wm.C. McHARRIS, R.A. WARNER, and W.H. KELLY, Mich. State Univ.—The decay of 9.3 hr ^{62}Zn has been studied with high resolution Ge(Li) spectrometers. The sources were produced by the $^{63}Cu(p,2n)^{62}Zn$ reaction and then chemically separated. A total of 19 γ transitions including new ones at 385.2, 489.1, 881.4, 915.6, 1142.5, 1280.8, 1389.1, and 1429.9 keV have been placed in a level scheme with levels (spin, parity) at 0(1$^+$), 40.94(2$^+$), 243.44(2$^+$), 287.98(2$^+$), 426.3(3$^+$), 548.4(1$^+$), 637.5(1$^+$), 915.6(1$^+$), 1142.5(0$^+$,1$^+$), 1280.8(0$^+$,1$^+$), and 1429.9(1$^+$) keV. The spins were determined from log(ft's) and γ transition intensities and are in agreement with the results of Davidson, et al.[1]

*Supported in part by the USAEC and the NSF.
**Now at Los Alamos Scientific Laboratory, Los Alamos, New Mexico.
[1] W.F. Davidson, M.R. Najam, P.J. Dallimore, J. Hellström, and D.L. Powell, Nucl. Phys. A154, 539(1970).

Amer. Phys. Soc. Washington Meeting, Apr. 1972

Rotational Bands in ^{181}W Excited in the $^{180}Hf(\alpha,3n)$ Reaction.* F.M. BERNTHAL, R.A. WARNER, and R.W. GOLES, Mich. State Univ.—As part of a systematic investigation of the rotational band structure associated with the 9/2$^+$[624] Nilsson orbital in N=105 and 107 isotones, in-beam γ-ray spectroscopy has been used to deduce the band structure of $^{181}W_{107}$. Although still strongly mixed with the other members of the $i_{13/2}$ family of Nilsson orbitals, the 9/2$^+$[624] band in ^{181}W is markedly less perturbed than the corresponding band in ^{179}W reported earlier.[1] On the basis of γ-ray energies, intensities, and angular distributions, and γ-γ coincidence data, 9/2$^+$ band members in ^{181}W are established up to spin 29/2 at 113.4, 251.2, 414.6, 599.7, 814.6, 1039.7, 1310.8, 1560.9, and probably 1899.8 and 2156.8 keV. Less complete data have been obtained for the negative parity bands in ^{181}W. Analysis of the "parity unique" 9/2$^+$[624] band in terms of Coriolis coupling will be discussed.

*Work supported by the USAEC and the NSF.
[1] F.M. Bernthal and R.A. Warner, BAPS 16, 1146(1971).

Amer. Phys. Soc. Washington Meeting, Apr. 1972

γ-γ Coincidences from $^{56}Fe(p,n\gamma)^{56}Co$ Below 2.8 MeV of Excitation.* L.E. SAMUELSON, R.A. WARNER, W.H. KELLY, and F.M. BERNTHAL, Mich. State Univ.—A Ge(Li)-Ge(Li) spectrometer was used to study γ-γ coincidences from the $^{56}Fe(p,n\gamma)^{56}Co$ reaction at proton bombarding energies of 7.38 and 8.36 MeV. Based upon coincidence evidence and γ-ray energy sums, we have placed 32 γ-ray transitions from 19 excited states in ^{56}Co. The energies in keV of states from which de-excitation γ rays are observed to be in coincidence are 158.4, 829.6, 970.2, 1114.5, 1450.6, 1720.1, 1930.2, 2059.7, 2224.5, 2288.3, 2289.8, 2304.7, 2357.2, 2464.8, 2610.0, 2635.3, 2647.2, 2665.3, and 2729.6. Errors in the level energies are ±0.2 keV up to and including the 1720.1 keV state and ±0.8 keV for higher lying states. These results incorporate the 21 γ rays previously repotted by R. DelVecchio et al.,[1] from n-γ coincidence experiments using the same reaction.

*Work supported in part by the USAEC and the NSF.
[1] R. DelVecchio et al. to be published in the Phys. Rev. Feb.(1972).

Amer. Phys. Soc. Washington Meeting, Apr. 1972

Levels in ^{141}Pm Populated by the Decay of ^{141g}Sm.* R.R. TODD, R.A. WARNER, R.E. EPPLEY, W.H. KELLY, and Wm.C. McHARRIS, Mich. State Univ.—The decay of 11.3 m ^{141g}Sm has been studied with high resolution Ge(Li) spectrometers. The sources were produced directly by the ^{142}Nd(^{3}He,4n)^{141}Sm reaction and indirectly by the reaction ^{141}Sm(p,4n)^{141}En $\xrightarrow{\varepsilon}$ ^{141}Sm. On the basis of half-life determinations and identification in cross bombardments, 11 transitions have been identified as belonging to the decay of ^{141g}Sm. Various coincidence experiments have resulted in the placement of levels at 403.9, 438.4, 728.0, 1292.7, 1495.7, 2004.5, 2037.7 keV in the daughter ^{141}Pm. Comparisons are made with levels in other odd proton nuclei in the region.

*Supported in part by the NSF and the USAEC.

Amer. Chem. Soc. Boston Meeting, Apr. 1972

Anomalous ε/β^+ Decay Branching Ratios.* R.B. FIRESTONE and Wm.C. McHARRIS, Mich. State Univ. Relative positron feedings have been measured at the MSU Cyclotron by 511 keV-511 keV-γ triple coincidence experiments in which both halves of an 8x8 in NaI(Tl) split annulus are gated on the 511 keV $\gamma^{\pm}$ positron annihilation peak and a third coincidence (resolving time, $2\tau\sim100$ nsec) is required among these and a Ge(Li) detector. ε/β^+ decay branching ratios are then inferred from these relative feedings by normalizing to "good" transitions in which the theoretical branching ratios are thought to apply. Measurements of branching ratios have thus far been made for the decays of ^{143}Sm, ^{143}Eu, and ^{145}Gd. Although the bulk of the data agrees with theoretical predictions within statistical significance, there are some striking instances in which the experimental branching ratios differ widely from theoretical predictions. Decay to the 1173.0 keV ($1/2^+$) and 1514.5 keV($3/2^+$) levels in ^{143}Pm and the 808.5 keV($1/2^+$) level in ^{145}Eu yield ε/β^+ branching ratios 3.8, 1.8, and 13.0 times the theoretical values, respectively, indicating strong hindrance of the positron decay branch. Similarly, decay to the 1566.3 keV level in ^{143}Sm gives a branching ratio 0.4 times the theoretical value indicating strong hindrance of the electron capture decay.

*Supported in part by the USAEC and the NSF.