

SECTION II
ABSTRACTS OF TALKS AT MEETINGS
(July 1972-June 1973)

$^{43}\text{Ca}(p,t)^{41}\text{Ca}$ and $^{42}\text{Ca}(p,t)^{40}\text{Ca}$ Reactions at 42 MeV. KAMAL K. SETH, Northwestern University, W. STEWART, Lewis Research Center (NASA), and W.A. LANFORD, W. BENENSON, and B.H. WILDENTHAL, Mich. State Univ. — In a previous (p,t) experiment¹ at 52 MeV on ^{45}Sc and ^{44}Ca almost identical $L=0$ transitions to the 1.838 MeV 0^+ state in ^{42}Ca and the 1.410 $7/2^-$ state in ^{43}Sc were found. It was suggested that the 1.410 state in ^{43}Sc consists largely of the $7/2^-$ proton weakly coupled to the 1.838 MeV 0^+ state of the core ^{42}Ca . We now report (p,t) experiments at 42 MeV on ^{43}Ca and ^{42}Ca targets using MSU cyclotron a position sensitive proportional counter in the focal plane of the split-pole spectrograph. Differential cross sections for states in $^{40,41}\text{Ca}$ upto about 6 MeV excitation were measured from 3° to 50° with an energy resolution of about 30 keV. "Pure" $L=0$ transitions were found both to the g.s. and the 2.959 MeV state in ^{41}Ca . Comparison of these with the $L=0$ transition to the g.s. and the 3.353 MeV 0^+ state in ^{40}Ca once again suggests that the 2.959 MeV $7/2^-$ state in ^{41}Ca consists largely of a $f7/2$ neutron weakly coupled to the 3.35 MeV 0^+ excited state of the core ^{40}Ca .

*Supported by the National Science Foundation.
¹K.K. Seth et al., Bull. Amer. Phys. Soc. 17, 535 (1972) GG9.

The $^{60}\text{Ni}(p,d)^{59}\text{Ni}$ Reaction at 35 MeV. * J.A. NOLEN, JR., R.G.H. ROBERTSON, and S.C. EWALD, Mich. State Univ. — The $^{60}\text{Ni}(p,d)^{59}\text{Ni}$ reaction has been studied with the MSU cyclotron-magnetic spectrograph system. Angular distributions have been measured from 3° to 90° using a resistive wire gas proportional counter. Additional data were recorded at 4 angles in nuclear emulsions with a resolution of ~ 5 keV. The angular distributions display more pronounced $\ell=3$ j-dependence and less $\ell=1$ j-dependence than seen at lower energies.¹ Good fits to the $\ell=1$ shapes have been obtained with DWBA calculations, but these calculations do not fit the $\ell=3$ angular distributions. Accurate excitation energies and several new spin assignments have been determined for many levels up to 7.5 MeV excitation in ^{59}Ni .

*Supported by the National Science Foundation.
¹C. Glashausser and M.E. Rickey, Phys. Rev. 154, 1033(1967).

The Decay of ^{199}Pb . * R.E. DOEBLER, WM. C. MCHARRIS, and W.H. KELLY, Mich. State Univ., and Lawrence Berkeley Laboratory, Berkeley, Calif. — ^{199}Pb was produced using $\sqrt{35}$ MeV ^3He beams from the MSU Cyclotron to induce the $(^3\text{He},4n)$ reaction on separated isotope ^{200}Hg . Gamma rays emitted in the decay of 90-min ^{199}Pb were studied with Ge(Li) and NaI(Tl) detectors in a variety of singles and coincidence experiments, including a two-dimensional γ - γ coincidence experiment of 4096×4096 channels. A total of 117 γ transitions have been observed. Excited states in ^{199}Tl accommodating 89 of these transitions have been placed at 0, 366.90, 720.26, 1120.90, 1241.67, 1482.25, 1502.00, 1528.2, 1554.10, 1632.00, 1658.47, 1695.25, 1725.4, 1749.6, 1768.5, 1891.0, 1898.1, 1930.4, 1959.45, 1977.8, 2031.5, 2159.0, 2206.7, 2226.5, 2237.3, 2367.3, 2433.5, 2547.4, and 2643.2 keV. The systematics of the odd-A Tl nuclei, including ^{201}Tl and ^{199}Tl , will be discussed in terms of single-particle shell

model states coupled to core states of the corresponding Pb nuclei.

*Supported in part by the U.S. Atomic Energy Commission and by the National Science Foundation.

Study of the (p,t) Reaction on the Even Isotopes of Lead. * W.A. LANFORD, Mich. State Univ. — The (p,t) reaction has been studied on ^{208}Pb , ^{206}Pb , and ^{204}Pb using the 35 MeV proton beam from the MSU Cyclotron. Angular distributions have been measured from 3° to 68° using a position sensitive proportional counter in the focal plane of a magnetic spectrometer. This system gave 30 keV (FWHM) resolution. Additional exposures were taken with nuclear emulsions which gave 15 keV resolution. Comparison of the observed relative cross sections for a given L-transfer with the DWBA prediction using the shell-model wave functions of J.B. McGrory to describe ^{208}Pb , ^{206}Pb , and ^{204}Pb show generally good agreement. A forward peaked angular distribution was observed for the transition to the 3^+ unnatural parity state at 1.340 MeV in ^{206}Pb .

*Supported by the National Science Foundation.

Rotational Bands in ^{183}Os Excited in the $^{182}\text{W}(\alpha,3n\gamma)$ Reaction. * F.M. BERNTHAL, R.A. WARNER, and C.L. DORS, Mich. State Univ. — The in-beam γ -ray study of $N = 105$ and 107 isotones has been extended to the odd-mass osmium nuclei. Gamma-ray energies, intensities, and γ - γ coincidence data have been used to construct a preliminary ^{183}Os level scheme. Members of the $9/2^+[624]$ ground band at 96.5, 219.3, 375.6, 541.7, 764.2, 951.5, 1256.0, 1442.5, 1844.6, and 2017.3 keV have been established up to spin $29/2$. The $9/2^+[624]$ band is found to be nearly as strongly perturbed by the Coriolis interaction as is the analogous band in ^{179}W . The data for this band in ^{183}Os have also been analyzed by diagonalization of the Coriolis interaction matrix.

*Supported by the US Atomic Energy Commission and the National Science Foundation.

Electron-Nucleus Inelastic Scattering Calculations Using the WKB Distorted Wave Born Approximation. * G.R. HAMMERSTEIN and H. MCMANUS, Mich. State Univ. — Cross sections for inelastic electron-nucleus scattering are calculated in Born approximation taking Coulomb distortion of the electron waves into account via a three-dimensional WKB approximation. The results are compared with experiment and with the results of exact numerical partial wave calculations.

*Supported in part by the National Science Foundation.

Levels to Spin 16 in ^{180}W and ^{182}Os Excited in the $(\alpha,4n)$ Reaction, * R.A. WARNER, and F.M. BERNTHAL, Mich. State Univ.—The γ -ray spectra accompanying $^{180}\text{W}(\alpha,4n)$ and $^{182}\text{Os}(\alpha,4n)$ reactions have been studied as part of a systematic investigation of the spin dependence of moments of inertia (I) in nuclei for which the $i_{1/2}$ family of neutron orbitals is nearly filled. The ground-band cascades have been determined with the aid of γ - γ coincidence data, and a preliminary analysis places the 10^+ , 12^+ , 14^+ , and 16^+ levels at 1664, 2236, 2824, and 3415 keV, respectively in ^{180}W , and at 1810, 2343, 2836, and 3314 keV in ^{182}Os . The sharp increase in I reported in more neutron-deficient nuclei by several groups is also seen in these nuclei. Analysis in progress will yield more precise results for these and other $N=106$ -110 species. The results will be discussed in light of a recently proposed model.¹

* Work supported by the U.S. Atomic Energy Commission and the National Science Foundation. F.S. Stephens and R.S. Simon, Nucl. Phys. **A183** (1972) 257.

A Charge Division Position Sensitive Proportional Counter System, * W.A. LANFORD, W. BENENSON, G.M. CRAWLEY, E. KASHY, I.D. PROCTOR, and W.F. STEELE, Mich. State Univ.—We describe a charge division position sensitive proportional counter system which is extensively used in the focal plane of the MSU magnetic spectrometer. The system has the following characteristics: the position resolution is about 1 mm (FWHM); the active length is 25 cm; the maximum counting rate is more than 5×10^3 cps. The normal operating configuration is the proportional counter backed with a plastic scintillation counter. This system has available for particle identification: the ΔE signal from the proportional counter, the time-of-flight of the particle through the spectrograph, the total energy of the particle from the scintillation counter, and the momentum of the particle from its position in the focal plane. Spectra of various reactions studied with this counter will be shown.

* Supported by the National Science Foundation.

A=25 Mass Quartets, * W. BENENSON, E. KASHY, and I.D. PROCTOR, Mich. State Univ.—The mass excesses of the lowest $T=3/2$ states in ^{25}Al and ^{25}Mg and of the ground state of ^{25}Na have been measured with high precision. The states were excited by the $^{27}\text{Al}(p,t)$, $^{27}\text{Al}(p,^3\text{He})$, $^{26}\text{Mg}(p,d)$, and $^{26}\text{Mg}(d,^3\text{He})$ reactions. The same reactions on ^{12}C and ^{16}O present in the targets served as calibrations. The results were fit with the isobaric multiplet mass equation to obtain the coefficients for both the $5/2^+$ and $3/2^+$ multiplets. A small positive cubic term is indicated for the $3/2^+$ multiplet.

* Work supported by the National Science Foundation.

(p,d) Studies of the Germanium Isotopes, * D.L. SHOW, B.H. WILDENTHAL, and J.A. NOLEN, Mich. State Univ.—Angular distributions have been measured for the states in ^{71}Ge and ^{73}Ge up through an excitation energy of 4 MeV. Spectra were taken between the angles of 6° and 60° in the lab with an energy resolution of 8-12 keV FWHM. The proton bombarding energy was 35 MeV. In most cases the j -dependence observed in the $\ell=3$ transfers allow unique spin assignments to the $5/2^-$ and $7/2^-$ states. Preliminary studies of the $^{70}\text{Ge}(p,d)$ reaction at a proton energy of 24 MeV and at angles $>90^\circ$ indicate the presence of sufficient j -dependence in the $\ell=1$ transfers to distinguish between the $1/2^-$ and $3/2^-$ states.

* Work supported by the National Science Foundation.

Studying Nuclei with 30 to 40 MeV Protons and 3 to 4 keV Resolution, * H.G. BLOSSER, Mich. State Univ.—An energy-loss spectrograph system is in use at the MSU Cyclotron Laboratory; overall energy resolutions in 1 in 10,000 or better have been achieved in a number of experiments. The resolution of an energy-loss system is mainly determined by the luminosity of the effective beam source.¹ This condition is then ideal for a "single-turn" cyclotron with its intense position-ion source. Spectra with 3 keV resolution at 30 MeV typically require 30 minutes running time. Several beam-sensing feedback loops are important elements in the practical application of this technique as is a computerized on-line resolution meter.² A momentum matching calibration procedure allows absolute measurements with an accuracy of 3 to 4 keV.³

* Supported by the National Science Foundation. ¹B.L. Cohen, Rev. Sci. Instr. **33**, 85(1962). ²Blosser, et al., Nucl. Instr. Meth. **91**, 61(1971). ³Trentleman & Kashy, Nucl. Instr. Meth. **82**, 304(1970).

γ - γ Coincidences from the $^{48}\text{Ti}(p,n\gamma)^{48}\text{V}$ Reaction below 3.36 MeV of Excitation, * L.E. SAMUELSON, R.A. WARNER, and W.H. KELLY, Mich. State Univ., E.M. BERNSTEIN, R. SHAMU, Western Mich. Univ.—A Ge(Li)-Ge(Li) spectrometer was used to study γ - γ coincidences from the $^{48}\text{Ti}(p,n\gamma)^{48}\text{V}$ reaction at proton bombarding energies of 5.97, 6.48, 7.03, and 8.33 MeV. Based upon coincidence evidence and γ -ray energy sums, we have placed 62 definite and 8 possible γ -ray transitions from 41 excited states in ^{48}V . The energies in keV of states from which deexcitation rays are observed to be in coincidence are 308.3 \pm 0.1, 420.8 \pm 0.1, 427.9 \pm 0.1, 518.8 \pm 0.1, 613.4 \pm 0.1, 627.3 \pm 0.1, 745.1 \pm 0.1, 765.0 \pm 0.1, 1055.9 \pm 0.1, 1099.3 \pm 0.1, 1264.6 \pm 0.2, 1521.5 \pm 0.2, 1557.5 \pm 0.2, 1685.6 \pm 0.2, 1781.0 \pm 0.2, 1998.6 \pm 0.2, 2096.9 \pm 0.3, 2118.5 \pm 0.5, 2179.5 \pm 0.5, 2258.1 \pm 0.9, 228.9 \pm 1.0, 2321.7 \pm 1.2, 2333.1 \pm 0.6, 2372.7 \pm 0.6, 2391.2 \pm 0.7, 2408.2 \pm 0.7, 2458.2 \pm 1.2, 2471.8 \pm 1.2, 2574.8 \pm 1.0, 2579.1 \pm 1.2, 2586.6 \pm 1.2, 2604.7 \pm 1.4, 2607.4 \pm 1.4, 2715.7 \pm 1.5, 2793.0 \pm 1.6, (2823.1 \pm 1.2), 2915.2 \pm 1.8, 2969.2 \pm 1.8, 3022.6 \pm 2.0, 3048.7 \pm 2.0, and (3200.5 \pm 2.5).

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Excited States in ^{140}Pr below 1.2 MeV as Determined by $^{141}\text{Pr}(p,d)$ and $^{140}\text{Ce}(p,n\gamma)$ Reaction Studies, JEAN GUILLE, R.W. GOLES, C.B. MORGAN, R.A. WARNER, Wm. C. McHARRIS, and W.H. KELLY, Mich. State Univ. and E.M. BERNSTEIN and R. SHAMU, Western Mich. Univ.—Seven-keV FWHM resolution $^{141}\text{Pr}(p,d)$ data taken at 35 MeV have been used to determine the states below 1.5 MeV excitation in the odd-odd nucleus $^{140}\text{Pr}_{81}$. The γ decays of these states are being studied using the $^{140}\text{Ce}(p,n\gamma)$ reaction. Gamma-ray excitation functions, γ -ray singles, and Ge(Li)-Ge(Li) coincidence experiments have been performed. A partial level scheme can be constructed with states at 0, 28, 191.9, 270.9, 286.7, 419.7, 574.4, 604.3, 861.6, 888.0, 904.1, 966.6, 1053.5, 1182.9, and 1228 keV. The more complex and more complete scheme is being constructed from the γ -ray data.

*Supported in part by the National Science Foundation, the Atomic Energy Commission, and the Research Corporation.

Current States of A=101 Nuclei, R.R. TODD, W.H. KELLY, Wm. C. McHARRIS, F.M. BERNTHAL, and R.A. WARNER, Mich. State Univ.††—The Nuclear DATA sheets for nuclei in the A=101 mass chain have been revised. Nuclear structure data from particle reactions, radioactive decay, and Coulomb excitation studies have been evaluated and compiled. Adopted level properties and decay schemes will be briefly summarized. Disagreements and gaps in the current data will be discussed.

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Helium Jet Recoil Transport Plus Aqueous Chemistry, K.L. KOSANKE, Wm. C. McHARRIS, Mich. State Univ.—The helium-jet recoil transport (HeJRT) method has been used as part of a system performing fast aqueous chemical separations. The HeJRT system¹ is used to generate activities and to transport them into the chemical system. Entrapment of the activities in the aqueous solution is accomplished by merely allowing a mixing of the flow of aqueous solution feeding the chemical apparatus. The low pressure (down stream) end of the HeJRT system is operated at atmospheric pressure to allow easy performance of the chemistry and sample handling. The operation of the system was demonstrated by a separation of Ga activities from Zn and Cu activities (resulting from 30 MeV protons on natural Zn targets) using ion exchange techniques. The total time elapsing between the production of activities and the completion of the chemistry was ≤ 1 second.

¹K.L. Kosanke, G.C. Giesler, Wm. C. McHarris, MSU Cyclotron Laboratory Annual Report 1970-71, p. 42.

The ϵ/β^+ Decay of ^{143}Eu , R.B. FIRESTONE, Wm. C. McHARRIS, and W.H. KELLY, Michigan State Univ.— ^{143}Eu was produced by 28-MeV protons on enriched (95.10%) $^{144}\text{Sm}_{203}$ targets at the

Michigan State University Sector-Focused Cyclotron. Activities produced were transported by means of a rabbit transport system to counting areas where the predominant 2.3-min ^{143}Eu was counted for 10 min. The 8.8-min daughter activity, ^{143}Sm , was studied in separate experiments, and transitions related to ^{143}Eu decay generally were easily elucidated. Both γ -ray singles and Ge(Li)-Ge(Li) megachannel coincidence experiments involving large Ge(Li) detectors were performed, and, with the aid of (p,d) reaction studies on ^{144}Sm , definite levels in ^{143}Sm were found at $0(3/2^+)$, 107.6(1/2⁺), 1106.6(5/2⁺), 1368.5(7/2⁺), 1536.2(5/2⁺), 1565.3, 1714.7(5/2⁺), 1912.1, and 2069.5 keV (5/2⁺). Additional levels are strongly indicated at 2101.7, 2166.7, 2227.5, 2270.2, 2312.4, 2356.5, 2409.4, 2557.3, and 2586.4 keV but are fed too weakly to be confirmed in coincidence experiments. ϵ/β^+ feeding branching ratios were measured and indicated anomalous β^+ enhancement to the 1565.3-keV level; this is currently under investigation.

The ϵ/β^+ Decay of ^{143}Sm , Wm. C. McHARRIS, R.B. FIRESTONE, and W.H. KELLY, Mich. State Univ.— ^{143}Sm was produced from the decay of ^{143}Eu , which was made in copious yields by 28-MeV protons on enriched (95.10%) $^{144}\text{Sm}_{203}$ targets at the Michigan State University Sector-Focused Cyclotron. Activities produced were transported by a rabbit transport system to counting areas where the 2.3-min parent, ^{143}Eu , was allowed to decay for at least 10 min after which the 8.8-min ^{143}Sm was counted for about 30 min. Both γ -ray singles and Ge(Li)-Ge(Li) megachannel coincidence experiments involving large Ge(Li) detectors were performed, and, with the aid of (p,d) reaction studies and previous work [D. DeFrenne, E. Jacobs, and J. Demuynck, Z. Phys. 237, 327(1970)], levels were placed definitely at $0(5/2^+)$, 271.9(7/2⁺), 1056.2(3/2⁺), 1173.0(1/2⁺), 1402.5(3/2⁺), 1514.5(3/2⁺), 1613.3, 1816.8, and 2081.1 keV. Levels were strongly indicated at 1854.2, 2008.9, 2192.9, 2445.6, 2613.7, 2920.6, 3050.1, and 3156.8 keV, but were fed too weakly to appear in coincidence experiments. ϵ/β^+ feeding branching ratios were measured and indicated anomalous γ retardation to the 1173.0-, 1402.5-, and 1514.5-keV levels. This anomaly is currently under investigation.

The Low Lying Levels of ^{118}Sb .* W.B. CHAFFEE, C.B. MORGAN, R.A. WARNER, W.C. McHARRIS, W.H. KELLY, Mich. State Univ., E.M. BERNSTEIN, and R. SHAMU, Western Mich. Univ.—The charged particle reactions $^{118}\text{Sn}(^3\text{He},t)$, $^{117}\text{Sn}(^4\text{He},t)$, $^{117}\text{Sn}(^3\text{He},d)$ and the gamma rays from the reaction $^{118}\text{Sn}(p,n\gamma)^{118}\text{Sb}$ have been used to identify the energy levels of ^{118}Sb lying below 1200 keV of excitation. 86 gamma rays have been observed in the (p,n γ) reaction as probably associated with the de-excitation of ^{118}Sb . Of these 52 gammas have been observed in (p,n $\gamma\gamma$) coincidence experiments. A tentative decay scheme has been constructed incorporating 24 levels at the following energies (in KeV): 51, 166, 238, 324, 403, 540, 606, 622, 628, 652, 740, 788, 802, 862, 937, 953, 985, 1019, 1041, 1096, 1117, and 1159, and 1182.

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The $^{64}\text{Zn}(p,t)^{62}\text{Zn}$ Reaction at 35 MeV.*
 R.A. HINRICH, Mich. State Univ. and SUNY-College at Oswego.—The $^{64}\text{Zn}(p,t)$ reaction to states in ^{62}Zn has been studied at a bombarding energy of 35 MeV using the Mich. State Cyclotron. Angular distributions were taken between 6° and 60° using a wire counter and emulsion plates in an Enge split-pole spectrograph. 35 levels in ^{62}Zn , many unreported, were observed up to an excitation energy of 5.4 MeV. Spin-parity assignments have been made for most of these levels by comparison both with DWBA calculations and with empirical characteristic shapes of known states. 0^+ states were tentatively identified at 1.88, 3.96 and 5.17 MeV; the state at 1.88 MeV may be the 0^+ member of the two phonon triplet, previously identified in other Zn isotopes but not in ^{62}Zn .¹

*Work supported in part by the National Science Foundation.

¹L.C. Farwell, J.J. Kraushaar and H.W. Baer, to be published.

A Survey of the ($^3\text{He}, ^7\text{Be}$) Reaction at 70 MeV.* W.F. STEELE, G.M. CRAWLEY, and S. MARIPUU, Mich. State Univ.—The 70 MeV ^3He beam of the Michigan State University Cyclotron has been used to observe spectra and angular distributions from the ($^3\text{He}, ^7\text{Be}$) reaction on a number of different targets. A position sensitive gas proportional counter system is used in the focal plane of an Enge split-pole broad range magnetic spectrograph to measure the momentum of $^7\text{Be}(4^+)$ ions. Particle identification is achieved through the use of the differential energy loss of the particles in the gas counter, and the time-of-flight of the ions in the spectrograph. Results will be presented for targets of ^{12}C , ^{16}O , and ^{24}Mg . In the $^{24}\text{Mg}(^3\text{He}, ^7\text{Be})^{20}\text{Ne}$ spectrum the 4.97 MeV 2^- level is only weakly excited while the 5.62 MeV 3^- state has the strongest cross-section observed.

*Supported by the National Science Foundation.

A Study of Proton Inelastic Scattering on ^{207}Pb , ^{208}Pb , and ^{209}Bi .* W.T. WAGNER and G.M. CRAWLEY, Mich. State Univ.—Low-lying states in these isotopes have been studied using the 35 MeV proton beam from the MSU cyclotron. Angular distributions from 10° to 100° were measured using both photographic emulsions and a position sensitive proportional counter in the focal plane of a magnetic spectrograph. Using a dispersion matching technique, the data obtained with the nuclear emulsions had a resolution of 5-8 keV FWHM. In addition to the weak coupling states in ^{207}Pb and ^{209}Bi many other excited states were seen in the three nuclei. Microscopic DWBA calculations for some of these states will be presented.

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AMERICAN PHYS. SOC. WASHINGTON MEETING, APR. 1973

Yrast States of $^{182,184,186,188}\text{Os}$
 Populated by (α, xn) Reactions. R.A. WARNER, F.M. BERNTHAL, J.S. BOYNO, and T.L. KHOO, Mich. State Univ.—The γ -ray spectra accompanying $^{182,184,186}\text{W}(\alpha, xn)$ and $^{186}\text{W}(\alpha, 2n)$ reactions

have been studied to establish the ground-band cascade in four Os isotopes. Anisotropy and γ - γ coincidence data lead to the moments of inertia plotted below against rotational energy as defined by Johnson et al.¹

*Work supported by the US Atomic Energy Commission and National Science Foundation.
¹A. Johnson, H. Ryde, and J. Sztarkier, Phys. Letters **34B**, 605(1971).

Twin Back-Bending Curves in ^{154}Gd .*
 T.L. KHOO, F.M. BERNTHAL, J.S. BOYNO and R.A. WARNER, Mich. State Univ.—The even-even nucleus ^{154}Gd has been studied by means of the $^{154}\text{Sm}(\alpha, 4n\gamma)^{154}\text{Gd}$ reaction at a bombarding energy of 48 MeV. Both γ -singles and γ - γ coincidence measurements were performed. The members of both the ground and β -bands were determined up to spin 18. A conventional plot¹ of ω^2 vs ω^2 confirmed the backbending effect previously observed² in the β -band. In addition, the ground band exhibits the same effect at a critical spin value of 18. These phenomena may be explained in terms of the Stephens & Simon model³ by considering a decoupled 2 quasi-particle band which intersects both the β - and ground bands.

*Work supported by US Atomic Energy Commission and National Science Foundation.

¹A. Johnson, H. Ryde and J. Sztarkier, Nucl. Phys. **A179**, 753(1972).

²D. Ward, R.L. Graham, J.S. Geiger and H.R. Andrews, Bull. Am. Phys. Soc. **18**, 36(1973).

³F.S. Stephens and R.S. Simon, Nucl. Phys. **A183**, 257(1972).

β^+ Decay of ^{65}Ge .* R.G.H. ROBERTSON and SAM. M. AUSTIN, Mich. State Univ.—The experiments by which the new isotope ^{64}Ge was produced¹ have also yielded information on the decay of ^{65}Ge . Enriched ^{64}Zn targets were bombarded with 50 MeV ^3He ions from the MSU cyclotron, and Ge chemically separated. The half-life of ^{65}Ge was found to be only 30.0 ± 1.2 sec, in contrast to the previous measurement² of 1.5 min. Nine γ -rays were assigned to ^{65}Ge with energies (and absolute intensities per 100 ± 10 decays) of 62.0 (24), 190.7(10), 587.8(2.5), 649.8(33), 809.3(21), 1070.4(1.3), 1229.8(2.2), 1688.4(3.6) and 1879.6(3.6) keV. Energy sums and the $^{64}\text{Zn}(\text{He}, d)^{65}\text{Ga}$ reaction³ indicate that levels at 0.0, 62.0, 190.7, 649.8, 809.3 and 1879.6 keV are populated in the β^+ decay.

*Supported by the National Science Foundation.
¹R.G.H. Robertson and S.M. Austin, Phys. Rev. Lett. **29**, 130(1972).

²N.T. Porile, Phys. Rev. **112**, 1954(1958).

³M.G. Betigeri et al., Nucl. Phys. **A100**, 416(1967).

(p,n) Reactions to the Isobaric Analog States of ^{48}Ca , ^{90}Zr , ^{120}Sn , and ^{208}Pb at 25 MeV. * D.M. PATTERSON, R.R. DOERING, and A.I. GALONSKY, Mich. State Univ.—Differential cross sections have been measured for the reactions $^{48}\text{Ca}(p,n)^{48}\text{Sc}$, $^{90}\text{Zr}(p,n)^{90}\text{Nb}$, $^{120}\text{Sn}(p,n)^{120}\text{Sb}$, and $^{208}\text{Pb}(p,n)^{208}\text{Bi}$ exciting the isobaric analogs of the target ground states. The incident proton energy was 25 MeV. The neutron spectra were obtained using the time-of-flight technique. The time resolution was typically 0.5 nsec (FWHM). The angular distributions generally extend from 0° to 160° (in the lab) in 5° steps. The current status of the DWBA analysis will be presented.

* Supported by the National Science Foundation and the Office of Naval Research.

Shell Model Calculation of Exotic (od-1s)-Shell Nuclei: The Heavy Oxygen and Fluorine Isotopes. * W.A. LANFORD and B.H. WILDENTHAL, Mich. State Univ.—The spectra and wave functions of $^{17-24}\text{O}$ and $^{17-24}\text{F}$ have been calculated in the complete space of (A-16) nucleons in $d_{5/2}$, $s_{1/2}$, $d_{3/2}$ shell model space. There is very good agreement between the predictions and experiment for the nuclei for which there exist experimental data. The oxygen isotopes corresponding to filling the $d_{5/2}$ shell (^{22}O) and the $s_{1/2}$ shell (^{24}O) are predicted to have first excited states at 3.22 and 5.38 MeV, respectively. It is hoped such shell model calculations may be helpful in designing experiments to study these nuclei.

* Supported by the National Science Foundation.

A High Resolution Study of the $^{208}\text{Pb}(p,d)^{207}\text{Pb}$ and $^{207}\text{Pb}(p,d)^{206}\text{Pb}$ Reactions. * W.A. LANFORD and G.M. CRAWLEY, Mich. State Univ.—The $^{208}\text{Pb}(p,d)^{207}\text{Pb}$ and $^{207}\text{Pb}(p,d)^{206}\text{Pb}$ reactions have been studied with 35 MeV protons using the high resolution (5-7 keV FWHM) cyclotron-spectrometer system at MSU. Angular distributions were measured from 6° to 50° for both reactions. By carefully measuring the relative cross-sections on these two isotopes, spectroscopic factors for the $^{207}\text{Pb}(p,d)^{206}\text{Pb}$ reactions were deduced relative to the spectroscopic factors for the $^{208}\text{Pb}(p,d)^{207}\text{Pb}$ reactions to the $2p_{1/2}$, $1f_{5/2}$, $2p_{3/2}$, $1i_{3/2}$, $1f_{7/2}$, and $h_{9/2}$ "single-hole-state". These "relative-spectroscopic" factors are in remarkably good agreement with the shell model predictions of McGrory.¹

* Supported by the National Science Foundation. 1.J.B. McGrory, Bull. Am. Phys. Soc. 17, 579 (1972).

Studies of Giant Multipole Resonance in Inelastic Scattering of 70 MeV ^3He . * A. MOALEM, W. BENENSON and G.M. CRAWLEY, Mich. State Univ.—The giant dipole resonance (G.D.R.) region in ^{209}Bi , ^{208}Pb , ^{197}Au , ^{90}Zr , ^{40}Ca and ^{27}Al was studied using inelastic scattering of 70 MeV ^3He particles. Measured spectra at forward angles exhibit a wide peak approximately 3 MeV below the excitation energy of the G.D.R. The FWHM of the peak is larger than that obtained for the G.D.R. from photoneutron reactions. This suggests the excitation of another resonance at about 11 MeV. Similar results have been obtained in other inelastic

scattering experiments^{1,2} and has been interpreted as a giant resonance is discussed and the transition strength is compared with calculations from a nuclear scattering model for the G.D. and quadrupole states.

* Supported by the National Science Foundation. 1.M.B. Lewis and F.E. Bertrand, Nucl. Phys. A196, 337(1972). 2.F.R. Buskirk et al. Phys. Lett. 42B, 194 (1972).

Shell Model Calculations in the A=52-56 Nuclei. * P. HAUGE and B.H. WILDENTHAL, Mich. State Univ.—A modified surface-delta interaction is obtained for the A=52-56 nuclei by a least-squares fitting to numerous experimental levels in the region. The truncated basis includes up to four holes in the $F_{7/2}$ shell and all possible particle excitations in the $p_{3/2}$ orbit. The rms deviation to the fitted levels is then further reduced by allowing some of the two-body matrix elements to vary. From this resultant effective interaction, we calculate spectroscopic factors and various electromagnetic properties of these nuclei. Comparison with other shell model calculations as well as possible improvements in the model space are also considered.

* Supported by the National Science Foundation.

Shell Model Study of Argon and Potassium Nuclei. * A.O. EWWARAYE, Antioch College, Yellow Springs, Ohio and S. MARIPUU, Mich. State Univ.—Shell model calculations have been performed for argon and potassium nuclei with A=38-46. Excitation energies, M1 transition probabilities, magnetic moments and s-factors for one-nucleon transfer reactions have been calculated. Different model spaces and different realistic and phenomenological interactions have been tried. The effect of particle-hole states is discussed.

* Supported by the National Science Foundation.

High Resolution Proton Inelastic Scattering on ^{208}Pb . * W.T. WAGNER and G.M. CRAWLEY, Mich. State Univ.—Angular distributions for protons scattered from ^{208}Pb have been measured at 35 MeV bombarding energy. Use of nuclear emulsions in a Enge split-pole spectrograph and dispersion matching enable a typical resolution of 5-8 keV FWHM to be obtained. The first excited 3^- state and first two 5^- states were fairly strongly excited in this reaction as were low lying 2^+ , 4^+ , 6^+ , and 8^+ states. States previously identified as unnatural parity 4^- and 6^- configurations were clearly observed although weakly populated as was a natural parity 7^- state. Distorted Wave calculations including exchange and using the wave functions of True, et al.¹ and an effective interaction with both tensor and spin orbit components will be presented.

* Supported by the National Science Foundation. 1.W.W. True, et al., Phys. Rev. C3, 2421(1971).

Current Status of A=104 Nuclei.* L.E. SAMUELSON, ** W.H. KELLY, Wm. C. MCHARRIS, F.M. BERNTHAL, and R.R. TODD, *** Mich. State Univ.—The Nuclear Data sheets for all known nuclei in the A=104 mass chain from A=40 to 50 have been revised. Nuclear structure data from particle reactions, radioactive decay, Coulomb excitation, and nuclear fission products have been evaluated and compiled. Adopted level properties and decay schemes will be briefly summarized. Disagreements and gaps in the current data will be discussed.

- * Supported in part by the National Science Foundation and the U.S. Atomic Energy Comm.
 ** Nuclear Information Research Associate. Work supported by the National Science Foundation through the National Academy of Sciences-National Research Council.
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Isospin Mixing in $f_{7/2}$ Shell. G. BERTSCH and B.H. WILDENTHAL, Mich. State Univ.—Isospin mixing in $f_{7/2}$ nuclei is calculated using the pure $f_{7/2}$ model space and the empirical interaction from the mass 42 spectra. The level shifts among the different members of the mass 42 multiplet give rise to the isospin mixing. Mixing in six nuclear states has been measured experimentally; we find reasonable agreement in magnitude and sign in four cases. The case of Sc^{44} confirms the evidence from the A=42 spectra that there is a non-Coulomb charge dependence of the effective interaction. In the table below, theoretical and experimental amplitudes of the T> state are listed (x1000).

Nucleus	$\alpha(T>)$ Theory	$\alpha(T>)$ Exp.
$Sc^{44}(2^+)$	4 x10 ⁻³	4 x10 ⁻³
$Ti^{46}(4^+)$	2	0.4
$Ti^{48}(6^+)$	3	-0.2±0.2
$V^{48}(4^+)$	2	2
$Mn^{52}(6^+)$	1.7	3
$Mn^{52}(2^+m)$	2	2

Energy Levels of ^{116}Sb Below 1.5 MeV.* C.B. MORGAN, J.A. GUILLE, R.A. WARNER, L.E. SAMUELSON, Wm. C. MCHARRIS, W.H. KELLY, Mich. State Univ. E.M. BERNSTEIN, and R. SHAMU, Western Mich. Univ.—The reaction $^{116}Sn(p,n)$ was used to identify the energy levels of ^{116}Sb below 1500 keV of excitation. Eighty-nine γ rays appear to belong to the de-excitation of ^{116}Sb . A tentative decay scheme has been constructed incorporating levels at the following energies (in keV) 94, 103, 411, 455, 468, 518, 576, 613, 654, 732, 815, 824, 883, 999, 1021, 1127, 1157, 1124, 1441. Gamma ray angular distribution measurements have been used to determine the spins of the lower energy states. These results will be discussed.

- * Work supported by the National Science Foundation and Atomic Energy Commission (MSU) and a grant from the Research Corporation (WMU).

Higher-Order Effects shown by the (p,t) Reaction on the Deformed Nucleus, ^{165}Ho . R.W. GOLES,† R.A. WARNER, Wm. C. MCHARRIS, and W.H. KELLY, Mich. State Univ.—30-MeV protons from the MSU Sector-Focused Cyclotron were used to study the $^{165}Ho(p,t)^{163}Ho$ reaction. Triton spectra were taken at 5° intervals between 10° and 75°, using an

Engel split-pole magnetic spectrograph; the overall resolution was typically better than 10 keV FWHM. The $7/2^- [523]$ ground-state rotational band was strongly excited at least up to the $17/2^-$ member at 720 keV, as was the $k=2=3/2^-$ γ -vibrational band, where members up to $13/2^-$ at 1075 keV were seen. However, no evidence was seen of a $k=2$ γ -vibrational or the (predicted to be high-lying) β -vibrational band. The angular distributions were complex and reminiscent of those found in the $^{159}Tb(p,t)^{157}Tb$ reaction [Goles, Warner, McHarris, and Kelly, Phys. Rev. Letters 24, 802(1972)], indicating that collective and higher-order effects play an important role.

- * Supported in part by the National Science Foundation and the U.S. Atomic Energy Comm.
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Errors in Charge Densities from Electron Scattering. J. BORYSOWICZ and J.H. HETHERINGTON, Mich. State Univ.—Errors on the charge distribution as derived from electron scattering are determined and it is shown that they depend largely on assumptions about the possible large q behavior of the form factor (i.e. at larger q-values than have been measured). We use rather general expansions for $\rho(r)$, for example the cosine series or a set of spline well determined and not very dependent on the set of functions used for expansion. The error in the charge distribution depends on assumptions about and knowledge of the errors in $f(q)$. Charge densities and their errors will be presented for He^3 and for He^4 based on electron scattering data. Some previous studies¹ of the errors in charge distributions have not precisely stated the assumptions about $f(q)$ at large q-values and have obtained rather large errors in $\rho(r)$. Our method is applicable to nuclei of larger z.

- ¹ J. Friedrich and F. Lenz, Nucl. Phys., A183, 523(1972).

A Study of the $^{43}Ca(p,d)^{42}Ca$ Reaction at 42 MeV. KAMAL K. SETH, A. SAHA, Northwestern University, W STEWART, Lewis Research Center (NASA), and W.A. LANFORD, W. BENENSON, and B.H. WILDENTHAL, Mich. State Univ.*—The neutron pickup reaction, $^{43}Ca(p,d)^{42}Ca$ has been studied at $E_p=42$ MeV using the MSU cyclotron. Deuteron pickup reactions were detected in a position sensitive proportional counter (backed by a plastic scintillation counter to permit particle identification) mounted in the focal plane of a split-pole magnetic spectrometer. An energy resolution of about 30 keV was obtained. Differential cross sections were measured in 3° steps from 6° to 55° for about 30 transitions to states in ^{42}Ca upto about 7.5 MeV excitation. It is found that the l -assignment ambiguities in earlier ($^3He, \alpha$) experiment of comparable resolution are removed in our work and a much more reliable determination of spectroscopic strengths is made possible.

- * Supported by the National Science Foundation.
 † U. Lynen, H. Oeschler, R. Santo, and R. Stock, Nucl. Phys. A127, 343(1969).

Review of Instrumentation Systems of the MSU Cyclotron Laboratory. H.G. BLOSSER, Mich. State Univ.—The cyclotron is a variable-energy isochronous machine of nominal 50 MeV energy and provides beams of protons, deuterons, helions, and alphas. The cyclotron provides unusually precise beams; with careful adjustment 0.05% energy spread, 0.5 mm/mrad horizontal emittance, and 5.0 mm/mrad axial emittance. Internal selection slits give routine 100% extraction efficiency. Using a dispersion matching 1 in 10,000 energy resolution can be obtained in the 90 cm Enge split-pole spectrograph. The laboratory also has a modern computer system with a locally designed timesharing monitor which is able to handle major computing assignments (including distorted wave calculations, shell-model calculations, etc.) while concurrently offering a wide variety of data taking options to the experimentalist. Other major facilities include a 40" precision scattering chamber, a neutron time-of-flight facility and a helium jet transport system.

* Supported by the National Science Foundation.

(p,n) Reactions to the Isobaric Analog States of ^{48}Ca , ^{90}Zr , ^{120}Sn , and ^{208}Pb at 25 and 35 MeV. R.R. DOERING, D.M. PATTERSON, AARON GALONSKY, and J.G. BRANSON, Mich. State Univ.—Differential cross sections have been measured for the reactions $^{48}\text{Ca}(p,n)^{48}\text{Sc}$, $^{90}\text{Zr}(p,n)^{90}\text{Nb}$, $^{120}\text{Sn}(p,n)^{120}\text{Sb}$, and $^{208}\text{Pb}(p,n)^{208}\text{Bi}$ to the isobaric analogs of the target ground states. Proton energies of 25 and 35 MeV were used. The angular distributions were taken at 0° and in 5° steps between 10° and 160° . Macroscopic and microscopic DWBA fits to the data will be presented.

* Supported by the National Science Foundation and the Office of Naval Research.

The $^{48}\text{Ca}(^3\text{He}, ^7\text{Be})^{44}\text{Ar}$ Reaction at 70 MeV. W.F. STEELE, G.M. CRAWLEY, and S. MARIFUU, Mich. State Univ.—Lifetime measurements of ^{44}Ar have been made,^{1,2} but by techniques not permitting extraction of the mass or spectrum. Using the α -pickup reaction, ($^3\text{He}, ^7\text{Be}$), on a ^{48}Ca target, we have been able to observe the spectrum of ^{44}Ar , hence permitting a mass determination. Although we observe 4 or 5 states in ^{44}Ar , measurement of an angular distribution of any of them is impractical because of the very low differential cross section ($<1 \mu\text{b/str}$) and the dominance of Carbon and Oxygen contamination. A comparison will be made with the $^{40}\text{Ca}(^3\text{He}, ^7\text{Be})^{36}\text{Ar}$ reaction which yields differential cross sections on the order of 50 times greater.

* Supported by the National Science Foundation.
1.J. Hudis, et al., Nucl. Phys. A151, 634(1970).
2.R.E. Larson and C.M. Gordon, Nucl. Phys. A133, 237(1969).

Anomalous ϵ/β^+ Decay Branching Ratios.* R.B. FIRESTONE and Wm. C MCHARRIS, Mich. State Univ.—The ϵ/β^+ decay branching ratios for decays of ^{145}Gd , ^{143}Sm and ^{143}Eu were measured for transitions to numerous daughter levels. $\beta^+\gamma$ coincidence experiments were used to get relative positron feedings, and x-ray-coincidence experiments provided relative electron capture feedings. Instances of severe anomalies in the ϵ/β^+ ratios were observed for transitions to the 808.5-keV level of ^{145}Eu , the 1173.8-, 1403.9- and 1515.7-keV levels of ^{143}Pm , and the 1566.3-keV level of ^{143}Sm . These ratios deviated from theoretical ratios by factors of 20, 5, 5, 5 and 0.4 respectively. All were allowed transitions with relatively high log ft values. It is generally assumed that such results are evidence of Fierz interference which would bring into question the V-A Theory of beta decay.

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Decay of ^{177}Ta to Levels in ^{177}Hf .* B.D. JELTEMA and F.M. BERNTHAL, Mich. State Univ.—Levels in ^{177}Hf populated by decay of 56.6 hr ^{177}Ta have been studied by γ -ray singles and γ -ray coincidence spectroscopy. The activity was produced by bombarding natural Lu foil with a beam of 30 MeV alpha particles produced by the MSU cyclotron. Several new levels have been added to the decay scheme proposed by West, et al.,¹ and multipolarities have been assigned for 24 of the 42 observed transitions with use of the conversion electron data of West. The previously proposed isomeric level at 421.0 keV thought to be $I^\pi=3/2^+$ is excluded by our data. A doublet is identified at 742.1 and 745.9 keV with the upper member being the $7/2^+[633]$ state proposed earlier. The presence of this doublet may alter the interpretation of transfer reaction data.²

* Supported in part by the U.S. Atomic Energy Commission and the National Science Foundation.
1.H.I. West, et al., Phys. Rev. 124, 527(1971).
2.F.A. Rickey, Jr., et al., Phys. Rev. 170, 1157(1968).

Half-lives of the 308.3- and 518.8-keV States of ^{48}V . L.E. SAMUELSON, C.B. MORGAN, T.L. KHOO, and W.H. KELLY, Mich. State Univ.—The reaction $^{48}\text{Ti}(p,n\gamma)$ with $E_p=7.20$ MeV was used to measure the half-lives of the 308.3- and 518.8-keV states of ^{48}V . The ^{48}V γ rays were counted with a high-resolution, small-volume planar Ge(Li) spectrometer in 5.19-nsec time bands between 62.3-nsec spaced beam bursts of the MSU Sector-Focused Cyclotron. The measured half-lives are 7.12 ± 0.04 and 2.72 ± 0.06 nsec for the 308.3- and 518.8-keV states, respectively. No other ^{48}V states below 1.7 MeV of excitation were observed to have half-lives greater than 1 nsec.

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Barely Deformed Nuclei at High Spin.*

(Invited paper) R.A. WARNER, Mich. State Univ.—Some high-spin states of even-even nuclei lying just within the boundary of the rare-earth deformed region appear at energies surprisingly low, considering the well-behaved spacing of levels in the cascade de-exciting them.¹ When similar behavior was first discovered² in ¹⁶⁰Dy, it was interpreted as a sharp change in the moment of inertia caused by a nuclear phase transition. The effect was subsequently found in other nuclei with neutron number $90 \leq N \leq 96$. A specific explanation³ involving two-quasiparticle states is put to the test by the recent data on nuclei with as many as 112 neutrons. Yrast levels above spin 14 appear depressed in ^{182,184,186}Os. In ¹⁵⁴Gd, at the lower edge of deformation, levels in both the ground and β bands are affected. These new results, particularly those for the osmium isotopes, reveal the phenomenon to be more general than was expected by many investigators. The multiple γ feeding observed proceeding to many of these high-spin states is of additional interest.

- * Supported by the U.S. Atomic Energy Comm. and National Science Foundation.
- ¹R.A. Warner and F.M. Bernthal; Bull. Am. Phys. Soc. 17, 899(1972); R.A. Warner, F.M. Bernthal, J.S. Boyno, T.L. Khoo, and G. Sletten, to be published.
- ²A. Johnson, H. Ryde and J. Sztarkier, Phys. Letters 34B, 605(1971).
- ³F.S. Stephens and R. Simon, Nucl. Phys. A183, 257(1972).