SECTION II

ABSTRACTS OF TALKS AT
AMERICAN PHYSICAL SOCIETY MEETINGS

(July 1974–June 1976)
Study of the (p,d) Reaction on Odd-Hacont Nuclei of the sd-Shell. R.B. WILDENTHAL, Mich. State Univ.—Results of \( ^{7}\)Be, \( ^{8}\)B, \( ^{9}\)Be, \( ^{10}\)B, \( ^{11}\)C, \( ^{12}\)C and \( ^{13}\)B have been bombarded with 35-Mev protons and the emergent deuteron spectra measured with good energy resolution (+2 kev) and good counting statistics between \( \gamma \) and \( 10^\circ \). The analysis of the data yields insights into i) the meaningfulness of a DWBA interpretation of this type of reaction; ii) the limits of viability of sum-rule analyses of complex transfer data; iii) the stability and consistency of the agreement between general shell-model expectations and DWBA-extracted experimental trends; and iv) the success, and the attendant limitations, of the predictions of spectroscopic details via the shell model.

*Supported in part by the U.S. National Science Foundation.

CCBA Calculations of (p,t) Reactions in the Lower sd Shell. C.H. KING, H. MANN, M.A.H. RASMUSSEN, and R.B. WILDENTHAL, Michigan State Univ.—We have investigated the influence of multistep inelastic-plus-transfer processes on the reaction \( ^{12}\)C(p,1\( ^{11}\)C)\( ^{11}\)Be and \( ^{12}\)C(p,t)\( ^{12}\)Be by performing coupled-channel Born approximation (CCBA) calculations. These calculations were made assuming the macroscopic rotational model to describe the inelastic scattering and form factors based on shell model wavefunctions to describe the transfers. We have found that a meaningful comparison of the results of (p,t) reactions on highly collective nuclei with predictions of the shell model must include such multistep processes explicitly. The cross section for the \( ^{12}\)C(p,t)\( ^{12}\)Be reaction to the first 2\( ^{+}\) is, for example, increased by a factor of 2000 by the inclusion of these processes. A discussion of the influence on the calculations of uncertainties in the optical model parameters will be presented.

*Supported by the National Science Foundation.

Rotational Band Structure of \( ^{17}\)F. C.L. DORES, F.M. BERNHARDT, T.L. KIDD, and C.H. KING, Michigan State Univ.—The rotational band structure of \( ^{17}\)F is being investigated, via low-energy gamma ray spectroscopy. Levels in \( ^{17}\)F are populated in the \( ^{17}\)O(p,\( d\)) reaction induced by 37 Mev alphas from the MSU Cyclotron. \( \gamma \)-rays coincident, angular distribution, prompt and delayed singles data are being used to characterize the band structure. The ground band has been identified up to spin 16 and the \( K=\frac{3}{2} \) octupole band to spin 12. Agreement with \( ^{17}O \) decays data for the lower spin members of these bands is good. Other bands associated with \( ^{17}F \) are also seen and will be discussed.


(a,d) Reaction on Several Odd-A Nuclei in the \( 2\)A-\( 4\)A Mass Range. W.S. CHEN, R.B. WILDENTHAL, and H. MANN, Michigan State Univ.—We have measured the angular distributions at 40 Mev for \( (a,d) \) reactions on \( ^{7}\)Be, \( ^{12}\)C, \( ^{17}\)O, and \( ^{19}\)F, as well as \( ^{20}F \), using the alpha beam from the MSU Cyclotron. The normalization was obtained by monitoring elastically scattered alpha particles with a solid state detector. The outgoing duterons were analyzed in a split-pole magnetic spectrograph and detected in a position-sensitive single-wire proportional counter with an energy resolution of about 80 kev. The dominant peak in each spectrum was assigned 13/2\( ^{-} \) for \( ^{7}\)Be\( (1.24 \text{ Mev}) \) and 17/2\( ^{-} \) for \( ^{17}\)O\( (7.01 \text{ Mev}) \), 19/2\( ^{-} \) for \( ^{19}\)F\( (1.84 \text{ Mev}) \), and 19/2\( ^{-} \) for \( ^{12}\)C\( (2.22 \text{ Mev}) \) on the basis of strength and shape of angular distributions. The results for other levels as well as the predictions of shell-model calculations will be reported.

*Submitted by C.H. King.
*Work supported by the National Science Foundation.

High Spin Level Structure in \( ^{30}P \). M. PIIPERT, R.J. COMEY, F.S. WALT, Purdue Univ., and F.M. BERNHARDT, C.L. DORES, T.L. KIDD, Michigan State Univ.—Levels of \( ^{30}P \) populated in the \( ^{30}O(p,\gamma) \) reaction have been studied using the M.S.U. cyclotron. The measurements have included prompt and delayed \( \gamma \)-ray singles, \( \gamma \)-\gamma coincidence, angular distribution and excitation function determinations. An extensive high spin level scheme will be presented and compared with that of \( ^{31}P \) which we established earlier. Three intense de-excitation branches are observed in each nucleus, one involving even-spin positive parity levels and the other a 5\( ^{-} \), 7\( ^{-} \), 9\( ^{-} \) level sequence. In both nuclei, isomeric 12\( ^{-} \) states intrude into the positive parity yrast sequences giving the appearance of highly exaggerated back-bending type behavior. In addition, there is considerable side-feeding into the high-spin members of these bands. \( ^{31}P \) with a dominant role in the de-excitation schemes have been discovered. The interpretation of these findings will be discussed.

*Work supported by the U.S.A.E.C. and the NSF.

*Supported by the National Science Foundation.

128
Comparative Study of (p, 1) and (p, 2He) Reactions on T2 and T2* Targets. The investigation has been extended to include the effect of the energy dependence of the interaction potential for these reactions. We have measured the (p, 1) and (p, 2He) reactions on T2 and T2* targets for energies between 30 and 70 MeV. The results show that the (p, 1) reaction is more sensitive to the energy dependence than the (p, 2He) reaction. The energy dependence of the (p, 1) reaction is more significant than that of the (p, 2He) reaction.

*Supported by the National Science Foundation.

Improved Energy Resolution with the MSU Cyclotron. J.A. Nolen, J.M. and R.J. Miller, Mich. State U.—With the recent advances in high-resolution power large solid angle magnetic spectrometers such as the QD system, energy resolution of 1 part in 10^5 FWHM should be obtained when not limited by the accelerator. Such resolution has been achieved in the Engle split-pole spectrometer at the MSU cyclotron by operating in the high-energy mode with the spectrometer set to 2.6 MeV. Recent cyclotron improvements and further reductions in the aperture to 0.084 mm have resulted in improved resolution, 0.18 ± 0.005 MeV at 50 MeV protons. The parameters of the cyclotron which are most significant in the energy loss mode will be discussed and empirical data on the effects of various targets on the energy resolution will be presented.

*Supported by the National Science Foundation.

Observation of T2 States in 4He. R.W. Hoffman, W.M. Robinson, M.G. Pugmire, J.E. Goodman, Brookhaven National Lab.—The lowest T2 states in 4He and 5He have been observed via the 19MeV (p, 2He) and (p, 3He) reaction products, thus completing the first electronic transition in 4He. The 19MeV (p, 2He) and 19MeV (p, 3He) reactions have been measured with the 4He target and the (p, 2He) and (p, 3He) reactions have been measured with the 5He target. The results are in agreement with the predictions of the shell-model wave functions.

The Production of 7Li in the (p, t) Reaction. H.H. Kossut, L.M. Kemen, M.G. Pugmire, and W. Austin, Mich. State U.—Measurements of the 7Li production in the (p, t) reaction at 240 MeV have been made. The results are in agreement with the predictions of the shell-model wave functions.

*Supported by the National Science Foundation.

Observation of T2 States in 4He and 5He. R.W. Hoffman, W.M. Robinson, M.G. Pugmire, J.E. Goodman, Brookhaven National Lab.—The lowest T2 states in 4He and 5He have been observed via the 19MeV (p, 2He) and (p, 3He) reaction products, thus completing the first electronic transition in 4He. The 19MeV (p, 2He) and 19MeV (p, 3He) reactions have been measured with the 4He target and the (p, 2He) and (p, 3He) reactions have been measured with the 5He target. The results are in agreement with the predictions of the shell-model wave functions.

The Production of 7Li in the (p, t) Reaction. H.H. Kossut, L.M. Kemen, M.G. Pugmire, and W. Austin, Mich. State U.—Measurements of the 7Li production in the (p, t) reaction at 240 MeV have been made. The results are in agreement with the predictions of the shell-model wave functions.

*Supported by the National Science Foundation.

Electrical Properties of the Inelastic n-Group from the 7.66 MeV State of 12C and the 3-Alpha Reaction Rate. R.W. Hoffman, W.M. Robinson, M.G. Pugmire, and W. Austin, Mich. State U.—The 3-Alpha reaction rate for the 7.66 MeV state of 12C was measured. The results show that the 3-Alpha reaction rate is proportional to the branching ratio for the 7.66 MeV state of 12C. Unfortunately, the results are not in agreement with the predictions of the shell-model wave functions. The results are in agreement with the predictions of the shell-model wave functions.

Research supported by the National Science Foundation.

Energy of the 7Li Target. R.W. Hoffman, W.M. Robinson, M.G. Pugmire, and W. Austin, Mich. State U.—The energy of the 7Li target in the (p, t) reaction is 240 MeV. The results are in agreement with the predictions of the shell-model wave functions.

Research supported by the National Science Foundation.
Characteristics of a 4000(2/3) MeV Superconducting Heavy-Ion Cyclotron. R.A. BROOKES, B.A. JENNINGS, and W.W. SCHEER, Michigan State University. Recent studies at MSU have led to an attractive design for a compact heavy-ion cyclotron. The main field is derived from a pair of superconducting coils of 56° I.D., 5-1/2" wide and 19" high. The coils are housed in an independent cylindrical cryostat with a clear, 85" dia., room temperature bore. A 4 sector iron pole tip inserted in this bore provides focusing adequate for 100 MeV protons. The pole tip and the iron yoke increase the 3.1 tesla air core field, such that the average field of the coil and iron together is 4.7 tesla. The field edge is relatively sharp; extraction with conventional electromagnetic elements is feasible although superconducting magnetic shields appear to be a superior technique. Engineering consultants estimate the coil, cryostat, refrigeration system, yoke and pole tips to cost $929,000. Including a 4 dee rf system, vacuum system, injection system, etc. the cost of the complete cyclotron appears to be well below $2,000,000.

Supported by the National Science Foundation.

New Tests of the Isobaric Multiplet Mass Equation. R.G.H. ROBERTSON, Michigan State University. Until recently the IME could only be experimentally tested in the T=3/2 multiplets, which have four members. A series of new experiments on T=2 states now permit tests of the IME in isobaric quintets. By means of the reactions $^8$Li($^9$Be,$^9$Be)$^9$Be(T=2), $^{18}$O($^9$Be,$^9$Be)$^9$Be(T=2), and $^{10}$Be($^9$Be,$^9$Be)$^{16}$O(T=2), a quintet has been completed for the first time, and an appreciable departure from the IME is indicated. Also, the observation of the $^{18}$O($^9$Be,$^9$Be)$^{16}$O reaction brings to 9 the number of T=2 states known in the A=20 quintet. The implications for the IME of these and other new results will be discussed.

Supported by the National Science Foundation.

High-Spin Level Structure of $^{198}$W. J.A. JETLENN, M.H. BETHWAITE, P.G. DUNN, and C.J. DORES, Michigan State University. — The $^{198}$W($^{16}$O,$^{16}$O)$^{198}$W reaction was used to carry out in-beam x-ray spectroscopy of $^{198}$W. Three-parameter (γ−γ) coincidence, angular distribution, excitation function, and prompt and delayed γ-ray singles measurements were used to assign 59 levels to the $^{198}$W level scheme. Eleven rotational bands were identified, and most of these were characterized. The large number of bands populated results from an unusually high density of states near the yrast band. The 1.4-keV $^{10}$I isomer previously observed by Nordhagen was characterized from intraband branching ratios to be predominantly the 9/2+(624), 7/2+(615) two-quasineutron state, and indications are that a crossing between this band and the highly regular ground band should occur near spin 16. A low-lying probabily 17/2+ two-proton state was found to decay promptly to the ground band, a behavior attributed to an accidental near-degeneracy of that state and the spin-6 member of the yrast band.

Supported by the National Science Foundation.

The $^{19}$O($^{16}$O,$^{16}$F) Reaction. L.R. HEDDEK and W.T. FORSTNER, University of Pennsylvania; B.H. WILDETHAL, H. MANN, and W.T. CHEN, Michigan State University. Angular distributions have been measured for states below 8 MeV in $^{18}$F populated in the $^{19}$O($^{16}$O,$^{16}$F) reaction at E$_x$=47.5 MeV. Outgoing deuterons were detected in a proportional counter placed in the focal plane of a split-pole magnetic spectrometer. The target was Au-backed WO$_3$. SMM angular distributions calculated with the use of (ad) 2-hole-model wave functions give reasonable agreement with the data, especially for the high-spin states.

Supported by the National Science Foundation.
Weak Coupling Relations Revealed by (p,t) Reactions on 23Mg and 24Mg. H. NAHN, W. H. WILDENHALL, Mich. State Univ. and Northwestern Univ.-In a recent series of (p,t) experiments on 23Mg and 24Mg nuclei, we have discovered weak coupling relations between excited 0^+ states in even-A nuclei and corresponding 7/2^- states of odd-A nuclei. In the present series of (p,t) experiments on 197Au, 208Pb, and 209Bi, we have observed strong coupling relations between excited 0^+ states in even-A nuclei and corresponding 7/2^- states of odd-A nuclei. It was found that enhanced L=0 transitions are only observed in the g.s. and to one 7/2^- state in each odd-A nucleus at an excitation energy which is approximately 400 keV lower than the energy of 0^+ state in the even-A partner. In the present (p,t) experiments on 197Au, 208Pb, and 209Bi, similar L=0 enhancements are observed for the 3/2^- state in 197Au and correspondence is established with the L=0 transition to the 3/2^- state in 198Hg. The weak coupling interpretation is examined in terms of multi-shell-model calculations.

*Supported in part by the National Science Foundation.  
States in $^{116}$Sn from the Beta Decay of $^{116Te}$ and the $(\gamma,\alpha)$ Reaction. C.R. MORNAS, S.A. YULK, R.A. WARNER, R.J. SAMMISLOD, W.C. MCKARRIS, W.H. KELLY, Mich. State Univ., E.M. BERNSTEIN, and R.S. SHAMU, Western Mich. Univ. --The beta decay of $^{116}\gamma$ Sn is observed to directly feed 4 excited levels in $^{116}Zr$. These 4 states and 13 others were observed in the $(\gamma,\alpha)$ experiments. Spin and some parity assignments have been made based upon the beta decay in conjunction with in-beam gamma-ray angular distributions and excitation function measurements to 21 levels below 1250 keV. These are 0$(3/2^+)$, 93(7/2$^-$), 103(6/2$^+$), 119(8/2$^-$), 255(2/2$^+$), 486(0/2$^+$), 509(1/2$^-$), 517(0/2$^-$), 550(2/2$^+$), 756(2/2$^+$), 612(4/4$^-$) keV. The lifetime of the hindered 455.5 keV state has also been measured to be 1.846 ± 0.1 ns.

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**Now at Dept. of Physics, Purdue Univ., W. Lafayette, Indiana.

$^*\gamma$-ray Quasi-Particle Band in $^{116}$Sn. T.U. KHOO, F.M. HERMAN, R.H. RUBENSTEIN, and R.A. WARNER, Mich. State Univ. --A $^*\gamma$-ray quasi-particle level in $^{116}$Sn has been established at 2866 keV and its lifetime measured at 0.617 ns. Its configuration is probably (7/2$^+$), 9/2 (5/2$^-$), 7/2 (5/2$^+$), 5/2 (5/2$^+$) which it decays through two previously identified $^*\gamma$ two quasi-particle bands. The isomer was produced in the 7.6 MeV reaction, revealing an unusually high proportion of $^*\gamma$-ray singles. The decays of these levels produce the synthesis of a delayed coincidence technique to be described, we have isolated the $^*\gamma$-ray which feeds the isomer, and by $^*\gamma$-ray coincidence measurements constructed a well-behaved rotational band upward to spin 18$^+_1$. The model structure of this band is as yet unknown.

Supported by the National Science Foundation.

High Spin Level Structure of $^{170}$Tm. C.L. DORS, T.U. KHOO, F.M. HERMAN, C.H. KING, Mich. State Univ. --Levels in $^{170}$Tm are being investigated via the $^{170}$Er $(\gamma,n_\alpha)$ reaction using gamma-ray singles, angular distribution, excitation function, $^*\gamma$, and $^*\gamma$-ray coincidence data. Three bands based on the 1/2$^+$ (central), 5/2$^-$ (512), and 7/2$^-$ (632) states have been tentatively identified. The low spin members of the 1/2$^+$ (central) ground band show agreement with recent copper-electron data (Kreil). The 5/2$^-$ (512) and 7/2$^-$ (632) band structure will be discussed in light of the sharp decrease in the $^*\gamma$-ray angular correlation function expected to occur in this region. Relevant to the 170 ground state band structure reported earlier by us, its second band structure is expected to be a 5. The 5/2$^-$ (512) band has a slightly larger deformation than that expected for the 7/2$^-$ (632) band. The structure of these bands is now under investigation.

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

The Decay of $^{149}$Sm$^{238}$U. R.A. WARNER, R.B. FIRESTORM, W.C. MCKARRIS, and W.H. KELLY, Mich. State Univ. --$^{149}$Sm$^{238}$U was produced by 14 MeV neutrons enriched to $^{100}$Sm targets at the Michigan State University Sector-Focused Cyclotron. The activity produced was then transported to a 6-MeV transport system to a low background area. The results of the pair of experiments were performed. Isomer in $^{149}$Sm$^{238}$U 27.300 (2) keV is reported with a half-life of 100 ns and an angular coefficient $\alpha=16.9(2)\%$. The 11/2$^-$ isomer decays to the 19/2$^-$ state at $^{150}$Sm which is consistent with the nearby 1/2$^+$ 11/2$^-$ isomers (11/2$^-$). The (2,6) values were calculated for all of the 149$^{151}$Sm$^{153}$I decay through 14 MeV neutrons by indicating almost constant reduced transition probabilities throughout this region.

*Supported by the USAEC and the NSF.

Resolution of the $c/\delta$ Anomalies. R.B. FIRESTORM, W.A. WARNER, W.C. MCKARRIS, and W.H. KELLY, Mich. State Univ. --Large anomalies for $c/\delta$ ratios from $^{149}$Sm$^{238}$U and $^{149}$Sm$^{238}$U 27.300 (2) keV and $^{150}$Sm$^{153}$I decay are explained in terms of second-order interferences. Reasonable values of the Morita parameter $c/\delta$ are shown to yield $c/\delta$ ratios greater than 100 times the normal allowed predictions. The general correction terms for calculated $c/\delta$ ratios, like the original Morita's simplification, are given for small $c/\delta$ ratios. The new correction terms, like Morita's simplification, are used to calculate $c/\delta$ ratios and the lower spin to position decay. In addition, small anomalies in the accurately measured $^{149}$Sm$^{238}$U 27.300 (2) keV $c/\delta$ ratio is shown to lead to a value of $c/\delta$ identical to that obtained from $^{149}$Sm$^{238}$U 

*Supported by the USAEC and the NSF.


Empirically Renormalized Hamiltonians for $^{12}$C($p,p')^12$C Shell-Model Calculations. R. H. VON DORN and E. M. ROSS, Michigan State Univ. We have determined Hamiltonians for full $^1g_9/2-^3d_{5/2}$ shell-model calculations which are optimised relative to the level-energy data at either the lower or upper end of the $^1s-^1d$ shell. We describe above the general procedures by which these empirical matrix elements are obtained from the two-type starting values. The data set for the lower $^1s-^1d$ shell interaction is comprised of 200 levels, while the upper $^1s-^1d$ shell set is comprised of 160 levels. Mass-independent, state-independent $^1d-^3d$ body Hamiltonians suffice to fit the known binding energy data either over the range $A=17-26$ or $A=26-39$ with an rms deviation of 0.2 keV, at the level of 9 data elements per parameter. However, it is not possible to fit in similar fashion the $A=17-26$ and $30-39$ data simultaneously.

The MSU On-Line Mass Identification System. H. K. EDMONSTON, K. MOSKATE, W. L. PHILMANN, and R. H. KELLY, Michigan State Univ. We describe the recent improvements to the mass identification system for the MSU cyclotron, including the addition of the $^1s-^1d$ body Hamiltonians for the $^1d-^3d$ shell interactions.


Resolution of Discrepancies Associated with Analog States of 25 and 26. AARON GALOSNY, G.M. CRAVENS, R.W. DOBBINS, F.J. HILLER, and S.H. PATERSON, MICH. STATE UNIV.—It has been reported that the cross section for the reaction $^{25}P \rightarrow ^{25}P_0$ (aES) at 25 MeV is $5.4 \text{ mb}$, whereas the cross section for proton decay of the IAS is almost 15 nb. The discrepancy may be due to errors in determining each of the cross sections. A larger ($\sim 50$) cross section is extracted from the data if a Lorentzian, not a Gaussian line shape is assumed for the IAS. A small ($\sim 100$) cross section is obtained if one takes proper recognition of the fact that the background in the region of the peak is expected to be peaked right under the IAS peaks. The Coulomb-barricade cutoffs for the proton evaporation spectrum produces the background peak. Similar effects arise with targets of the lead isotopes. The peaked proton background may also resolve a discrepancy noted in determining the widths of these IAS.


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

First Observation of $^{95}Np$. E. KASHY, W. BENEDICT, W. HILTLER, H. NAPP, and L. KONINCH, MICH. STATE UNIV.—A new reaction, $(^9He, ^8Be)$, has been used to measure the mass of the previously unobserved isotope $^{95}Np$. The $74 \text{ MeV} ^9He$ beam of the MICH. SYNCHROTRON interacting with the target, and the products were analyzed in an Enge split-pole spectograph. The position in the focal plane was determined with a resistive wire proportional counter. Particle identification was accomplished by measuring the specific ionization of the particles as well as their pulse height in a plastic scintillator and their time of flight in the spectograph. The $(^9He, ^8Be)$ reaction on $^{27}Al$, which leads to $^{95}Np$, was also observed, and the transitions in the $^9$ ground state and $1,275 \text{ MeV}$ $1^+$ state of $^{94}Np$ served as calibration for the $^{95}Np$ mass. A preliminary value of $55,532 \pm 35$ MeV for the mass excess of $^{95}Np$ has been obtained. Details of the experiment and comparison of the results with various mass prediction will be presented.

*Supported by the National Science Foundation.

Energy Levels of $^{13}P$. J.A. NIELSEN and H. NAPP, MICH. STATE UNIV.—Spectra of protons inelastic scattering from $^{13}F$ at 15 MeV have been recorded on nuclear emulsions in an Enge split-pole magnetic spectograph with a resolution of 2.5 keV FWHM. Excitation energies for the states observed have been determined with uncertainties of $<0.1 \text{ keV}$ independent of previous assignments in $^{13}F$. In the bound state region of the spectrum below the 7.3 MeV excitation energy, several new levels have been identified. Of the approximately 75 particle-bound states observed in the region between 7.3 and 10 MeV excitation, many correspond to levels seen previously as resonances, but many were previously unknown. The two sets of levels will be compared to determine the behavior of the direct $(p, p')$ reaction for level density measurements.

*Supported by the National Science Foundation.

Shell-Model Calculations for the Zircon Isotopes. J.R. VAN HEEREN, W. CHUNG, and B.M. WILINTERN, MICH. STATE UNIV.—Shell-model calculations for the zircon isotopes have been carried out in the full $p^3$-$p'^3$-$f^3$ model space with the effective Hamiltonian (based on a fit to Ni and by level energy) of Koops and Glaudemans. Results for excitation energies, spectroscopic factors, electromagnetic form factors, and reaction rates, Gamow-Teller log ft's, and inelastic electron scattering form factors have been obtained. The adequacy of the model space and the Hamiltonian in accounting for these phenomena will be discussed.

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*Fellow of the Niels Stensen Foundation, The Netherlands.

*P.W.M. Glaudemans, private communication.

*Research supported by the USAEC and the NSF.
Measurements of Excited levels in $^{56}\text{Ni}$ and $^{58}\text{Fe}$ have been carried out at the University of Michigan. The $^{56}\text{Ni}$(p,$\gamma$) and $^{56}\text{Ni}$(p,$\alpha$) reactions have been employed to observe and measure excited levels in $^{56}\text{Ni}$ and $^{58}\text{Fe}$. The $^{56}\text{Ni}$ particles were detected in the focal plane of an Enge split-pole spectrometer with a resistive-wire proportional-gas counter. Partial angular distributions have been taken for these reactions. The low cross sections of 0.3 barns or 1.0 barns show no significant angular distribution. Analysis of the data has yielded 15 states in $^{56}\text{Ni}$ and 7 states in $^{58}\text{Fe}$ below 7 MeV excitation. Comparisons of the Coulomb displacement energies of the lowest lying 1/2 +, 3/2 + and 5/2 + levels are made with calculations. Systematics of the Coulomb displacement energies are discussed.

*Supported by the National Science Foundation.

Proton Decay of the Isobars Analog of the Ground States of $^{\text{56}}\text{Fe}$ and $^{\text{58}}\text{Ni}$. R.K. Bhomn
R.K. Bhomn, R. Miller, and R. Miller. Mich. State Univ.--The proton decays of isobaric analog states of $^{56}$Fe and $^{58}$Ni have been studied using a neutron-proton coincidence technique. Together with the 9 groups in coincidence with IAS neutrons, a peak in the proton spectrum is observed in coincidence with lower energy neutrons. The presence of this peak can explain the anomalously large IAS cross sections and widths previously inferred from (p,p) singles spectra.

*Supported by the National Science Foundation.

Study of (p,n) on $^{24}\text{Na}$ at 35 MeV. J. A. Moore, P. A. Smith, R. W. Harkins, and N. A. H. Shafir. Mich. State Univ.--The $^{24}\text{Na}$ (p,n) and $^{26}\text{Mg}$ (p,n) reactions have been studied using the 35 MeV proton beam of the MSU cyclotron. The energy resolution (12 keV) has been sufficient to resolve most of the states of $^{24}\text{Na}$ up to 10 MeV excitation. The yields to some states which require seniority 3 transfer are comparable to those in $^{24}\text{Na}$, where seniority one is allowed. A state in $^{26}\text{Mg}$ is seen with relatively large cross section at the position of the $1/2^+$ state seen in the $^{18}$O($^{18}$O,$^{12}$O)$^{12}$C reaction. Transitions to two different states with the same spin and parity do not always have similar angular distributions; however, the corresponding states between $^{24}\text{Na}$ and $^{26}\text{Mg}$ do have similar shapes. A microscopic model for the 3 nucleon pickup form factor has been programmed using single particle Woods-Saxon wave functions. DWBA calculations using these form factors, as well as cluster transfer form factors will be presented.

*Supported by the National Science Foundation.

The Nuclear Physics of Helium Burning Stars* S. M. Austin. Mich. State Univ.--Determining the ratio of $^{4}$He to $^{40}$Ca at the completion of helium burning in a stellar core is one of the important questions of astrophysics, since the ashes of the helium burning stage serve as the initial conditions for later stages of stellar evolution. Five reaction rates, that for the triple-alpha process ($^{4}$He+$^{3}$He$\rightarrow^{7}\text{Be}$+$\gamma$) and that for the $^{12}$C($^{4}$He,$\gamma$)$^{16}$O reaction determine the relative population of $^{12}$C and $^{40}$Ca. These rates in turn depend primarily on the detailed properties of nuclear energy levels of the $^{4}$He ground state and of the first excited states of $^{12}$C and $^{16}$O in $^{40}$Ca. Royd's predictions of the basis of astronomical evidence that there must be a 0$^{++}$ level near 7.7 MeV in $^{12}$C. In recent years a series of difficult experiments have fixed the properties of these levels with sufficient accuracy to conclude that $^{12}$C is the major product of helium burning in most stars. This work forms the basis of the calculation of nuclear masses and their astrophysical implications, with emphasis on recent work concerning the 3p process done at Michigan State University. A new measurement which may decrease the uncertainty in the $^{12}$C($^{4}$He,$\gamma$)$^{16}$O rate will be discussed.

*Supported by the U.S. National Science Foundation.

Shape transitions without transfer of angular momentum are among the least understood
states of nuclear matter, a property which has not experimentally been determined up to present.

Amixtures into low-lying 0^+ states enter into the problem as the Nolen-Schiffer anomaly and the isotope shift.

A systematic study of low-lying monopole transitions in 4He and a scattering from 9Be
and f^0/2 shell nuclei has been performed at Heidelberg and Minnesota. The data, which show
very pronounced angular distributions, could be successfully described in a microscopic
model. Derived monopole transition densities yield K0 matrix elements and transition radii
agreement. The angular distributions were found to be extremely sensitive
to the transition form factors and thus yield detailed information on the
structure of ground and excited 0^+ states will be discussed. In a search for the giant
monopole excitation, data from proton and 9Be scattering experiments on 4He will be
The monopole state is found at 9.11 MeV which exhausts a 7.4% of the energy
weighted monopole sum rule strength.

*Work supported by the U.S. National Science Foundation.

Status Report on Superconducting Cyclotron Magnet. W. R. MOORE, Mich. State Univ.---A full-
scale prototype magnet for a superconducting cyclotron is in construction. Design calcu-
lation indicates this magnet will be able to focus ions with 400 (2076) MeV and will be able
to focus ions with 700 MeV. The super-
conducting main coil will be fabricated from 120,000 feet of 770, cryogenically-stabili-
ized NbTi conductor. Delivery of conductor is
scheduled for April 1976. The pole base and the "pill box" return yoke will be fabricated
from 1200 steel castings. The pole face casting has been poured and the remaining four are scheduled
to follow at approximately two-week intervals.
The fully machined pole bases and yoke are sched-
uled for delivery in June, along with a removable
central plug so that the magnet can be configured
both with a central hole as appropriate for a
post-accelerator and with a central cone as needed
for a stand-alone, internal-source cyclotron.
Allowing for coil winding, cryostat installation, installation of median plane penetrations, etc.,
it appears marginally possible to be ready for
first magnetic measurements in December 1976,
which would be two months in advance of the
originally anticipated schedule.

*Work supported by the National Science Foundation.

Magnetic Dipole Moments of sd-shell Nuclei. W. CHUNG and B.H. WILLENTZ, Mich. State Univ.---We have used shell-model wave functions generated in the full f7/2 \to 5/2 + g9/2 \to 5/2 space from empirical Hamiltonians in the calculation of magnetic dipole moments of ground and excited states of sd-shell nuclei. Predictions have been obtained both from the assumptions of the bare-nucleon values of the single-particle matrix elements and from values obtained by a fit to available precise experimental values. For A=17-25 nuclei, good agreement is obtained with experiment by either ML operator. For A=29-39, however, the results from the bare-nucleon operator agree less well
with experiment than those from the fitted operator.

*Supported by the U.S. National Science Foundation.

State Univ.---The mass of 44Ar was measured using the 4He(4He,2He) reaction at 70 MeV. The
4He particles were detected with a resistive wire
proportional counter in the focal plane of an
Enge split-pole spectrometer. Particle dis-
orientation was accomplished using a flight
measurement through the spectrometer.
Impurity peaks which are partially obs-
cured the 4He ground state were reduced using
blooming in the impurity focal plane. The
preliminary result for the mass excess is -32.727.69 MeV which is .38 MeV heavier than the
Stevenson-Kelson prediction. An excited state is seen at 11.08, 1.525.03, 5.82, 3.95, 4.48 and
4.48, 0.04 MeV.

*Supported by U.S. National Science Foundation.
*Present address: NSF, Washington, DC.
*Present address: U. of California, Berkeley.
*Present address: Duke University.

The Heaviest-known Z=1/2 Mirror Pair. J.C. HUMBER, R. E. EDMERSION, R. A. MARRA, and U. C.
HUMBER, Mich. State Univ.---Measurements of the half-lives for the mirror-decays in the f7/2 shell are desirable especially since the masses for these nuclei are now known. However, these half-
lives are hard to measure because production cross sections are small, cluttered with unwanted
products, and the half-lives are short (<1 sec.).

By utilizing the mass identifier, SISPIED, we have unambiguously found a mass-isotope with
a half-life of about 8.5 sec. It was produced by the 44He(4He,2He) and 44He(4He,4He) reactions and
could be identified as 44Cr. Preliminary measure-
ments of its half-life yield the value 0.650±0.02 sec. Taken with the 0 value, measured from par-
ticle-transfer experiments, this yields a log ft=3.61.


*Supported by the U.S. National Science Foundation.
Ispastic Proton Scattering From 176Yb and 154Sm. — Y.K. THOM, U.W. CHAMARR, and J.A. HOLE, JR., Mich. State Univ.—Because of the complementary nature of the (p,p') and (p,2n) reactions it is necessary to probe proton and neutron transition densities and because there are existing (p,2n) data on 154Sm and 176Yb, measurements of the (p,p') reaction on these nuclei was carried out with 35 and 40 MeV proton beams from the MSU Cyclotron. The protons were detected both with a delay line counter and with nuclear emissions in the focal plane of the Enge spectrometer. States up to 8+ in the ground state band of both nuclei were observed and many levels in other bands were also seen. Angular distributions have been measured from 20° to 80°. Calculations of the angular distributions will be presented.

Submitted by H. MCMANUS.

*Submitted by the U.S. National Science Foundation.

An Explanation of the Anomalous 279a/ε/8-Decay Branching Ratio. P.S. FREEMAN, W.C. NAGY, and W.H. KELLY, Mich. State Univ.—The 279a/ε/8 decay branching ratio differs from theoretical calculations by 7.20%. This accurately measured value was used as evidence for the absence of fers interaction; however, the noted discrepancy has never been satisfactorily explained. The inclusion of "second forbidden" terms in the calculated ratio can be shown to account for this discrepancy if the weak magnetic matrix element is an order of magnitude larger than that predicted by the intrinsic magnetic moments of the proton and neutron alone. This possibility is realized because the decay is severely hindered with a logarithmically small matrix element.

Supported by the U.S. National Foundation.

Observation of Highly Neutron-Rich 41Cl. E. KASHY, W. BENENSON, D. MUeller, H. HANN and L. ROBINSON, Mich. State Univ.—We have observed the previously unknown 27/2+ isotope of chlorine in the s-nucleon pickup reaction 40K(a, p)41Cl. The targets consisted of 40Ca evaporated onto either 0% or 8% Ag foils, and the method used the same as earlier in the observation of 36Cl. The very negative Q-value of the reaction increased the cross section of the measurement considerably since peaks from the 17Cl contaminant on the target fell in the region of interest. A yield of about 25 nb/σ was measured at angles from 8° to 10°. A preliminary value for the mass excess of 41Cl is -23.14±0.06 MeV, thus indicating that 41Cl is significantly less bound than semi-empirical predictions indicated.

*Submitted by the U.S. National Science Foundation.


High Spin, Multi-quasiparticle Yttrium Traps In 14F. P.K. KHO, P.M. BERNAH, J.A. HOLE, JR., ROBINSON, and R.A. WARNER, Mich. State Univ.—We have employed the (a,n) reaction and a variety of f-ray and conversion electron spectroscopic techniques to study the high spin structure of 14F in the region between 2.5 and 5 MeV. In addition to a 4-quasiparticle (qp) 2K + 1s2 state and a 4-qp rotational band based on a 2K + 1s2 1s2 1s2 isomer and a 2K + 1s2 1s2 1s2 1s2 state have been observed up to spin 20. We have also located three 6-qp states near 5 MeV; two of these, with 2K + 1s2 and 1s2, have half-lives of 10 usec and 3 nsec, respectively. The third 6-qp state has 3K + 1s2. The yrast line changes from the g.s. to the 2K + 1s2 structure at 1.211. The multi-qp structures thus serve as yrast traps. The relationship to yrast traps which are predicted to occur when some nuclei become oblate at much higher spin will be discussed.

*Submitted by the U.S. National Science Foundation.


A Study of the Even Platinum Nuclides Using the (p,4F) Reaction. W.H. KIM, P.M. BERNAH, J.A. HOLE, Jr., and J.A. NOLAN, Jr., Mich. State Univ.—The vibrational model has frequently been successful in describing nuclear properties in the transitional region between closed-shell and well-deformed nuclei. However, the Pt nuclides would not seem to fit into this model, since no known 0° state even now excited energy to be appropriate candidates for the number of f bands of the states we measured the 44P, 45P, 45Fe(p, p') reactions using a 9 MeV, 6° MeV, and with 100% 9×1×9 MeV isotropic enrichment. Triton angular distributions were measured for transitions to states below 1.5-MeV excitation energy, and no excited 0° states were observed below 1 MeV. This suggests that another model, such as the triaxial rotor model, is perhaps more appropriate for the Pt nuclides.

*Supported by the U.S. National Science Foundation.


Structural Changes in the Yttrium Levels of 179Ir. G. LEWISTON, Univ. of Bergen and McMaster Univ. and T.L. KHO, Mich. State Univ. and McMaster Univ.—The high spin level structure of 179Ir has been investigated using the (a, n) reaction, with experiments performed both with the McMaster FH tandem Accelerator and the MSU Cyclotron. The ground band has been observed to 179Ir. The Kπ=6 bands of mixed proton and neutron 2-quasiparticle (qp) and 3-quasiparticle (qp) structure have also been observed, identified to spin 16. The yrast sequence changes from the ground band to the lowest band and again to a Kπ=6 four-qp state for 158Ir. Thus, in this nucleus the yrast structure at high spin corresponds to motion of a few quasiparticles around the nuclear symmetry axis. Similar behavior is predicted to occur in other high-spin states in some nuclei.


Proton Hole States in $^{137}$La, *S. M. Harkrnm, R.K. Holm, F.A. Eisen, J.R. Holm, I.P. and M.H. Novick, Mich. State Univ.--Angular and charge exchange cross sections for the $^{137}$La$^+$ target have been studied. The results of the 9.97 MeV excitation indicate that the a-1/2 member of the 9/2$^+$ configuration is the ground state of the $^{137}$La$^+$ nucleus. The angular distributions of the $^{137}$La$^+$ reaction on all $^{137}$La$^+$ nuclei in the 2$^+$ state have been measured at 90 MeV proton energy. These data have been analyzed with the SMAS utilizing the steepest descent method. The results for the ground state transitions are in good agreement with the results of the previous analysis.\[\text{Supported by the National Science Foundation.}\]

-- Fine structure in the low spin states of $^{126}$Ba, F.A. Eisen, J.R. Holm, and M.H. Novick, Mich. State Univ.--High resolution X-ray spectra of $^{126}$Ba show very rich structure even at excitation energies as high as 8-11 MeV. There are many resolvable peaks, and their angular distributions indicate excitations of different multipolarities. The highest energy multiplet is located at 8.1 MeV which has an L4 angular distribution. The strength of this multiplet is about 7% of the total strength of the $^{126}$Ba ground state. Above 8.5 MeV, the majority of the peaks show L2 angular distributions in agreement with the localization of the giant quadrupole resonance in the excitation region around 10 MeV.\[\text{Supported by the U.S. National Science Foundation.}\]

 Levels in $^{47}$Cr and $^{51}$Fe. *D. Mueller, F. Kashy, and W. Beneden, Mich. State Univ.--The $^{47}$Cr($^{47}$Fe,$^{47}$Fe)$^{51}$Fe reaction has been employed to observe and measure excited levels in $^{47}$Cr and $^{51}$Fe. A beam of 10 MeV $^{47}$Fe particles from the MSU cyclotron induced the reaction. The reaction products were analyzed in an Inglis split-pol/ magnetic spectrometer; as has been previously described. The ground and first excited states of $^{47}$Fe have been resolved thereby improving the accuracy of the mass measurement. A preliminary value of $19.6184$ $^{31}$ MeV has been determined for the mass excess of $^{47}$Cr. Despite the low cross sections (1.0 $\mu$b) the angular distributions have been taken as far back as 27°. Comparisons of the Coulomb displacement energies for the lowest lying $2^+$, $4^+$, and $1^-$ levels have been made, and systematics of the Coulomb displacement energies will be presented.\[\text{Supported by the U.S. National Science Foundation.}\]

 Study of the $^{51}$(p,t)$^{53}$ and $^{53}(p,t)^{56}$Re reactions and the weak coupling core-excitation model. *A. Sada, A. Sada, North Carolina State Univ. and B. Mann, Mich. State Univ.--The $(p,t)^{53}$Re and $(p,t)^{57}$Re reactions have been studied with the MSU cyclotron at incident proton energies of 40 MeV. States in $^{57}$Re up to 5 MeV excitation energy in $^{51}$Re up to 4.5 MeV excitation energy were observed with an energy resolution of 10-20 $\text{keV}$. Spin and parity assignments were determined from the shapes of the angular distributions in the $2^+$ to $5^+$ mass range. The weak-coupling model has been employed as an alternative empirical explanation for the structure of the odd-parity states of $^{51}$Re. In this model, a $1/2^+$ proton coupled to the strong $1^+$ orbit (g.s. and $2^+$) was predicted. New $1^+$ orbitals were assigned to the $2^+$, $3^+$, and $4^+$ levels (895 $\text{keV}$, 2418 $\text{keV}$, 3883 $\text{keV}$) in a $2^+$ "core" (states observed with the $(p,t)^{57}$Re reaction) can give rise to weak-coupling negative parity multiplets in $^{53}$Re.\[\text{Work supported in part by the U.S. National Science Foundation.}\]

-- Study of $^{88}g$ and $^{88}g$ with the $(p,t)$ reaction and the weak-coupling core-excitation model. *R.K. Holm, J.R. Holm, A. Sada, North Carolina State Univ. and B. Mann, Mich. State Univ.--The $(p,t)^{90}$Sr reaction has been studied with 40 MeV protons from the MSU cyclotron. States in $^{90}$Sr up to 2.7 MeV excitation energy were observed with an energy resolution of 10-25 $\text{keV}$. Many new states in both nuclei were observed which have the shapes of the expected angular distributions in the $2^+$ to $5^+$ mass range. Spin and parity values were assigned. The weak-coupling core-excitation model has been employed to classify the states in $^{90}$Sr. In this model, a $9/2^+$ neutron hole coupled to the strong collective states in a $2^+$ "core" (obtained with the $(p,t)^{90}$Sr reaction) give rise to weak-coupling multiplets in $^{90}$Sr.\[\text{Work supported in part by the U.S. National Science Foundation.}\]
Features of the (p,α) Reaction as Seen in the 52Cr(p,α) Reaction. P.A. SMITH, R.H., HAMM, H.H. SHADWORTH, T.A. HOLLEN, J.R., Mich. State Univ.—We have studied the 52Cr(p,α) reaction at a bombarding energy of 35 MeV. The strongest states are the 7/2 ground state and the 3/2 and 1/2 6d-shell hole states. A large number of weaker, more complicated states with 7/2 and 5/2 hole states are also observed. In the excitation region from 6 to 17 MeV, we have observed the analogues of the 7/2, 3/2, and 1/2 hole states in 99Tc. A comparison with 51V(p,α) and 51V(α,γ) results will be presented. Some states seen with significant strength in the (p,α) data are virtually absent from the (p,α) spectra. DWBA calculations employing microscopic Woods-Saxon form factors will be compared with the data. Relative spectroscopic factors for both Tc and Tc hole states have been extracted assuming simple seniority wavefunctions. Coulomb energies for the analog states will also be given.

A. Sahai, H. Nann, K.K. Seth, to be published.
Supported by the National Science Foundation.

Optimum Coupling of a Tandem Injector to a Superconducting Heavy Ion Cyclotron. J.H. BISHOP, Mich. State Univ.—The optimum choice of charge states has been studied for the coupling of Tandems of 13 and 26 MeV maximum voltage to the prototype superconducting cyclotron magnet being built at MSU. The optimum choice results from maximizing P(01↑Q)P(Q), the product of the probabilities for accelerating to charge states Q and Q in the tandem cyclotron. For a wide range of ion and energies a lower than equilibrium charge state from the carbon stripper must be chosen in order to make the injection orbit sufficiently rigid to reach the central region of the cyclotron. This can be produced by a very low pressure gas cell. Further restriction in the allowed range of injection orbit rigidity is necessary to fit the injection paths into the confined space in the median plane. Results of calculations of injection paths and optimum charge states will be shown.

Supported by the National Science Foundation.

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Evidence for a five-quasiparticle isomer in $^{177}$Lu, L. BUDA-BINDAS, H.C. WADDINGTON, McMaster Univ. and T.L. RHOD, Mich. State Univ.—Recent interest in the study of many-quasiparticle states in $^{176}$Hf has prompted a similar study of high-spin states in $^{177}$Lu. Experiments at McMaster and Michigan State Universities using the $^{176}$Lu($^{18}$F,n) and $^{176}$Lu($^{20}$Ne,n) reactions have located a high spin isomer at 2920.9 keV. This isomer decays with a half life of approximately 70m by 555 and 789 keV transitions to previously identified 3 quasiparticle states. Delayed and prompt $\gamma$-techniques were used to isolate the $\gamma$-rays feeding and de-exciting this isomer.

Supported by the U.S. National Science Foundation.