Section II

Abstracts of Oral Papers

July 1968-June 1969

SUBMITTED TO THE MIAMI MEETING OF THE APS, NOVEMBER 1968

The (p,t) reaction on ^{36}A, ^{32}S, ^{28}Si, ^{24}Mg, and ^{20}Ne.*

R. A. Paddock, W. Benenson, P. J. Locard**, and I. D. Proctor, Michigan State University.

The (p,t) reaction has been studied on the N=Z even-even nuclei of the 2s-1d shell using the proton beam from the Michigan State University Isochronous Cyclotron. The proton energies were in the range from 40 MeV to 45 MeV. ΔE-E semiconductor counter telescopes were used, and particle identification was carried out either on-line with an SDS Σ-7 computer or with analogue circuitry of the Goulding type. Over all energy resolution on the order of 100 keV was obtained. Excitation energies for low lying ($E_x \leq 5$ MeV to 8 MeV) levels in the neutron deficient residual nuclei have been obtained along with angular distributions from about 10° to 90° for the more strongly excited states. Besides the ground states, about 15 levels were observed in ^{34}A, about 5 levels in ^{30}S, about 6 levels in ^{26}Si, about 12 levels in ^{22}Mg, and about 10 levels in ^{18}Ne. The precision of excitation energy assignments varied from 20 keV to 50 keV.

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* Research supported in part by the National Science Foundation.

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SUBMITTED TO THE MIAMI MEETING OF THE APS, NOVEMBER, 1968

Comparison of the Reactions $(\alpha, {}^3He)$ and $(\alpha, {}^3H)$ on ${}^{16}O$ and ${}^{24}Mg$*. I. D. Proctor (introduced by W. Benenson), W. Benenson, R. A. Paddock, and P. J. Locard†, Michigan State University. 46-MeV alpha particles from the Michigan State University Isochronous Cyclotron were used to study the $(\alpha, {}^3He)$ and $(\alpha, {}^3H)$ reactions. Angular distributions were taken between 7.5° and 75° in the lab using the ΔE-E semiconductor counter telescopes. Particle identification was performed on-line with an SDS Σ-7 computer. Differential cross sections were obtained for the ground state and the first three excited states of ${}^{17}O$ and ${}^{17}F$ and the ground state and first four excited states of ${}^{25}Mg$ and ${}^{25}Al$. Theoretical predictions for these states are being calculated with the DWBA code JULIE and will be compared to experimental results. It is found that $(\alpha, {}^3He)$ cross sections are approximately twice as large as $(\alpha, {}^3H)$ cross sections to analog levels in both the ${}^{16}O$ and ${}^{24}Mg$ experiments.

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*Research supported in part by the National Science Foundation.
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SUBMITTED TO THE MIAMI MEETING OF THE APS, NOVEMBER 1968

$T_z + 1$ and $T_z + 2$ Analog States in Titanium Isotopes.*

P. J. Plauger and E. Kashy, Michigan State University. Energy spectra and angular distributions for the (p,d) and (p,t) reactions on Ti isotopes have been measured using the proton beam from the Michigan State University sector-focused cyclotron. In the $^{48}Ti(p,d)^{47}Ti$ case, spectra have been measured at incident energies of 29.8, 35.2, 40.0 and 45.0 MeV with an energy resolution of about 60 keV, and over an angular range of 8^o to 90^o. The specific purpose was the investigation of the $T_>$ vs. $T_<$ spectroscopic factors, which have raised a number of questions in an earlier investigation[1]. Using the (p,t) reactions, a search was made for $T=T_z + 2$ levels in ^{44}Ti, ^{46}Ti and ^{48}Ti. Preliminary results indicate an excitation energy of 9.36 ± 0.02 MeV for the ^{44}Ti analog to the ^{44}Ca ground state. This agrees well with the value of 9.35 ± 0.12 MeV previously reported[2]. DWBA analysis of these data is in progress.

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*Work supported in part by the National Science Foundation.

[1] R. Sherr, B. F. Bayman, E. Rost, M. E. Rickey and C. G. Hoot, Phys. Rev. 139, B5(1272).

[2] G. T. Garvey, J. Cerny and R. H. Pehl, Phys. Rev. Letters 12 726(1964).

SUBMITTED TO THE MIAMI MEETING OF THE APS, NOVEMBER 1968

Proton Inelastic Scattering from ^{50}Ti, ^{51}V, and ^{52}Cr.*

B. M. Preedom, C. R. Gruhn, T. Kuo, C. Maggiore and J. Frink, Michigan State University. Angular distributions have been measured for proton inelastic scattering from ^{50}Ti, ^{51}V and ^{52}Cr using 40-MeV protons from the Michigan State University sector-focused cyclotron. The scattered protons were detected using a Ge(Li) crystal with an overall energy resolution of 40 keV (FWHM). The differential cross-sections for levels up to 8 MeV of excitation were obtained over an angular range from 10° to 80°. Deformation parameters for the strongly excited states in ^{50}Ti and ^{52}Cr have been extracted using collective-model Distorted Wave calculations. A comparison of these values with published values will be presented. Recent microscopic calculations[1] for inelastic scattering to the first 2^{+} and 4^{+} states in ^{50}Ti will be compared to the data and to the collective model calculations. The angular distributions for the low-lying states in ^{51}V will be compared to the predictions of a microscopic calculation based on recoupling within a $(1f_{7/2})^{3}$ configuration as well as a collective model calculation assuming weak coupling.

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* Work supported in part by the National Science Foundation.

1) H. McManus and F. Petrovich, Bull. Am. Phys. Soc. 13, 631(1968).

SUBMITTED TO THE MIAMI MEETING OF THE APS, NOVEMBER, 1968

A Position Sensing Detector Array For A Charged Particle Magnetic Spectrograph. D. L. Allan, G. V. Ansell and R. K. Jolly*, AERE, Harwell. An array of eight position sensing detectors has been mounted in the focal plane of the Harwell broad range charged particle magnetic spectrograph and used successfully to measure the deutron spectrum from the reaction $^{56}Fe(d,d')$ using a PDP-8 computer. Details of the system components and its operation will be presented.

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SUBMITTED TO THE MIAMI MEETING OF THE APS, NOVEMBER 1968

Energy Loss Straggling of Protons in Silicon.* T. M. Amos†, J. J. Kolata, Michigan State University, and H. Bichsel††, University of Southern California. A 200 micron surface barrier silicon detector was bombarded with protons from the Michigan State University sector-focused cyclotron. The beam energy was varied in steps of 2 MeV between 4 and 42 MeV, and the energy loss straggling distributions thus obtained were compared with the predictions of the straggling theories of Vavilov[1] and Tschalar[2]. At the higher energies the agreement between the Vavilov theory and the experimental distributions is excellent, but becomes steadily worse for energies below 20 MeV. This discrepancy increases with decreasing initial proton energy and may be attributed chiefly to an appreciable variation of proton energy within the detector, in which case the Vavilov theory is not strictly applicable. However, the distribution functions of Tschalar, which do account for such a variation, agree well with the data for energy losses up to 80% of the incident energy, the maximum energy loss observed in the experiment.

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* Work supported in part by the National Science Foundation.
† NASA Fellow
†† Supported by Public Health Service Research Grant CA08150 from the National Cancer Institute.

1 P. V. Vavilov, Zh. Eksp. Theor. Fiz. 32, 320 (1957) [Sov. Phys. - JETP 5, 749 (1967)].

2 C. Tschalar, Nucl. Instr. & Methods 61, 141 (1968), and RHEL/R161, Rutherford Laboratory Report.

SUBMITTED TO THE MIAMI MEETING OF THE APS, NOVEMBER 1968

The Spin Dependent Part of the Effective Interaction and the $^{16}O(p,p')^{16}O$(8.88 MeV) Reaction,* Sam M. Austin and P. J. Locard,** Michigan State University. To the extent that the DWA is valid, inelastic scattering to unnatural parity states such as the 2^- state at 8.88 MeV in ^{16}O can proceed only via the spin dependent part V_{10} of the effective interaction. We have used the DWA to analyze available data[1] on the $^{16}O(p,p')^{16}O$(8.88 MeV) reaction in the energy range from 23.4 to 46.1 MeV. While multiple excitation is probably important this analysis should provide a starting point for future coupled channels calculations. Optical model parameters were taken from the literature. The particle hole wave functions of Gillet and Vinh Mau were used; the results were not sensitive to the small configurations in the wave functions. At 46 MeV where the DWA should be best, an interaction with a Yukawan shape and a 1.0F range yields a strength of 20 MeV. The impulse approximation[2] accounts for only about 1/7 of the cross section at this energy. Other available information on V_{10} will be summarized.

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* Research supported in part by the National Science Foundation.

** Present Address: Centre d'Etudes Nucleaires de Grenoble, France.

1 J. R. Richardson, J. M. Cameron, W.T.H. van Oers and J. W. Verba, Bull. Am. Phys. Soc. 12, 1190(1967).

2 H. McManus, F. Petrovich and D. Slanina, Bull. Am. Phys. Soc. 12, 12(1967).

SUBMITTED TO THE MIAMI MEETING OF THE APS, NOVEMBER, 1968

Gamma-ray studies of the decay of 5.5-hour Nd^{139m}.*

D. B. Beery, Wm. C. McHarris, J. J. Kolata and W. H. Kelly. Michigan State University. The decay scheme of Nd^{139m} has been investigated using Ge(Li) and NaI(Tl) detectors. The Ge(Li) detector has been used to identify and determine the energies and intensities of 46 gamma rays. On the basis of coincidence and anti-coincidence experiments, coupled with energy sums and relative intensities, levels are established in Pr^{139} at energies (spins and parities) of 0 ($5/2^+$), 113.8±0.2 ($7/2^+$), 821.9±0.2 ($11/2^-$), 828.1±0.2, 851.9±0.2, 1024.0±0.2, 1369.6±0.4, 1523.2±0.4, 1624.5±0.2, 1834.1±0.2, 1927.1±0.2, 2048.9±0.3, 2174.3±0.3 and 2196.7±0.3 keV. The half-live of the 851.9 keV state has been found to be approximately 40 nsec. These states are populated by electron capture decay of the Nd isomer which occurs 5 percent of the time. These levels accommodate 35 of the gamma rays which represent all but about 1.5 percent of the total observed gamma intensity. The placement of the remaining weak transitions and the decay of the 30 min ground state of Nd^{139} are presently under investigation.

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

SUBMITTED TO THE MIAMI MEETING OF THE APS, NOVEMBER 1968

Inelastic proton scattering to the second excited state of ^{209}Bi and the microscopic description of inelastic proton scattering.* Walter Benenson, P. J. Locard**, Sam M. Austin and C. N. Davids, Michigan State University. 39.4 MeV protons from the Michigan State University sector-focused cyclotron were used to study inelastic proton scattering to the level at 1.61 MeV in ^{209}Bi. The scattered protons were detected with a Ge(Li) detector with an overall resolution of 45 keV. Both the ground state and second excited state were described as single-particle states ($1h_{9/2}$ and $1i_{13/2}$). Neglecting core-polarization, the impulse-approximation[1] shows that the 15 S=1 amplitudes contribute about 90% of the cross-section, so that the reaction yields a good measurement of the spin-flip part of the interaction ($V_{p,p}^{S=1} = V_{10} + V_{11}$). Using a real interaction with a range of 1.0F gives $V_{p,p}^{S=1}$ = 50 MeV, in fair agreement with the value of 37 MeV obtained from lighter nuclei. The experimental distribution is reproduced quite well. Core-polarization enhances only the 5 S=0 amplitudes and gives a poorer fit to the data assuming $V_{p,p}^{S=1}$ = 37 MeV and a constant effective charge of 2.0e. However, the fit is improved by letting the effective charge decrease for higher transferred angular momenta.

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* Research supported in part by the National Science Foundation.

** Present address: Centre d'Etudes Nucleaires de Grenoble, France.

1) H. McManus, F. Petrovich and D. Slanina, Bull. Am. Phys. Soc. Ser. II, 12, 12 (1967).

SUBMITTED TO THE MIAMI MEETING OF THE APS, NOVEMBER 1968

The States of ^{117}Sn.* G. Berzins**, D. B. Beery, W. B. Chaffee, W. H. Kelly, and Wm. C. McHarris, Michigan State University. Gamma-rays emitted in the decay of 2.8-h ^{117}Sb have been investigated with Ge(Li) detectors. Gamma-rays of energies (and relative intensities) 158.5 (99.6), 553.2 (0.07), 846.2 (0.04), 861.7 (0.29), 1004.5 (0.22), 1020.6 (0.09), 1021.0 (0.10), 1287.6 (0.026), 1339.5 (0.009), 1420.1 (0.016), 1446.4 (0.051), and 1578.0 (0.018) keV have been observed. On the basis of energy sums, relative intensities, and two-dimensional Ge(Li)-Ge(Li) coincidence experiments, states are placed in ^{117}Sn at 0 ($1/2^+$), 158.5 ($3/2^+$), 711.7 ($17/2^+$), 1004.5 ($3/2^+$), 1020.2 ($5/2^+$), 1179 ($5/2^+$), 1446.4 ($3/2^+$, $5/2^+$), 1498.0 ($5/2^+$, $3/2^+$), and 1578.3 keV ($5/2^+$, $3/2^+$). The spin assignments have been made on the basis of log ft values and relative photon intensities from ^{117}Sb decay, aided in some cases by ^{117}In decay, and also from information gleaned from nuclear reactions data. The structures of the states are discussed in terms of current nuclear models, and the behavior of these states is followed as a function of neutron number.

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** Now at the Los Alamos Scientific Laboratory.

SUBMITTED TO THE MIAMI MEETING OF THE APS, NOVEMBER 1968

A new M4 transition in the N=81 series nuclei.* R. E. Eppley, Wm. C. McHarris, and W. H. Kelly, Michigan State University. During the investigation of the gamma-spectrum of Gd^{145}, a short lived isomer has been observed. The isomeric transition energy has been determined to be 721.4±0.5 keV, with a half-life of 88±4 seconds. This isomer has been prepared with the Michigan State University cyclotron by the Sm^{144}(,3n)Gd^{145m} reaction. The bombardments were for periods of 45-60 seconds at 300 na., at an alpha energy of 42 MeV. Because of the system resolution, and the cleanliness of the reaction, no chemical separation was necessary before counting. All measurements were carried out with a Ge(Li) detector (7cc. coaxial, FWHM=2.5 keV for Cs^{137}) and associated electronics feeding directly into the Sigma-7 computer. The spectra of the isomeric state were followed by printing out a portion of the computer memory at 15 second intervals. The conversion coefficient is presently being measured. On the basis of the half-life and the transition energy, this appears to be another M4(11/2- to 3/2+) analogous to others previously reported in the N=81 series (Te^{133}, Xe^{135}, Ba^{137}, Ce^{139}, Nd^{141}, and Sm^{143}). Since M4 transitions are generally regarded as being relatively "pure", they should be useful in studying the systematic changes of the single particle states involved. At present these changes, such as the systematic changes in the radial matrix elements, are under investigation.

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

SUBMITTED TO THE MIAMI MEETING OF THE APS, NOVEMBER 1968

Structure of ^{14}N from the $^{15}N(p,d)^{14}N$ reaction.* James L. Snelgrove and E. Kashy, Michigan State University. Energy spectra and angular distributions have been measured for the $^{15}N(p,d)^{14}N$ reaction using 39.8 MeV protons accelerated by the Michigan State University sector-focused cyclotron. Spectroscopic factors for levels populated in the (p,d) date by $\ell n = 1$ pickup were extracted from comparison to DWBA calculations, in a manner similar to that previously used in an investigation of the $^{16}O(p,d)^{15}O$ reaction between 25 and 45 MeV[1]. These spectroscopic factors were found to be in excellent agreement with the intermediate coupling predictions[2], with the two levels at 9.17 and 10.43 MeV (Both 2^+, T=1) sharing the 1p strength for the level predicted at 9.524 MeV[2]. The 13.72 MeV level of ^{14}N has been assigned $J^\pi = 1^+$, T=1 on the basis of the comparison with the theoretical predictions and a width of 210 ± 30 keV has been determined for this level. These and data on other levels observed in this experiment will be presented and discussed.

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* Research supported in part by the National Science Foundation.

1) J. L. Snelgrove and E. Kashy, Bull. Am. Phys. Soc. 13, 630(1968).
2) S. Cohen and D. Kurath, Nucl. Phys. 73, 1(1965).

SUBMITTED TO THE MIAMI MEETING OF THE APS, NOVEMBER 1968

Precision 40 MeV Proton Scattering Systematics in the Nickel Isotopes.* K. M. Thompson, C. R. Gruhn, B. M. Preedom, Michigan State University. The inelastic scattering of 40 MeV protons has been measured using the Michigan State University sector-focused, variable-energy cyclotron. The scattered protons were detected simultaneously in two Ge(Li), charged-particle detectors separated by 20 degrees. These detectors were used with a new high-precision goniometer. Angular distributions were taken for ^{58}Ni, ^{60}Ni, ^{62}Ni, and ^{64}Ni over an angular range of 15 to 90 degrees. Collective model DWBA calculations were made to extract the deformation parameters for the various excited states. A discussion of the results of this work as well as comparisons with previously published works will be presented.

*Research supported in part by the National Science Foundation.

SUBMITTED TO THE NEW YORK MEETING OF THE APS, February 1969

Gamma-ray studies of the decay of 30-min. Nd^{139g}.*

D. B. Beery, Wm. C. McHarris, and W. H. Kelly. Michigan State University. Photons emitted following the decay of 30-min Nd^{139g} have been investigated with Ge(Li) and NaI(Tl) detectors. Sources were prepared with the Michigan State University cyclotron by the $Pr^{141}(p,3n)Nd^{139g+m}$ reaction. On the basis of coincidence and anticoincidence experiments, energy sums, and relative intensities, states were placed in Pr^{139} at 0 $(5/2^+)$, 113.8 ± 0.2 $(7/2^+)$, 405.0 ± 0.4, 589.2 ± 0.5, 916.8 ± 0.4, 1074.4 ± 0.6, 1311.8 ± 0.6, 1328.2 ± 0.7, 1405.5 ± 0.7, 1449.5 ± 0.7, and 1501.2 ± 1.0 keV. These levels accommodate 15 of the gamma rays (21 total) which represent >85% of the total observed gamma intensity. Approximately 90% of the beta transitions have been found to go directly to the ground state of Pr^{139}. The placement of the remaining weak unplaced γ-transitions is made difficult by the presence of the 5.5-hour Nd^{139m} decay gamma rays.

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

SUBMITTED TO THE NEW YORK MEETING OF THE APS, February 1969

Production Cross-Sections of Light Elements from Proton Spallation of Carbon*. Cary N. Davids, Sam M. Austin, and Helmut Laumer, Michigan State University. Spallation fragments of masses 6 through 12 have been observed from the proton bombardment of a thin carbon target. Mass separation was accomplished by a method previously described[1], using energy and time-of-flight information. At a proton energy of 39.8 MeV, total cross-sections were measured by integrating angular and energy distributions for each mass. The results are: Mass 6: 10.2 ± 2.1 mb, mass 7: 35 ± 7 mb, mass 8: $1.8 \pm .8$ mb, mass 10: 16 ± 5 mb, mass 11: 95 ± 33 mb, mass 12: 40 ± 14 mb. The mass 10 yield is primarily ^{10}B, which has not been previously measured. The significance of these measurements to astrophysical problems will be discussed, and also results at neighboring energies will be presented.

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*Research supported in part by the National Science Foundation.

[1] C. N. Davids, S. M. Austin, Bull. Am. Phys. Soc. 13, 882(1968).

ABSTRACT - INVITED PAPER

1969 PARTICLE ACCELERATOR CONFERENCE, MARCH 1969

Synchrocyclotron Improvement Programs*. Henry G. Blosser, Michigan State University. Increasingly the significant experiments in the energy range of the synchrocyclotron demand higher intensity and duty cycle. Mindful of this, and of the approaching operational status of high intensity facilities at Los Alamos and Zurich, the several laboratories with plans for continuing synchrocyclotron programs have in progress or under study improvement programs for increasing the intensity and duty cycle of their accelerators. The principal revisions contemplated include: (a) new rf systems to provide higher dee voltage and increased cycling rate, with details carefully matched to requirements for maximizing the accelerated particle flux, (b) new central region designs utilizing hooded arc sources and electric and magnetic fields shaped for maximum focusing, (c) spiral ridge magnet pole tips to reduce the range of frequency modulation and strengthen focusing, and (d) redesigned extraction systems which in combination with the improved emittance characteristics of the new central region will lead to much higher extraction efficiencies than in the past. The principal features of these revisions will be reviewed with comments on the particular configurations contemplated by several typical major laboratories.

*Work supported in part by the National Science Foundation.

IMPROVEMENTS IN THE MICHIGAN STATE UNIVERSTIY CYCLOTRON RF SYSTEM*

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Summary

A new all solid state dee voltage amplitude regulator has been built for the MSU Cyclotron. It should lead to a factor of two improvement in the energy resolution of the external beam with a consequent increase in the ratio of beam-on-target to internal beam for most experiments. The RF drive to the final amplifier is regulated at a 10 mW level via an FET tetrode amplifier (Fig. 1). The gain of the FET is controlled by a signal proportional to the difference between a reference voltage and the sum of demodulated signals from each dee. Protective circuits are included which remove RF drive to the final amplifier in the event of severe dee sparking, and limit final grid and anode voltages as guards against clumsy cyclotron operators. Peak-to-peak noise levels of the dee voltage of less than 0.07% are achieved and with careful adjustments noise levels of less than 0.05% have been obtained. Since the cyclotron is usually operated with internal beam pulse-widths of less than 0.5 nsec. corresponding to an energy spread due to phase width alone of 0.04%, noise on the dee voltage makes a significant contribution to the over-all energy resultion of the external beam.

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*Work supported in part by the National Science Foundation.

Proton Spin Flip at 30 MeV in the Reaction $Sn^{120}(p,p'\gamma)Sn^{120*}$.† J. J. Kolata, A. Galonsky, R. Howell and R. Sager, Michigan State Univeristy. By use of the method of Schmidt et al.[1], whereby one measures the p'-γ correlation for gamma rays perpendicular to the scattering plane, we have determined the percentage of protons having their spins flipped in the process of exciting the first excited (2+) state of Sn^{120}. Percentage spin flip was measured for proton scattering angles 30° to 155°. A backward peak reaching 50% at 155° is accounted for by the spin-orbit force which fits elastic scattering and polarization[2] in the entrance and exit channels. Spin flip in the forward hemisphere is larger, by a factor of about 3, than we compute when using the best optical parameters[2] for entrance and exit channels and either a collective or a microscopic model for the inelastic interaction. Integrated over all scattering angles the total spin flip is about 10%.

†Work supported in part by the National Science Foundation.

[1] F. H. Schmidt et al., Nucl. Phys. 52, 353 (1964).

[2] G. R. Satchler, Nucl. Phys. A92, 273 (1967).

Analytic subject 55.5

A. Galonsky
Fellow, American Physical Society

High-Intensity Sub-nanosecond Pulsing System.*

H. G. Blosser and R. St. Onge, Michigan State University.

A new phase selection system using slits on the 18th and 28th turns has been installed in the MSU variable energy cyclotron. With this system gamma ray time-of-flight distributions of 0.2 to 0.25 nanoseconds fwhm are routinely obtained with time averaged beam currents of 10 μa. Using the 60 nanosecond repetition period the instantaneous current during the burst is estimated to be 3 ma. The beam burst is moreover believed to be appreciably shorter than the observed γ distribution due to time spreads arising in the measuring equipment. Measurements with improved equipment are planned. Details of the phase selection system will be described.

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*Work supported by the National Science Foundation.

Analytic Subject 52.2

H. G. Blosser
Member, American Physical Society

Gamma rays from protons on ^{10}B, and the excitation energy of the first excited state of ^{10}C.* R. A. Paddock, S. M. Austin, W. Benenson, I. D. Proctor, and F. St. Amant, Michigan State University. The $^{10}B(p,n\gamma)^{10}C$ reaction has been used to measure the energy of the first excited state of ^{10}C. An enriched ^{10}B target was bombarded with 11.4 MeV protons from the Michigan State University Sector Focused Cyclotron and the resulting gamma rays were detected with a 20 cc Ge(Li) detector at 90° with respect to the beam. The excitation energy of the first excited state of ^{10}C was found to be 3.3527 MeV with an error assignment of 1.5 keV. Excitation energies for the first four excited states of ^{10}B will also be reported.

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*Research supported in part by the National Science Foundation.

Analytic Subject No. 53.2

R. A. Paddock
Member APS

SUBMITTED TO THE WASHINGTON MEETING OF THE APS, APRIL 1969

The Decay Scheme of Zn^{63}.* G. C. Giesler, Wm. C. McHarris, and W. H. Kelly, Michigan State University. We have re-examined the the decay of 38.4-min Zn^{63} with Ge(Li) detector systems. The Zn^{63} sources were prepared by the $Cu^{63}(p,n)Zn^{63}$ reaction, using the proton beam of the MSU Sector-Focused Cyclotron, and they were separated from the copper targets by chloride anion-exchange. A total of 31 γ-rays, including a number not previously reported, were observed. On the basis of energy sums, relative intensities, coincidence and anticoincidence data, and known Cu^{63} levels from scattering experiments, we have placed all but three in a decay scheme with levels in Cu^{63} at 0 (3/2-), 669.4 (1/2-), 961.8 (5/2-), 1326.3 (7/2-), 1412.1 (5/2-), 1547.4 (1/2-, 3/2-), 2062.8, 2081.9, 2094.7, 2336.4, 2496.7, 2513.8, 2536.1, 2697.5 2717.2 2780.6, 2805.1, 2857.9, 2887.7, and 3045.3 keV. Differences between this level scheme and existing level schemes will be discussed, and intrinsic structures for some of the states will be suggested.

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

Analytic subject 54.2

Wm. C. McHarris
Member, American Physical Society

SUBMITTED TO THE WASHINGTON MEETING OF THE APS, APRIL 1969

Decays of Ba^{131m}, Ba^{133m}, and Ce^{137g+m}.* W. H. Kelly, D. B. Beery,† and Wm. C. McHarris, Michigan State University. We have reinvestigated the decay schemes of the relatively accessible nuclides 14.6-min Ba^{131m}, 38.9-h Ba^{133m} 9.0-h Ce^{137g}, and 34.4-h Ce^{137m}, using a high-resolution, moderately-efficient Ge(Li) detector system. Sources were prepared with the proton beam from the MSU Sector-Focused Cyclotron to induce the reactions $Cs^{133}(p,n)Ba^{133m}$, $Cs^{133}(p,3n)$ Ba^{131m}, and $La^{139}(p,3n)Ce^{137g+m}$. Previously published decay schemes of Ba^{131m} utilizing scintillation detectors were confirmed. In addition to the 276.09-keV $M4$ isomeric transition, we found evidence for direct ε-decay from 11/2- Ba^{133m} (Q_ε = 763 keV) to a high-spin (11/2, 9/2) state at 632.5 keV in Cs^{133} States in La^{137} at 10.5, 447.1, 493.1, 709.1, 781.5, 926.6, and 1171.9 keV were found to be populated directly by Ce^{137g}; at 762.2, 835.4, and 1004.8 keV, by Ce^{137m}. This is in substantial agreement with the primary results of an unpublished report,[1] but includes more precise energy, γ-ray intensity, and log ft values. We also discuss narrowing down the spin and parity assignments to these states and suggest possible intrinsic structures for many of them.

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

†Present Address: Manchester College, North Manchester, Indiana.

[1]R. B. Frankel, Ph. D. Thesis, Lawrence Radiation Laboratory Report UCRL-11871 (1964).

Analytic subject 55.2

Wm. C. McHarris
Member, American Physical Society

SUBMITTED TO THE WASHINGTON MEETING OF THE APS, APRIL 1969

The Population of States in Ce^{140} by Pr^{140} Decay.* D. B. Beery,† W. H. Kelly, and Wm. C. McHarris, Michigan State University. The β^{+}/ε decay of 3.39-min Pr^{140} has been studied to complement information known about states in $N = 82$ Ce^{140} from the better-known β^{-} decay of La^{140} and from scattering experiments. The parent, 3.3-d Nd^{140} ($Q_{\varepsilon} \approx 300$ keV, no γ-rays), was prepared by the $Pr^{141}(p,2n)Nd^{140}$ reaction, using the proton beam from the MSU Sector-Focused Cyclotron, and the Pr^{140} was studied in equilibrium with its parent. Ge(Li) detectors in singles and coincidence configurations were used to obtain γ-ray spectra. On the basis of energy sums, relative intensities, coincidence data, and some already-known properties of the Ce^{140} states, we have placed states at 0 (0+), 1596.0 (2+), 1903.0 (0+), 2348.3 (2+), 2521.7 (2+), 3119.0 (1+,2+), and [3017.3 (0+,1+,2+)] keV as being fed by Pr^{140} decay. Assignments for the first six were known from earlier work but are quite consistent with our log *ft* and relative photon intensity values. The upper three states have not been observed previously to be populated by Pr^{140} decay. We shall discuss the structures of some of the rigid Ce^{140} states in terms of quasiparticle configurations and will also discuss the effects of this rigid core on states in nearby odd-mass and odd-odd nuclei.

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*Supported in part by the National Science Foundation and by the Atomic Energy Commission.
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Analytic subject 55.2

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A Three-Quasiparticle Interpretation of the High-Lying Negative-Parity States in Pr^{139}.* Wm. C. McHarris, D. B. Beery,† and W. H. Kelly, Michigan State University. The electron-capture decay of 11/2- Nd^{139m} populates primarily a multiplet of states at 1624.5, 1834.1, 1927.1, 2048.8, 2174.3, and 2196.7 keV in Pr^{139} rather than the $h_{11/2}$ state at 821.9 keV. The high-lying states de-excite by many highly enhanced low-energy γ-ray transitions to other members of the multiplet, and γ-ray transitions to lower states in Pr^{139} appear to be hindered. This is interpreted as the configuration of Nd^{139m} $[(\pi d_{5/2})^2(\nu d_{3/2})^{-2}(\nu h_{11/2})^{-1}]$ being peculiarly suited for populating three-quasiparticle states having the configuration $(\pi d_{5/2})(\nu d_{3/2})^{-1}(\nu h_{11/2})^{-1}$. Results of calculations on this multiplet, both within the framework of the simple shell model and in the quasiparticle formalism are presented. The effects of impurities in the states on the transition rates of very highly hindered electromagnetic transitions will also be discussed.

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Analytic subject 51.2

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The Electron Capture Decay of Pb^{200}*

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ABSTRACT

Pb^{200} was produced in high yield by using 34 MeV protons from the MSU Sector-Focused Cyclotron to induce the $Tl^{203}(p,4n)Pb^{200}$ reaction on both natural thallium and separated isotope Tl^{203}. It was also obtained from Bi^{200}, which was produced by bombarding separated Tl^{203} with 50 MeV He^3 from the MSU Cyclotron. The Bi^{200} was chemically separated from the Tl target and then loaded onto an anion-exchange column, from which the Pb^{200} was eluted and counted. Gamma-rays from the Pb^{200} decay were studied using two Ge(Li) detectors singly and in coincidence with each other as well as in coincidence and anti-coincidence with NaI(Tl) detectors. Thirteen gamma transitions were found, having the following energies (and relative intensities): 109.4 (0.89), 142.4 (9.7), 147.6 (≡100), 161 (0.8), 235.3 (10.5), 257.0 (11.0), 268.6 (13.0), 289.4 (doublet) (7.8), 302.6 (0.31), 315.2 (0.45), 450.5 (7.9), 525.4 (0.79), and 605.3 keV (1.2). These transisitons have been placed in a consistent decay scheme on the basis of coincidence measurements, relative intensities, and energy sums and differences. The levels in Tl^{200} populated in the decay of Pb^{200} lie at 0, 147.6, 257.0, 289.1, 289.9, 450.4, 525.4, and 605.3 keV. The transition probabilities and our spin assignments will be discussed in terms of single quasi-particle states influenced by collective effects.

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Abstract for invited paper to be presented at the symposium on "Major National Nuclear Chemistry Facilities", J. R. Huizenga, Chairman. This symposium will be held during the Spring 1969 Meeting of the American Chemical Society, Division of Nuclear Chemistry and Technology, in Minneapolis.

"The Michigan State University 50-MeV Sector-Focused Cyclotron"*

Wm. C. McHarris

Nuclear chemical research at Michigan State University is centered around the MSU Cyclotron in the Department of Physics, and the nuclear chemistry group works in close co-operation with the nuclear physics groups. The MSU Cyclotron now produces beams of protons (present E_{max}=50 MeV), deuterons (≈23 MeV), He^3 (75 MeV), and α particles (≈46 MeV), which have been used for a wide variety of spectroscopic and scattering experiments. Usable beams of C^{12} (E_{max}≈75 MeV), N^{14} (≈100 MeV), and O^{16} (≈125 MeV) should be available within a few months. Single-turn extraction allows us to obtain intense beams (tens of μA) with close to 100% extraction and a raw energy spread of 0.1%. The beam divergence is ≈1 mm-mrad. After passing through an external analyzing system, the energy spread is less than can be measured, although scattering experiments performed by nuclear physicists have achieved resolutions of 20 keV FWHM, using Ge proton detectors fabricated at the Cyclotron Laboratory. And with a split-pole, broad-range magnetic spectrograph presently being installed, resolutions of 5 keV or better are expected. Current projects, in addition to spectroscopic studies and scattering reactions, include in-beam γ-ray studies and plans for placing the 6-sector "orange" β-ray spectrometer on-line and also for using an electric quadrupole mass filter as an on-line isotope separator.

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OPERATIONAL EFFICIENCY OF A SIGMA-7 TIMESHARING SYSTEM

by

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ABSTRACT

The general requirements of a timesharing system are: simultaneous operation of realtime routines with high response speed (10US); process control with medium response times (10MS); teletype terminals requiring human response times; and background batch high computational efficiency. All this should be done with little overhead and fit into a minimum size machine.

The solution to these problems is presented in a description of our JANUS SYSTEM. The machine configuration, software layout, swapping method, task scheduling, and dynamic resource allocation are described. In addition the structure, operation and flexibility of tasks under the JANUS SYSTEM is described.

High-Precision High-Transmission Cyclotron Operation*

H. G. Blosser
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The energy spread and emittance of the external beam of a modern cyclotron are largely due to time fluctuations in dee voltage amplitude and to the substantial phase width of the beam—contributions from magnetic field fluctuations or from rf frequency variations are usually much smaller reflecting the high precision with which these latter two quantities can be stabilized. For high resolution applications ($\Delta E/E$ = 1/10,000), nearly all of the beam reaching the users target can be shown to come from a narrow range of rf phase ($\sim 2°$) and only at times when the dee voltage matches the "central ray" value to the same accuracy as the energy precision requirement. Background, activation, and thermal dissipation problems are of course all enormously eased if "bad" beam (the beam which will fail to reach the users target) is eliminated at an early stage of the acceleration process which implies that the rf must be accurately stabilized and the beam phase width restricted to a narrow interval. As regards the phase width, a system of slits now in routine use in the MSU cyclotron yield a phase spread of only 1.5° for currents up to 15μa—if the cyclotron is carefully tuned to minimize the energy spread (correcting longitudinal space charge effects) the contribution of the phase width to the energy spread is about 1 in 20,000. With such narrow phase groups the energy spread is dominated by rf fluctuations; experimentally this is vividly evidenced by the transmission thru a 1 in 10,000 analysis which is observed to be twice as high for 0.07% rf ripple as for 0.14%. (The percentage energy spread of the whole beam is also observed to closely match the rf ripple percentage.) Interestingly the gross radial emittance of the external beam is also observed to vary approximately linearly with rf ripple indicating that the normally employed measurement procedure does not actually measure the true emittance but rather a combination of emittance and dispersion. Procedures have been developed to separate these two pheonomena—the resulting true emittance is typically 0.7 mm-mr radially by 5.0 mm-mr axially for the MSU cyclotron. A further interesting by-product of the narrow phase group system is the ability to ex post facto correct data by reading the rf voltage each time a scattering chamber count is recorded, computing the Q value ($=E_{counter}-aV_{rf}$) and thus obtaining high resolution spectra even when the analysis system is set to transmit a much broader energy interval.

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