Section III

Abstracts of Papers Submitted for Publication but not yet published

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(p,d) Reaction in the Titanium Isotopes*

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ABSTRACT

Angular distributions for $^{48}Ti(p,d)^{47}Ti$ were obtained for E_p = 25-45 MeV to study the energy dependence of various methods of extracting spectroscopic factors. In the DWBA analysis for the principal ℓ_n = 1, 2 and 3 transitions, it was found that correcting for finite-range and non-locality in the interaction eliminated the energy dependence observed in spectroscopic factors obtained with local zero-range calculations. On the basis of these results, spectroscopic factors were measured for $^{46,48,50}Ti(p,d)^{45,47,49}Ti$ and compared to the sum-rule predictions of French and Macfarlane. Most of the disagreement observed is attributed to incorrect treatment of Q dependence in the calculations.

NUCLEAR REACTION: $^{50,48,46}Ti(p,d)$ E=25-45 MeV; measured $\sigma(E,\theta)$; deduced spectroscopic factors. Enriched targets.

* Work supported in part by the National Science Foundation.

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Use of Thin Semiconductor Position Sensitive Detectors in Magnetic Spectrographs*

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ABSTRACT

Thin position sensitive silicon surface-barrier detectors in a magnetic-spectrograph have been found to yield good position resolution and a high degree of discrimination between various particles.

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*Work supported by the National Science Foundation.

Measurement of T_Z=-3/2 Masses and the Isobaric Multiplet Mass Equation*

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ABSTRACT

Precise measurements of the masses of ^{9}C, ^{13}O, and ^{21}Mg have been made using a magnetic spectrograph. The results are used to test the isobaric multiplet mass equation.

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Study of the Level Structure of N = 82 Nuclei via Proton-Transfer Reactions*

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ABSTRACT

Measurements of the angular distributions of the (^{3}He,d) and (d,^{3}He) reactions on the stable, even-mass N = 82 isotones are presented and discussed. In each of the residual nuclei formed in these reactions, ^{135}I, ^{137}Cs, ^{139}La, ^{141}Pr, ^{143}Pm, and ^{145}Eu, the lowest two levels are populated with significant strength, one by ℓ_p = 4 transfer and one by ℓ_p = 2 transfer. Analysis indicates that these states result from coupling a $1g_{7/2}$ or $2d_{5/2}$ proton (or proton hole) to the respective $J^\pi = 0^+$ target ground states. The relative energies of these

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states change as a function of mass, the $5/2^+$ state lying 590 keV above the $7/2^+$ state in ^{135}I and 330 keV below the $7/2^+$ state in ^{145}Eu. Spectroscopic factors extracted from the data with DWBA analysis indicate that the active particles in the target ground states predominantly occupy the $1g_{7/2}$ and $2d_{5/2}$ orbits, with the ratio of $1g_{7/2}$ protons to $2d_{5/2}$ protons varying from 3.5/0.5 for ^{136}Xe to 6.3/3.6 for ^{144}Sm. The pick-up reactions reveal small admixtures of $1h_{11/2}$, $3s_{1/2}$, and $2d_{3/2}$ protons into the heavier target ground states. These orbits, together with the $1g_{7/2}$ and $2d_{5/2}$, constitute the major shell which fills between Z = 50 and 82. The stripping experiments locate the centroid energies of these higher three orbits relative to the $5/2^+$ and $7/2^+$ states. It is found that the centroids of the $1h_{11/2}$, $3s_{1/2}$, and $2d_{3/2}$ single-particle states relative to the ground states decrease monotonically from excitations of 1.9, 2.1, and 2.1 MeV, respectively, in ^{137}Cs to excitations of 0.72, 0.81, and 1.1 MeV in ^{145}Eu.

Shell-Model Calculations for Even-Parity States in A = 18-22*

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ABSTRACT

Using the full basis of Pauli-allowed $(0s)^4(0p)^{12}(1s,0d)^{A-16}$ states, we have performed conventional shell-model calculations for A = 18-22. Seven alternative (1+2)-body Hamiltonians were used. Two of these were the "realistic" Hamiltonians proposed by Kuo and Brown, and by Kuo, for A = 18. Five others were obtained by choosing five different adjustable forms for the (1+2)-body Hamiltonian operator, and then optimizing the free parameters in these forms so as to get least-square fits to measured energy-level data in A = 17-22. For levels which seem to be members of ground-state bands, all seven Hamiltonians yield fair-to-good reproduction of experimental data for the following kinds of observables: excitation energies, spectroscopic factors for single-nucleon transfer, electric quadrupole moments, intra-band B(E2) strengths, and magnetic moments. Within ground-

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state bands there is generally very striking similarity between our shell-model E2 results and the E2 results predicted by a strong-coupling rotational model. This general similarity, and the exceptions to it, can be explained qualitatively by arguments involving SU_3 shell models. For observables involving levels outside ground-state bands the agreement with experiment is spotty, and there is considerable sensitivity to the choice among our seven Hamiltonians. Again, SU_3 considerations are helpful in explaining these features. Some very simple shell models can account for the pattern of weakness and strength seen among our shell-model B(M1) values.

ANOMALOUS L=1 SHAPES OF ANGULAR DISTRIBUTIONS FOR (^{3}He,t) TRANSITIONS TO 0^+ ANTI-ANALOG STATES IN ^{64,66}Ga and ^{40}K*

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ABSTRACT

The (^{3}He,t) reaction on ^{64,66}Zn and ^{40}Ar to the 0^+ analog and anti-analog states has been studied at 35 MeV. The angular distributions for the $T_<$ 0^+ states show an L=1 shape, implying a need for modifications in the conventional description of (^{3}He,t) reactions.

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Ultra-High Resolution Spectrometer System for Charged Particle Studies of Nuclei*

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ABSTRACT

This paper describes an arrangement for introducing feedback into a charged particle magnetic analysis system for nuclear reaction studies. In initial tests of the system, a resolution of 5 keV has been obtained in (p,p') studies at 30 MeV with 70% of the cyclotron internal beam on target. This corresponds to a resolving power $p/\Delta p$ of 12,000. Essential features of the system, in addition to the feedback, are a careful definition of the cyclotron source by means of internal slits and the use of dispersion matching to cancel the effect of coherent on-target energy spread.

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Proton Scattering and the Optical Model
Differences Between ^{40}Ca and ^{48}Ca*

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ABSTRACT

Elastic proton scattering from ^{48}Ca and ^{40}Ca has been measured at 25, 30, 35, and 40 MeV. The root mean square radius determined by the optical model is 0.15 fermi larger for ^{48}Ca relative to ^{40}Ca, consistent with the $A^{1/3}$ law.

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Improving the Energy Resolution and Duty Factor of Isochronous Cyclotrons*

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ABSTRACT

A separated turn isochronous cyclotron can produce beams having a precise energy resolution together with a substantial duty factor if the effective voltage wave form is "flat-topped". Optimum flat-topping results are presented for five different harmonic combinations: n = 1 and 2; n = 1, 2, and 3; n = 1, 2, 3, and 4; n = 1 and 3; n = 1, 3, and 5. For a given energy resolution, the improvement in duty factor with each added harmonic is quite impressive. The success of this technique is limited by certain practical problems which are examined.

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Experimental Studies of the Neutron-Deficient Gadolinium Isotopes. II. Gd^{145m}

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ABSTRACT

The N=81 isomer Gd^{145m} is characterized as having a half-life of 85 ± 3 sec and an M4 isomeric transition of 721.4 ± 0.4 keV. It also has a direct β^+/ε branch to the $h_{11/2}$ state at 716.1 keV in Eu^{145}. The intensity of this branch is 4.7% of the decay, implying a log ft of 6.2. The M4 transition probability is calculated and compared with the trends among other isomeric transitions in this region.

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States in Odd-Odd Tl^{200} Populated by the Electron-Capture Decay of Pb^{200}

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ABSTRACT

Low-spin states in Tl^{200} have been studied via the decay of 21.5-h Pb^{200}, which was prepared by the reactions, $Tl^{203}(p,4n)Pb^{200}$, $Hg^{202}(\tau,5n)Pb^{200}$, and $Tl^{203}(\tau,6n)Bi^{200}\rightarrow Pb^{200}$. Its γ-rays were studied in singles, coincidence, anticoincidence, and Ge(Li)-Ge(Li) two-dimensional (2048x2048 channel) coincidence experiments. Nineteen γ transitions have been assigned to the decay of Pb^{200}, and all have been placed in a consistent level scheme. States in Tl^{200} populated by Pb^{200} decay lie at 0 ($I\pi$=2-), 147.63(0-), 257.19(1-), 289.24 (2-,1-), 289.92(1-), 450.56(1-), 525.54(1-), and 605.44 keV (1-). Our spin and parity assignments are based on measured conversion coefficients, relative photon intensities, and log ft values. The structures of the states are discussed in terms of the coupling of the possible single-particle states in adjacent odd-A nuclei. We also place an upper limit of 1 sec on the half-life of any possible isomeric state in Pb^{200} itself.

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Ge(Li)-Ge(Li) Compton Scattering Problems

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ABSTRACT

We present results from our investigations of Compton scattering between Ge(Li) γ-ray detectors in coincidence experiments. Such scattering can generate false peaks that can be mistaken for photopeaks. The effects of varying gate position, gate width, background subtraction, and angle between detectors are discussed, and suggestions are made for recognizing and minimizing spurious effects.

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Experimental Studies of Neutron-Deficient Gadolinium Isotopes
III. The Strange Case of Gd^{145g}

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ABSTRACT

The γ-rays emitted following the decay of 21.8-min Gd^{145g} have been studied using Ge(Li) and NaI(Tl) detectors in a variety of singles, anticoincidences, pair-coincidence, and two-dimensional ("megachannel") coincidence experiments. Of the 38 γ-rays attributed to this decay, 27 (accounting for >97% of the intensity) have been placed in a consistent decay scheme that includes 20 states in Eu^{145}. All of the single-proton states between Z=50 and 82 are seen (including the $h_{11/2}$ state populated directly by the decay of Gd^{145m}), and the associated β and γ transitions are accounted for quite well using simple shell-model arguments. In addition, we propose an explanation for the abrupt change in decay properties of the N=81 isotones that occurs at Gd^{145g}, viz., the lack of observable population directly to the Eu^{145} ground

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state but 72.6% of its decay going to states at 1757.8 and 1880.6 keV. With a $(\nu s_{1/2})^{-1}$ ground state for Gd^{145}, these "fast" β transitions can be represented as

$$(\pi h_{11/2})^{2n}(\nu s_{1/2})^{-1} \; (\pi h_{11/2})^{2n-1}(\nu h_{9/2})(\nu s_{1/2})^{-1},$$

making the final states another example of three-quasiparticle states being populated by the β^+/ε decay of nuclei below N=82.

Straightforward Elucidation of Complex Shell-Model States by the β Decay of Nuclei Far from Stability

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Nuclei far from stability have sufficient β-decay energy to populate high-lying, multi-particle states. Just below major closed shells the configurations of some of these, usually involving one or more high-spin states, are such that their decay is forced to populate unique, well-defined multi-particle states. From the study of these decays a wealth of information can be obtained about states at several MeV that normally is not available about states much closer to the ground state. And, using a severely truncated basis space, meaningful shell-model calculations can be made both on their energies and the ratio of β- and γ-transitions into and out of them. We present several examples of these that have been studied in our laboratory.

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Some odd-mass N=79 and 81 isotones make good examples. 5.5-h $_{60}Nd^{139m}_{79}$, with $I^{\pi}=11/2^-$ and Q_{ε} 3 MeV, populates a multiplet of six high-spin ($9/2^-$ and $11/2^-$) states lying between 1624.5 and 2196.7 keV in Pr^{139}. There are many enhanced transitions between members of the multiplet, while the transitions to states lower in the nucleus appear to be highly hindered. The β decay can be interpreted as $(\pi d_{5/2})^2(\nu d_{3/2})^{-2}(\nu h_{11/2})^{-1} \rightarrow (\pi d_{5/2})(\nu d_{3/2})^{-1}(\nu h_{11/2})^{-1}$, and the latter configuration does appear to be the major component of the six states. A shell-model calculation using as a basis only this configuration plus $(\pi h_{11/2})(\nu d_{3/2})^{-2}$, the configuration of the $11/2^-$ "isomeric" states at 821.9 keV in Pr^{139}, yielded excellent energy agreement, although considerable $(\pi g_{7/2})^{-1}(\nu d_{3/2})^{-1}(\nu h_{11/2})$ [$x(\pi d_{5/2})^2$ qualitatively] has to be added to obtain the transition ratio even between states in the multiplet. $_{62}Sm^{141m}_{79}$, the next member of the series, displays similar behavior, populating a three-particle multiplet of at least five states lying between 1166.4 and 2118.0 keV in Pm^{141}. Here the admixture of $(\pi g_{7/2})^{-1}(\nu d_{3/2})^{-1}(\nu h_{11/2})$ appears to be stronger, somewhat surprising when one compares the expected order of filling of these orbits.

β decay of several odd-mass members of the N=81 isotones elucidates a complementary feature of shell-model states, viz., the filling and occupation numbers of $h_{11/2}$ proton pairs. The sudden break in β-decay properties at $_{64}Gd^{146g}_{81}$, where states at 1757.8 and 1880.6 keV in Eu^{145} are populated rather than the ground state, as had been the case in $_{60}Nd^{141g}_{81}$ and $_{62}Sm^{143g}_{82}$

decays, can be interpreted thusly: The $(\pi h_{11/2})^{2n}$ occupation increases with additional protons rather rapidly because this orbit is dropping in energy, so at Gd^{145} it is expected to have appreciable occupancy. Also, the $\nu s_{1/2}$ and $\nu d_{3/2}$ states have crossed, making Gd^{145g} an $s_{1/2}$ state. The β decay follows, as $(\pi h_{11/2})^{2}(\nu s_{1/2})^{-1} \rightarrow (\pi h_{11/2})^{1}(\nu h_{9/2})^{1}(\nu s_{1/2})^{-1}$. That the $(\pi h_{11/2})^{2n}$ occupation is indeed increasing is borne out by the increased direct β population from Gd^{145m} to the $h_{11/2}$ state in Eu^{145}. The log ft for direct population from Nd^{141m} to the $11/2^-$ state in Pr^{141} is >7(>0.01% population), while it drops to $\tilde{\sim}6.7$ for Sm^{143m} and to $\tilde{\sim}6.2$ for Gd^{145m}.

Properties of the ^{209}Bi Ground State Analogue in ^{209}Po*

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ABSTRACT

The analogue of the ground state of ^{209}Bi was investigated by both the ^{209}Bi(p,n)^{209}Po and the ^{209}Bi(p,n$\bar{p}$)^{208}Bi reactions. The Coulomb energy difference ^{209}Po-^{209}Bi was determined as 18.92$\pm$.03 MeV, and the relative partial widths for proton decay into the $p_{1/2}$, $f_{5/2}$, and $p_{3/2}$ channels were determined. The total width of the analogue state was found to be 380$\pm$60 keV.

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Shell-Model Structure of ^{35}Cl-^{35}Ar*

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ABSTRACT: Energy levels, E2 and M1 observables, and spectroscopic factors are calculated for ^{35}Cl-^{35}Ar, and compared with experimental data. The theoretical results are obtained by computations in a full $(0s)^4(0p)^{12}(1s,0d)^{A-16}$ shell-model vector space. Two alternative "realistic" interactions are used.

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Experimental Studies of Neutron-Deficient Gadolinium Isotopes

I. The Electron-Capture Decay of Gd^{149}

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ABSTRACT

γ-rays emitted in 9.4-day Gd^{149} have been studied with Ge(Li) and NaI(Tl) detectors. 25 γ-rays have been attributed to the decay of Gd^{149} with energies and relative intensities of 149.6(233), 214.5(0.81), 252.3(1.1), 260.5(5.8), 272.0(15), 298.5(127), 346.5(≡100), 405.5(3.7), 430(0.33), 459.9(2.4), 478.7(0.95), 496.4(7.2), 516.4(11), 534.2(13), 645.2(5.9), 663.3(1.1), 666.2(3.9), 748.2(35), 788.6(30), 812.4(0.55), 863(0.32), 875.8(0.90), 933.3(2.2), 939.1(9.0), and 947.7 keV (3.7). On the basis of coincidence and anticoincidence experiments, relative intensities, and energy sums, states in Eu^{149} have been placed at 0, 149.6, 459.9, 496.2, 534.2, 666.0, 748.2, 794.8, 812.4, 875.8, 933.3, 939.1, and 1097.3 keV. The Eu^{149} x-ray

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intensity has also been measured. From our γ-transition intensities and published conversion-electron intensities, conversion coefficients were obtained for most of the electromagnetic transitions, thus allowing multipolarity assignments to be made for these transitions. These assignments, together with the log ft values, were then used for the placement of limits on the spins of the deduced levels. Our proposed decay scheme is compared with previously published decay schemes and is discussed in terms of current models.