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Argonne National Laboratory
PHYSICS DIVISION SUMMARY REPORT
January—March 1969

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ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
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PHYSICS DIVISION SUMMARY REPORT

January—March 1969

Lowell M. Bollinger, Division Director

Preceding Summary Reports:

ANL-7436, January-March 1968

ANL-7481, Annual Review

ANL-7512, April-December 1968

FOREWORD

The Physics Summary is issued several times per year for the information of the members of the Division and a limited number of other persons interested in the progress of the work. It includes short reports on highlights of the current research, abstracts or short summaries of oral presentations at meetings, abstracts of papers recently accepted for publication, and publication notices of papers appearing in recent journals and books. Many of these reports cover work still in progress; the results and data they present are therefore preliminary, tentative, and often incomplete.

The research presented in any one issue of the Summary is only a small random sample of the work of the Physics Division. For a comprehensive overview, the reader is referred to the ANL Physics Division Annual Review issued each summer, the most recent being Argonne National Laboratory Report ANL-7481, which reports research in the year ending 31 March 1968.

The issuance of these reports is not intended to constitute publication in any sense of the word. Final results will be submitted for publication in regular professional journals or, in special cases, presented in ANL Topical Reports.

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I. RESEARCH HIGHLIGHTS

These research highlights are Physics Division contributions to the Physical Research Monthly Report which the Laboratory Director's Office sends to the Division of Research of the U.S. Atomic Energy Commission. They report interesting work that is currently in progress or that has just been completed.

DISCUSSION OF A MIDWEST ACCELERATOR FOR NUCLEAR CHEMISTRY AND PHYSICS

On 11 January 1969, many of the leading nuclear chemists and physicists of the Midwest gathered at O'Hare airport for a one-day meeting to discuss a proposal for an advanced accelerator for nuclear physics and chemistry research. This group consisted of 36 representatives from 26 universities, and 28 from Argonne.

The O'Hare meeting was organized by the Chemistry and Physics Divisions of Argonne with the objectives of: (1) presenting the proposed accelerator concept, (2) discussing the kind of research that should be done with it, and (3) giving the prospective users from the universities an opportunity to contribute their ideas at a very early stage in the project. About half of the available time was reserved for general discussion.

The accelerator system considered at the O'Hare meeting would consist of two major components—a TU tandem Van de Graaff and an open-sector isochronous cyclotron. This pair of accelerators would operate in two alternative modes, as is illustrated in Fig. 1. For heavy-ion acceleration, the tandem would inject into the cyclotron to produce intense ion beams with energies up to or greater than the Coulomb barrier for all ions. Alternatively, the two accelerators would be used independently and simultaneously for two different experiments.

Fig. 1. The two alternative modes of operation of the MTC system.

For example, the TU tandem would produce protons up to an energy of at least 32 MeV (perhaps as high as 40 MeV) whereas the variable-energy cyclotron would span the energy range 40—350 MeV. Thus, the system would have immense versatility; it would be unmatched as a heavy-ion accelerator and for light ions it would permit refined measurements in an energy range that is not covered by any existing or funded variable-energy machine. Equally important (for a system intended as a regional facility), the proposed accelerator system would be capable of supporting a large volume of research.

The proposed accelerator system seemed to be received with enthusiasm by the university representatives, and the Argonne group felt that they were given a mandate to proceed with the development of the proposal.

THE SCATTERING OF PHOTONS BY THE NUCLEAR COULOMB FIELD

H. E. Jackson and K. J. Wetzel

One of the earliest predictions of quantum electrodynamics, made by Delbrück in 1933, was that photons should be elastically scattered by an electric field. The process can be regarded as a manifestation of vacuum polarization, a nonclassical phenomenon predicted by quantum electrodynamics and confirmed in the famous experimental observations of the Lamb shift in the atomic spectrum of hydrogen. Because of its fundamental nature, interest in the experimental verification of Delbrück scattering has remained very high and in the succeeding thirty years many experiments have been attempted—but none had been completely successful. The prediction has now been confirmed by the Argonne experiment described below.

Because the effect is so small, only the electric fields of atomic nuclei are strong enough to make the process observable. But in this case several other types of elastic scattering occur and inelastic scattering also produces high background at photon energies close to those of interest. Consequently very high resolution is necessary in detecting the elastically scattered photons, and the contributions of the competing reactions must be very carefully determined. Both these points proved to be pitfalls in the earlier studies and only recently have experimental techniques and data on competing reactions been sufficiently refined to permit a clean and conclusive experiment.

In a high-resolution measurement of the scattering of 10.8-MeV photons, recently completed at Argonne, the elastic scattering of photons has for the first time been resolved experimentally from inelastic contributions. The results showed that for scattering angles less than 45° the process is indeed dominated by Delbrück scattering. The high-intensity internal-target facility at the CP-5 reactor was used to generate a beam of 10.8-MeV photons by means of the $^{14}\text{N}(n, \gamma)^{15}\text{N}$ reaction in a 250-g melamine target. Radiation scattered

Fig. 2. Differential elastic-scattering cross sections measured for 10.83-MeV photons. The dashed curve represents the values calculated if Delbrück scattering is neglected; the solid curve follows the values obtained by including the most recent theoretical estimates of the Delbrück amplitudes. At forward angles the cross sections are enhanced by as much as a factor of three due to the presence of the Delbrück effect.

by external Pb and U targets was detected in a large-volume Ge(Li) detector with an energy resolution width of 15 keV at 10 MeV. In analyzing the data, recent results from related experiments were used in a careful determination of the contributions from the coherent scattering processes (namely nuclear resonance scattering, Thomson scattering, and Rayleigh scattering). The data (Fig. 2) indicate that the measured cross section is much larger at forward angles than that calculated with no Delbrück amplitude. This is interpreted as an unambiguous observation of the Delbrück effect.

Good agreement between the measured and calculated cross sections supports the reliability of recent estimates of the Delbrück amplitudes made by a group at CERN. Our results not only confirm

the existence of Delbrück scattering but suggest that the interaction can, and should, now be experimentally studied in considerable detail.

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II. REPORTS AT MEETINGS

The abstracts and summaries that follow are not necessarily identical to those submitted for the meeting. In some cases, the authors have corrected or expanded abstracts; and summaries of contributed papers commonly have been shortened.

Fifth Mössbauer Methodology Symposium Boston, Massachusetts, 2 February 1969

MÖSSBAUER EFFECT IN RADIOACTIVE MATERIALS

A. J. F. Boyle* and G. J. Perlow

Preliminary results of various workers with the isotopes 2.6-yr Pm^{147} , 7.2-yr Ba^{133} , 87-yr Sm^{151} , and 47-hr Sm^{153} are treated as examples of the general considerations which apply to using unstable isotopes as the absorbing nuclei for the Mössbauer effect.

For Ba^{133} the authors have measured the difference Δg between the ground-state and excited-state gyromagnetic ratios: $\Delta g = 1.98 \pm 0.03$ nm. The excited state is at 12.29 keV and the spin sequence is $\frac{3}{2}^+ \rightarrow \frac{1}{2}^+$. The source was 39-h $\text{Ba}^{133\text{m}}$ produced in a cyclotron bombardment. Effects as large as 2% were observed with absorbers of about 1 mCi strength. All dimensions were of the order of 1 mm.

The 36-keV E1 transition in Sm^{153} is not populated in any radioactive decay and was produced by neutron capture in Sm^{152} . The source ($^{152}\text{Sm}_2\text{O}_3$) for the experiment[†] was in the central flux of the reactor, and the transition was distinguished from the intense general

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[†] This experiment performed by the authors in collaboration with L. M. Bollinger, R. K. Smither, and G. E. Thomas.

background with the help of a crystal reflection. The absorber ($^{152}\text{Sm}_2\text{O}_3$ irradiated almost to saturation) was vibrated in the beam just outside the reactor face. The experimental linewidth of the Mössbauer velocity spectrum was 10 mm/sec, which suggests that the lifetime of the transition is between 1 and 3 nsec.

American Physical Society
New York, 3—6 February, 1969

GAMMA DECAY OF $T=\frac{3}{2}$ STATES IN Na^{21}

R. C. Bearse, G. C. Morrison, J. C. Legg,* and R. E. Segel
Bull. Am. Phys. Soc. 14, 124 (January 1969)

The γ decays of the two lowest $T=\frac{3}{2}$ states¹ in Na^{21} at 8.973 MeV ($\frac{3}{2}^+$, $\frac{5}{2}^+$) and 9.216 MeV ($\frac{1}{2}^+$) have been studied as resonances in the $\text{Ne}^{20}(\text{p}, \gamma)$ reaction by use of a gas cell and a 30-cc Ge(Li) detector. For the lower resonance we find three branches: to the $\frac{3}{2}^+$ ground state ($\leq 14\%$), to the $\frac{5}{2}^+$ first excited state (41%), and to the $\frac{7}{2}^+$ second excited state (45%). These results imply $J = \frac{5}{2}^+$ for the $T=\frac{3}{2}$ state. On the simple rotational model, only transitions connecting $K = \frac{1}{2}$ (Nilsson orbit #6) and $K = \frac{3}{2}$ (#7) bands are possible. In particular, a $J = \frac{5}{2}^+$, $K = \frac{1}{2}$ assignment for the $T=\frac{3}{2}$ state leads to the observed branching ratios. The second resonance decays predominantly to the ground state in agreement with the model. At most, there is an 8% branch to the $\frac{1}{2}^+$ state at 2.41 MeV. If the 2.41-MeV state is $K = \frac{1}{2}$ (#9), no transition is expected. On both resonances, transitions to higher excited states are obscured because of background. A search for resonances corresponding to higher $T=\frac{3}{2}$ states was unsuccessful.

* Kansas State University, Manhattan, Kansas.

¹A. B. McDonald, J. R. Patterson, and H. Winkler, Bull. Am. Phys. Soc. 13, 652 (1968).

ELECTRON g FACTORS OF LOW-LYING STATES OF Tb I.

W. J. Childs and L. S. Goodman

Bull. Am. Phys. Soc. 14, 84 (January 1969)

The atomic-beam magnetic-resonance technique is being used for a further investigation of the properties of low-lying atomic levels of Tb^{159} . Preliminary values of the electron g factor in

the $4f^9 6s^2$ configuration are: ${}^6H_{15/2}$, 1.32514 (5); ${}^6H_{13/2}$, 1.276 (1). For the $4f^8 5d 6s^2$ configuration we find the values: ${}^8G_{15/2}$, 1.45623 (10); ${}^8G_{13/2}$, 1.46448 (5); ${}^8G_{11/2}$, 1.51654 (5); ${}^8G_{9/2}$, 1.54114 (20); ${}^8G_{7/2}$, 1.476 (1); ${}^8G_{5/2}$, 1.355 (1); ${}^8G_{3/2}$, 1.022 (2); ${}^8D_{11/2}$, 1.529 (1). The labels assigned to the states are those of Meinders and Klinkenberg¹; they are somewhat arbitrary because of the substantial departure of the atom from the LS limit for some levels. No information on the ${}^8D_{9/2}$ level (2554 cm^{-1}) has been obtained as yet. The hyperfine interaction constants are also being measured.

¹ E. Meinders and P. F. A. Klinkenberg, *Physica* **38**, 253 (1968).

NGR MEASUREMENTS WITH ${}^{238}\text{U}$

S. L. Ruby, G. M. Kalvius,* B. D. Dunlap,* G. K. Shenoy,*
M. B. Brodsky,[†] and D. Cohen[‡]

Bull. Am. Phys. Soc. **14**, 134 (January 1969)

Using the α decay of ${}^{242}\text{Pu}$ as the source of the 45-keV radiation from the first excited state (2^+) to the ground state (0^+), Mössbauer absorption has been observed in ${}^{238}\text{U}$. The resolution obtainable in these experiments is limited due to the short half-life of the 2^+ state (0.23 nsec) and the low counting rate caused by the long half-life of the parent ${}^{242}\text{Pu}$ (4×10^5 yr), the high internal conversion coefficient (~ 730), and the small half-thickness of 45-keV gamma radiation in Pu ($\sim 50 \text{ mg/cm}^2$). Compounds measured were UO_2 , $(\text{UO}_2)(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$, UC, UO_3 , and U metal in the temperature region between 77° and 4.2°K . With PuO_2 as a source, a single but slightly broadened emission line was obtained. For compounds having large

* Solid State Science Division.

[†] Metallurgy Division.

[‡] Chemistry Division.

hyperfine fields, the splitting parameters could be measured. For instance, the internal magnetic field in UO_2 is 2700 ± 200 kOe; the quadrupole interaction in the uranyl ion is $e^2qQ = -5800 \pm 400$ MHz.

NEUTRON RESONANCES OF Mo

Hla Shwe* and R. E. Coté†

Bull. Am. Phys. Soc. 14, 104-105 (January 1969)

The neutron transmission of Mo isotopes at neutron energy up to about 1.5 keV have been measured with the Argonne fast chopper. The use of samples enriched in Mo^{95} and in Mo^{97} , in addition to samples of natural Mo, has made possible the unambiguous isotopic assignment for a majority of the resonances. Bollinger's probability approach¹ is used to interpret many resonances as those due to p-wave neutrons. Measurements of the radiation widths for resonances at neutron energy less than 200 eV show that there is little or no difference between the radiation width for s-wave and p-wave resonances.

* Permanent address: Department of Physics, Ripon College, Ripon, Wisconsin.

† Deceased.

¹ L. M. Bollinger and G. E. Thomas, Phys. Rev. 171, 1293 (1968).

Conference on Computer Systems in Experimental Nuclear Physics
Skytop, Pennsylvania, 3-6 March 1969

AUTOMATIC COUNTING OF TRACKS IN NUCLEAR EMULSIONS

John R. Erskine and Robert H. Vonderohe*

A scanning machine to process nuclear track plates exposed in a broad-range magnetic spectrograph is now in operation. The system uses a PDP-9 digital computer to do pattern recognition and to control the scanning head. A high-resolution image-dissector tube scans the emulsion with a resolution of about 5 μ . The computer identifies line segments as tracks if they have the proper length and orientation. The machine scans about 50 times as fast as the average scanner. Counting accuracy is found to be influenced by brightness of tracks, fog level in the emulsion, length of tracks, dirt, and number of tracks in a given area. How these and other factors influence the performance of the machine will be discussed.

*Applied Mathematics Division.

EXPERIENCE WITH A MULTI-COMPUTER MULTI-EXPERIMENT SYSTEM

D. S. Gemmell

The computer system that serves the 15-MeV tandem Van de Graaff and 4-MeV Dynamitron accelerators at Argonne National Laboratory will be described and some examples of its use will be given. The system contains three small computers (two ASI 2100 and one ASI 210) which are compatible in both hardware and software. One of these computers is on-line at each accelerator and one is used mostly in off-line applications. The three machines have some interconnections between them and in addition there is a link to the Argonne

CDC 3600. A significant feature (especially at the tandem location) is the very wide variety of experiments to which the computer system is applied. As a consequence, the emphasis in software is placed upon the development of a large set of subprograms which can rapidly and flexibly be put together and called from simple Fortran main programs. This readily allows the majority of the physicists (who can program in Fortran) to make the system do what they want it to do.

ARGONNE COMPUTER-CONTROLLED SCATTERING CHAMBER

J. L. Yntema

The 70-in. scattering chamber at the Argonne tandem was designed to permit the accumulation of data with maximum efficiency. The chamber is shown in Fig. 3. It basically consists of four independent arms which rotate about a common axis. The angular position of each arm can be determined to better than $1'$. The detector blocks mounted on the arms can be moved radially in 1-mm steps. The target holder allows the insertion of eight targets, which can be introduced through a vacuum lock. Targets can be changed during the bombardment. The angle between the target and the beam direction is remotely controlled. The beam collimator has two circular defining apertures 1.5 mm in diameter and 1 m apart. The detector arms are supported at their outer edge by a ring gear driven by a stepping motor. The motors are customarily set for the appropriate number of steps to move the detector arm in multiples of 0.1° . Since it is difficult to interface a television picture of variable quality with the computer, a 6-digit decitrak was mounted on each of the gear rings. A switch enables the experimenter to select the appropriate decitrak for the decitrak readout. Since the decitrak reads from the gear ring, it is necessary to know the calibration of the decitrak with respect to the primary optical system. If the desired accuracy is not better than 0.07° , it is not necessary to

Fig. 3. View of the scattering chamber.

correct the decitrak reading. Obviously each arm can carry several detector systems.

A laser beam is used routinely to align the collimator with the axis of the scattering chamber and to align the scattering chamber with the direction of the tandem beam. The current on the last aperture of the collimator is minimized during the run. The angular positions of the arms and of the target are read from the photoengraved glass circles centered on the axis of the chamber. These circles are read through a pentaprism system at the bottom of the chamber and can also be remotely observed by use of a television camera.

The chamber has been used with as many as eleven independent detector systems for (p,p) and (d,p) experiments. More recently it has been used in (O^{16}, O^{16}) scattering on Mg^{24} , an experiment

in which arm 1 carried six detectors, arm 2 three detectors, arm 3 one detector, and arm 4 two detectors. This arrangement allowed us to perform six elastic-scattering coincidence experiments simultaneously and permitted the 48 data points to be acquired in 4 hours rather than the 24 hours otherwise necessary. Two problems in the operation of the device are immediately apparent: (1) the bookkeeping becomes involved and (2) the possibilities for collisions inside the chamber (with either movable or fixed objects) are not negligible. A third problem is the time required to prepare the system for the next run. By interfacing the scattering chamber with the system 169 described by Gemmell (preceding report), such problems are eliminated. The computer moves the nine components of the scattering chamber, records their positions, identifies the spectrum associated with each detector, and records the number of integrator counts and the reading of the frequency meter. In principle, the computer clears the memory of the seven analyzers and the section of the external memory used for pulse-height analysis; and it always does it after the data have been recorded on magnetic tape and on the line printer. The program does not allow a detector arm to enter a forbidden space, and thus eliminates the collision problem. After the run, the top half of the first bank of the external memory is used for intermediate storage to allow data analysis while the next run is in process. This analysis can be done either on the oscilloscope or with a standard program. Since the whole experiment is under computer control, it becomes possible to let the computer make some decisions based on criteria supplied to it.

In the coincidence experiment described above, the computer has been allowed to determine the appropriate positions of arms 2, 3, and 4 for a given position of arm 1 and to determine the appropriate sequence of motions on the basis of the no-collision criterion. In another experiment, the computer has determined the optimum number of integrator counts needed to obtain the angular distribution of protons elastically scattered from Mo at 3° intervals, with 3%

statistics for at least 75% of the points. In this experiment the solid angles subtended by the four detectors were adjusted to give approximately equal counting rates. The remote control of radial distance was necessary in this case. With the computer determining the angular positions in one experiment and the optimum number of integrator counts in another experiment, it becomes feasible to have the computer determine both the optimum angular positions and the length of the runs in subsequent experiments.

1969 Particle Accelerator Conference—Accelerator Engineering
and Technology

Washington, D. C., 5—7 March 1969

A LOW-POWER MAGNETIC CHANNEL WITH DIPOLE COMPENSATION
T. Khoe,* R. Benaroya,[†] J. J. Livingood, W. J. Ramler,[†]
and W. Wesolowski[†]

Bull. Am. Phys. Soc. 14, 219 (February 1969)

A magnet channel capable of guiding deflected 60-MeV protons through the fringing field of an AVF cyclotron without perturbing inner orbits has been tested in a 0.4-scale model. The full-scale channel will be composed of a 1010 steel cylindrical shell 3.00 in. OD, 1.18 in. ID, and 10 in. long with an external dipole winding extending to 5.92 in. OD. A cosinusoidal distribution of current density is approximated by dividing the winding into 16 sections, with centers 22.5° apart, and by making $N_\theta = N_0 \cos \theta$, where N is the number of turns in a section and θ is the altitude angle of the center of a section. Scaling the model measurements to full size, the power is 14 kW with $\frac{3}{8}$ -in. square OD and $\frac{1}{8}$ -in. round ID water-cooled copper conductors at 330 A, and the field at the midpoint inside the channel is reduced from 7000 to 90 G, with a 20 G/in. gradient across the ID on the median plane. As close as 5 in. from the outside edge of the coil, the first harmonic introduced is 1.1 G. Without dipole current, the field in the channel is 1560 G with a 16.2-G first harmonic at the same distance.

* Accelerator Division.

[†] Chemistry Division.

Second Conference on Nuclear Isospin
Asilomar Conference Grounds, Pacific Grove, California,
13—15 March 1969

ANALOG RESONANCES IN HEAVIER NUCLEI*
M. H. Macfarlane

*Rapporteur's talk; ANL Physics Division Informal Report PHY-1969D.

PROTON-INDUCED ANALOG RESONANCES*
George C. Morrison

This paper reviews recent experimental work on analog resonances observed in proton elastic and inelastic scattering. It proceeds by examples chosen to illustrate the kinds of information that has become available and the extraction procedures involved. Most attention is concentrated on analog resonances in inelastic scattering. The scope of the review is summarized by the following table of contents.

1. Introduction
2. Elastic Proton Scattering
 - a. Extraction of Spectroscopic Factors
 - b. Polarization in Elastic Scattering
3. Inelastic Scattering of Protons
 - a. Particle-Hole States
 - b. Core-Coupled Resonances
4. Conclusions

*Invited paper; ANL Physics Division Informal Report PHY-1969C.

AN EXPERIMENTAL TEST OF THE BARSHAY-TEMMER THEOREM
VIA THE REACTIONS $^{10}\text{B}(\alpha, ^7\text{Li}_{\text{gs}})^7\text{Be}_{\text{gs}}$ and $^{10}\text{B}(\alpha, ^7\text{Be}_{\text{gs}})^7\text{Li}_{\text{gs}}$
A. Richter,* H. T. Fortune, and B. Zeidman

A possibility of exploring the problem of charge independence of the nuclear forces is an experimental test of the Barshay-Temmer theorem.¹ The theorem states that in a nuclear reaction

$$A + B \rightarrow C + C', \quad (1)$$

in which C and C' are members of the same isobaric-spin multiplet (isobaric analog states) and the isobaric spin of either A or B is zero, the differential cross section of the reaction products will exhibit symmetry about 90° in the center-of-mass system. The theorem is true only if, in Eq. (1), isobaric spin T is strictly conserved and if C and C' are exactly connected by rotation in isobaric-spin space.

The present experiment tests the theorem via the reaction

in which $T = 0$ in the entrance channel and the ground states of ^7Li and ^7Be are members of a $T = \frac{1}{2}$ multiplet. The measurements were performed with a 45-MeV α beam from the Argonne 60-in. cyclotron. A particle-multiplier system was fed by the pulses from a counter telescope consisting of a 33- μ dE/dx and a 300- μ E semiconductor detector in an 18-in. precision scattering chamber. A 500- μ detector was placed after the E detector and operated in anticoincidence with the (dE/dx)·E system. In order to minimize instrumental asymmetries, both ^7Li and ^7Be were simultaneously measured with the same detecting system. Figure 4 displays typical ^7Li and ^7Be spectra obtained at $\theta_{\text{lab}} = 15^\circ$. The energy resolution width in both spectra is about 150 keV (FWHM) and results primarily from kinematics. The ^7Li spectrum contains a continuous background caused by the reaction $^{11}\text{B} + \alpha \rightarrow ^7\text{Li} + ^8\text{Be}$ from the 4% impurity of ^{11}B in the ^{10}B target. (The Q value for the

* On leave of absence from the Max-Planck Institut für Kernphysik, Heidelberg, Germany.

¹ S. Barshay and G. M. Temmer, Phys. Rev. Letters 12, 728 (1964).

Fig. 4. Typical ${}^7\text{Li}$ and ${}^7\text{Be}$ spectra obtained at $\theta_{\text{lab}} = 15^\circ$. The convention followed in labeling the peaks is that in the nuclear reaction $A(B,C)C'$, the double index $[i,j]$ linked with the peaks in the C spectrum denotes C' being left in its i th and C in its j th excited state. The main peaks of interest are the ones corresponding to the ground-state transitions $[0,0]$. Since ${}^7\text{Li}$ and ${}^7\text{Be}$ both have only bound (and hence detectable) states, the spectrum of outgoing ${}^7\text{Li}$ particles is composed of a doublet for each level (bound and unbound) of ${}^7\text{Be}$, and vice versa.

${}^{11}\text{B}(\alpha, {}^7\text{Li}) {}^8\text{Be}$ reaction is -8.76 MeV, whereas for ${}^{10}\text{B}(\alpha, {}^7\text{Li}) {}^7\text{Be}$, $Q = -16.2$ MeV.) However, both background subtraction and determination of the area under the peaks were unambiguous.

In the present experiment, the fore-and-aft symmetry required by the Barshay-Temmer theorem for the ground-state transitions implies that (at a fixed scattering angle) the counting rate for the ground-state transitions should be the same for both outgoing particles. The resulting angular distributions are shown in the upper part of Fig. 5. As is apparent from the spectra of Fig. 4, the counting rate for both ground-state-to-ground-state transitions are the same

within the uncertainty from background and statistics. In order to provide a quantitative test of the symmetry obtained, the ratio R between the two transitions at each angle has been plotted in the lower part of Fig. 5. These ratios are unity within the error due to background and statistics. Averaging and weighting them with their reciprocal squared errors results in $\bar{R}_1 = 1.021 \pm 0.030$. Weighting the ratios with only their statistical errors yields $\bar{R}_2 = 1.022 \pm 0.025$, while the unweighted average is $\bar{R}_3 = 1.026$. All three numbers conform to the symmetry predicted by the Barshay-Temmer theorem. It is still possible that the fore-and-aft symmetry may be due to reasons other than the ones stated. Symmetry could be caused by an accidental combination of partial-wave reaction amplitudes.¹

In the present experiment this seems highly unlikely. However, reaction channels other than the ones leading to the mirror states should show asymmetries. The cross sections into those channels are presently being analyzed together with the transition leaving both ${}^7\text{Li}$ and ${}^7\text{Be}$ in their first excited states, which also should be symmetric. We also measured the reaction ${}^{11}\text{B} + {}^3\text{He} \rightarrow {}^7\text{Li} + {}^7\text{Be}$ to determine its symmetry properties.

Fig. 5. Angular distributions for the ground-state transitions of the reactions ${}^{10}\text{B}(\alpha, {}^7\text{Li}){}^7\text{Be}_{\text{gs}}$ and ${}^{10}\text{B}(\alpha, {}^7\text{Be}){}^7\text{Li}_{\text{gs}}$ (upper part) and the ratio R of the two transitions (lower part). The errors are due to background and statistics.

In conclusion, the symmetry found in the present experiment points to the extreme similarity of the analog ground states of ${}^7\text{Li}$ and ${}^7\text{Be}$ and implies further that the interaction responsible for the cross section is strongly charge independent.

We wish to acknowledge the assistance of O. J. Clayton as well as the help from the operating staff of the cyclotron.

COULOMB ENERGIES

J. P. Schiffer

SINGLE-PARTICLE ANALOG-STATE ANOMALIES IN THE SCATTERING OF PROTONS FROM Au^{197} , Pt^{196} , AND W^{184}

J. P. Schiffer, P. Kienle,* and G. C. Morrison

The elastic and inelastic excitation functions for protons from Au^{197} , Pt^{196} , and W^{184} have been studied. For Pt^{196} in particular, similarities to the scattering from Pb^{208} and Pb^{206} are found for the elastic and inelastic scatterings to the 2^+ and 3^- states. The identification of an anomaly with the $g_{9/2}$ resonance is quite clear cut. The elastic scattering from Au^{197} is very similar to that from Pt^{196} , but inelastic data were not obtained. The scattering from W^{184} bears some resemblance to the above results, though the identifications are not quite so clear. The results seem to indicate the persistence of gross-structure effects originating in the neutron single-particle states of the parent nucleus.

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COMPARISON OF SPECTROSCOPIC FACTORS FROM (p, p_0) AND (d, p) REACTIONS ON BARIUM ISOTOPES

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The early assumption that the analysis of strong isobaric analog resonances in elastic proton excitation functions would lead to a reliable means of extracting accurate single-particle strengths has now become the subject of controversy. In our studies of proton elastic scattering on the five stable even-even barium isotopes (masses 130—138), we observe strong s-, p-, d-, and f-wave analog resonances. These have been related to the $2f_{7/2}$, $3p_{3/2}$, $3p_{1/2}$ neutron single-particle levels above and the $3s_{1/2}$, $2d_{3/2}$ levels below the N=82 closed shell which we observe in the (d, p) reactions on the same targets. Thus we are in a position to compare the spectroscopic factors extracted by resonance analysis with those from the DWBA methods using the same set of smoothly varying optical-model parameters from isotope to isotope.

Excitation functions for elastic scattering of protons have been obtained at several angles from 90° to 170° in the energy range $E_p = 7-12$ MeV. These have been analyzed (Fig. 6) with the resonance-fitting program BRIGIT¹ to extract proton partial widths Γ_{LJ}^p , total widths, resonance energies, and phases. Single-particle widths $\Gamma_{s.p.}^p$ have been calculated according to the method of Mahaux and Weidenmüller² by use of the code GPMAIN.³ A real, volume-type

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¹ C. F. Moore and L. Parish, University of Texas, Center for Nuclear Studies, Technical Report No. 2, 1967; C. F. Moore, private communication.

² C. Mahaux and H. A. Weidenmüller, Nucl. Phys. A89, 33 (1966); H. A. Weidenmüller, Nucl. Phys. A99, 269 (1967); A99, 289 (1967).

³ S. A. A. Zaidi and S. Darmodjo, Phys. Rev. Letters 19, 1446 (1967); S. A. A. Zaidi (private communication).

Fig. 6. Typical (p, p_0) excitation functions (absolute uncertainties $\pm 20\%$) and theoretical fit.

symmetry potential V_1 was used; its shape was a Woods-Saxon well with the same radius r_0 and diffuseness a_0 as the real optical potential in the Lane equations.⁴ However, $\Gamma_{s.p.}^P$ was found to be sensitive to changes of r_0 and a_0 unless $\langle R_R^2 \rangle$, the mean-square radius of the well, was kept constant according to

$$5 \langle R_R^2 \rangle = 3r_0^2 A^{2/3} + 7\pi^2 a_0^2. \quad (1)$$

A similar effect has been noted in the analysis of (d, p) reactions.⁵ The

⁴A. M. Lane, Nucl. Phys. **35**, 676 (1962).

⁵J. F. Sharpey-Schafer, Phys. Letters **26B**, 652 (1968).

Fig. 7. S_{pp} and S_{dp} as functions of the well diffuseness for fixed radii, $r_0 = r_n = 1.20 F$.

elastic-scattering spectroscopic factors were calculated from the ratio $S_{pp} = \Gamma_{LJ}^P / \Gamma_{s.p.}^P$.

The angular distributions of the (d, p) reactions at $E_d = 12$ MeV were compared with DWBA calculations by use of code JULIE. The choice of r_n and a_n of the bound-state neutron potential well was restricted by an equation similar to (1) above.⁵ Uncertainties arise from the choice of a sharp radial cutoff without which it was impossible to fit the shapes of the measured angular distributions.

Since both S_{pp} and S_{dp} are sensitive to the diffuseness (a_0 and a_n , respectively) if r_0 and r_n are fixed, they may be plotted as functions of a_0 ($= a_n$). Figure 7 shows this variation for $r_0 = r_n = 1.20 F$. It is obvious that both S_{dp} and S_{pp} show a marked dependence on the diffuseness parameter and hence on the root-mean-square (rms) radius $\langle R_R^2 \rangle^{1/2}$ of the well, as expressed in Eq. (1). Unfortunately the rms radius is not sufficiently well known.

It is evident that the gradients of the lines from the (p,p) and (d,p) analyses are in general somewhat different. In principle then, their intersection could provide a unique spectroscopic factor for each level and in addition values of $\langle R_R^2 \rangle$ for each target. In the present study no consistent crossover is found. However, it seems clear that there exists a discrepancy between the two approaches which is outside the experimental error.

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CURIE-TEMPERATURE ANOMALY OF THE ISOMER SHIFT IN IRON

R. S. Preston, I. Goroff,* and F. M. Mueller†

Bull. Am. Phys. Soc. 14, 386 (March 1969)

The isomer shift in iron shows¹ an abrupt change as the material passes through the Curie temperature. This behavior can be accounted for by an abrupt change in the total number of s valence electrons. Here we consider the effects of long-range magnetic order through a simple molecular-field model. Our calculations show that the strong s-d hybridization² in iron causes sharp structure in the s-like part of the density of states. As the temperature goes down through T_c , the increasing Zeeman splitting of the d bands slides the Fermi energy through the structure in the s-like density. A previous calculation of the isomer shift³ used the density-of-states curve of Cornwell.⁴ The present calculation, using the QUAD technique,⁵ directly integrates ψ^2 ($r = 0$) over the occupied states of the Brillouin zone with high accuracy instead of considering separately the s density of states and the valence function as done in the previous calculation.

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¹ R. S. Preston, S. S. Hanna, and J. Heberle, Phys. Rev. 128, 2207 (1962); R. S. Preston, Phys. Rev. Letters 19, 75 (1967).

² F. M. Mueller, Phys. Rev. 153, 659 (1967).

³ R. Ingalls, Phys. Rev. 155, 157 (1967), and references therein.

⁴ J. F. Cornwell, thesis, Imperial College, London, England (unpublished).

⁵ F. M. Mueller, J. W. Garland, M. H. Cohen, and K. H. Bennemann (to be published).

III. ABSTRACTS OF PAPERS ACCEPTED FOR PUBLICATION

PHOTOIONIZATION OF HIGH-TEMPERATURE VAPORS. V. CESIUM HALIDES: CHEMICAL SHIFT OF AUTOIONIZATION

J. Berkowitz

J. Chem. Phys. (15 April 1969)

From the thresholds for photodissociative ionization of cesium halide molecules, results have been obtained for the dissociation energies of the diatomic molecules. The values of D_0 obtained are CsCl, 105.6 ± 1.6 kcal/mole; CsBr, 96.2 ± 1 kcal/mole; CsI, 82.3 ± 1 kcal/mole. For D_0 (CsF), the interpretation is in doubt. The dissociation energies of the molecular ions CsBr^+ and CsI^+ have also been measured, as have the heats of formation of Cs_2F^+ , Cs_2Cl^+ , and Cs_2Br^+ . Several autoionization peaks have been observed in the ionization efficiency curves of the cesium halides, somewhat displaced in energy from their positions in atomic cesium. In particular, the $(5p)^6 6s \rightarrow (5p)^5 (6s)^2$ transition, which occurs at 12.306 eV in atomic cesium, is shifted to 12.1, 12.4, 12.5, and 12.6 eV, for CsF, CsCl, CsBr, and CsI, respectively. These peaks are also present in the ionization efficiency curves of the dimer ions. Some consequences of these results are discussed.

PHOTOIONIZATION OF HIGH-TEMPERATURE VAPORS. VI. S_2 , Se_2 , AND Te_2

J. Berkowitz and W. A. Chupka

J. Chem. Phys. (15 May 1969)

From the photoionization-efficiency curves of S_2 , Se_2 , and Te_2 , the thresholds for formation of parent and fragment ions have been determined. The ionization potentials of Se_2 and Te_2 obtained from these measurements are 8.88 ± 0.03 and 8.29 ± 0.03 eV, respectively. For $D_0^0(\text{S}_2)$, the value 101.0 ± 0.2 kcal/mole is deduced, in general agreement with other techniques. The result $D_0^0(\text{Te}_2) = 62.3 \pm 0.2$ kcal/mole distinctly favors one of two proposed thermochemical values. The experimental result $D_0^0(\text{Se}_2) = 78.6\text{--}83.2$ kcal/mole has considerable uncertainty but tends to favor the highest of three spectroscopic possibilities. Evidence is presented for a 0.35 ± 0.04 -eV splitting between the 0_g^+ ground state of Te_2 and the 1_g state.

PHOTOELECTRON SPECTROSCOPY OF AUTOIONIZATION PEAKS

J. Berkowitz and W. A. Chupka

J. Chem. Phys. (15 August 1969)

A vacuum ultraviolet monochromator has been combined with a retarding-field electron-energy analyzer to study the distribution of photoelectrons from autoionizing states of hydrogen and nitrogen. In most cases involving hydrogen, the photoelectrons produced are mono-energetic and correspond to autoionizing transitions in which Δv is a minimum, i. e., the ejected electrons have the minimum kinetic energy. There is one possible exception to this generalization.

Different mechanisms appear to be operative in the nitrogen autoionizations. In general, several bundles of electrons, corresponding to the formation of several ionic states, are observed. Whereas vibrational relaxation of the core appears to explain the results with hydrogen, an alternative mechanism involving configuration interaction has been examined in an attempt to rationalize the nitrogen results. This proposed mechanism implies that relative transition probabilities in the autoionization process are dominated by Franck-Condon factors connecting the quasi-discrete state and the ionic state. The ratio of Franck-Condon factors is very sensitive to the choice of internuclear distance for the quasi-discrete state. In many cases, it is possible to find a plausible internuclear distance for which the ratio of Franck-Condon factors agrees with experiment. If the Franck-Condon factors are indeed the major determinant of relative transition probabilities, photoelectron spectroscopy offers a method for determining the internuclear distances of the quasi-discrete states. One autoionizing transition in nitrogen, as yet unassigned, does not seem to fit this mechanism.

PHOTOIONIZATION OF HCN: THE ELECTRON AFFINITY AND HEAT OF FORMATION OF CN

J. Berkowitz, W. A. Chupka, and T. A. Walter

J. Chem. Phys. (15 February 1969)

A re-examination of the photoionization of HCN has revealed two processes, $\text{HCN} + h\nu \rightarrow \text{H}^+ + \text{CN}^-$, and $\text{HCN} + h\nu \rightarrow \text{H}^+ + \text{CN} + e$, not previously reported. The difference in threshold values for the two processes leads directly to the electron affinity for CN, 3.82 ± 0.02 eV. The threshold for the second process leads to $\Delta H_f^0(\text{CN}) = 105.5 \pm 2$ kcal/mole, but $\Delta H_f^0(\text{HCN})$ remains a major source of uncertainty.

LEVEL STRUCTURE OF LOW-LYING EXCITED STATES OF Ga^{66}
POPULATED BY THE DECAY OF 2.2-h Ge^{66}

H. H. Bolotin and D. A. McClure

Phys. Rev. (20 April 1969)

The decay of 2.2-h Ge^{66} to levels in Ga^{66} has been investigated by use of both singles and coincidence gamma-ray spectroscopic techniques that made exclusive use of high-resolution $\text{Ge}(\text{Li})$ detectors. The internal-conversion electron spectrum was also studied. A total of 23 transitions were observed in this decay; these were incorporated in a complete and unambiguous level scheme that differs markedly from those previously proposed. The excitation energies of the states in Ga^{66} found to be populated in this decay are 43.8, 108.9, 234.0, 290.9, 381.8, 514.6, 536.6, and 706.0 keV. The half-life of the Ge^{66} activity was redetermined to be 2.23 ± 0.10 h. The half-life of the first excited state was measured by delayed-coincidence techniques to be 21 ± 2 nsec. The multipolarities of many of the transitions were determined. Spin and parity assignments of many of the excited states were inferred and severe limitations could be imposed on the spin assignments of the remainder of the levels. The log ft values of all β branches were established, and limits on the amount of isobaric-spin impurity present in the ground state of Ge^{66} were set. The level characteristics were found to be consistent with expectations derived from theoretical considerations.

ELECTROMAGNETIC TRANSITION STRENGTHS IN Pb^{206} , Pb^{207} , AND Pb^{208} FROM THRESHOLD PHOTONEUTRON CROSS-SECTION MEASUREMENTS

C. D. Bowman,* B. L. Berman,* and H. E. Jackson

Phys. Rev. (20 February 1969)

The photoneutron cross sections for Pb^{206} , Pb^{207} , and Pb^{208} have been measured for photon energies up to 40 keV above threshold. Several resonances were resolved for each isotope. Most of the resonances seen in the Pb^{207} and Pb^{208} spectra correspond to resonances detected by neutron-capture or total cross-section measurements on Pb^{206} and Pb^{207} , respectively. Values for $\Gamma_{\gamma 0}$, the ground-state γ -ray width, were determined for a number of resonances in each target. By comparison with the neutron-capture experiments, the multipolarities of the γ -ray transitions were determined, and an average

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γ -ray transition strength was obtained. The M1 transition strengths for Pb^{206} and Pb^{207} were found to be markedly enhanced over the expected value. One E2 transition in Pb^{208} was found to have a strength of 0.14 Weisskopf units, and there is a possibility of two other E2 transitions with similar strength.

MÖSSBAUER EFFECT IN 7.2-yr Ba^{133}

A. J. F. Boyle and G. J. Perlow
Phys. Rev. (10 April 1969)

The Mössbauer effect has been observed with the 12.29-keV transition in 7.2-yr Ba^{133} . The absorber contained 0.75 mCi (2 μg) of the isotope. The source was 39-h $\text{Ba}^{133\text{m}}$. The absorber was a thin disk 1.2 mm in diameter. The source diameter was 1 mm and the mean separation 0.5 mm. A line width about 3 times natural was found with an observed dip of 0.95% at 4.2°K and 0.34% at room temperature.

NEUTRON-CAPTURE GAMMA-RAY STUDIES OF THE LEVEL STRUCTURE OF THE Te^{124} NUCLEUS

D. L. Bushnell, R. P. Chaturvedi, and R. K. Smither
Phys. Rev. (20 March 1969)

The gamma-ray spectrum resulting from thermal-neutron capture in Te^{123} was investigated with the Argonne 7.7-m bent-crystal spectrometer. The observed spectrum consisted of 75 gamma rays with energies between 100 keV and 1.1 MeV. The spectrometer used a new split-source technique which allowed simultaneous measurement of the $\text{Te}^{123}(n, \gamma)\text{Te}^{124}$ spectrum from capturing samples with two different isotopic enrichments of Te^{123} and thus gave immediate isotopic identification for the (n, γ) spectrum. The $\text{Te}^{123}(n, \gamma)\text{Te}^{124}$ spectrum was also measured with Ge(Li) detectors in the energy regions 0.5—4.0 MeV (112 lines) and 5.5—9.5 MeV (63 lines) by use of the Argonne in-pile facility. The associated spectrometer has a long, split NaI ring which surrounds a Ge(Li) detector and was used to enhance the full-energy spectrum (anticoincidence) and the double-escape spectrum (coincidence). The above thermal-neutron-capture spectrum was combined with the results of an average-resonance-capture spectrum taken with the same Ge(Li) facility but with the target surrounded with

boron. These (n, γ) experiments were then combined with all previous work to develop and extend the level scheme of Te^{124} and to define many of the details of the gamma decay of these levels. The new values (keV) for the first 15 level energies and J^π are: ground state, 0^+ ; 602.42 ± 0.02 , 2^+ ; 1247.99 ± 0.05 , 4^+ ; 1324.82 ± 0.05 , 2^+ ; $(1655.9 \pm 0.2, 0^+)$; (1736.5 ± 0.3) ; (1747.40 ± 0.16) ; 1956.18 ± 0.11 , 3^+ , 4^+ ; 2037.68 ± 0.07 , 2^+ ; 2090.65 ± 0.35 , 0^+ , 2^+ ; 2152.04 ± 0.15 , 0^+ , 2^+ ; 2181.20 ± 0.40 , $1, 2$; 2293.10 ± 0.30 , 3^- ; 2322.57 ± 0.20 , 0^+ , 2^+ ; 2452.9 ± 2.6 , 0^+ , 2^+ . The parentheses indicate uncertainty in the level assignments while the underlined spins and parities indicate new values.

The relative intensities of γ rays from states at ~ 2 MeV suggest that E2 transitions to the two-phonon states at 1248 and 1325 keV are enhanced relative to transitions to states at 0 and 602 keV; so these 2-MeV levels are very likely collective and possibly vibrational. The (n, γ) data imply a neutron binding energy $E_n = 9425 \pm 2$ keV for Te^{124} .

MAGNETIC MOMENT OF THE FIRST EXCITED STATE IN ^{83}Kr BY THE MÖSSBAUER EFFECT

L. E. Campbell, G. J. Perlow, and M. A. Grace*
Phys. Rev. (20 February 1969)

The magnetic moment of the 9.3-keV first excited state in ^{83}Kr has been measured by use of the Mössbauer effect. Source and absorber were solid krypton at 4.2°K with the absorber in a longitudinal magnetic field of 77.8 kOe from a superconducting solenoid. The ratio R of the g factor of the $\frac{7}{2}^+$ excited state to that of the $\frac{9}{2}^+$ ground state is found to be $+1.249 \pm 0.002$, from which $\mu(\frac{7}{2}^+) = -(0.939 + 0.002) \mu_N$ without diamagnetic correction. If the ground state could be considered a pure configuration of three $g_{9/2}$ neutron holes coupling to $J = \frac{9}{2}$ and the excited state a recoupling within the same configuration, then $R = 1$. Furthermore, the M1 transition matrix element would vanish. The transition is indeed retarded. It appears from the work of Noya, Arima, and Horie that a modest admixture into each state of the configuration obtained by promoting one $g_{9/2}$ neutron to $g_{7/2}$ can in the main account for both the observed transition rate and the excess in R .

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HYPERFINE STRUCTURE AND g_J VALUES OF LOW LEVELS OF ^{159}Tb

W. J. Childs and L. S. Goodman

J. Opt. Soc. Am. (July 1969)

The hyperfine (hfs) interaction constants and electron g factors have been measured for 14 low atomic levels of ^{159}Tb by the atomic-beam magnetic-resonance technique. The results for the magnetic-dipole hfs constants tend to support the intermediate-coupling eigenvectors deduced by Arnoult and Gerstenkorn on the basis of computer fits to the optically observed atomic energy levels. The electric-quadrupole hfs constants are more difficult to understand, however, and the number of basis states spanned by the eigenvectors may have to be increased.

PHOTOIONIZATION OF ETHYLENE WITH MASS ANALYSIS

W. A. Chupka, J. Berkowitz, and K. M. A. Refaey

J. Chem. Phys. (1 March 1969)

The photoionization-efficiency curve of ethylene has been shown to have vibrational structure at the threshold for production of the first excited state of the parent ion. Autoionization of superexcited states in this region does not occur significantly. Appearance potentials were measured for the fragment ions C_2H_3^+ , C_2H_2^+ , and CH_2^+ . The thermochemical values obtained were $D_0^0(\text{C}_2\text{H}_3-\text{H}) = 3.85 \text{ eV}$; $D_0^0(\text{CH}_2-\text{CH}_2) \leq 8.28 \text{ eV}$; $\Delta H_{f_0}^0(\text{CH}_2) \leq 95.5 \text{ kcal/mole}$.

ON HIGH-FREQUENCY FIELDS IN SOLENOIDAL COILS

N. Contaxes* and Albert J. Hatch

J. Appl. Phys. (August 1969)

A little-known result of Townsend and Donaldson is extended to show that for a solenoid carrying ac or rf current the ratio of the average applied longitudinal field E_z to the induced azimuthal field E_θ at the periphery of the solenoid is equal to the ratio of the circumference of the solenoid to its pitch. For conventional solenoidal coils such as are used to excite electrodeless rf discharges, this ratio is typically $\geq 15-30$. Applicability of the E_z/E_θ ratio to the design of coils and shields is discussed.

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DISTRIBUTION OF CHARGE IN Th^{232} AND U^{238} DETERMINED BY MEASUREMENTS ON MUONIC x RAYS

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C. C. Trail,[†] R. A. Carrigan, Jr.,[‡] P. D. Gupta,[‡] R. B.
Sutton,[‡] M. N. Suzuki,[‡] and A. C. Thompson[‡]

Phys. Rev. (20 March 1969)

The energies and intensities of the x rays of muonic atoms of Th^{232} and U^{238} were measured. Analysis of the data was performed using the rotational model of strongly deformed nuclei to include dynamic quadrupole interactions. The distribution of nuclear charge was represented by a modified Fermi distribution which involves three parameters, namely, the intrinsic quadrupole moment Q_0 , the half-density radius $c = c_0 A^{1/3}$, and the skin thickness t . It was found that the allowed ranges of values for Q_0 , c_0 , and t were for thorium 9.58—9.83 b, 1.155—1.143 F, and 1.54—1.87 F, and for uranium 11.20—11.41 b, 1.150—1.142 F, and 1.600—1.87 F, respectively. However, if specific values for two of these parameters are chosen, the third is determined with an error smaller than the above ranges: 0.5% for Q_0 , 0.25% for c_0 , and 0.6% for t .

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$\text{B}^{11}(\text{He}^3, \alpha)\text{B}^{10}$ REACTION AT 33 MeV

D. Dehnhard, N. Williams, and J. L. Yntema

Phys. Rev. (20 April 1969)

Differential cross sections of the $\text{B}^{11}(\text{He}^3, \alpha)\text{B}^{10}$ reaction leading to seven states up to 5.2 MeV excitation energy have been measured at forward angles at an incident energy $E(\text{He}^3) = 33$ MeV. The angular distributions have been analyzed in terms of the distorted-wave Born approximation on the assumption that the direct neutron-pickup process is predominant. Relative spectroscopic factors have been extracted and are found to be in good agreement with Cohen and Kurath's theoretical predictions and with the results of the $\text{B}^{11}(p, d)\text{B}^{10}$ experiment at 33.6 MeV.

GENERATION AND STATISTICAL ANALYSIS OF SYNTHETIC CROSS SECTIONS

P. Hoffman-Pinther,* P. P. Singh,* and D. W. Lang
Nucl. Phys. (1969)

A program has been written to synthesize cross sections similar to those measured in nuclear experiments. These cross sections have been analyzed in the spirit of the Ericson theory with the aim to determine the limitations associated with recovering the average values of quantities used to generate the synthetic cross sections. It is shown that the mean cross section, the mean width of nuclear levels, and the autocorrelation coefficient can be measured with uncertainties that depend upon the size of the sample cross sections and that the normal experimental measurement is systematically low. The values of the above quantities as obtained by the statistical analysis of the cross section are compared with those derived from theoretical predictions and reasonable agreement is found between the two. Quantitative effects of finite sample size, ratio Γ/D of nuclear level width to level spacing, and number ν of open channels are demonstrated.

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THE COMPUTATION OF MÖSSBAUER SPECTRA, II

John R. Gabriel* and Duane Olson
Nucl. Instr. Methods (15 April 1969)

The extension of the computer programs UNIXTL, LVSPHS, and PDRHXT to deal with transitions of mixed multipolarity, and the use of density matrices to calculate Mössbauer spectra in the case where neither source nor absorber is a single unpolarized line are discussed. Methods for testing the programs and finding errors are outlined.

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DELBRÜCK SCATTERING OF 10.8-MeV GAMMA RAYS

H. E. Jackson and K. J. Wetzell

Phys. Rev. Letters (12 May 1969)

The differential cross section for elastic scattering of 10.83-MeV photons by Pb and by U has been measured for scattering angles between 20° and 150° . The elastic scattering has been resolved from inelastic contributions for the first time. For scattering angles less than 45° , this process is dominated by the Delbrück effect.

LEVEL DENSITY OF A FERMI SYSTEM: NONPERIODIC PERTURBATIONS OF THE ENERGY-LEVEL SCHEME

Peter B. Kahn* and N. Rosenzweig

J. Math. Phys. (April 1969)

The level density of a degenerate Fermi system is modified by the perturbation in the position of a single-particle level. To study this effect, miscellaneous exact relations between the level densities of the perturbed and unperturbed system are derived. For the special case of the perturbed uniform model, these connections become a set of recursion relations which lead to a complete solution of the problem. Results are also obtained in the saddle-point approximation, and these have a simple interpretation in terms of the usual Fermi occupation probabilities. If a single-particle level is deleted from the scheme, the resultant diminution in the level density persists indefinitely with increasing excitation energy. Information about the adequacy of the saddle-point approximation is obtained by comparison with some exact solutions.

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POSSIBLE SPIN DEPENDENCE IN PROTON INELASTIC SCATTERING

J. C. Legg* and J. L. Yntema

Phys. Rev. Letters (12 May 1969)

An anomaly, apparently a final-state spin dependence, has been observed in proton inelastic scattering from ^{63}Cu , ^{65}Cu , and

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^{67}Zn . The excited-core model of inelastic scattering cannot produce such an effect. Indeed, no current theory of inelastic scattering based on the distorted-wave Born approximation can even qualitatively predict such an effect.

MAGNETIC CHARGE QUANTIZATION AND ANGULAR MOMENTUM

H. J. Lipkin,* W. I. Weisberger,* and M. Peshkin
Ann. Phys. (N. Y.) (June 1969)

The quantum mechanical problem of an electric charge moving in the field of a magnetic charge is discussed and solved by algebraic methods which exhibit the direct relation between charge quantization and angular momentum. Commutation relations which lead to the Lorentz force equation are assumed. The operators are realized by constructing the irreducible representations of the three-dimensional Euclidean group in an angular-momentum basis. The Dirac quantization formula for the charges is obtained as a necessary and sufficient condition for the realization of all the observables. The construction proceeds by simple angular-momentum coupling calculations without resort to singular strings in x space. It is emphasized that the charge quantization does not follow from the operator equations of motion and rotation invariance alone. This treatment, like all previous ones, uses additional assumptions that may not be physically inescapable.

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CORRECTIONS TO THE HARTREE-FOCK APPROXIMATION FOR HOMOGENEOUS NUCLEAR MATTER

James J. MacKenzie
Phys. Rev. (20 March 1969)

The convergence of a modified Goldstone linked-cluster expansion for the binding energy of nuclear matter is considered for the Tabakin and Elliott-Flowers potentials. It is argued that a comparison of the first-order term with the second-order term cannot give a direct indication of the convergence of the series. Calculations have therefore been performed to evaluate all terms through third order. For the Elliott-Flowers potential the third-order terms amount to 26% of the second-order contribution; for the Tabakin potential they are less than about 10%.

EFFECTIVE-INTERACTION FORMULATION OF BOUND AND CONTINUUM SHELL-MODEL CALCULATIONS

K. W. McVoy and W. J. Romo
Nucl. Phys. (1969)

The Bloch-Horwitz effective interaction, or reaction matrix, $\mathcal{V}(E)$, plays a central role in most of the current realistic shell-model calculations of bound-state nuclear spectra. Its relation to continuum shell-model calculations is less widely appreciated, however, and the purpose of the present review is to formulate the usual bound-state calculation in a manner which is readily generalized to describe scattering as well, in order to show that the analytic continuation of $\mathcal{V}(E)$ to continuum energies is just the effective or closed-channel interaction which appears in the reaction formalisms of MacDonald and Feshbach. Since the utility of the effective-interaction concept in practical calculations appears to depend on the convergence of its Born series, this convergence is discussed in terms of Weinberg eigenvalues, and its relation to the state dependence of $\mathcal{V}(E)$ is indicated.

MULTIPOLE ANALYSIS OF PARTICLE-PARTICLE OR PARTICLE-HOLE MULTIPLETS

M. Moinester,* J. P. Schiffer, and W. P. Alford*
Phys. Rev. (20 March 1969)

Recent data on particle-hole multiplets in Bi^{208} have been analyzed in terms of the Racah multipole decomposition. The resulting multipole coefficients are very similar for the various multiplets. A comparison with other known multiplets in Cl^{38} , K^{30} , Sc^{42} , Sc^{48} , Sc^{50} , Nb^{92} , and Bi^{210} also shows a remarkable similarity. These empirical results show that the spectra of such multiplets are determined reasonably well by one set of multipole coefficients, independent of the single-particle orbits involved. It has been pointed out by Kurath that a simple δ -function two-body force with spin exchange fits these average multipole coefficients as well as more complicated interactions.

* Nuclear Structure Research Laboratory, University of Rochester, Rochester, New York.

PROPERTIES OF THE 3.39-MeV STATE IN B^{12}

F. P. Mooring, J. E. Monahan, and R. E. Segel
Phys. Rev. (20 February 1969)

The 3.39-MeV state in B^{12} has been studied in the $B^{11} + n$ system, where the state appears as a resonance at a (lab) neutron energy of 20.8 ± 0.5 keV. Comparison of the neutron scattering and transmission measurements with the $B^{11}(d,p)$ data requires that the resonance be d wave. Various considerations leave 3^- as the only plausible assignment. For a spin of 3, the neutron width is $\Gamma_n = 3.1 \pm 0.6$ eV, which is about equal to the Wigner limit. Neutron-capture measurements, in which the residual B^{12} activity was observed, clearly showed the resonance and yielded a total radiation width $\Gamma_\gamma = 0.025 \pm 0.008$ eV. The 18.36-MeV state in C^{12} appears to be the $T_z = 0$ analog of this state.

STUDY OF THE $Ca^{48}(He^3,p)Sc^{50}$ REACTION

H. Ohnuma, J. R. Erskine, J. A. Nolen, Jr., J. P. Schiffer,
and P. G. Roos*
Phys. Rev. (20 January 1969)

The $Ca^{48}(He^3,p)Sc^{50}$ reaction was studied with a magnetic spectrograph at a bombarding energy of 12 MeV. Energy levels of Sc^{50} were obtained. Spins and parities for these levels were assigned on the basis of a comparison between the experimental and calculated angular distributions. Distorted-wave Born-approximation theory and the shell-model wave functions due to Kuo and Brown were used to calculate the angular distributions.

*University of Maryland, College Park, Maryland.

EXPERIMENTAL STUDY OF THE (d,t) REACTION ON EVEN-MASS Mo ISOTOPES

H. Ohnuma and J. L. Yntema
Phys. Rev. (20 February 1969)

The (d,t) reaction on $Mo^{92,94,96,98}$ was studied with the 23-MeV deuteron beam from the Argonne cyclotron. The experimental angular distributions of triton groups were compared with the distorted-wave Born approximation (DWBA) theory, and the ℓ values

and the spectroscopic factors were determined. The level structure of the Mo^{91} nucleus is very similar to that of Zr^{89} . Evidence for core excitation in Mo^{92} was found. The results for the other isotopes show that neutron orbits higher than the $2d_{5/2}$ shell are admixed in the ground-state configuration of these nuclei. These results are compared with previous data and with shell-model calculations.

STUDY OF THE J DEPENDENCE IN THE (d, He^3) REACTION

H. Ohnuma and J. L. Yntema

Phys. Rev. (20 February 1969)

The J dependence of the angular distributions in the (d, He^3) reactions was experimentally observed at small angles in the 2p proton pickup. This J dependence is qualitatively reproduced by distorted-wave calculations which indicate that the effect arises mainly from the deuteron spin-orbit potential. The calculated angular distributions are strongly dependent on the Q value of the reactions and the incident deuteron energy. The calculations also show that the J dependence is localized at the surface of the nucleus, and is very sensitive to the volume of the real part of the deuteron optical potential. This sensitivity may be understood by considering the role of the spin-orbit term in the optical potential. The sensitivity of the calculated angular distributions to the other parameters is investigated.

STUDY OF THE $\text{Zr}^{94}(\text{He}^3, d)\text{Nb}^{95}$ REACTION

H. Ohnuma and J. L. Yntema

Phys. Rev. (20 March 1969)

The $\text{Zr}^{94}(\text{He}^3, d)\text{Nb}^{95}$ reaction was studied with 34-MeV He^3 particles from the Argonne cyclotron. Experimental angular distributions were analyzed on the basis of the distorted-wave Born-approximation theory to determine the l values and spectroscopic factors. The results are compared with the previous data on the (d, He^3) reactions on Mo and Zr isotopes, and the proton configurations of the nuclei in this region are discussed.

CONDUCTIVITY AND MÖSSBAUER MEASUREMENTS IN DOPED ICE

I. Pelah* and S. L. Ruby

J. Chem. Phys. (July 1969)

Measurements have been made on the recoilless (NGR) absorption of Sn^{4+} ions in 0.2 M SnCl_4 frozen aqueous solutions (FAS) as a function of time and temperature. These reproduce most of the effects, including the anomalous transient disappearance of the Mössbauer effect, seen by previous workers using Fe^{2+} and Fe^{3+} ions in FAS. The electrical conductivity of the SnCl_4 FAS was also measured, and found to "follow" the NGR results very closely, despite the great differences in the fundamental mechanisms of these two phenomena. There is evidence for melting of part of the FAS above 200°K .

*Solid State Science Division.

GRAVITY-INDUCED ELECTRIC FIELD NEAR A CONDUCTOR

Murray Peshkin

Phys. Letters (1969)

A qualitative theoretical model is consistent with the experimental result of Witteborn and Fairbank.

PRECISION DETERMINATION OF THE D-T NEUTRON SEPARATION ENERGY

W. V. Prestwich and G. E. Thomas

Phys. Rev. (20 April 1969)

The neutron separation energy for the $\text{D}(\text{n}, \gamma)\text{T}$ reaction has been determined by observing the γ -ray transition with a pair spectrometer consisting of a NaI annulus and a Ge(Li) detector. The energy of the transition was determined relative to an appropriate precision standard. The value obtained, $6257.60 \pm 0.3 \text{ keV}$, is in good agreement with previous values and represents a significant improvement in precision.

DISPERSION OF ATOMIC GYROMAGNETIC RATIOS—APPROACH TO STATISTICAL EQUILIBRIUM

N. Rosenzweig and B. G. Wybourne*

Phys. Rev. (5 April 1969)

The dispersion of the gyromagnetic ratios about their mean value is calculated as a function of the magnitude of the spin-orbit coupling parameter for some energy matrices of the complete electrostatic and spin-orbit interactions in the f^6 and f^7 electron configurations. It follows from orthonormality alone that the dispersion assumes its greatest value in the LS-coupling limit. As the magnitude of the spin-orbit coupling is increased, the energy matrix becomes more complex, its pseudorandom character is intensified, and the value of the dispersion declines monotonically until it reaches a minimum value which corresponds approximately to a state of statistical equilibrium. Some aspects of the observed variation may be understood with the help of some schematic models for the transformation matrix connecting the LS and intermediate coupling schemes. The minimum values of the dispersion about the mean are roughly equal to the values predicted by a statistical model in which all of the LS components of the wave function are assumed to be statistically equivalent.

* Chemistry Division.

LIFETIMES OF EXCITED STATES OF V^{51} , Ni^{61} , Ga^{69} , As^{75} , Br^{79} , Rb^{85} , and Sb^{123}

E. N. Shipley, R. E. Holland, and F. J. Lynch

Phys. Rev. (20 June 1969)

The lifetimes of states at low excitation in several odd-A nuclei have been measured by a pulsed-beam technique. The results of the measurements for the levels at the excitation energies listed in parentheses are

V^{51} (320 keV),	$(0.28 \pm 0.05) \times 10^{-9}$ sec;
Ni^{61} (67 keV),	$(7.3 \pm 0.3) \times 10^{-9}$ sec;
Ga^{69} (320 keV),	$< 0.1 \times 10^{-9}$ sec;
As^{75} (199 keV),	$(1.30 \pm 0.25) \times 10^{-9}$ sec;
As^{75} (280 keV),	$(0.43 \pm 0.08) \times 10^{-9}$ sec;
Br^{79} (217 keV),	$< 0.2 \times 10^{-9}$ sec;
Rb^{85} (150 keV),	$(1.01 \pm 0.10) \times 10^{-9}$ sec;
Sb^{123} (160 keV),	$(0.82 \pm 0.10) \times 10^{-9}$ sec.

NEUTRON RESONANCES OF Mo ISOTOPES

Hla Shwe and R. E. Coté

Phys. Rev. (20 March 1969)

The neutron transmission of Mo isotopes for neutron energy $E_n \lesssim 1.5$ keV has been measured with the Argonne fast chopper. The use of samples enriched in Mo^{95} and in Mo^{97} as well as samples of natural Mo has made possible the unambiguous isotopic assignment of the resonances. Some ten new resonances have been detected and measured; all of these have been assigned to either Mo^{95} or Mo^{97} . On the basis of a probability approach recently suggested by Bollinger, a great majority of these newly observed resonances have been interpreted as being due to p-wave neutrons. For Mo^{95} , the mean radiation width calculated from the measurements for the resonances at $E_0 = 44.7$ and 159.6 eV is $\langle \Gamma_\gamma \rangle_{\ell=0} = 185 \pm 15$ meV. This is to be compared with $\langle \Gamma_\gamma \rangle_{\ell=1} = 277 \pm 67$ meV for the two p-wave resonances at $E_0 = 110.3$ and 117.9 eV. For Mo^{96} , the widths are $(\Gamma_\gamma)_{\ell=0} = 330 \pm 50$ meV for the resonance at 131.3 eV, and $(\Gamma_\gamma)_{\ell=1} = 530 \pm 100$ meV for the resonance at $E_0 = 113.5$ eV. For Mo^{97} , the radiation widths are $(\Gamma_\gamma)_{\ell=0} = 127 \pm 13$ meV for the s-wave resonance at $E_0 = 70.9$ eV, and $\langle \Gamma_\gamma \rangle_{\ell=1} = 154 \pm 20$ meV for four of the p-wave resonances detected in this experiment. The values for Mo^{98} are $(\Gamma_\gamma)_{\ell=0} = 170 \pm 80$ meV for the s-wave resonance at $E_0 = 428.9$ eV, and $(\Gamma_\gamma)_{\ell=1} = 110 \pm 15$ meV for the p-wave resonance at $E_0 = 12.1$ eV. The strength functions calculated for these nuclides are $S_0(\text{Mo}^{95}) = (0.5_{-0.2}^{+0.5}) \times 10^{-4}$, $S_1(\text{Mo}^{95}) = (5_{-3}^{+10}) \times 10^{-4}$; $S_0(\text{Mo}^{97}) = (0.5_{-0.2}^{+0.4}) \times 10^{-4}$, $S_1(\text{Mo}^{97}) = (6_{-2}^{+11}) \times 10^{-4}$; and $S_0(\text{Mo}^{98}) = (2_{-1}^{+4}) \times 10^{-4}$. The resonance-capture integral for natural Mo has been calculated to be 27 ± 2 b.

RECOIL BROADENING OF SECONDARY TRANSITIONS IN NEUTRON-CAPTURE GAMMA-RAY CASCADES

K. J. Wetzel

Phys. Rev. (20 April 1969)

Recoil Doppler broadening has been observed in secondary gamma-ray transitions (4–9 MeV) in cascades following thermal-neutron capture in ^{10}B and ^{14}N . An increase in linewidth (typically 0.5–1.5 keV) is measured by use of a Ge(Li) pair spectrometer. An ambiguity in the γ_1 - γ_2 angular correlation $W(\theta)$ exists in most cases and introduces an uncertainty in the calculated linewidths, but measured widths generally fall within the range of the calculations. A comparison of results in ^{15}N from a gas sample and from a melamine sample shows an attenuation of the effect for the 5271- and 5299-keV

levels, and estimates of their lifetimes are consistent with known values. For ^{15}N levels showing no attenuation, the estimated lower limits on the lifetimes are also consistent with previous measurements; the lifetime for the 8313-keV level is an improvement over existing information. A more accurate value for the lifetime of the 6741-keV level in ^{11}B is also deduced from a comparison of the calculated and the observed broadening. It is also shown that in certain cases the Doppler broadening could provide information about the spin of the capturing state through the dependence of $W(\theta)$ on J_c .

MÖSSBAUER EFFECT OF ^{129}I IN PYRIDINE COMPLEXES OF IODINE MONOHALIDES

C. I. Wynter,* J. Hill,* W. Bledsoe,* G. K. Shenoy,[†] and
S. L. Ruby

J. Chem. Phys. (1 May 1969)

The values of isomer shift and quadrupole interaction at the ^{129}I nucleus in IBr and ICl complexes with cyclic nitrogen bases have been measured. These have been used to estimate σ and π bondings in these complexes. All these complexes exhibit a linear N—I—X ($\text{X} \equiv \text{Cl}, \text{Br}$) linkage. Although the bromine complexes show a systematic dependence of the isomer shift on the basicity of the complexing cyclic amines, no such trend is observed in chlorine complexes.

* A & T State University of North Carolina, Greensboro, North Carolina.

[†] Solid State Science Division.

IV. PUBLICATIONS SINCE THE LAST REPORT

PAPERS AND BOOKS

PHOTOIONIZATION OF HCN: THE ELECTRON AFFINITY AND HEAT OF FORMATION OF CN

J. Berkowitz, W. A. Chupka, and T. A. Walter
J. Chem. Phys. 50, 1497-1500 (15 February 1969)

MEASUREMENT OF A AND B COEFFICIENTS IN THE DECAY OF POLARIZED NEUTRONS

C. J. Christensen, V. E. Krohn, and G. R. Ringo
Phys. Letters 28B(6), 411-412 (6 January 1969)

PHOTOIONIZATION OF ETHYLENE WITH MASS ANALYSIS

W. A. Chupka, J. Berkowitz, and K. M. A. Refaey
J. Chem. Phys. 50, 1938-1941 (1 March 1969)

PHOTOIONIZATION STUDY OF ION-MOLECULE REACTIONS IN MIXTURES OF HYDROGEN AND RARE GASES

W. A. Chupka and Morley E. Russell
J. Chem. Phys. 49, 5426-5437 (15 December 1968)

NEUTRON RESONANCES OF Th^{230}

R. E. Coté, H. Diamond (Chemistry), J. E. Gindler (Chemistry),
and Hla Shwe
Phys. Rev. 176, 1421-1423 (20 December 1968)

POSSIBLE DOORWAY-STATE STRUCTURE IN THE SCATTERING OF NEUTRONS BY Fe

A. J. Elwyn and J. E. Monahan
Nucl. Phys. A123(1), 33-53 (1968)

FREQUENCY-SHIFTING METHOD OF EXCITING A PLASMA IN A RESONANT CAVITY

S. L. Halverson (Electronics) and Albert J. Hatch
Appl. Phys. Letters 14(2), 79-81 (15 January 1969)

GENERATION AND STATISTICAL ANALYSIS OF SYNTHETIC CROSS SECTIONS

P. Hoffman-Pinther,* P. P. Singh,* and D. W. Lang
Nucl. Phys. A127(2), 241-269 (1969)

* Indiana University, Bloomington, Indiana.

ACCURATE CALCULATION OF THE REACTION MATRIX IN LIGHT
NUCLEI AND IN NUCLEAR MATTER

A. Kallio and B. D. Day

Nucl. Phys. A124(1), 177-198 (1969)

SMALL-ANGLE SCATTERING OF NEUTRONS BY HEAVY NUCLEI

F. T. Kuchnir, A. J. Elwyn, J. E. Monahan, A. Langsdorf, Jr.,
and F. P. Mooring

Phys. Rev. 176, 1405-1415 (20 December 1968)

PARTICLE-HOLE MULTIPLETS IN ^{208}Bi

T. T. S. Kuo

Nucl. Phys. A122, 325-342 (1968)

THE OPTICS OF DIPOLE MAGNETS

John J. Livingood

(Academic Press, New York, 1969), 261 + xvii pages

EFFECTIVE-INTERACTION FORMULATION OF BOUND AND CON-
TINUUM SHELL-MODEL CALCULATIONS

K. W. McVoy and W. J. Romo

Nucl. Phys. A126(1), 161-180 (1969)

STUDY OF THE $\text{Ca}^{48}(\text{He}^3, p)\text{Sc}^{50}$ REACTION

H. Ohnuma, J. R. Erskine, J. A. Nolen, Jr., J. P. Schiffer,
and P. G. Roos*

Phys. Rev. 177, 1695-1698 (20 January 1969)

EXPERIMENTAL STUDY OF THE (d, He^3) REACTION ON EVEN-A
ISOTOPES OF Mo

H. Ohnuma and J. L. Yntema

Phys. Rev. 176, 1416-1421 (20 December 1968)

MAGNETIC BEHAVIOR OF THE Pt+Fe SYSTEM NEAR Pt_3Fe

D. Palaith,[†] C. W. Kimball (Solid State Science), R. S. Preston,
and J. Crangle (Metallurgy)

Phys. Rev. 178, 795-799 (10 February 1969)

(d, He^3) REACTION ON THE CHLORINE ISOTOPES AT 23.35 MeV

N. G. Puttaswamy and J. L. Yntema

Phys. Rev. 177, 1624-1628 (20 January 1969)

* University of Maryland, College Park, Maryland.

[†] Northern Illinois University, DeKalb, Illinois.

REPORTS AT MEETINGS

Proceedings of the Conference on Slow-Neutron-Capture Gamma-Ray Spectroscopy Held at Argonne National Laboratory, 2—4 November 1966, edited by F. E. Throw (Argonne National Laboratory, Argonne, Illinois, 1968), Report No. ANL-7282

INVESTIGATION OF CONVERSION-ELECTRON SPECTRA
FOLLOWING NEUTRON CAPTURE

E. Bieber

pp. 265-278

STUDY OF THE $F^{19}(n, \gamma)F^{20}$ REACTION

D. E. Blatchley and G. E. Thomas

pp. 71-77

PANEL DISCUSSION SUMMARIZING THE MEETING

L. M. Bollinger, R. E. Chrien,* J. A. Harvey,† O. W. B. Schult,‡ and J. Vervier§

pp. 533-584

MEASUREMENT OF RESONANCE-CAPTURE GAMMA-RAY
SPECTRA WITH A $1/E$ NEUTRON SPECTRUM

L. M. Bollinger and G. E. Thomas

pp. 523-531

GAMMA-RAY SPECTRAL ANALYSIS

H. H. Bolotin

pp. 255-263

LOW-LYING EXCITED STATES IN Ag^{108} AND Ag^{110} POPULATED
BY PRIMARY THERMAL-CAPTURE GAMMA RAYS

H. H. Bolotin

pp. 62-70

THERMAL-NEUTRON CAPTURE GAMMA-RAY STUDIES OF
THE EXCITED STATES OF ODD-A HAFNIUM ISOTOPES

H. H. Bolotin and A. I. Namenson

pp. 341-354

* Brookhaven National Laboratory, Upton, L.I., New York.

† Oak Ridge National Laboratory, Oak Ridge, Tennessee.

‡ Technical University, Munich and Brookhaven National Laboratory, Upton, L.I., New York.

§ C.E.N.-S.C.K., Mol, Belgium.

Slow-Neutron-Capture Gamma-Ray Spectroscopy (cont'd.)SUPERCONDUCTING INTERNAL-CONVERSION-ELECTRON
SPECTROMETER

S. B. Burson

pp. 279-285

ELECTROMAGNETIC TRANSITIONS IN Mg^{26}

R. T. Carpenter and D. E. Blatchley

pp. 375-380

USE OF A FAST CHOPPER IN RESONANCE-NEUTRON-CAPTURE
GAMMA-RAY STUDIES

R. E. Côté

pp. 427-439

THE $\text{Pt}^{195}(n, \gamma)\text{Pt}^{196}$ REACTION AS A ONE-CHANNEL PROCESS

R. E. Côté and W. V. Prestwich

pp. 501-506

GAMMA-RAY SPECTRA OF Co^{60} AND Mn^{56} FOLLOWING RESON-
ANCE CAPTURE IN Co^{59} AND Mn^{55}

W. V. Prestwich and R. E. Côté

pp. 492-500

GAMMA-RAY SPECTRUM FOLLOWING THERMAL-NEUTRON
CAPTURE IN Er^{166}

W. V. Prestwich and R. E. Côté

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THE LEVEL SCHEME OF Cd^{114} , BASED ON (n, γ) AND (d, p)
EXPERIMENTS

R. K. Smither

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THE USE OF CRYSTAL DIFFRACTION WITH A $\text{Ge}(\text{Li})$ DETEC-
TOR FOR HIGH-RESOLUTION GAMMA-RAY SPECTROSCOPY

R. K. Smither and A. I. Namenson

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INSTALLATION AND USE OF AN INTERNAL-TARGET FACILITY

G. E. Thomas

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GAMMA-RAY SPECTRA FROM CAPTURE OF THERMAL NEU-
TRONS IN B^{10} , C^{12} , AND C^{13}

G. E. Thomas and L. M. Bollinger

pp. 84-88

Conference on Semiconductor Nuclear-Particle Detectors and Circuits,
Gatlinburg, Tennessee, 15—18 May 1967

USE OF Ge(Li) DETECTORS IN GAMMA-RAY SPECTROSCOPY:
APPLICATIONS AND BASIC CONSIDERATIONS

H. H. Bolotin

Semiconductor Nuclear-Particle Detectors and
Circuits (Proceedings of a Conference conducted
by the Subcommittee on Instruments and Techniques,
Committee on Nuclear Science), edited by W. L.
Brown, W. A. Higinbotham, G. L. Miller, and
R. L. Chase (Printing and Publishing Office,
National Academy of Sciences, Washington, D.C.,
1969), Publication 1593, pp. 660-683

Proceedings of the International Conference on Electromagnetic Sizes
of Nuclei, Carleton University, Ottawa, Canada, 22—24 May 1967

COULOMB ENERGIES AND NEUTRON RADII

J. A. Nolen, Jr.

pp. 244-253

2ème Colloque International sur les Interactions entre les Champs
Oscillants et les Plasmas, Saclay, 15—19 January 1968. III. Confinement
et Stabilisation par les Champs H.F. Seuls ou Associes a un Champ
Magnetique Statique (L'Institut National des Sciences et Techniques
Nucleaires, Saclay, 1968)

FREQUENCY-SHIFTING METHOD OF EXCITING PLASMAS
IN FUNDAMENTAL-MODE RESONANT CAVITIES

Albert J. Hatch, S. L. Halverson (Electronics), and
A. E. Froehlich

pp. 987-1023

POTENTIAL-WELL THEORY OF CONFINEMENT OF PLASMAS
IN NONUNIFORM RADIOFREQUENCY FIELDS

Albert J. Hatch, M. Hasan, and W. E. Smith (Applied
Mathematics)

pp. 949-986

Nuclear Physics and Solid State Physics Symposium, Indian Institute of Technology, Guindy, Madras 36, India, 27 February—1 March 1968

NUCLEAR STRUCTURE CALCULATIONS

R. D. Lawson

Proceedings of the Nuclear Physics and Solid State Physics Symposium, 1968, Nuclear Physics
(Physics Committee, Department of Atomic Energy, Government of India, Bombay, 1968),
pp. 17-31

International Symposium on Nuclear Structure, Dubna, USSR, 4—11 July 1968

RADIATIVE TRANSITIONS FROM HIGHLY-EXCITED NUCLEAR STATES

L. M. Bollinger

Nuclear Structure, Dubna Symposium, 1968
(International Atomic Energy Agency, Vienna, 1968), pp. 317-347

NUCLEAR SPECTROSCOPY WITH AVERAGE SPECTRA FROM NEUTRON-RESONANCE CAPTURE

L. M. Bollinger and G. E. Thomas

International Symposium on Nuclear Structure, Dubna, USSR, 4-11 July 1968, Contributions
(Joint Institute for Nuclear Research, Dubna, 1968), Dubna publication D-3893, p. 117

MEASUREMENT OF INTERNAL-CONVERSION COEFFICIENTS OF NEUTRON-CAPTURE GAMMA RAYS WITH A SUPER-CONDUCTING SPECTROMETER

S. B. Burson

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(Joint Institute for Nuclear Research, Dubna, 1968), Dubna publication D-3893, p. 174

SURVEY OF SINGLE-PARTICLE AND COLLECTIVE STATES OF THE ACTINIDES BY USE OF TRANSFER REACTIONS

J. R. Erskine, A. M. Friedman (Chemistry), T. H. Braid, and R. R. Chasman (Chemistry)

International Symposium on Nuclear Structure, Dubna, USSR, 4-11 July 1968, Contributions
(Joint Institute for Nuclear Research, Dubna, 1968), Dubna publication D-3893, p. 61

Proceedings of the Conference on the Electron Capture and Higher Order Processes in Nuclear Decays, Debrecen, Hungary, July 15—18, 1968, edited by D. Berényi (Eötvös Lóránd Physical Society, Budapest, 1968), Vol. 3

PROPERTIES OF STATES EXCITED IN $^{181}_{75}\text{Re}$ AND $^{182}_{75}\text{Re}$
FOLLOWING ORBITAL ELECTRON CAPTURE IN $^{181}_{76}\text{Os}$ (105 m)
AND $^{182}_{76}\text{Os}$ (22 h)

S. B. Burson

pp. 475-479

American Physical Society, New York, 3—6 February 1969

GAMMA DECAY OF $T=\frac{3}{2}$ STATES IN Na^{21}

R. C. Bearse, G. C. Morrison, J. C. Legg,* and R. E. Segel

Bull. Am. Phys. Soc. 14, 124 (January 1969)

ELECTRON g FACTORS OF LOW-LYING STATES OF Tb I

W. J. Childs and L. S. Goodman

Bull. Am. Phys. Soc. 14, 84 (January 1969)

NGR MEASUREMENTS WITH ^{238}U

S. L. Ruby, G. M. Kalvius (Solid State Science), B. D. Dunlap (Solid State Science), G. K. Shenoy (Solid State Science), M. B. Brodsky (Metallurgy), and D. Cohen (Chemistry)

Bull. Am. Phys. Soc. 14, 134 (January 1969)

NEUTRON RESONANCES OF Mo

Hla Shwe and R. E. Coté

Bull. Am. Phys. Soc. 14, 104-105 (January 1969)

1969 Particle Accelerator Conference—Accelerator Engineering and Technology, Washington, D.C., 5—7 March 1969

A LOW POWER MAGNETIC CHANNEL WITH DIPOLE COMPENSATION

T. Khoe (Accelerator Division), R. Benaroya (Chemistry), J. J. Livingood, W. J. Ramler (Chemistry), and W. Wesolowski (Chemistry)

Bull. Am. Phys. Soc. 14, 219 (February 1969)

* Kansas State University, Manhattan, Kansas.

American Physical Society, Philadelphia, 24—27 March 1969

CURIE TEMPERATURE ANOMALY OF THE ISOMER SHIFT
IN IRON

R. S. Preston, I. Goroff (Metallurgy), and F. M.
Mueller (Solid State Science)

Bull. Am. Phys. Soc. 14, 386 (March 1969)

ANL TOPICAL REPORT

PROCEEDINGS OF THE CONFERENCE ON SLOW-NEUTRON-CAPTURE
GAMMA-RAY SPECTROSCOPY HELD AT ARGONNE NATIONAL
LABORATORY, 2—4 NOVEMBER 1966

edited by F. E. Throw

Argonne National Laboratory Topical Report ANL-7282
(November 1968)

PHYSICS DIVISION INFORMAL REPORTS

ANL-AUA DISCUSSION OF A MIDWEST ACCELERATOR FOR NUCLEAR
CHEMISTRY AND PHYSICS (A report of a conference held at O'Hare
Airport, Saturday, 11 January 1969)

Physics Division Informal Report PHY-1969A (January
1969)

THE PHYSICAL INTERPRETATION OF QUANTUM THEORIES OF
GRAVITATION

H. Ekstein

Physics Division Informal Report PHY-1969B (March 1969)

STUDENT REPORTS

PROGRAMMED ANALYSIS OF I^{125} INTERNAL CONVERSION DATA

Stan Amundson

ACM student report to St. Olaf College, Northfield,
Minnesota (December 1968)

INVESTIGATION OF MULTI-WIRE PROPORTIONAL COUNTER

John L. Himes

CSUI-ANL student report to Mansfield State College,
Mansfield, Pennsylvania (2 May 1969)

V. PERSONNEL CHANGES IN THE ANL PHYSICS DIVISION

NEW MEMBERS OF THE DIVISION

Research Associate

Dr. Walter Henning, Technische Hochschule München, Germany.

Study of the hyperfine anomaly in ^{193}Ir ; calculations of Coriolis mixing in deformed odd-A nuclei. Came to Argonne on 17 January 1969.

Postdoctoral

Dr. Reimar N. Spohr. Photoionization and photoelectron energy

analysis. Came to Argonne on 2 January 1969.

Resident Associates

Dr. Lawrence E. Conroy, Department of Chemistry, University of

Minnesota, Minneapolis. Chemical aspects of the Mössbauer effect. (CEA affiliate, Faculty Research Participation Program.) Came to Argonne on 17 March 1969.

Dr. Margaret M. Stautberg, DePaul University, Chicago, Illinois.

Nuclear structure studies by use of the (He^3, t) and (He^3, p) reactions. (CEA affiliate.) Came to Argonne on 24 March 1969.

Student Aides (ACM)

Mr. Richard H. Heisterberg, Knox College, Galesburg, Illinois.

Working with G. T. Wood on conversion-electron spectroscopy from nuclear reactions. Came to ANL on 17 March 1969.

Mr. Crispin A. Schamp, Ripon College, Ripon, Wisconsin. Working with S. B. Burson on the study of the energy levels of ^{179}Hf , ^{181}Hf , and ^{175}Yb through gamma-ray spectroscopy and magnetic spectroscopy of internal-conversion electrons following thermal neutron capture. Came to ANL on 6 January 1969.

CSUI-ANL Honor Students

Mr. Richard L. Boudrie, Western Michigan University, Kalamazoo, Michigan. Working with G. C. Morrison on nuclear-structure research at the tandem Van de Graaff. Returned to ANL on 3 February 1969.

Mr. John L. Himes, Jr., Mansfield State College, Mansfield, Pennsylvania. Working with T. H. Braid on the construction and testing of a multiwire proportional counter for detecting ionizing radiation. Came to ANL on 3 February 1969.

Mr. William S. Paciesas, Seton Hall University, South Orange, New Jersey. Working with A. J. Hatch on measurement of impedance of high-frequency plasmas. Came to ANL on 3 February 1969.

Mr. Richard F. Sattilaro, New York Institute of Technology, New York, New York. Working with R. H. Siemssen on analysis of data on the elastic scattering of O^{16} on Mg^{24} and Mg^{26} . Came to ANL on 3 February 1969.

Scientific Assistant

Mr. Bruce J. Zabransky had been a co-op technician in Physics since 8 February 1965. He was made permanent as a technician on 16 December 1968 and has since been promoted to a scientific assistant as of 27 January 1969.

DEPARTURES

Mr. Stuart O. Goldman, scientific assistant, has been in the Physics Division since 30 January 1967. He terminated at ANL on 28 February 1969.

Mr. Charles W. Schmidt, scientific assistant, has been in the Physics Division since 1 September 1964. He terminated at ANL on 20 March 1969.