ANL-7384

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Argonne National Laboratory

PHYSICS DIVISION SUMMARY REPORT

July—September 1967

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Physics
AEC Research and
Development Report

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

PHYSICS DIVISION SUMMARY REPORT

July—September 1967

Lowell M. Bollinger, Division Director

Preceding Summary Reports:

ANL-7312, January-March 1967
ANL-7354, Annual Review
ANL-7355, April-June 1967

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-7354, which reports research in the year ending 31 March 1967.

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.

ENERGY DEPENDENCE OF HIGH-ENERGY K CONVERSION COEFFICIENTS

R. K. Smither

The K conversion coefficients for gamma-ray energies in the range from 1 to 9 MeV have been measured in a study of the $^{113}Cd(n,\gamma)^{114}Cd$ reaction. This is the first experiment with high enough precision to distinguish between E1 and M1 transitions over the entire energy range; the E1 points fall along a line that is clearly separated from that for M1 and E2 transitions. This ability to distinguish between the different multipolarities at high gamma-ray energies is proving to be very useful in assigning the parities of low-lying states.

The $^{113}Cd(n,\gamma)^{114}Cd$ gamma-ray spectrum from 1 to 9 MeV was measured with the Argonne Ge-diode gamma-ray spectrometer facility at the CP-5 research reactor.[1] The relative intensities of the observed gamma rays were combined with the corresponding K conversion-electron intensities taken from the work of v. Egidy and Kaiser[2] to obtain the experimental values for the K conversion coefficients, which are plotted on a log-log scale in Fig. 1. The crosses in Fig. 1 indicate

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[1] G. E. Thomas, D. E. Blatchley, and L. M. Bollinger (to be published, 1967).

[2] T. v. Egidy and W. Kaiser, Z. Physik 201, 378 (1967).

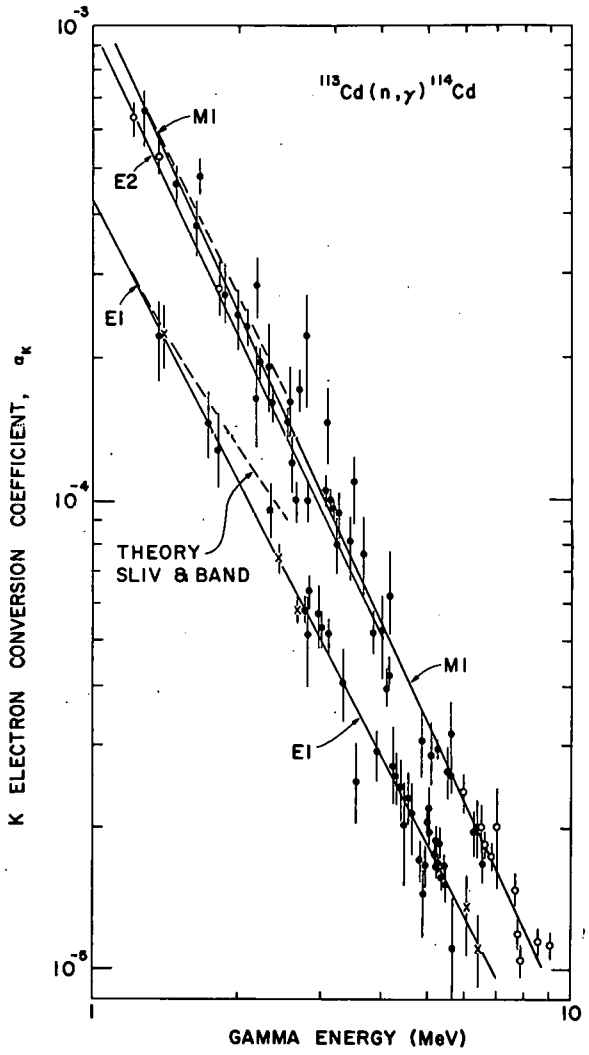

Fig. 1. Experimental values for K conversion coefficients of the 1—9-MeV gamma rays from $^{113}Cd(n,\gamma)^{114}Cd$. The crosses indicate known E1 transitions while the open circles indicate known M1 and E2 transitions. The solid lines which follow the data depend on energy as $E_\gamma^{-1.96}$ and $E_\gamma^{-2.18}$ for the E1 and M1 radiations, respectively. The dashed lines are the theoretical predictions of Sliv and Band (Ref. 3).

conversion coefficients for known E1 transitions, while the open circles indicate known M1 or E2 transitions. The important feature of these data is that the experimental points fall into two separate families or groups: one that can be associated with known E1 transitions and one that can be associated with known M1 and E2 transitions. It is this previously unobserved separation at high energies that enables one to assign multipolarities to the high-energy gamma rays and, by use of these multipolarities, to assign parities to many of the low-lying states in ^{114}Cd.

The solid lines on this log-log plot are straight-line extrapolations of the theoretical predictions of Sliv and Band[3] up to 1 MeV. At higher energies, their theoretical curves (dashed lines in Fig. 1) deviate from the solid lines drawn through the experimental points. This deviation is most noticeable for the E1 curve. The experimental values for the conversion

[3] L. A. Sliv and I. M. Band, Coefficients of Internal Conversion, University of Illinois Report 57-ICC-K1.

coefficients are normalized to theory at the 1209- and 1364-keV (E2) lines. A transition is plotted in Fig. 1 only if it appears as a well resolved peak in the Ge-diode spectrum. With the relatively high resolution of the Ge-diode detector, this selection of the data is quite straightforward. In the work of v. Egidy and Kaiser[2] this type of selection was not attempted. The poorer resolution of their conversion-electron data as well as that of the (n, γ) data[4] they combine with their work to obtain conversion coefficients would have made this type of selection quite difficult, especially in the 2—5-MeV region where the spectrum is quite complicated. The reduction in the uncertainty in the relative gamma intensities obtained in the Ge-diode work also facilitates the separation of the conversion coefficients into two groups.

The E1 and M1 K conversion coefficients vary as $E_\gamma^{-1.96}$ and $E_\gamma^{-2.18}$, respectively. The error bars shown in Fig. 1 reflect possible systematic errors in the calibration of the relative efficiencies of both the conversion-electron spectrometer and the Ge-diode detector (as well as statistical errors in the data). These possible systematic errors are believed to change slowly with energy and thus could change the energy dependence of both multipoles but would not change the ratio of the conversion coefficients. The error bars are therefore larger than would be appropriate if one were interested only in separating the two groups of conversion coefficients into E1 and M1 multipoles. The ratio of the K conversion coefficients is $\alpha(M1)/\alpha(E1) = 1.7$ at 9 MeV. This is smaller than the ratio $\alpha(M1)/\alpha(E1) = 2.7$ observed at 1 MeV but is still large enough to distinguish between E1 and M1 multipoles. This separation allows one to determine the parities of a great many of the low-lying states in ^{114}Cd. This contradicts a plausible inference from the theoretical predictions of Sliv and Band,[3] who calculated the

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[4] L. V. Groshev, A. M. Demidov, V. A. Ivanov, V. N. Lutsenko, and V. I. Pelekhov, Nucl. Phys. 43, 669 (1963).

conversion coefficients between 1 and 2.5 MeV. A linear extrapolation of their curves suggests that the values of the M1 and E1 coefficients might actually cross at 8 or 9 MeV, or at least approach each other so closely that experimentally no difference could be observed; but this is not the case for the $^{113}Cd(n,\gamma)^{114}Cd$ spectrum.

Details of the (n,γ) measurements will be described in a full-length paper on ^{114}Cd. In this paper, which is now being prepared by the author, the above information is combined with new information on the low-energy portion of the (n,γ) spectrum and a related set of $^{113}Cd(d,p)^{114}Cd$ angular distributions to further develop the level scheme of ^{114}Cd. A similar investigation of the E1 and M1 conversion coefficients from the $^{149}Sm(n,\gamma)^{150}Sm$ is now in progress.

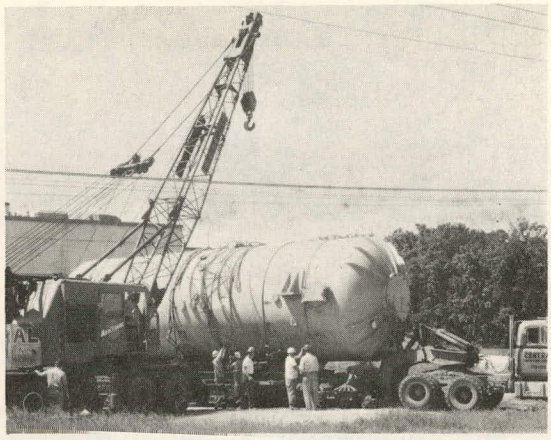
CONVERSION OF THE TANDEM VAN DE GRAAFF ACCELERATOR

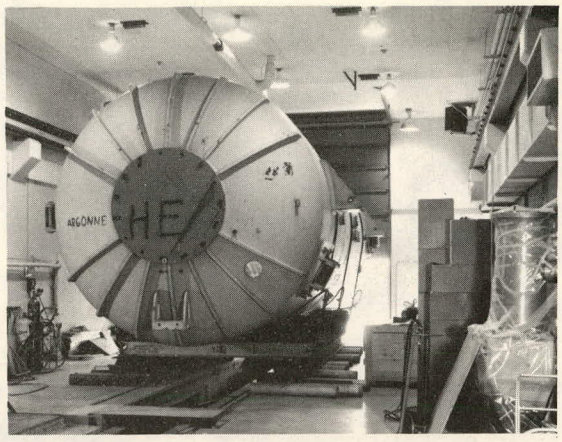
F. P. Mooring and J. R. Wallace

During the summer the Argonne model EN tandem Van de Graaff accelerator has been converted to a model FN tandem. At the same time the gas-handling system is being changed so that sulfur hexafluoride can be used as the insulating gas instead of the more usual mixture of nitrogen and carbon dioxide. The conversion kit was purchased from High Voltage Engineering Corporation, Burlington, Massachusetts. The converted machine has produced proton beams with energies as high as 15.0 MeV and analyzed currents in excess of 10 μA. The converted machine will eventually produce ion energies greater than 15 MeV—possibly as high as 18 MeV. Since this is the first instance of a tandem Van de Graaff being converted to a higher energy model, the success of the conversion is being watched with interest by the owners of similar Model EN tandems in other laboratories.

In anticipation of this conversion, the remodeling of the accelerator vault was begun last winter and was carried as far as it could be without serious interference with the operation of the existing EN machine. The experimental program at the EN was continued until 9 June 1967, when the accelerator was shut down for disassembly. In ten days the injector, the negative-ion source, and the low-energy beam-line systems were removed from the accelerator vault, the EN Van de Graaff was dismantled, those parts that were to be reused were sorted out and set aside, and the accelerator vault was cleared to make way for the remaining modifications of the building in preparation for the installation of the larger FN pressure vessel.

On 2 July the pressure tank, mounted on skids, was unloaded from the truck and started into the vault, as shown in the small photographs in Fig. 2. The modifications of the vault were complete





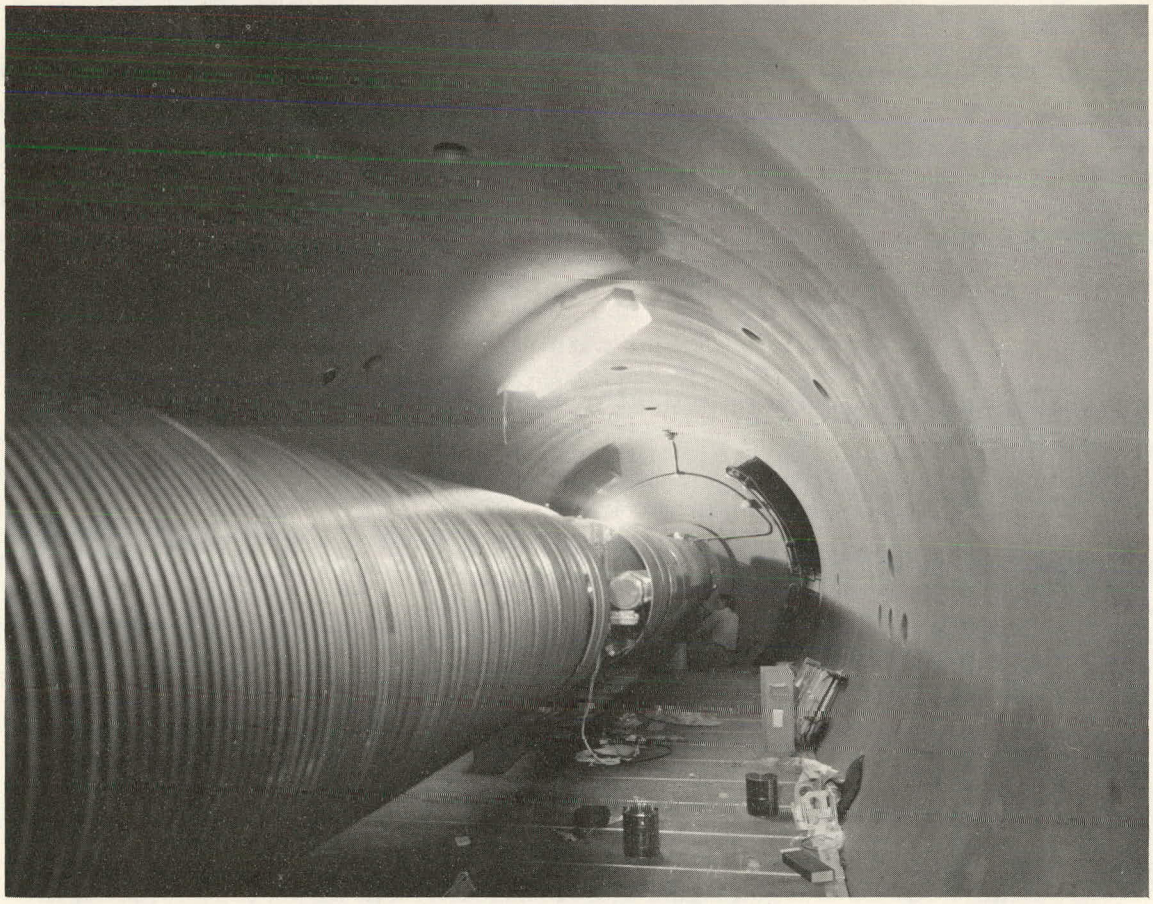


Fig. 2. Installation of the new FN tandem. The two small pictures at the top show the tank being moved into the vault on 2 July 1967. The larger picture below shows the high-voltage structure inside the tank as it looked on 21 July 1967 when its assembly was almost completed.

by 7 July so the tank could be rolled to approximately its final position. It took four days to remove it from the skids and to align it within the tolerances allowed. The assembly of the FN accelerator (large photograph in Fig. 2) began immediately. By 10 August it was completed and the new machine was pressurized for the first time. The initial testing and conditioning were then begun. Acceptance tests were completed by the last week of August, and the experimental program was started anew during that week.

During the acceptance tests several minor mechanical failures within the terminal of the converted machine required opening the tank for repairs, but these were not serious and were easily corrected. The conversion went very well indeed and was completed more than two weeks ahead of schedule. However, the installation of the new gas-handling system has been somewhat slower. In the period of several weeks before this system is ready for use, the insulating gas will have to be discarded whenever repairs become necessary inside the pressure tank. For this reason, the initial tests were made with mixtures of nitrogen and carbon dioxide obtained from a local supplier. By mid-October the new gas-handling system should be complete, and the expected advantages of using SF_6 as the insulating gas ascertained.

PERTURBATION OF THE STATISTICAL PROPERTIES OF NUCLEAR STATES AND TRANSITIONS BY INTERACTIONS THAT ARE ODD UNDER TIME REVERSAL

Norbert Rosenzweig, J. E. Monahan, and M. L. Mehta

Calculations indicate that the statistical properties of nuclear states and transitions may be perturbed significantly by a small interaction that is odd under the operation of time reversal. Analyses to set an upper limit on such perturbations, and thus on the magnitude of the time-reversal violating part of the interaction, offer a sensitive approach to the investigation of this important theoretical problem.

It has been known for some years that the theoretically predicted distributions of the widths and spacings of nuclear energy levels depend upon whether or not the nuclear Hamiltonian is invariant under the operation of time reversal. For example, if the Hamiltonian for a heavy nucleus is entirely even under time reversal (exactly time-reversal invariant), then the distribution of reduced neutron widths and also the distribution of partial radiation widths are predicted to be the well known Porter-Thomas distribution (the curve labeled $\epsilon^2 = 0$ in Fig. 3). On the other hand, if the residual interaction of the even

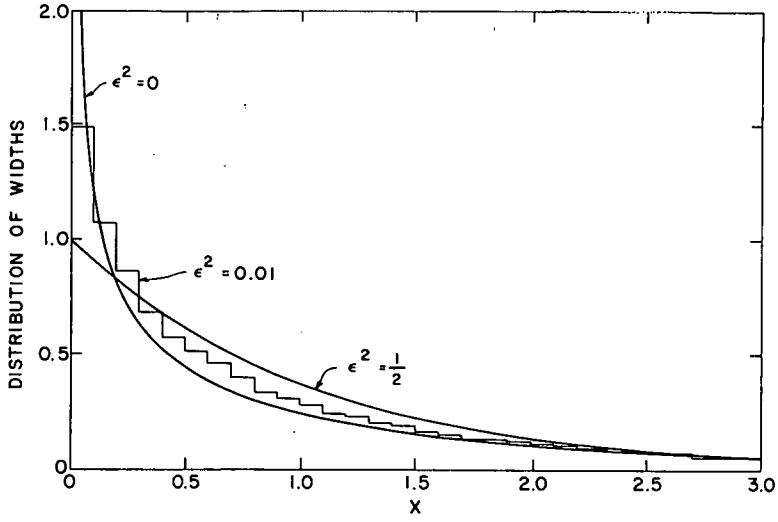


Fig. 3. Probability density of width X for three values of ϵ^2. The curve labeled $\epsilon^2 = 0$ corresponds to the case of exact time-reversal invariance and results in the Porter-Thomas distribution. The smooth curve labeled $\epsilon^2 = \frac{1}{2}$ corresponds to the case in which the even and odd parts of the residual interaction are on the average equal in magnitude. The histogram represents the width distribution corresponding to the value $\epsilon^2 = 0.01$.

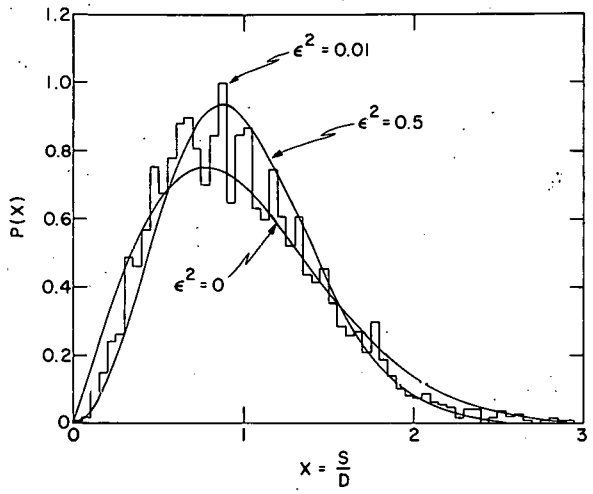


Fig. 4. Probability density of spacing between adjacent energy levels. The curve labeled $\epsilon^2 = 0$ corresponds to the case of exact time-reversal invariance. The curve labeled $\epsilon^2 = 0.5$ (calculated by Kahn) corresponds to the case in which the even and odd parts are, on the average, equal in magnitude. The histogram represents the spacing distribution corresponding to the value $\epsilon^2 = 0.01$.

part were on the average of the same magnitude as that of the odd part, then the theory predicts a pure exponential distribution (curve labeled $\epsilon^2 = \frac{1}{2}$ in Fig. 3). Similar differences apply also to the distribution of the spacings between neighboring energy levels of the same spin and parity. The curve labeled $\epsilon^2 = 0$ in Fig. 4 represents the distribution predicted on the basis of Wigner's random-matrix model together with the assumption of strict time-reversal invariance, whereas the curve labeled $\epsilon^2 = \frac{1}{2}$ corresponds to the case in which the even and odd parts are, statistically speaking, equal.

While the distributions labeled $\epsilon^2 = 0$ in Figs. 3 and 4 are in good qualitative agreement with the experimental data, obtained particularly from neutron resonance experiments on heavy target nuclei, appreciable deviations are by no means excluded. Since the idea that the nuclear forces may have a small odd part has recently been entertained rather seriously, the perturbations of the standard distributions (labeled $\epsilon^2 = 0$) have been calculated as a function of the parameter ϵ^2 that serves as a measure of the relative magnitudes of the odd and even parts. More precisely,

$$\frac{\epsilon^2}{1 - \epsilon^2} \equiv \frac{\langle (H^{odd})^2 \rangle}{\langle (H^{even})^2 \rangle} .$$

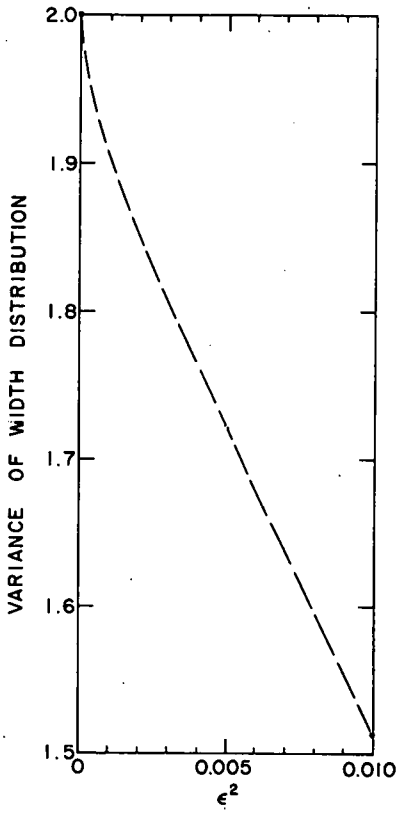


Fig. 5. Relative variance $\langle X^2 \rangle - 1$ of the width distribution as a function of ϵ^2 for a random-matrix model of high dimensionality.

Here the numerator and denominator represent the respective average values of the squares of the matrix elements of the odd and even parts.

The important conclusion reached through our recent calculations is that a relatively small time-reversal-violating (odd) part would produce a relatively large shift of the standard distributions. For example, the histograms in Figs. 3 and 4 represent the theoretical predictions for $\epsilon^2 = 0.01$, obtained on the basis of a Monte-Carlo random-matrix calculation.

The remarkable sensitivity of the results to the presence of a small odd part in the nuclear Hamiltonian may be further illustrated by a plot (Fig. 5) of the dependence of the relative variance $\langle \Gamma^2 \rangle - 1$ of the width distribution as a function of ϵ^2. It should be noted how rapidly the variance declines from the Porter-Thomas value of 2 for $\epsilon^2 = 0$ to about 1.5 for $\epsilon^2 = 0.01$. A comparison of the theory with some recent data on neutron and partial radiation widths leads to the tentative conclusion that ϵ^2 must be less than 0.01, which represents a rather small upper limit to the magnitude of the odd part.

HIGH-RESOLUTION STUDIES OF AUTOIONIZATION IN H_2

J. Berkowitz and W. A. Chupka

The recently-developed photoionization mass spectrometer at Argonne has been used to study autoionization in H_2 with a photon resolution width of 0.04 Å. This high resolution (an order of magnitude higher than previously reported) made it possible to separate the many autoionizing lines and to set limits on their natural widths. In the course of this study the accepted value of the ionization potential of H_2 was observed to be in error by a small but significant amount.

The Argonne experiment was a study of the absorption spectrum of molecular hydrogen when it is irradiated by ultraviolet. In the familiar direct photoelectric process, absorption of ultraviolet radiation at wavelengths near 800 Å leads to prompt ejection of an electron. Since any excess energy of the photon appears as kinetic energy of the escaping electron, this direct ionization produces a continuous absorption spectrum. About thirty years ago, however, the absorption spectrum of molecular hydrogen in the 800-Å region was found to include blurred lines of preferential absorption at certain wavelengths. These lines were shown to be due to an indirect process called autoionization.

In autoionization, the photon excites the molecule to a state slightly above the energy required for emission of an electron. Because the excitation energy is only partially given to the electron, the remainder appears as vibrational and rotational motions of the molecule. This latter energy can be transferred subsequently to the excited electron and result in its ejection. Since absorption of the photon excites the molecule to a definite quantum state, it results in an absorption line in the spectrum; but since the lifetime of the state is very short, its energy is indefinite and the line is blurred.

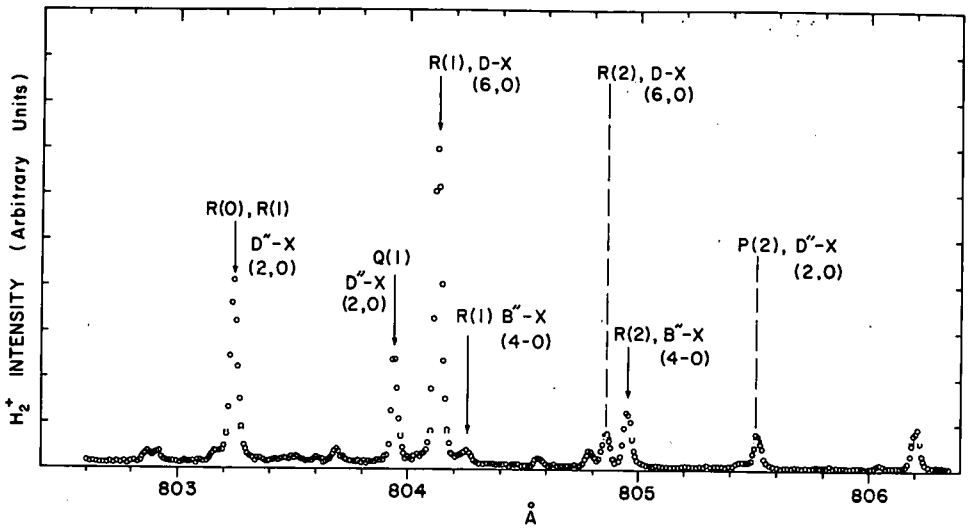


Fig. 6. Photoionization efficiency of H_2 near threshold.

Autoionization was discovered in a careful examination of the absorption spectrum of H_2; it was observed that blurred absorption lines occurred at short wavelengths but not at longer ones. The onset of the blurred absorption lines was interpreted as the threshold for autoionization, but this technique can be quite misleading. Blurring can be due to other causes, and autoionizing states with very long lifetimes can go unrecognized because of the very slight blurring. Hence the new Argonne studies, like a few earlier ones, recognized autoionization by the more direct method of detecting the positive H_2 ions that are ultimately formed by the process. The precision in the earlier studies was limited by the lack of intensity in the ultraviolet source and/or by insufficient detector sensitivity. This difficulty has been overcome in the Argonne instrument by means of an improved monochromator and mass spectrometer.

A portion of the threshold region of the ionization curve for H_2 is shown in Fig. 6. In the early absorption studies, the peak labeled R(2), D-X was seen as a broadened line (indicating autoionization) but the sharpness of peak R(1), D-X appeared to indicate no autoionization. Since the ionization potential of H_2 appeared to be

bracketed between these two wavelengths, it was inferred that I. P. (H_2) = 124 429 ± 13 cm^{-1}. However, the ion yield in the present experiment clearly indicates that R(1), D-X results from autoionization; but R(0), D-X does not appear. The latter was conclusively demonstrated by examining the autoionization spectrum of para-H_2, which has no peaks originating from odd-numbered rotational levels. When this was done, the R(0), D-X peak (which would appear at 803.9 Å) was entirely absent. The bracketing technique then implies 124 393 cm^{-1} < I. P. (H_2) < 124 416 cm^{-1}.

The peaks displayed in Fig. 6 are not appreciably broader than the instrumental linewidth of the monochromator, and the same is true for nearly all of the remaining peaks in the autoionization spectrum of H_2—most of them at wavelengths shorter than those in Fig. 6. A natural linewidth much less than this instrumental width implies a lifetime $\gtrsim 10^{-12}$ sec. This lower limit is in sharp disagreement with a recently developed theory of the autoionization rates in H_2, which predicts some lifetimes in the range between 10^{-13} and 10^{-12} sec.

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.

5th International Conference on the Physics of Electronic and Atomic Collisions

Leningrad, U.S.S.R., 17-23 July 1967

HIGH-RESOLUTION PHOTOIONIZATION AND MASS ANALYSIS OF SMALL MOLECULES

J. Berkowitz and W. A. Chupka

We have recently put into operation at this laboratory an apparatus of improved design for the study of photoionization phenomena.[1] The vacuum ultraviolet monochromator, of near-normal-incidence type, appears to be an order of magnitude more efficient, and has higher ultimate resolution, than the previously used Seya-Namioka designs. The mass spectrometer has been designed to collect ions from a relatively large source region with high efficiency. The union of these components, together with the best available light sources for the vacuum ultraviolet, results in an apparatus of much higher sensitivity than heretofore achieved. This high sensitivity has been exploited in three general directions.

(a) Low-abundance processes, previously not observed in photoionization experiments, could be observed in detail. Examples are ion-pair formation in alkanes ($H^- — R^+$) and in H_2, which are ca. 3

[1] J. Berkowitz and W. A. Chupka, J. Chem. Phys. 45, 1287 (1966).

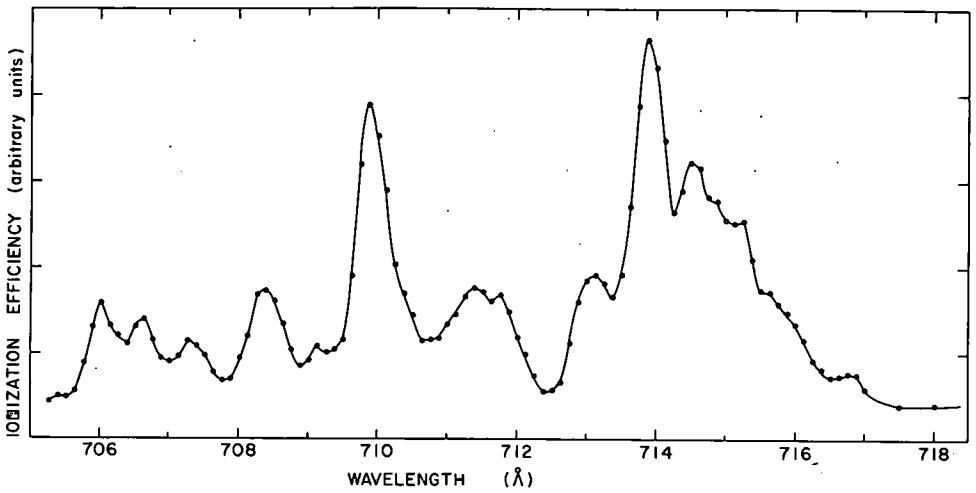


Fig. 7. Ionization-efficiency curve for the production of H^- from H_2.

orders of magnitude weaker than the major ionization process. A sample spectrum of H_2, verified by observing positive and negative ions, is shown in Fig. 7.

(b) With the available sensitivity, it has been possible to use narrow slits and operate in the third order of a 1-m monochromator, thereby achieving an energy resolution width of 0.04 eV. This is an order of magnitude higher resolution than experiments of similar type have attained. It has thus far proved extremely useful in re-examining the photoionization spectrum of H_2^+. The individual rotational peaks contributing to the autoionization that dominates the H_2^+ spectrum are cleanly resolved. By comparing the spectrum of normal and para-hydrogen, it was unequivocally demonstrated that Beutler's analysis[2] of the absorption spectrum of hydrogen in this spectral region is in error; this leads to a revised value for the ionization potential of H_2. By comparing the absorption and photoionization spectra of H_2 under conditions such that the rotational components are completely resolved, some conclusions can be drawn regarding autoionization probability as a function of symmetry and energy.

[2] H. Beutler and H. O. Jünger, Z. Physik 100, 80 (1936).

Previous studies[3,4] have demonstrated the significance of autoionization in the spectra of the noble gases. At threshold, direct ionization can readily be observed in xenon and krypton, and is followed by the Rydberg series of autoionization peaks. In the case of argon, an autoionizing level appears very close to the ionization potential. This spectral region has been examined with the higher resolution available to us, to see the effect of the two modes of ionization on threshold behavior.

(c) Apart from the pioneering work of Terenin,[5] there have been few photoionization experiments on low-volatility materials by use of mass analysis. The reasons are primarily the increased thermal background generated, and the weaker signals necessitated by working with molecular beams. The sensitivity and intensity available in our apparatus have enabled us to overcome these obstacles in a number of important cases. Photoionization of the molecules S_2 and Se_2 has been studied and the predominance of autoionization in the spectra of several atoms and simple molecules has been observed.

The so-called threshold law for photoionization has frequently been referred to in the literature as a step function. Even if a step function properly described the ionization to a single state at threshold, it has never been clear how far beyond the onset such behavior would be maintained. If one assumes perfect step-function behavior, the first derivative of a photoionization-efficiency curve should yield the probability of excitation of the various states of the ion. The latter information can also be obtained by examining the electron spectrum resulting from photoionization of the same molecule. Hence, a comparison

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[3] H. Beutler, Z. Physik 93, 177 (1935).

[4] R. E. Huffman, Y. Tanaka, and J. C. Larrabee, J. Chem. Phys. 39, 902 (1963).

[5] A. Terenin and B. Popov, Phys. Z. Sowjetunion 2, 299 (1932).

of the results of the two approaches provides useful insight into the validity of the "threshold law," as well as providing detailed information on the internal energy distribution of a molecular ion which is critical to the calculation of its unimolecular decomposition. Recent results on the photoionization[6] and photoelectron analysis[7] of the alkanes provides the first useful comparison of this type.

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[6] W. Chupka and J. Berkowitz, J. Chem. Phys. (submitted for publication).

[7] J. Berkowitz, H. Ehrhardt, and T. Tekaat, Z. Physik (accepted for publication).

Gordon Research Conference on Photonuclear Reactions
Tilton, New Hampshire, 14—18 August 1967

ANGULAR DISTRIBUTIONS IN THE Si^{28} GIANT RESONANCE

N. G. Puttaswamy, L. Meyer-Schützmeister, D. S. Gemmell, R. C. Bearse, and R. E. Segel

The fact that the gamma-ray angular distributions from (p,γ) reactions are to a large measure energy independent has been taken to imply[1] that a "single configuration" dominates the giant-dipole resonance. On the other hand, the particle-hole model,[2] which is so successful in explaining the main features of the giant resonance, predicts that the giant resonance will normally consist of a number of different particle-hole states.

Theoretical angular distributions for the $Al^{27}(p,\gamma_0)$ reaction have now been calculated by Eisenberg and collaborators[3,4] at several energies through the giant-resonance region and recently by Wahsweiler and Greiner[5] in the upper part of the giant resonance. Even though this reaction has been studied before,[6] a detailed comparison with theory has not been possible since angular distributions were taken only over certain arbitrarily selected regions and, in fact, data were not taken at most of the points for which calculations have been made. In the present work, therefore, angular distributions have been measured (in larger steps than previously) over the entire giant-resonance region.

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[1] R. G. Allas, S. S. Hanna, L. Meyer-Schützmeister, R. E. Segel, P. P. Singh, and Z. Vager, Phys. Rev. Letters 13, 628 (1964).

[2] G. E. Brown and M. Bolsterli, Phys. Rev. Letters 3, 472 (1959).

[3] J. B. Seaborn and J. M. Eisenberg, Can. J. Phys. 42, 2497 (1964).

[4] S. A. Farris and J. M. Eisenberg, Nucl. Phys. 88, 241 (1966).

[5] H. G. Wahsweiler and W. Greiner, Phys. Rev. Letters 19, 131 (1967).

[6] P. P. Singh, R. E. Segel, L. Meyer-Schützmeister, S. S. Hanna, and R. G. Allas, Nucl. Phys. 65, 577 (1965).

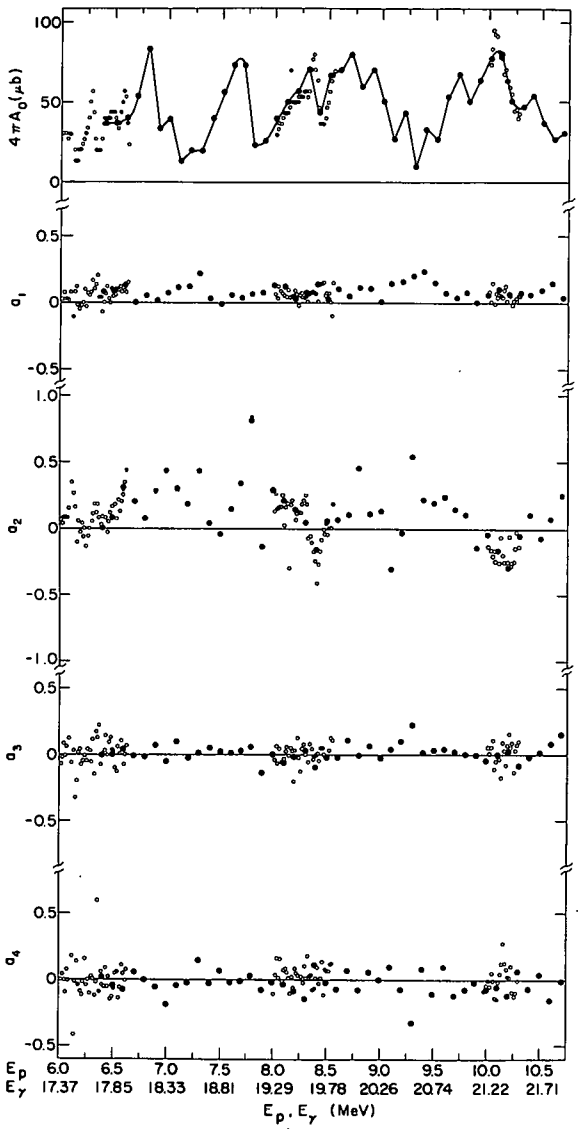

Fig. 8. The angular-distribution coefficients A_0, a_1, a_2, a_3, and a_4 for γ_0. Included are the results from Ref. 6 (open circles).

The experimental arrangement was similar to that used in the other radiative-capture studies at Argonne.[7] Six-point angular distributions on either side of the beam tube were taken by each of two large NaI(Tl) crystals, one 25 cm in diameter by 20 cm thick and the other 25 cm in diameter by 30 cm thick. Data were taken every 100 keV with a 780-$\mu g/cm^2$ ($\approx$ 30 keV thick to 8-MeV protons) Al-foil target. The gamma rays γ_0 to the ground state and γ_1 to the first excited state in Si^{28} stood out clearly in the spectra and the statistics were ample—the number of counts in the γ_0 peak averaged about 800 and in the γ_1 peak about 1100. For each crystal, the angular distribution of gamma rays was fitted by the expression $d\sigma/d\Omega = A_0 [1 + \sum_n a_n P_n (\cos \theta)]$, $n = 1, \cdots, 4$. The results obtained from the two crystals were in good agreement and hence they were averaged. Figure 8 shows the results that were obtained for γ_0. Only for a_2 is there a significant variation with energy. The coefficient a_4 is approximately zero, as

[7] R. E. Segel, Z. Vager, L. Meyer-Schützmeister, P. P. Singh, and R. G. Allas, Nucl. Phys. A93, 31 (1967).

expected; its fluctuations about zero were not well correlated between the two crystals and can be used to estimate the experimental error. From our data (Fig. 8), $\langle a_4^2 \rangle_{av}^{1/2} = 0.09$; and, since errors in a_n can be expected to increase with increasing n, this value can be taken as an upper limit on the errors in the other a_n. In contrast $\langle (a_2 - \bar{a}_2)^2 \rangle_{av}^{1/2} = 0.22$, where $\bar{a}_2 = \sum a_2 A_0 / \sum A_0 = 0.11$. Thus some variations in the angular distributions of the E1 radiation from the giant resonance are established.

The presence of one-point peaks in the plot of a_2 as a function of energy indicates that at least some of the fluctuations are less than 100 keV wide. It can be seen from the results of the earlier experiment,[6] in which data were taken in 15-keV steps, that the fluctuations in a_2 (Fig. 8) appear to have the 60-keV width that was found for the fluctuations in the yield curve. Structure due to particle-hole states, on the other hand, should be at least several hundred keV wide.

In order to compare the experimental results with the theoretical calculations, the effects of the fine structure should be averaged out since calculations based on the particle-hole model do not consider the mixing of the particle-hole configurations with the narrow states of the compound nucleus. Therefore, the data were smoothed by redistributing each observation uniformly and symmetrically over a 500-keV interval. The fluctuations in a_2 are damped by this averaging, as can be seen in Fig. 9. However, some variations will still remain since the 60-keV structure will not be completely smoothed in 500-keV averaging. Both calculations[4,5] predict that there should be ~1-MeV-wide variations whose heights are substantially greater than any variations observed in the averaged data. The data do not allow ~1-MeV-wide variations in a_2 to be as much as $\frac{1}{3}$ of the a_2 predicted by Wahsweiler and Greiner[5] or $\frac{1}{6}$ of that predicted by Eisenberg and collaborators.[3,4] This confirms the conclusion of the latter authors that simple particle-hole

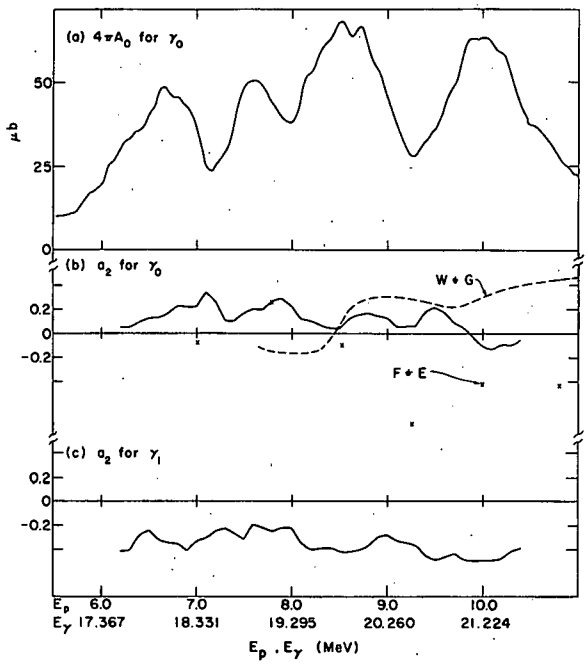

Fig. 9. Various results smoothed over 500 keV. (a) $Al^{27}(p, \gamma_0)$ yield curve. The data from Ref. 6 were used because of the greater energy range covered; in the region of overlap, the two experiments were in good agreement. (b) The coefficient a_2 for γ_0. The average is from the present data except between 6.0 and 6.4 MeV, where the old data (Ref. 6) were used. Also shown are the theoretical predictions of Ref. 5 (dashed line) and Ref. 4 (crosses). (c) The coefficient a_2 for γ_1.

calculations do not produce the observed near constancy in the angular distributions. The degree of variation shown by Wahsweiler and Greiner must be considered to be a lower limit since they do not cover the lower part (about 40%) of the (p, γ_0) giant resonance. Wahsweiler and Greiner predict that the value of a_2 in the range from 20 to 27 MeV is approximately constant at a value of about +0.3. Experimentally this region includes about 50% of the integrated (γ, p_0) yield and the measured a_2 is about -0.1.[6]

In conclusion, we find that in the $Al^{27}(p, \gamma_0)$ reaction a_2 does not show the broad variations with energy that are predicted by theory. The similar behavior of a_2 in every other case studied to date, including that of γ_1 here, indicates that the failure to find a reflection of a spectrum of particle-hole states in the angular distributions is characteristic of the giant resonance.

International Conference on Hyperfine Interactions Detected by Nuclear Radiation

Asilomar, Pacific Grove, California, 25—30 August 1967

MAGNETIC MOMENTS OF THE FIRST EXCITED STATE IN Cs^{133} AND Xe^{129} BY THE MÖSSBAUER EFFECT

L. E. Campbell, G. J. Perlow, and N. C. Sandstrom

ISOMER SHIFTS AND HYPERFINE SPLITTINGS OF THE 59.6-keV RESONANCE IN Np^{237}

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

Large isomer shifts of the 59.6-keV transition of Np^{237} in the 4+, 5+, and 6+ charge state are observed and interpreted. Preliminary evaluation gives the change in nuclear charge radius and in nuclear deformation as $\Delta\langle r^2\rangle/r^2 = -2.5 \times 10^{-4}$ and $\Delta\beta/\beta_0 = -5 \times 10^{-3}$ for these ground states of two different rotational bands. Magnetic and electric hyperfine interactions have been studied for several compounds and intermetallics from which the values for the ratio of nuclear moments have been found to be $g^*/g = 0.533 \pm 0.005$ and $Q_0{}^*/Q_0 \approx 1$. Magnetic fields from 50 kOe to 4800 kOe have been observed.

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*Solid State Science Division.

†Metallurgy Division.

‡Chemistry Division.

Third International Conference on Atomic Masses
Winnipeg, Manitoba, Canada, 28 August—1 September 1967

NUCLEAR Q-VALUE MEASUREMENTS ON A SERIES OF ACTINIDE NUCLEI

J. R. Erskine, A. M. Friedman,* T. H. Braid, and R. R. Chasman*

Reaction Q values were measured with the (d,p) and (d,t) reactions on targets of Th^{230}, Th^{232}, U^{234}, U^{236}, U^{238}, Pu^{240}, Pu^{242}, Cm^{244}, Cm^{246}, and Cm^{248}. The single-neutron separation energies derived from these Q values have led to many improvements in the atomic mass table for very heavy elements.

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*Chemistry Division.

American Physical Society Meeting
Seattle, 31 August—2 September 1967

PERTURBATION OF THE PORTER-THOMAS DISTRIBUTION BY INTERACTIONS WHICH ARE ODD UNDER TIME REVERSAL

Norbert Rosenzweig

Bull. Am. Phys. Soc. 12, 894-895 (August 1967)

If the nuclear Hamiltonian is not exactly time-reversal invariant, then the statistical properties of the spectrum will be perturbed. We have calculated the perturbation of the Porter-Thomas distribution of widths on the basis of the random-matrix model,[1] on the assumption that there is a small residual interaction which is odd under time reversal. The principles are similar to those employed in the treatment of atomic spectra with approximate constants of the motion.[2] The predicted effects are of noteworthy magnitudes. For example, if the ratio of the matrix elements $\langle (H^{odd})^2/(H^{even})^2 \rangle$ has a magnitude of 0.01, the resulting distribution lies about midway between the Porter-Thomas and exponential distributions, and the relative variance is reduced from the Porter-Thomas value of 2.0 to 1.5.

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[1] For an introduction to and review of the random-matrix model, see Statistical Theories of Spectra, edited by C. E. Porter (Academic Press, Inc., New York, 1965).

[2] N. Rosenzweig and C. E. Porter, Phys. Rev. 120, 1698 (1960).

International Conference on Nuclear Structure
Tokyo, 7—13 September 1967

PERTURBATIVE METHODS IN THE THEORY OF NUCLEAR LEVEL DENSITIES

P. B. Kahn* and N. Rosenzweig

Contributions, p. 353

The aim is to increase our understanding of the way in which nuclear level densities depend on the details of the arrangement of the independent-particle levels by considering specialized level schemes for which accurate solutions can be obtained in a closed form. It was shown[1] recently that if the energy level scheme is strictly periodic, then the dependence on the structure occurs only through an additive correction to the excitation energy in the standard formulas. On the other hand, the modifications produced by a non-periodic perturbation of a periodic scheme will usually have an altogether different character, which we shall illustrate with the help of the uniform scheme shown in Fig. 10.

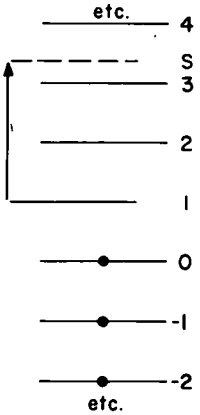

Fig. 10. Uniform model.

Let us see how the level density is affected by shifting a single-particle level from position 1 to an arbitrary position s shown above the 0 level. Let $\rho(Q, s)$ denote the level density at excitation energy Q and consider three results which are all obtained by an exact solution of the saddle-point problem. The first is

$$\rho(Q, 1) = \frac{\exp \pi \sqrt{\frac{2}{3}(Q - \frac{1}{24})}}{\sqrt{48\,(Q - \frac{1}{24})}}.$$

This is a well known result[1] which will play a reference role. The second is

*State University of New York, Stony Brook, N. Y.

[1] P. B. Kahn and N. Rosenzweig, Phys. Letters 22, 307 (1966).

$$\rho(Q,\infty) = \tfrac{1}{2}\rho(Q, 1).$$

Thus, the removal of a level leads to an energy-independent correction of a factor $\frac{1}{2}$ which has a simple interpretation in terms of a Fermi gas at zero temperature. Thirdly, for arbitrary s the solution does not have a simple form; the ratio $\rho(Q, s)/\rho(Q, 1)$ as a function of s for Q = 20 is plotted in Fig. 11. A comparison of the continuous curve (which represents the solution of the saddle-point problem) with the exact ratios (obtained by counting) indicates the adequacy of the analytical methods.

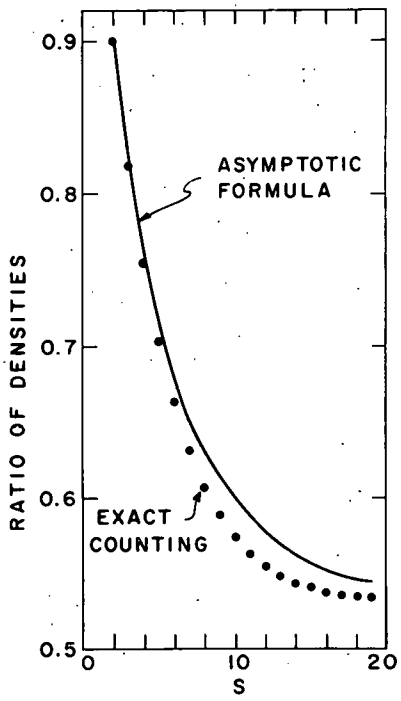

Fig. 11. Effect of shifting one level.

The calculations can be extended to two kinds of particles with angular momentum in arbitrary periodic schemes which are subjected to nonperiodic perturbations.

EXTENSION OF M3 MATRIX ELEMENTS

Dieter Kurath

Contributions, p. 371

Quadrupole deformation, which was introduced to account for enhanced E2 transitions, can also have appreciable effects on the matrix elements of other multipole operators. One of these is the M3 operator which aside from a weaker orbital contribution is proportional to the sum over nucleons

$$\sum_k \mu(k)\,[\,Y^2(k)x\sigma(k)]^{I=3}.$$

Experimental information on M3 moments is found in measurements[1] of the magnetic form factors by elastic scattering of electrons from Li^7, Be^9, B^{10}, and B^{11}. There are some difficulties in interpreting these results[1,2] in terms of purely 1p-shell configurations.

A microscopic picture of the effect of deformation in light nuclei is obtained with the technique of augmenting the deformed Nilsson orbitals by including $\Delta N=2$ admixtures. For the 1p orbitals this means including 2p and 1f admixtures with sufficient strength to fit the observed E2 properties of the ground-state bands. For a prolate field, the qualitative effect of the $\Delta N=2$ admixtures is to make the prolate orbitals more prolate and the oblate orbitals less oblate. The filled orbitals therefore provide a more deformed core which contributes strongly to E2 enhancement.

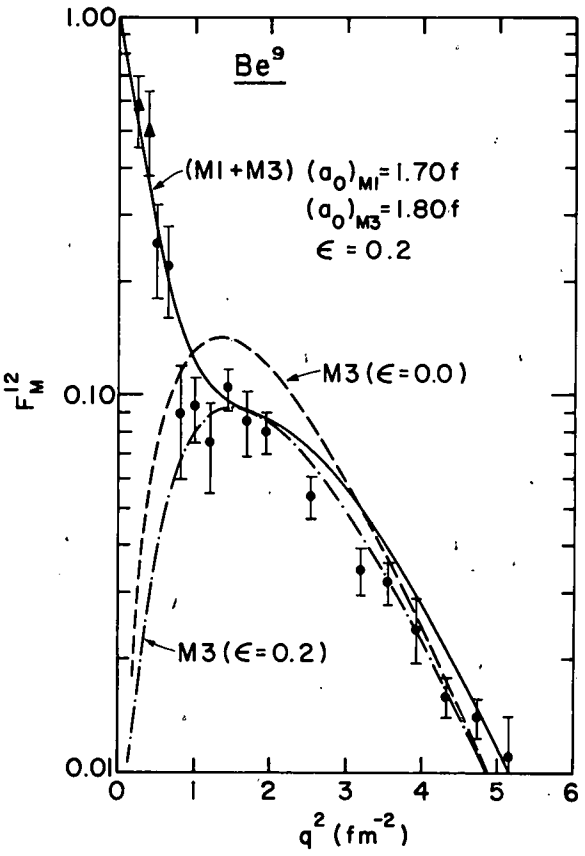

Fig. 12. Form factor for Be^9.

In the case of the M3 operator, the contributions from like nucleons in the same orbital with spins pointing in opposite ways tend to cancel each other. Therefore, the core contribution is overshadowed by that of the odd nucleon and the result need not be similar to the E2 case. For Li^7 and B^{11} the odd nucleon is in an orbital of shape similar to the core, so the effect

[1] R. E. Rand, R. Frosch, and M. R. Yearian, Phys. Rev. 144, 859 (1966).

[2] T. A. Griffy and D. U. L. Yu, Phys. Rev. 139, B880 (1965).

of $\Delta N=2$ admixture is to provide M3 enhancement. However, Be^9 has a prolate core with an odd loosely-bound neutron in an oblate orbital. Therefore, the $\Delta N=2$ admixture provides E2 enhancement but M3 suppression. A similar effect is calculated for B^{10}.

The magnetic form factor for Be^9 is given in Fig. 12 as a function of the square of momentum transfer. The solid curve is the calculated value including the $\Delta N=2$ admixtures determined by E2 properties. The broken curves give the M3 contributions with and without admixtures. The effect seems to be needed.

GIANT DIPOLE RESONANCE IN Ar^{36}

L. Meyer-Schützmeister, D. S. Gemmell, R. C. Bearse, N. G. Puttaswamy, and R. E. Segel

Contributions, p. 385

The radiative capture of protons by Cl^{35} has been studied over the range $4 \leq E_p \leq 12$ MeV which covers the excitation region $12.4 \leq E_x \leq 19.2$ MeV in Ar^{36}. The experiments were performed in a

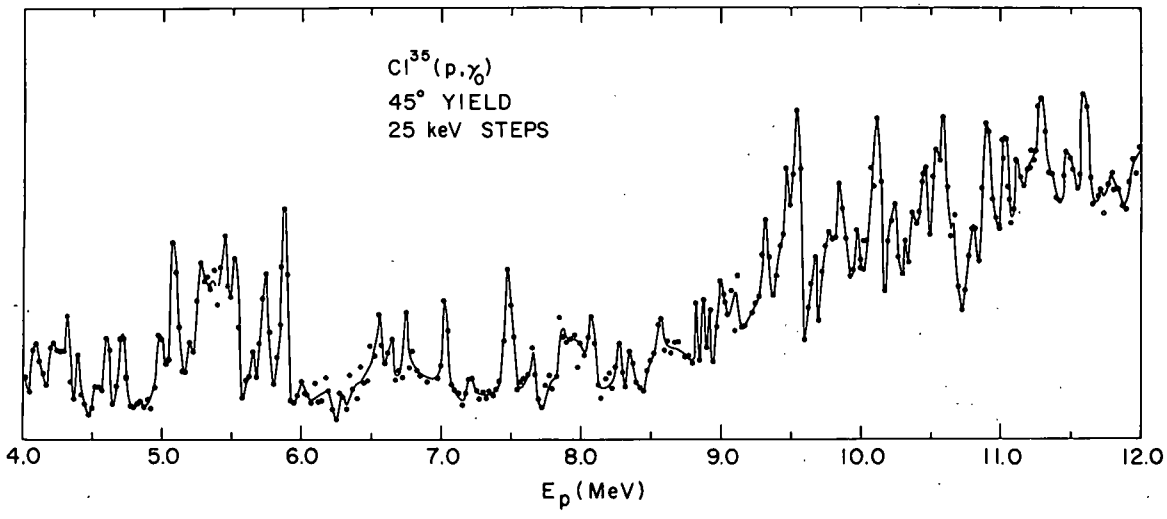

Fig. 13. Yield curve, taken in 25-keV steps, for the $Cl^{35}(p,\gamma_0)Ar^{36}$ reaction.

manner similar to the others previously reported by the Argonne group.[1] Figure 13 shows a yield curve taken in 25-keV steps with a 1.5 mg/cm^2 $BaCl_2$ target; the Cl^{35} enrichment was about 99%. Most of the yield curve in Fig. 13 was taken at 45° to the incident beam, but the portion from 7.0 to 8.5 MeV was taken at 90° and an adjustment was made for the gamma-ray angular distribution. The yield curve is dominated by the onset of the giant resonance but, because of the comparatively low Q and also because the giant resonance appears to come at a higher energy in Ar^{36} than in neighboring nuclides, the beam energy was not high enough to reach the peak of the giant resonance. There is a great deal of fine structure but, at least in the giant-resonance region, the direct-interaction component contributes most of the cross section.

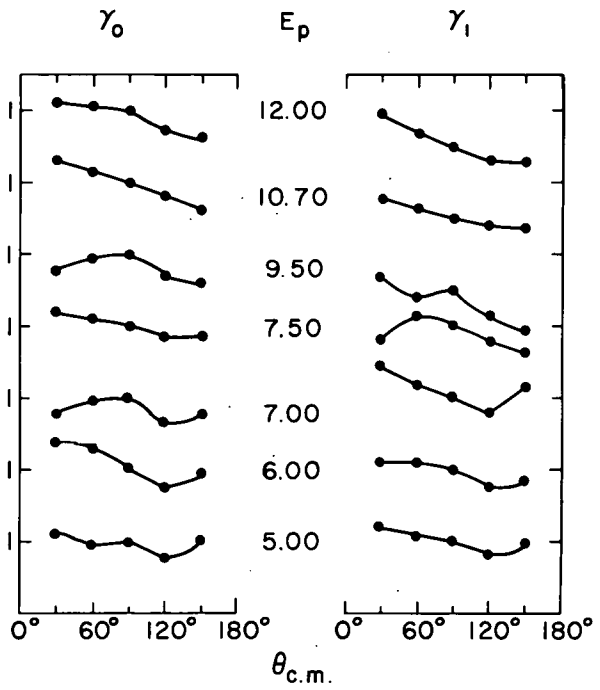

Fig. 14. Typical angular distributions observed for $Cl^{35}(p,\gamma)Ar^{36}, Ar^{36*}$.

The γ_1 yield curve is qualitatively similar to that obtained for γ_0 except that the γ_1 yield is still rising at the high-energy end. This indicates that the peak of the γ_1 giant resonance has not yet been reached. The integrated (γ, p_0) yield, obtained by detailed balance, is 0.060 MeV-b which is about 11% of the dipole sum—taken as $(2\pi^2 e^2 \hbar/Mc)(NZ/A)$.

Angular distributions were taken every 100 keV over the entire range; some samples are shown in Fig. 14. The

[1] R. G. Allas, S. S. Hanna, Luise Meyer-Schützmeister, and R. E. Segel, Nucl. Phys. 58, 122 (1964); P. P. Singh, R. E. Segel, L. Meyer-Schützmeister, S. S. Hanna, and R. G. Allas, ibid. 65, 577 (1965); R. E. Segel, Z. Vager, L. Meyer-Schützmeister, P. P. Singh, and R. G. Allas, ibid. A93, 31 (1967).

angular distributions show marked variations below the giant-resonance region but then settle down to the usual near-invariance at higher energy. The greater yield in the forward direction, indicative of E1-E2 interference, is quite marked.

AN ATTEMPT TO TEST THE RANDOM-MATRIX MODEL

J. E. Monahan and Norbert Rosenzweig

Contributions, p. 354

Although the standard theory of random matrices[1] based on Wigner's Gaussian ensemble has been very successful, the number of quantitative tests of the model have been rather limited,[2] and we consider it important to continue the consideration of statistics aimed at the detection of small deviations from the standard theory. We have calculated the distribution of a statistic Q_N which is a measure of the deviation between the ensemble average of the distribution function of the spacing, viz., the Gaudin-Mehta function $F(t)$,[3] and the empirical distribution function $F_N(t)$ based on N successive nearest-neighbor spacings. More precisely,

$$Q_N \equiv \int_0^\infty [F_N(t) - F(t)]^2 \, dt \, .$$

An examination of a random sample of 180 real symmetric matrices of dimension 100 from the Gaussian ensemble shows that the probability density of NQ depends very little on N and has a shape approximated by the histogram of Fig. 15. For a particular sequence

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[1] Statistical Theories of Spectra, edited by C. E. Porter (Academic Press, Inc., New York, 1965).

[2] F. J. Dyson and M. L. Mehta, J. Math. Phys. 4, 701 (1963).

[3] M. L. Mehta, Nucl. Phys. 18, 395 (1960); M. Gaudin, Nucl. Phys. 25, 447 (1961).

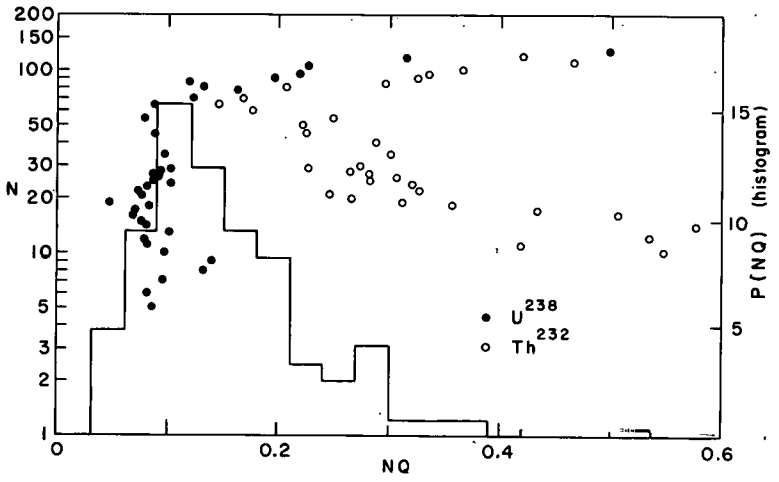

Fig. 15. Comparison between theory and experiment.

of empirical energy levels, NQ has a definite value, and a comparison between theory and experiment is made by noting whether the experimental value lies within an acceptable range of the most probable value 0.1.

We have formed all the sequences starting with the first levels for the observed[4] spectra of U^{239} and Th^{233} and the results are also shown in Fig. 15. The values for U^{239} (black dots) are in good agreement up to N = 70. On the other hand, for Th^{233} (open circles) theoretical and experimental results are incompatible. Our conclusions are similar to those of Ref. 2.

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[4] J. B. Garg, J. Rainwater, J. S. Petersen, and W. W. Havens, Jr., Phys. Rev. 134, B985 (1964).

STUDY OF THE (d,p) REACTION IN THE 1p SHELL

G. C. Morrison, J. P. Schiffer, R. H. Siemssen,* and B. Zeidman

Contributions, p. 259

This research was already reported in an earlier issue of the Physics Division Summary Report [ANL-7355, p. 35].

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GAMMA DECAY OF THE TWO LOWEST $T=\frac{3}{2}$ STATES IN Al^{25}

G. C. Morrison, D. Youngblood,* R. C. Bearse, and R. E. Segel

Contributions, p. 143

We have previously shown[1] how proton capture can be a good method for locating low-lying $T=\frac{3}{2}$ states in $T_z = -\frac{1}{2}$ nuclei. Such states may stand out in proton-capture yield curves since the gamma decay to the lower $T=\frac{1}{2}$ states is not forbidden and, in fact, can be especially strong because of the simple configurations that are characteristic of low-lying analog states. Proton capture to these states by a T=0 target is, of course, T forbidden. Consequently, the states will be much narrower than their $T_<$ neighbors but, unless isotopic-spin conservation inhibits the protons by a factor greater than about 10^4, the area under a capture resonance will still be proportional to the radiation width. Thus, one seeks strong, narrow capture resonances; and such a resonance was indeed found[1] for the lowest $T=\frac{3}{2}$ state in P^{29}.

Figure 16 shows a portion of the Al^{25} yield curve for the $Mg^{24}(p,\gamma)$ reaction. Since the Al^{25} positron activity was counted (between bursts of a mechanically chopped beam), the yield curve represents the sum of the transitions to the five bound states in Al^{25}. The two strong, narrow (< 3.5 keV wide) resonances represent Al^{25} states at

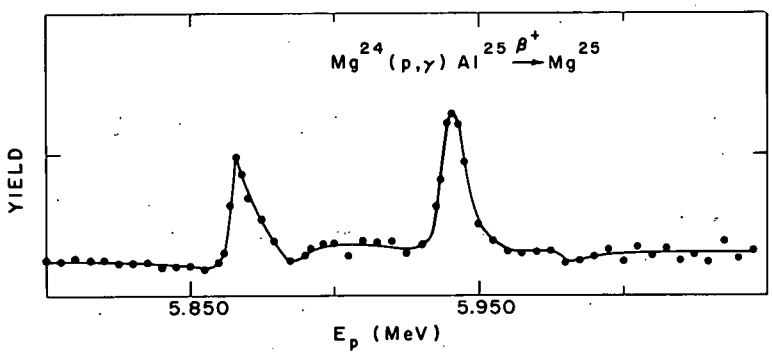

Fig. 16. Yield curve for the $Mg^{24}(p,\gamma)Al^{25}$ reaction. The resonances correspond to the two lowest $T=\frac{3}{2}$ states in Al^{25}.

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* Present address: The Cyclotron Institute, Texas A & M University, College Station, Texas.

[1] D. H. Youngblood, G. C. Morrison, and R. E. Segel, Phys. Letters 22, 625 (1966).

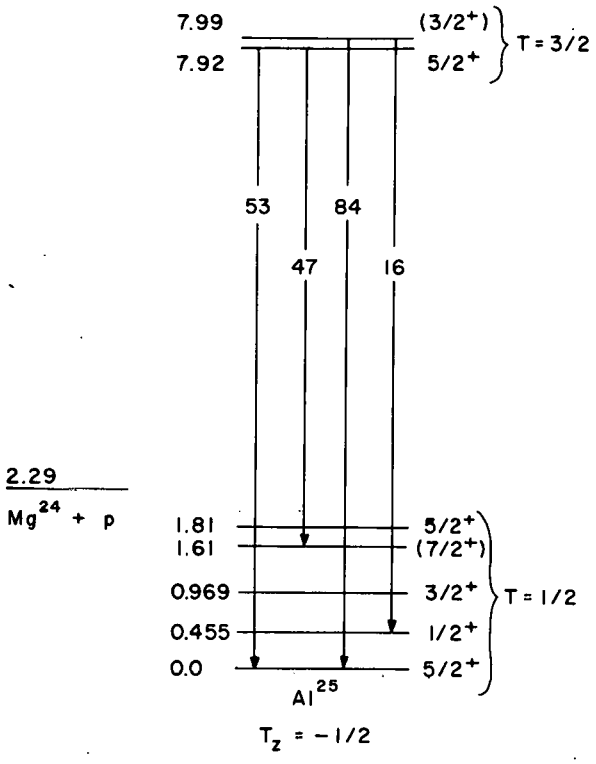

Fig. 17. Gamma-ray decay of the two lowest $T=\frac{3}{2}$ states in Al^{25}.

7.916 ± 0.012 and 7.985 ± 0.012 MeV. A 700-keV interval was searched and no other strong resonances were found. These are the two lowest $T=\frac{3}{2}$ states in Al^{25}. Their integrated yields, $(2J+1)\Gamma_p\Gamma_\gamma/\Gamma$, approximate 1.0 and 1.5 eV, respectively. In Na^{25}, their analogs are separated by 90 keV.

Gamma-ray spectra were taken on the two resonances with a lithium-drifted germanium detector. Spectra were also taken off-resonance, where no strong lines were seen. The decay scheme for these two states is shown in Fig. 17. The decay of the lower state is consistent with the $\frac{5}{2}^+$ expected from the Na^{25} analog. The decay of the upper state indicates that $\frac{3}{2}$ is the most likely assignment.

PRECISE COULOMB ENERGIES OF ISOBARIC PAIRS FROM THE (He^3, p) REACTION

J. A. Nolen, Jr., J. P. Schiffer, and N. Williams

Contributions, p. 118

When a singlet deuteron is transferred via the (He^3, p) reaction, it populates the isobaric analogs of states formed by a (t, p) reaction on the same target. The angular distribution of the (t, p) L=0 transition between ground states of even-even nuclei is very characteristic in shape; and as a result of two-particle correlations in the nuclear

ground states, it is also enhanced in magnitude. The (He^3, p) transition to the analog of the 0^+ ground state shares these properties. Thus the (He^3, p) reaction can be used to determine Coulomb displacement energies of even-even nuclei. In the present work analog states were located to ±15 keV absolute energy. A He^3 beam between 12 and 18 MeV was provided by the Argonne tandem Van de Graaff. The protons were analyzed by a magnetic spectrograph, which was set at at least two scattering angles for each isotope. The Coulomb displacement energies (Fig. 18, top) have been determined for $Ca^{42,44,46,48,50}$, and exposures have been made for Mg^{28}, Si^{32}, $Cr^{52,54,56}$, and $Ni^{60,62,64,66}$.

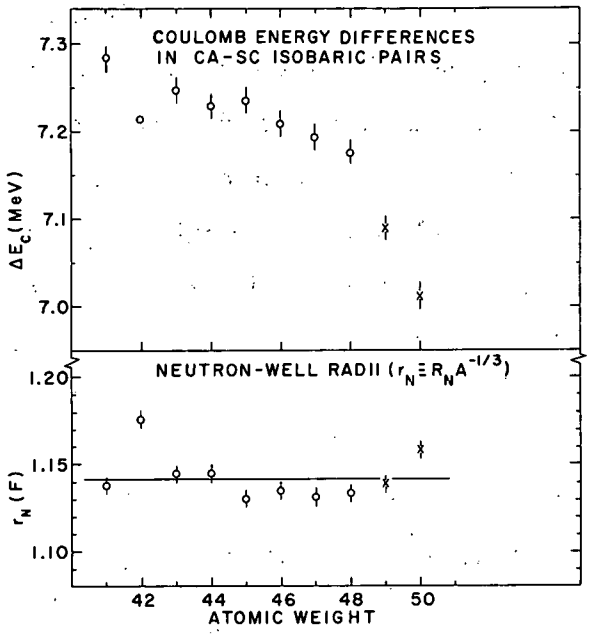

Fig. 18. Results for Ca. The plotted values of r_n fitted the empirical B_n and ΔE_c if $a_n = 0.65$ F, $r_{so} = r_n$, $a_{so} = a_n$, and $V_{so} = 10$ MeV.

We are attempting to interpret these Coulomb energies on the basis of a nuclear model. Since an analog state is formed by charge exchange of neutrons in the neutron excess, we assume that the Coulomb displacement energy of a given nucleus is determined by its charge distribution and the radial distribution of its neutron excess. We represent the latter by single-particle wave functions in a Woods-Saxon potential well. Empirical parameters for the charge distribution of the core can be taken from electron scattering or from work with muonic x rays. Calculation has shown that the wave functions of the protons in the analog state have a very high degree of overlap with the neutrons in the neutron excess. Therefore, the Coulomb displacement energy provides a probe of the neutron wave functions.

We have applied this model to the Coulomb displacement energies of the Ca isotopes. For a choice of diffuseness a_n of the Woods-Saxon well and of the spin-orbit parameters r_{so}, a_{so}, V_{so}, it was possible to find a combination of r_n and V_n which fitted the empirical binding energies B_n and Coulomb energy differences ΔE_c. Figure 18 (bottom) indicates the r_n found for each isotope of Ca. Since r_n is approximately constant, the neutron well radius varies as $A^{1/3}$.

THE LEVEL STRUCTURE OF Sc^{48}

H. Ohnuma, J. R. Erskine, J. A. Nolen, Jr., J. P. Schiffer, and N. Williams

Contributions, p. 119

We have studied the $Ca^{48}(He^3,t)Sc^{48}$ reaction with the 15-MeV He^3 beam from the Argonne tandem Van de Graaff. Triton spectra at 7°, 20° (Fig. 19), and 50° were obtained with a broad-range magnetic spectrograph. In the recent work of Schwartz,[1] the low-lying

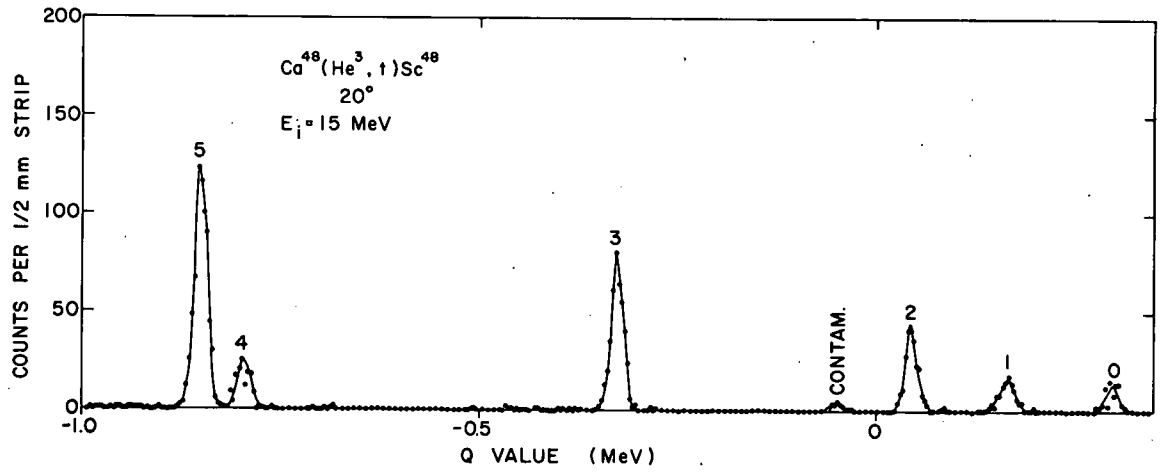

Fig. 19. Spectrum of tritons observed at 20° from the $Ca^{48}(He^3,t)Sc^{48}$ reaction at a bombarding energy of 15 MeV.

[1] J. J. Schwartz, Phys. Rev. Letters 18, 174 (1967).

states in Sc^{48} were assigned to the $(\pi f_{7/2})^{1}(\nu f_{7/2})^{-1}$ configuration on the basis of $\ell=3$ transitions seen in $Ti^{49}(t,\alpha)Sc^{48}$. With this information and the available information on Sc^{42} he calculated the energies of all levels of the $(\pi f_{7/2})^{1}(\nu f_{7/2})^{\pm 1}$ configuration. The 2^+ state in Sc^{48} was predicted to lie at 0.580 MeV, but no such group was observed. On the other hand Ball[2] had done similar calculations and had suggested that the 2^+ state in Sc^{48} might be much higher (1.19 MeV) and that in Sc^{42} the 3^+ and 5^+ states would be much higher than the 2^+ state. Since it is possible that the states with spins ≤ 2 may not be observed in $1f_{7/2}$ proton pickup reactions[2] on Ti^{49}, and since reactions leading to Sc^{48} had not been studied with high resolution, the $Ca^{48}(He^3,t)Sc^{48}$ reaction was chosen for the present experiment. We observed the Sc^{48} ground state and excited states at 132, 256, 625, 1097, and 1150 ± 3 keV. There was no indication of a new level at low excitation energy, but the 1097-keV level had not been previously seen.

TABLE I. Energies (MeV) of the $(\pi f_{7/2})^{1}(\nu f_{7/2})^{-1}$ configuration. Known energy levels which were assumed to have a given spin J and were used in the least-squares fit are not underlined. The underlined energies correspond to predictions, on the basis of this fit, for the other states of the configuration. Calculations with two sets of assumptions are given.

J	0	1	2	3	4	5	6	7
Sc^{48}	6.68	3.32	1.13	0.63	0.25	0.13	0.00	1.34
Sc^{42}	0.00	0.61	1.51	1.87	2.75	1.95	3.19	0.31
Sc^{48}	6.68	3.18	1.15	0.63	0.25	0.13	0.00	1.09
Sc^{42}	0.00	0.61	1.51	1.59	2.45	1.63	2.85	0.03

In order to see whether this level could be a candidate for the 2^+ state, we made a least-squares fit to the observed energies with reasonable assumptions based on available evidence. The results listed in Table I are very similar to those obtained by Ball.[2] It is likely that either the 1.097- or 1.150-MeV level in Sc^{48} is the 2^+ state and the 1.150-MeV level is favored from the $(p,n\gamma)$ experiment.[3] The 3^+

[2] J. B. Ball, Bull. Am. Phys. Soc. 11, 349 (1966).

[3] C. Chasman, K. W. Jones, and R. A. Ristinen, Phys. Rev. 140, B212 (1965).

and 5^+ levels in Sc^{42} are not necessarily as high as predicted by Ball. Preliminary measurements of p-γ coincidences[4] in the $Ca^{40}(He^3,p\gamma)Sc^{42}$ reaction seem to suggest that there are two or three levels around 1500 keV in Sc^{42}, all decaying to the 611-keV state. Our conclusion is that the 2^+ state of the $(\pi f_{7/2})^1(\nu f_{7/2})^{-1}$ configuration in Sc^{48} seems to lie above 1 MeV and not at about 600 keV; probable candidates are the 1.097-MeV level and the 1.150-MeV level. The 7^+ state may be one of these two levels, or a level around 1.4 MeV.

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[4] D. Cline (private communication); D. S. Gemmell, L. Meyer-Schützmeister, N. G. Puttaswamy, and H. Ohnuma (unpublished data).

PERTURBATION OF THE PORTER-THOMAS DISTRIBUTION BY INTERACTIONS WHICH ARE ODD UNDER TIME REVERSAL

Norbert Rosenzweig

Contributions, p. 340

In view of the notion that the nuclear Hamiltonian H may not be exactly invariant under time reversal, we report on a calculation of the perturbation of the Porter-Thomas[1] distribution which would be produced by a small odd part in the Hamiltonian.[2] Let H be constructed in a basis in which the even part is real and symmetric, and the odd part is purely imaginary and antisymmetric, and consider the distribution of N×N matrices:

$$F_N(\epsilon^2,H) \propto \exp\left[-\frac{\mathrm{Tr}(H^{\mathrm{even}})^2}{1-\epsilon^2}+\frac{\mathrm{Tr}(H^{\mathrm{odd}})^2}{\epsilon^2}\right].$$

The distribution of the width X is defined by

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[1] C. E. Porter and R. C. Thomas, Phys. Rev. 104, 483 (1956).

[2] For a recent review see E. P. Wigner, SIAM Review 9, 1 (1967).

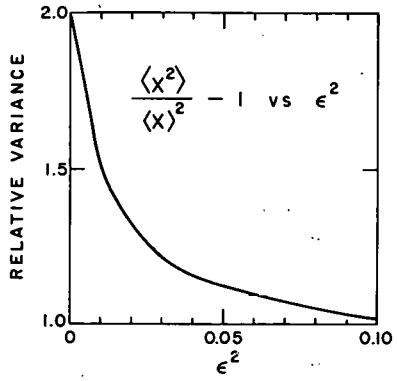

Fig. 20. Relative variance vs ϵ^2.

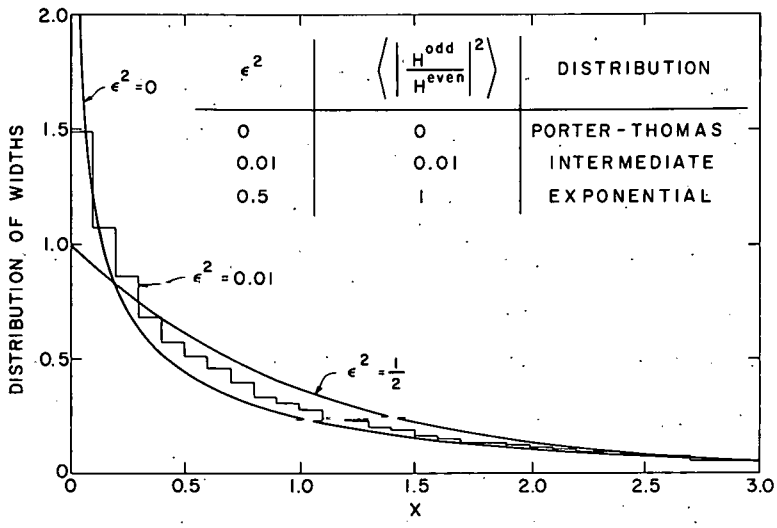

Fig. 21. Width distributions.

$$P_N(\epsilon^2, X) = \int \delta(X - NU^*_{11} U_{11}) F_N(\epsilon^2, H) dV_H ,$$

where U_{11} denotes an element of the unitary matrix which diagonalizes H and dV_H the volume element in the matrix space. For large N, the values of $\epsilon^2 = 0$ and $\frac{1}{2}$ correspond to the Porter-Thomas and exponential distributions respectively.[3] The transition between these extremes was studied with the help of a Monte-Carlo calculation in which the dependence of $P_N(\epsilon^2, X)$ on both ϵ^2 and N was examined.

The curve of Fig. 20 represents the relative variance of the width distribution as a function of ϵ^2, extrapolated to $N = \infty$. It is noteworthy how rapidly the relative variance decreases from the Porter-Thomas value of 2. The histogram of Fig. 21 represents the theoretical distribution corresponding to $\epsilon^2 = 0.01$ and N = 50, and is plotted together with the Porter-Thomas and exponential distributions.

We attempt a preliminary evaluation of the relative magnitude of the odd part of the nuclear Hamiltonian by comparing (Table II) the above results with some recent experimental determinations

[3] N. Ullah, J. Math. Phys. 4, 1279 (1963).

TABLE II

Reference	Reaction	Type	Relative variance	Inferred ϵ^2	Max. $\left\langle \left(\frac{H^{odd}}{H^{even}} \right)^2 \right\rangle$
a	$Au^{197}(n,\gamma)$	neutron	1.9 ± 0.2	0.003 ± 0.003	0.003
b	$Pt^{196}(n,\gamma)$	radiation	1.6 ± 0.4	0.01 ± 0.01	0.01

[a] J. Julien, S. de Barros, G. Bianchi, C. Corge, V. D. Huynh, G. le Poittevin, J. Morgenstern, F. Netter, C. Samour, and R. Vastel, Nucl. Phys. 76, 391 (1966).

[b] H. E. Jackson, J. Julien, C. Samour, A. Bloch, C. Lopata, J. Morgenstern, H. Mann, and G. E. Thomas, Phys. Rev. Letters 17, 656 (1966).

of the relative variance of the distributions of neutron width and partial radiation width.

DIRECT AND COMPOUND NUCLEAR REACTIONS—EXPERIMENTAL

J. P. Schiffer

LIFETIME OF THE 1.059-MeV STATE IN Al^{26}

R. E. Segel, D. H. Youngblood,* R. C. Bearse, A. E. Blaugrund,† and N. Williams

Contributions, p. 197

Mg^{24} targets, about 20 $\mu g/cm^2$ thick, evaporated onto copper backings, were bombarded with 3.9-MeV He^3 particles. Silicon counters detected the protons from the (He^3,p) reaction, thus defining the Al^{26} state being fed and the direction of the recoil. Gamma rays in coincidence with each of two proton counters were detected by a 9-cc

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Ge(Li) detector whose energy resolution width is about 3.0 keV. One proton counter was set at an angle corresponding to nearly the maximum Doppler shift while the other was placed to select a much smaller one. The measured shift is the difference between the energies of the coincident gamma rays. Shifts were measured for the 0.830-MeV gamma ray from the 1.059-MeV state and for the 0.418-MeV ground-state gamma ray from the second excited state. The latter served as a check since the lifetime of the second excited state is known (1.23×10^{-9} sec) and is much longer than the time for the recoils to come to rest.

The shift in the 0.830-MeV gamma ray was 4.55 ± 0.10 keV when the recoils were stopped in copper or nickel. In comparison, the full shift (measured for recoils into vacuum) agreed with the calculated value of 4.90 keV. No shift was observed for the 0.418-MeV gamma ray when the recoils were stopped in copper. With the aid of the stopping-power theory of Lindhard, Scharff, and Schiott[1] a lifetime of $(3.1^{+1.1}_{-0.8}) \times 10^{-14}$ sec was determined for the 1.059-MeV state.

An M1 transition contains a spin and an orbital component, and Kurath[2] has shown how the spin component can be computed from the analogous Gamow-Teller β decay. Kurath[2] has also shown that the amplitude of the orbital component is reduced by a factor of about 5 relative to the spin component. Therefore the transition speed can be estimated directly from the analogous β decay; the estimate can be expected to be most accurate where the spin component is fast, as evidenced by a low log ft for the β decay. The large orbital contribution required so that the orbital

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[1] J. Lindhard, M. Scharff, and H. E. Schiott, Kgl. Danske Videnskab. Selskab, Mat.-Fys. Medd. 33, 14 (1963).

[2] D. Kurath, quoted by A. E. Blaugrund, D. H. Youngblood, G. C. Morrison, and R. E. Segel, Phys. Rev. (in press).

component contributes significantly to the M1 speed in spite of the inhibiting factor and the low log ft (3.84) indicates that the $(d_{5/2})^{-2}$ configuration is a major component in the wave function of the first and third excited states in Al^{26} since s nucleons can make no orbital contribution. A similar situation has been examined[3] in P^{30} where, although some orbital contribution is indicated, its absolute value is considerably smaller than in Al^{26} so that in P^{30} the valence nucleons may well be largely in s states.

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[3] E. F. Kennedy, D. H. Youngblood, and A. E. Blaugrund, Phys. Rev. (in press).

NUCLEON-TRANSFER REACTIONS ON Mo ISOTOPES

J. L. Yntema and H. Ohnuma

Contributions, p. 307

Single-nucleon transfer reactions on Mo^{92} and Mo^{94} have been studied with 23-MeV deuterons and 35-MeV He^3 particles. The results (Fig. 22) indicate a notable j dependence for the $\ell=1$ transitions in the (d,He^3) reaction at forward angles—in agreement with predictions from distorted-wave theory. No j dependence is observed nor predicted for the (d,t) reaction in the same angular range.

The values of J and the spectroscopic factors are summarized in Table III. The sum of the $g_{9/2}$ and $p_{1/2}$ strengths of the $Mo^{92}(d,He^3)Nb^{91}$ reaction is 3.7 which, within errors, agrees with the sum-rule limit 4. This result indicates that the ground-state proton configuration of Mo^{92} is 65% $(p_{1/2})^2(g_{9/2})^2$ + 35% $(g_{9/2})^4$. This wave function agrees well with the shell-model predictions.[1] Predicted wave

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[1] N. Auerbach and I. Talmi, Nucl. Phys. 64, 458 (1965); S. Cohen, R. D. Lawson, and M. H. Macfarlane, Phys. Letters 10, 195 (1964); K. H. Bhatt and J. B. Ball, Nucl. Phys. 63, 286 (1965); J. Vervier, Nucl. Phys. 75, 17 (1966).

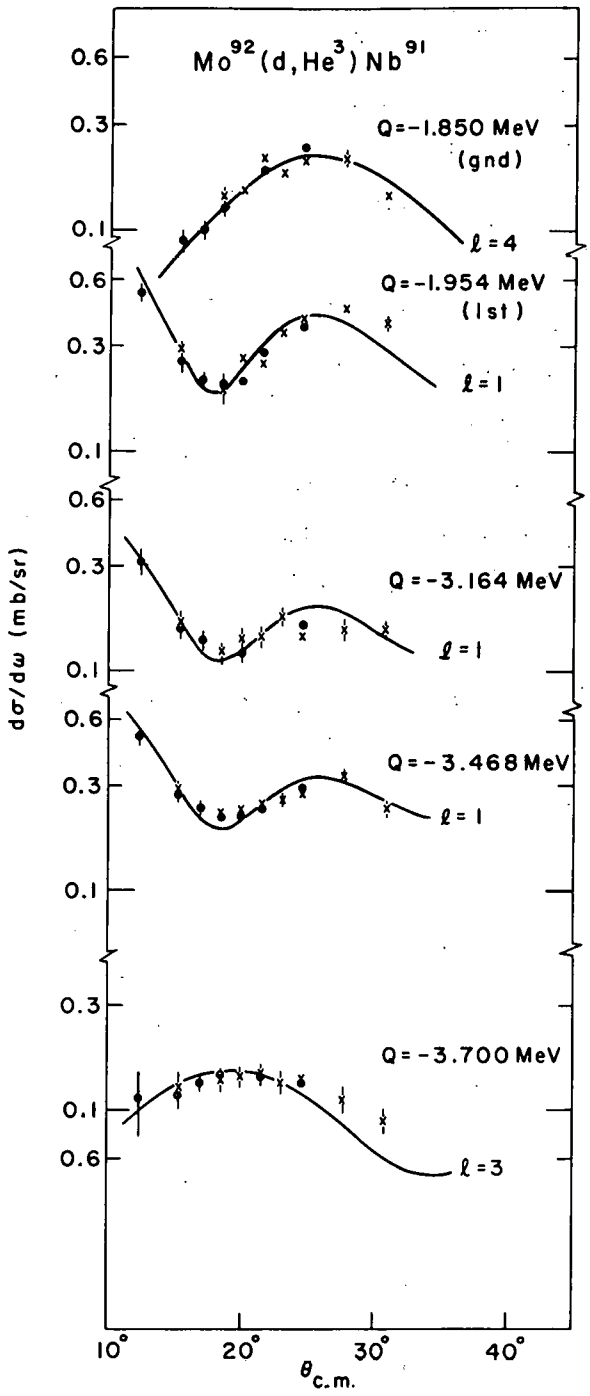

Fig. 22. Angular distributions for the $Mo^{92}(d,He^3)Nb^{91}$ reaction. Solid lines show the DWBA calculations.

TABLE III

$E_{exc.}$	j	c^2S
	$Mo^{92}(d,He^3)Nb^{91}$	
0	$\frac{9}{2}^+$	2.4
0.104	$\frac{1}{2}^-$	1.3
1.314	$\frac{3}{2}^-$	1.1
1.618	$\frac{3}{2}^-$	2.2
1.850	$\frac{5}{2}^-$	3.4
	$Mo^{92}(He^3,d)Tc^{93}$	
0	$\frac{9}{2}^+$	0.6
0.385	$\frac{1}{2}^-$	0.3
	$Mo^{92}(d,t)Mo^{91}$	
0	$\frac{9}{2}^+$	9.2
0.676	$\frac{1}{2}^-$	1.8
1.199	$\frac{3}{2}^-$	2.3
1.409	$(\frac{5}{2})$	0.2
	$Mo^{94}(d,t)Mo^{93}$	
0	$\frac{5}{2}^-$	0.9
0.958		0.1
1.50		
2.447	$(\frac{9}{2})^+$	3.4
2.568	$(\ )^-$	1.0
3.256	$(\ )^-$	0.8

functions also give $c^2S = 0.35$ for the $p_{1/2}$ transition and $c^2S = 0.7$ for the $g_{9/2}$ transition in the $Mo^{92}(He^3,d)$ reaction, in good agreement with the experiments. From the spectroscopic factors of the $Mo^{92}(d,t)Mo^{91}$ reaction, it is clear that little if any core excitation is present in the Mo^{92} ground state.

The excited states of Nb^{91} at 1.314 and 1.618 MeV have a $\frac{3}{2}^-$ spin. Unresolved $\ell = 2 + \ell = 4$ transitions at 1.5 MeV and a strong $\ell=4$ transition in the vicinity of the $\frac{21}{2}^+$ metastable state are observed in Mo^{93}. Shell-model calculations predict[1] the existence of a $\frac{9}{2}^+$ state very close to the $\frac{21}{2}^+$ state. The energy spectrum of Mo^{91} is very similar to that observed in the $Zr^{90}(p,d)Zr^{89}$ reaction.[2]

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[2] J. B. Ball and C. B. Fulmer, Bull. Am. Phys. Soc. 12, 526 (1967).

1967 International Congress on Magnetism
Boston, 11—16 September 1967

TEMPERATURE DEPENDENCE OF ISOMER SHIFT AND HYPERFINE FIELD NEAR THE CURIE POINT IN IRON

Richard S. Preston

Current theories of critical-point phenomena predict that in the region below the Curie temperature T_c, the spontaneous magnetization M of a ferromagnet varies with temperature T according to $M/M_0 = h(1 - T/T_c)^{\beta}$ for $T \rightarrow T_c$. Values of h and β have been calculated for theoretical models, and β is of special interest because of the possibility that it is a simple number such as $\frac{1}{3}$ or $\frac{1}{2}$. Measured values of β for various ferromagnets seem to cluster about these two values.

Pure iron is a favorable case for determining h and β by the Mössbauer effect since the hyperfine field should be closely proportional to M. However, previous results for iron[1] showed a rather sharp discontinuity in the isomer shift at T_c, and this is difficult to reconcile with the accepted opinion that the magnetic transition in iron is of higher than first order. If this were a first-order transition, then β would not be a meaningful parameter.

A more careful study of the Mössbauer effect in the vicinity of this transition is now being made. The temperature control has been further improved since the most recent results of this work were published[2] and the uncertainty in temperature during any run is now of the order of 0.03°C. It now appears that the jump in the isomer shift, although

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[1] R. S. Preston, S. S. Hanna, and J. Heberle, Phys. Rev. 128, 2207 (1962).

[2] Richard S. Preston, Phys. Rev. Letters 19, 75 (1967).

sharper than it seemed to be originally, is not really a discontinuity, but is in fact spread out over a temperature range of about $0.3^{\circ}C$.

When the values of h, T_c, and β are simultaneously adjusted for least-squares fits of the theoretical relation to the new data taken in two temperature ranges, the results are

$$\left.\begin{aligned}\beta &= 0.342 \pm 0.004\\ h &= 1.49 \pm 0.03\end{aligned}\right\} \quad \text{for } 0.99\, T_c \leq T \leq 0.999\, T,$$

and

$$\left.\begin{aligned}\beta &= 0.37 \pm 0.02\\ h &= 1.7 \pm 0.2\end{aligned}\right\} \quad \text{for } 0.999\, T_c \leq T \leq 0.9999\, T_c.$$

III. ABSTRACTS OF PAPERS ACCEPTED FOR PUBLICATION

PHOTOIONIZATION OF ETHANE, PROPANE, AND n-BUTANE WITH MASS ANALYSIS

William A. Chupka and Joseph Berkowitz

J. Chem. Phys. (October 1967)

Relative-photoionization-cross-section curves have been determined for parent and fragment ions of ethane, propane, and n-butane over the photon-energy range from the ionization potential to 14.0 eV. The data have been treated to give experimental breakdown curves which are in good qualitative and fair quantitative agreement with the predictions of the statistical theory of mass spectra. The results are also compared with data obtained by charge exchange, electron impact, and photoelectron energy analysis by other workers. Heats of formation of some ions have been obtained more accurately and the ionization potential of the C_2H_5 radical is confirmed to be 8.4 eV. Ion-pair formation of H^- is shown to occur at least for ethane and n-butane and very probably for propane.

PHOTOIONIZATION OF CH_3; HEAT OF FORMATION OF CH_2

W. A. Chupka and Chava Lifshitz

J. Chem. Phys. 47 (1 November 1967)

Methyl radicals produced by pyrolysis at various temperatures have been photoionized by photons in a 1.6-Å band width over the energy range 9.5—16.5 eV with mass-spectrometric detection. The curve of photoionization cross section for the parent ion shows that direct ionization predominates in the threshold region, and that the geometrical form of the positive ion in its ground state is very similar to that of the neutral radical. Hot bands and other vibrational features observed near threshold are only partly explained. The data are compared with absorption spectra and electron-impact curves. The ionization-efficiency curve for production of CH_2^+ from CH_3 is measured at several pyrolysis temperatures and the threshold for 0°K is determined to be 15.08 ± 0.03 eV. This yields the value 91.7 ± 1.0 kcal/mole for the heat of formation of the CH_2 free radical.

PHOTOIONIZATION OF THE CF_3 FREE RADICAL

Chava Lifshitz and William A. Chupka

J. Chem. Phys. (November 1967)

The photoionization-cross-section curve in the wavelength region 1420—860 Å was obtained for the CF_3 radical. The shape of the onset of the ionization-efficiency curve shows that the adiabatic ionization potential of the radical is much lower than the vertical one, and hence that the equilibrium configuration of the CF_3^+ ion is very different from that of the molecule. Autoionization probably accounts for some of the ionization near threshold. The ionization potential obtained was I. P. $(CF_3) = 9.25 \pm 0.04$ eV. The photoionization-efficiency curve for aniline was determined in the process of calibrating a nickel photoelectric detector.

HIGH-SENSITIVITY NEUTRON-CAPTURE GAMMA-RAY FACILITY

G. E. Thomas, D. E. Blatchley, and L. M. Bollinger

Nucl. Instr. Methods

An exceptionally sensitive experimental system for the measurement of neutron-capture gamma rays is described and the characteristics of the system are examined critically. The results of measurements on the gamma-ray spectra from neutron capture in ^{6}Li, ^{10}B, ^{12}C, ^{13}C, and ^{14}N are reported. Some of these data are used to derive an accurate calibration of the efficiency of the Ge(Li) gamma-ray spectrometer used in the measurements.

IV. PUBLICATIONS SINCE THE LAST REPORT

PAPERS AND BOOKS

THE ΛΛ-HYPERNUCLEUS $^{6}He_{\Lambda\Lambda}$
S. Ali* and A. R. Bodmer
Nuovo Cimento 50, 511-534 (1 August 1967)

COULOMB EXCITATION OF LOW-LYING EXCITED STATES IN Sc^{45}
A. E. Blaugrund, R. E. Holland, and F. J. Lynch
Phys. Rev. 159, 926-930 (20 July 1967)

LIFETIME OF THE 1.042-MeV STATE IN ^{18}F
A. E. Blaugrund, D. H. Youngblood, G. C. Morrison, and R. E. Segel
Phys. Rev. 158, 893-897 (20 June 1967)

DECAY OF Cu^{61} AND ENERGY LEVELS IN Ni^{61}
H. H. Bolotin and H. J. Fischbeck
Phys. Rev. 158, 1069-1072 (20 June 1967)

ENERGY LEVELS OF $_{68}Er^{166}$ AND $_{69}Tm^{166}$ (7.7 h) EXCITED IN THE DECAY OF $_{67}Ho^{166}$ (26.7 h), Ho^{166m} (1.2×10^{3} yr), AND $_{70}Yb^{166}$ (57 h)
S. B. Burson, P. F. A. Goudsmit,† and J. Konijn†
Phys. Rev. 158, 1161-1181 (20 June 1967)

CONTACT MAGNETIC-DIPOLE HYPERFINE STRUCTURE IN $3d^{N}4s^{2}$ ATOMS
W. J. Childs
Phys. Rev. 160, 9-10 (5 August 1967)

SPECTROSCOPIC FACTORS FOR THE 1p SHELL
S. Cohen and D. Kurath
Nucl. Phys. A101(1), 1-16 (1967)

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*IAEA, International Centre for Theoretical Physics, Trieste, Italy.

†Instituut voor Kernphysisch Onderzoek, Amsterdam, Holland.

SHELL MODEL OF THE NICKEL ISOTOPES
S. Cohen, R. D. Lawson, M. H. Macfarlane, S. P. Pandya, and Michitoshi Soga
Phys. Rev. 160, 903-915 (20 August 1967)

NEUTRON-PICKUP REACTIONS ON Mg^{26}
D. Dehnhard and J. L. Yntema
Phys. Rev. 160, 964-972 (20 August 1967)

ACCURATE CALCULATION OF THE REACTION MATRIX IN LIGHT NUCLEI
A. Kallio and B. D. Day
Phys. Letters 25B(2), 72-74 (7 August 1967)

LIFETIMES OF THE FIRST TWO LEVELS IN ^{30}P
E. F. Kennedy, D. H. Youngblood, and A. E. Blaugrund
Phys. Rev. 158, 897-900 (20 June 1967)

ENERGY LEVELS OF Fe^{59} FROM THE $Fe^{58}(d,p)Fe^{59}$ REACTION
E. D. Klema, L. L. Lee, Jr., and J. P. Schiffer
Phys. Rev. 161, 1134-1136 (20 September 1967)

M2 TRANSITIONS IN NUCLEI
Dieter Kurath and R. D. Lawson
Phys. Rev. 161, 915-924 (20 September 1967)

STRUCTURE OF PARTICLE-HOLE STATES IN Ba^{138}
G. C. Morrison, N. Williams, J. A. Nolen, Jr., and D. von Ehrenstein
Phys. Rev. Letters 19, 592-594 (4 September 1967)

THERMAL-NEUTRON-CAPTURE GAMMA-RAY STUDIES OF THE EXCITED STATES OF ODD-A HAFNIUM ISOTOPES
A. I. Namenson and H. H. Bolotin
Phys. Rev. 158, 1206-1213 (20 June 1967)

RESONANCE NEUTRON CAPTURE IN THE EVEN-A ISOTOPES OF TUNGSTEN
W. V. Prestwich and R. E. Coté
Phys. Rev. 160, 1038-1042 (20 August 1967)

PRECISION DETERMINATION OF THE C^{12}-C^{13} NEUTRON SEPARATION ENERGY
W. V. Prestwich, R. E. Coté, and G. E. Thomas
Phys. Rev. 161, 1080-1082 (20 September 1967)

INTERPRETATION OF MÖSSBAUER MEASUREMENTS IN TIN AND ANTIMONY

S. L. Ruby, G. M. Kalvius (Solid State Science), G. B. Beard,* and R. E. Snyder*

Phys. Rev. 159, 239-245 (10 July 1967)

TOTAL NEUTRON CROSS SECTION OF LANTHANUM

Hla Shwe, R. E. Coté, and W. V. Prestwich

Phys. Rev. 159, 1050-1056 (20 July 1967)

ABSOLUTE SPECTROSCOPIC FACTORS FOR (d,p) REACTIONS ON HEAVY DEFORMED NUCLEI

R. H. Siemssen and J. R. Erskine

Phys. Rev. Letters 19, 90-94 (10 July 1967)

LIFETIMES OF THE FIRST AND THE THIRD EXCITED STATES OF Ca^{41}

P. P. Singh, R. E. Segel, R. H. Siemssen, S. Baker, and A. E. Blaugrund

Phys. Rev. 158, 1063-1068 (20 June 1967)

ENERGY DEPENDENCE OF HIGH-ENERGY K CONVERSION COEFFICIENTS

R. K. Smither

Phys. Letters 25B(2), 128-129 (August 1967)

SCATTERING OF 43-MeV ALPHA PARTICLES BY THE TITANIUM ISOTOPES

J. L. Yntema and G. R. Satchler†

Phys. Rev. 161, 1137-1147 (20 September 1967)

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†Oak Ridge National Laboratory, Oak Ridge, Tennessee.

REPORTS AT MEETINGS

Intense Neutron Sources, Proceedings of a USAEC/ENEA Seminar, Santa Fe, New Mexico, 19—23 September 1966, USAEC Report CONF-660925 (Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U. S. Department of Commerce, Springfield, Virginia, 1966)

CONTRIBUTIONS TO PANEL DISCUSSION ON NEUTRON AND FISSION PHYSICS
L. M. Bollinger
pp. 803, 804, 811-814, 815, 816, 830

NUCLEAR PHYSICS EXPERIMENTS PERFORMED WITH NEUTRONS
L. M. Bollinger
pp. 47-88

CONTRIBUTION TO PANEL DISCUSSION ON NUCLEAR PHYSICS
G. R. Ringo
pp. 820-821

Abstracts of Papers to be Read at the International Conference on Hyperfine Nuclear Spectroscopy at Victoria University of Wellington, Wellington, New Zealand, 17—21 October 1966. (The Royal Society of New Zealand, Wellington, New Zealand, 1966)

THE MÖSSBAUER EFFECT IN METALLIC CESIUM
Gilbert J. Perlow and A. J. F. Boyle*
pp. 20-21

INTERPRETATION OF QUADRUPOLE SPLITTINGS AND ISOMER SHIFTS IN ANTIMONY AND TIN
S. L. Ruby, G. M. Kalvius (Solid State Science), R. E. Snyder,† and G. B. Beard†
pp. 6-7

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*University of Western Australia, Nedlands, Western Australia.

†Wayne State University, Detroit, Michigan.

1967 U. S. National Particle Accelerator Conference, Washington, D. C., 1—3 March 1967

DECADE OF PROGRESS IN CYCLOTRONS—FREQUENCY-MODULATED AND ISOCHRONOUS
T. K. Khoe (Particle Accelerator Division) and J. J. Livingood
Bull. Am. Phys. Soc. 12, 939 (August 1967)
IEEE Trans. NS-14(3), 23-28 (June 1967)

SIMPLE IMPROVEMENTS IN SMALL HIGH-VOLTAGE DC POWER SUPPLIES
Alexander Langsdorf, Jr.
Bull. Am. Phys. Soc. 12, 942 (August 1967)
IEEE Trans. NS-14(3), 143-144 (June 1967)

American Physical Society meeting, Seattle, 31 August—2 September 1967

PERTURBATION OF THE PORTER-THOMAS DISTRIBUTION BY INTERACTIONS WHICH ARE ODD UNDER TIME REVERSAL
Norbert Rosenzweig
Bull. Am. Phys. Soc. 12, 894-895 (August 1967)

Contributions, International Conference on Nuclear Structure, Institute for Nuclear Study, University of Tokyo, 7—13 September 1967

PERTURBATIVE METHODS IN THE THEORY OF NUCLEAR LEVEL DENSITIES
P. B. Kahn* and N. Rosenzweig
p. 353

EXTENSION OF M3 MATRIX ELEMENTS
Dieter Kurath
p. 371

GIANT DIPOLE RESONANCE IN Ar^{36}
L. Meyer-Schützmeister, D. S. Gemmell, R. C. Bearse, N. G. Puttaswamy, and R. E. Segel
p. 385

AN ATTEMPT TO TEST THE RANDOM-MATRIX MODEL
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*State University of New York, Stony Brook, New York.

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STUDENT REPORTS

A MASS SPECTROMETRIC INVESTIGATION OF MOLECULAR ION FRAGMENTATION INDUCED BY COLLISIONS WITH NEUTRAL, INERT ATOMS

Joseph L. Cecchi

ACM student report to Knox College, Galesburg, Illinois (July 1967)

DOMAINS OF LOW-PRESSURE HIGH-FREQUENCY DISCHARGES AND PLASMAS

Tommy D. Dickey

Summer Student Trainee report to Ohio University, Athens, Ohio (Summer 1967)

MEASUREMENT OF INTERNAL-CONVERSION COEFFICIENTS IN SHORT-LIVED RADIOACTIVE NUCLEI

Lynn D. Knutson

ACM student report to St. Olaf College, Northfield, Minnesota (July 1967)

THE MEASUREMENT OF MAGNETIC MOMENTS OF EXCITED STATES BY THE MÖSSBAUER EFFECT USING A SUPERCONDUCTING MAGNET

Norman C. Sandstrom

ACM student report to St. Olaf College, Northfield, Minnesota (July 1967)

V. PERSONNEL CHANGES IN THE ANL PHYSICS DIVISION

NEW MEMBERS OF THE DIVISION

Visiting Scientists

Mr. Carl J. Christensen, Danish AEC, Research Establishment, Risø. Asymmetries in the decay of polarized neutrons. Came to Argonne on 18 September 1967.

Dr. Paul Kienle, Technische Hochschule München, Germany. Table of $\Delta\langle r^2\rangle$; nuclear reactions with Ru^{102}, Ru^{104}; and Coulomb excitation of Sm^{152}. Came to Argonne on 3 August 1967 for a period of three months.

Visiting Scientist (Summer)

Dr. Michael A. Grace, Oxford University, England. Mössbauer effect. Came to Argonne on 1 August 1967.

Postdoctorals

Dr. H. Terry Fortune. Charged-particle reactions at Tandem and cyclotron. Came to Argonne on 5 September 1967.

Dr. Christopher M. Vincent. Analogy between bound and resonant states — applied to sequential decays, stripping to virtual levels, and calculation of resonance energies; nuclear reaction theory. Came to Argonne on 18 September 1967.

Resident Student Associate (Thesis)

Mr. Pieter F. Goudsmit, graduate student, University of Amsterdam, Netherlands. Working with S. B. Burson on β and γ spectroscopy of deformed nuclei. (OCUC affiliate.) Came to Argonne on 20 September 1967.

Student Aides (ACM)

Mr. Charles I. Gale, Lawrence University, Appleton, Wisconsin. Working with W. A. Chupka on photoionization of molecules. Came to ANL on 10 July 1967.

Mr. Gary G. Gimmestad, St. Olaf College, Northfield, Minnesota. Working with R. S. Preston on Mössbauer research. Came to ANL on 10 July 1967.

Mr. Steven A. Hubin, Ripon College, Ripon, Wisconsin. Working with S. B. Burson on gamma-ray spectroscopy. Came to ANL on 10 July 1967.

CSUI-ANL Honor Student

Mr. James D. Barter, Portland State College, Portland, Oregon. Working with L. S. Goodman on determining nuclear constants with atomic-beam magnetic-resonance machine. Came to ANL on 5 September 1967.

Technicians

Mr. James R. Clegg joined the Physics Division on 19 July 1967 to work with J. R. Wallace.

Mr. Michael M. Korter joined the Physics Division on 7 August 1967 to work with J. R. Wallace.

Mr. Roy T. Moorehead joined the Physics Division on 1 July 1967 to work with J. Berkowitz and W. A. Chupka.

Mr. Elliot S. Silber joined the Physics Division on 10 July 1967 to work with J. P. Schiffer.

Clerk

Mrs. Brenda M. Billoni joined the Physics Division on 25 September 1967 to assist C. Eggler.

PROMOTIONS

Dr. Ben Day became a permanent staff member on 1 September 1967.

Mr. Stuart O. Goldman was promoted to scientific assistant on 5 September 1967.

DEPARTURES

Dr. Donald E. Blatchley, postdoctoral, has been on the staff of the ANL Physics Division since 1 September 1965. He has worked on thermal-neutron-capture gamma rays; neutron decay experiments. He terminated at ANL on 8 September 1967 to go to Aerospace Corporation, San Bernardino, California.

Dr. Alpo J. Kallio, postdoctoral, has been on the staff of the ANL Physics Division since 2 September 1966. He has worked on nuclear shell structure, effective interactions of nucleons in nuclei, and nuclear matter. He terminated at ANL on 28 July 1967 to go to the Department of Physics, University of Oulu, Oulu, Finland.

Dr. Amnon Katz, visiting scientist from Weizmann Institute of Science, Rehovoth, Israel, has been on the staff of the ANL Physics Division since 15 July 1966. He has worked on infinite systems; Mach's principle and Newtonian limit in general relativity; overbinding of quarks. He terminated at ANL on 15 September 1967 to go to the Department of Physics, University of Washington, Seattle, Washington.

Dr. William V. Prestwich, research associate from McMaster University has been on the staff of the ANL Physics Division since 1 November 1965. He has worked on neutron resonance capture spectra in Co^{60}, Mn^{56}, tungsten isotopes, and thermal capture in Er^{166}. He terminated at ANL on 30 August 1967 to return to McMaster University, Nuclear Research Bldg., Hamilton, Ontario, Canada.

Dr. M. Hla Shwe, resident research associate and ACM-ANL supervisor under the sponsorship of the Office of College and University Cooperation from Ripon College has been on the staff of the ANL Physics Division since 25 May 1966. He has worked on total neutron cross section with the fast chopper; precision measurements of neutron-capture gamma rays. He terminated at ANL on 24 August 1967 to return to Ripon College, Ripon, Wisconsin.

Dr. Dave Youngblood, postdoctoral, has been on the staff of the ANL Physics Division since 7 September 1965. He has worked on charged-particle research with the Van de Graaff accelerators. He terminated at ANL on 31 August 1967 to go to The Cyclotron Institute, Texas A & M University, College Station, Texas.

Transfer

Mr. Larry Marek, technician in Physics since 13 December 1965, transferred to Particle Accelerator Division on 11 September 1967.