gestions from J. C. Phillips in the course of this work, and for stimulating discussions of this manuscript with J. C. Phillips, Albert Yu, and N. W. Ashcroft. We would also like to thank Phillip McKernan for the fabrication of the experimental tubes.

---

*Work supported by the National Science Foundation, Washington, D. C., and by the Advanced Research Projects Agency through the Center for Materials Research at Stanford University, Stanford, California.

†IBM Resident Fellow.

[1]J. G. Hanus, M. I. T. Solid State and Molecular Theory Group Quarterly Progress Report No. 44, 1962 (unpublished), p. 29.

[2]J. Yamashita, M. Kukuchi, and S. Wakoh, J. Phys. Soc. (Japan) 18, 999 (1963).

[3]L. F. Matthesis, Phys. Rev. 134, A970 (1964).

[4]B. Segall, Phys. Rev. 125, 109 (1962).

[5]G. A. Burdick, Phys. Rev. 129, 138 (1963).

[6]H. Ehrenreich, H. R. Philipp, and D. J. Olechna, Phys. Rev. 131, 2469 (1963).

[7]J. C. Phillips, Phys. Rev. 133, A1020 (1964).

[8]G. W. Gobeli and F. G. Allen, Phys. Rev. 127, 141 (1962); E. O. Kane, Phys. Rev. 127, 131 (1962).

[9]W. E. Spicer and R. E. Simon, Phys. Rev. Letters 9, 285 (1962).

[10]W. E. Spicer, Phys. Rev. Letters 11, 247 (1963).

[11]W. E. Spicer and N. B. Kindig, Solid State Commun. 2, 13 (1964).

[12]J. Dickey, Phys. Rev. 81, 612 (1951).

[13]C. N. Berglund and W. E. Spicer, Phys. Rev. 136, A1044 (1964).

[14]W. E. Spicer and C. N. Berglund, Rev. Sci. Instr. 35, 1665 (1964); and references given therein.

[15]C. N. Berglund and W. E. Spicer, Phys. Rev. 136, A1030 (1964).

[16]N. B. Kindig and W. E. Spicer, Phys. Rev. 138, A561 (1965).

[17]M. Shimizu, T. Takahashi, and A. Katsuki, J. Phys. Soc. (Japan) 18, 801 (1963).

[18]W. E. Spicer, C. N. Berglund, and A. Yu (unpublished).

[19]E. P. Wohlfarth, Proceedings of the International Conference on Magnetism, Nottingham, England, 1964 (The Institute of Physics and the Physical Society, University of Reading, Berkshire, England, 1965).

[20]A. J. Blodgett and W. E. Spicer (unpublished).

[21]A. Yu, private communication.

[22]J. C. Phillips, to be published.

POSSIBLE EVIDENCE OF DIPOLE-QUADRUPOLE INTERACTION IN As^{75}†

D. S. Fielder, J. Le Tourneux, K. Min, and W. D. Whitehead

University of Virginia, Charlottesville, Virginia

(Received 4 June 1965)

This paper reports the observation of a structure in the photoneutron-production cross section of the spherical nucleus As^{75}, which may be ascribed to the interaction of the dipole and quadrupole vibrations.[1,2] The experimental cross section is compared with the theoretical cross section based on the dipole-quadrupole interaction model.

The experimental arrangement was essentially the same as that previously reported.[3] The monoisotopic As^{75} sample weighed about 105 g and was contained in a thin-walled glass container. The collimated bremsstrahlung beam from the electron synchrotron irradiated this sample placed along the beam axis at the center of a neutron detector made of 13.5-cm thick paraffin layers and eight BF_3 counters embedded in a ring concentric about the beam-sample axis. The paraffin thickness was chosen to make the neutron detection efficiency least sensitive to its energy.[4] The neutrons were counted during the 700-μsec gating period following a 20-μsec time delay between the beam pulse and the triggering of the gating circuit to prevent the electron pile-up pulses. The beam was monitored by a transmission ionization chamber, and the detection efficiency of the whole system was determined to be 2.5% using a calibrated Ra-Be source. X-ray picture studies of the beam size at the target position before and after the runs ensured that the target intercepted the whole beam throughout the experiment. The neutron-yield curves were constructed in 0.5-MeV intervals from 10 up to 25 MeV of bremsstrahlung energy. A total of twenty separate runs were made with the total counting statistics at the top energy point better than 0.3%. After correcting for the background, the average net yield per unit monitor response was computed at each energy, and the net-yield curve was analyzed directly through the Penfold-Leiss inverse bremsstrahlung matrix[5] to unfold two independent and interlacing sets of cross sections in 1-MeV intervals.

The experimental cross section is shown by the solid line in Fig. 1. The error bars represent the uncertainty in the cross section due to the standard deviations in the yield points, and were computed by propagating these through the Penfold-Leiss matrix. The cross section shown is the sum, $\sigma(\gamma,n)+\sigma(\gamma,pn)+2\sigma(\gamma,2n)$, and no attempt was made to correct for the multiple-neutron emission. The integrated cross section up to 23 MeV is 744 ± 56 MeV-mb.

It is interesting to compare the present experimental results with the predictions of a model taking into account the interaction between dipole and quadrupole vibrations. The starting point of the latter is the phenomenological Hamiltonian[1,2]

$$H=H_0+H',$$

where

$$H_0=\sum_{\lambda=1}^{2}\left[\frac{1}{2B_\lambda}\sum_\mu \pi_{\lambda\mu}{}^*\pi_{\lambda\mu}+\frac{C_\lambda}{2}\sum_\mu \alpha_{\lambda\mu}{}^*\alpha_{\lambda\mu}\right],$$

and

$$H'=\frac{K}{\sqrt{5}}\sum_{\mu\nu}(-)^\mu\langle 11\nu\mu-\nu|2\mu\rangle\,\alpha_{1\nu}\alpha_{1\mu-\nu}\alpha_{2-\mu}.$$

The collective coordinates $\alpha_{1\nu}$ and $\alpha_{2\mu}$ are used to describe the dipole and quadrupole vibrations, respectively, and we take $K=-\frac{5}{2}$ $\times(\frac{3}{2}\pi)^{1/2}C_1$, so that the dipole frequency is inversely proportional to the axis along which it takes place. Taking as a basis the eigenvectors of H_0, it is possible to construct the energy matrix and diagonalize it. The solutions of the Schrödinger equation

$$H|N_1=1;i;I=1,M\rangle=E_i|N_1=1;i;I=1,M\rangle$$

can then be expanded as

$$|N_1=1;i;I=1,M\rangle=\sum_{N_2\nu}a_{N_2\nu}{}^i|N_1=1;N_2\nu l_2;I=1,M\rangle.$$

N_1 and N_2 are the number of dipole and quadrupole phonons, respectively. The quadrupole phonons are coupled to angular momentum l_2 and have seniority v.

Under the assumption that each level has a width $\Gamma_i=2\gamma_i$, the cross section for the dipole absorption of γ rays can be written as

$$\sigma(E)=2\pi^2\frac{\hbar e^2}{Mc}\frac{NZ}{A}\frac{E}{E_1}\sum_i(a_{00}{}^i)^2\frac{\gamma_i}{\pi[(E_i-E)^2+\gamma_i{}^2]}.$$

The extent to which the dipole-quadrupole interaction spreads the dipole state depends on the value of the parameter $k=-(KE_1/C_1)(E_2/2C_2)^{1/2}$. The particularly large value of this quantity for As^{75} has motivated the present investigation. E_2 and C_2 are determined by taking the average of their values for the two neighboring nuclei Ge^{64} and Se^{76}, namely $E_2=0.58$ MeV and $C_2=15.5$ MeV. The only free parameters in the calculation are E_1 and Γ_i. The very reasonable value $E_1=18.5$ is used and, in the absence of any more definite information, all the widths Γ_i are taken equal to 1.5 MeV.

The calculated cross section is compared with the experimental one in Fig. 1. Quite obviously the detailed agreement between the two shapes could be considerably improved by assigning a different width to the various levels: The peak at 20 MeV, for instance, would be brought down if it were given a larger width. Despite that, the dipole-quadrupole interaction model is seen to reproduce quite well the main features of the observed cross section.

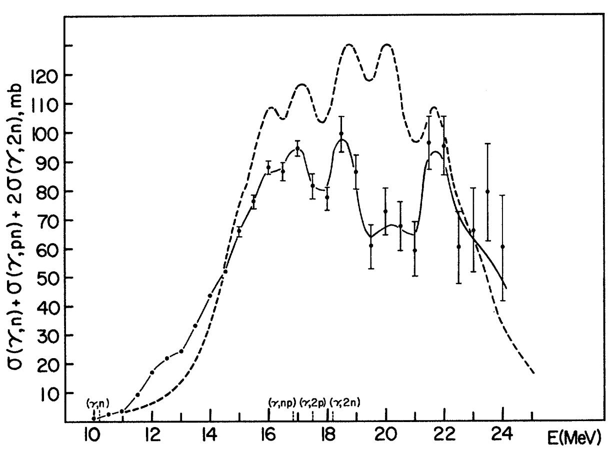

FIG. 1. Solid line: photoneutron production cross section of As^{75}; dashed line: total photoabsorption cross section.

†Partially supported by the National Science Founda-

tion and the U. S. Atomic Energy Commission.

[1]J. Le Tourneux, Kgl. Danske Videnskab. Selskab, Mat.-Fys. Medd. 34, No. 11 (1965).
[2]J. Le Tourneux, Phys. Letters 13, 325 (1964).
[3]K. Min and W. D. Whitehead, Phys. Rev. 137, B301 (1965).
[4]J. Halpern, A. K. Mann, and R. Nathans, Rev. Sci. Instr. 23, 678 (1952).
[5]A. S. Penfold and J. E. Leiss, Phys. Rev. 114, 1332 (1959).

LIE GROUP OF THE STRONG-COUPLING THEORY*

T. Cook†
University of Wisconsin, Madison, Wisconsin, and Argonne National Laboratory, Argonne, Illinois
and
C. J. Goebel
University of Wisconsin, Madison, Wisconsin
and
B. Sakita
Argonne National Laboratory, Argonne, Illinois
(Received 28 May 1965)

The purpose of this paper is three fold: (i) to show the Lie group of Goebel's theory[1] of strong coupling in static models; from this group the bands of isobar states are obtained as irreducible representations [they are of infinite dimension because the Lie group is noncompact]; (ii) to give a solution of the problem for two simple cases [symmetric scalar and symmetric pseudoscalar meson theory] by the help of the method of group contraction; and (iii) to indicate the possibility of higher symmetries. We will briefly sketch here the essential part of the strong-coupling theory, which serves as the physical derivation of the algebra. Consider the scattering of a scalar meson by a static isobar: "α" + "i" → "β" + "j", where α and β indicate the initial and final mesons, respectively, while i and j are isobar states. The Chew-Low[2] equation for this process is

$$T_{\beta\alpha}{}^{ji}(\omega) = -\lambda^2 \sum_k \left[\frac{(A_\beta)^{jk}(A_\alpha)^{ki}}{M_k - M_i - \omega} + \frac{(A_\alpha)^{jk}(A_\beta)^{ki}}{M_k - M_j + \omega}\right] - \sum_{\vec{p},k}\left\{\frac{[T_{\gamma\beta}{}^{kj}(\omega_p)]^* T_{\gamma\alpha}{}^{ki}(\omega_p)}{M_k + \omega_{\vec{p}} - M_i - \omega} + \frac{[T_{\gamma\alpha}{}^{kj}(\omega_p)]^* T_{\gamma\beta}{}^{ki}(\omega_p)}{M_k + \omega_{\vec{p}} - M_j + \omega}\right\}$$
$$+ (\text{two or more meson intermediate states}), \quad (1)$$

where M_i is the energy of the ith isobar and $\lambda(A_\alpha)^{ij}$ is the matrix element of the source of the meson α between the ith and jth isobar. The parameter λ represents the strength of the coupling, the A_α being kept finite as the strong-coupling limit ($\lambda^2 \to \infty$) is taken. In the strong-coupling limit all isobars are degenerate, $M_i \to M + O(1/\lambda^2)$, and so we write $M_i = M + \Delta_i/\lambda^2$, where Δ_i is kept finite. The scattering amplitude is finite in the physical region because of its unitarity property, so the pole terms [first two terms in (1)] must be finite in the strong-coupling limit. Expanding the pole terms in powers of $1/\lambda^2$, one obtains

$$T_{\beta\alpha}{}^{ji}(\omega)_{\text{pole}} \sim -\frac{\lambda^2}{\omega}([A_\beta, A_\alpha])^{ji} - \frac{1}{\omega^2}([A_\beta, [\Delta, A_\alpha]])^{ji} + O\left(\frac{1}{\lambda^2}\right), \quad (2)$$

where matrix notation is used for A's and Δ is a diagonal matrix with Δ_i as the ith diagonal element. To keep T_{pole} finite, in the strong-coupling limit one must have

$$[A_\beta, A_\alpha] = 0. \quad (3)$$