FIZIKA, 4 (1972) 65-68

LETTERS TO THE EDITOR

THE PHOTODISINTEGRATION OF ^{40}Ca THROUGH PROTON CHANNELS

D. BRAJNIK, D. JAMNIK, G. KERNEL, U. MIKLAVŽIČ and A. STANOVNIK

Institute Jožef Stefan, Ljubljana and University of Ljubljana, Yugoslavia

Received 25 June 1971

The cross sections for reaction channels with different configurations are of key interest for the understanding of the photonuclear giant resonance process. One way of obtaining such information is the study of cross sections leading to different states of the residual nuclei. It was the aim of the present work to get experimental data for calcium by measuring photoproton spectra. The protons resulted from bombardment of a 6.6 mg/cm^2 ^{40}Ca target by betatron bremsstrahlung gamma rays with endpoint energies ranging from 15.2 to 24.6 MeV. They were detected by silicon solid state spectrometers. The 90° differential photoproton cross sections corresponding to different excited states of the residual nucleus (Fig. 1) have been extracted from the photoproton spectra by means of a least-squares procedure.

The lower diagram of Fig. 1 shows the differential cross section for the reaction (γ, p_0) in which the residual nucleus ^{39}K is left in its ground state. The structure and the absolute value are in good agreement with an earlier measurement of the (γ, p_0) cross section[1] and with the data from the inverse reaction[2]. It is believed that the ground state of ^{39}K is a relatively pure $1\,d_{3/2}$ hole state[3]. In the $1\,p - 1\,h$ coupled-channel shell-model calculation of Marangoni and Saruis[4] it should therefore be compared to the cross section for the $1\,d_{3/2}$ hole channel. As seen from Fig. 1a the position of the main peak seems to be well reproduced.

For the (γ, p_1) channel, involving the 2.53 MeV $\frac{1}{2}^+$ first excited state of ^{39}K, the cross section appears to be concentrated to energies above 17.5 MeV.

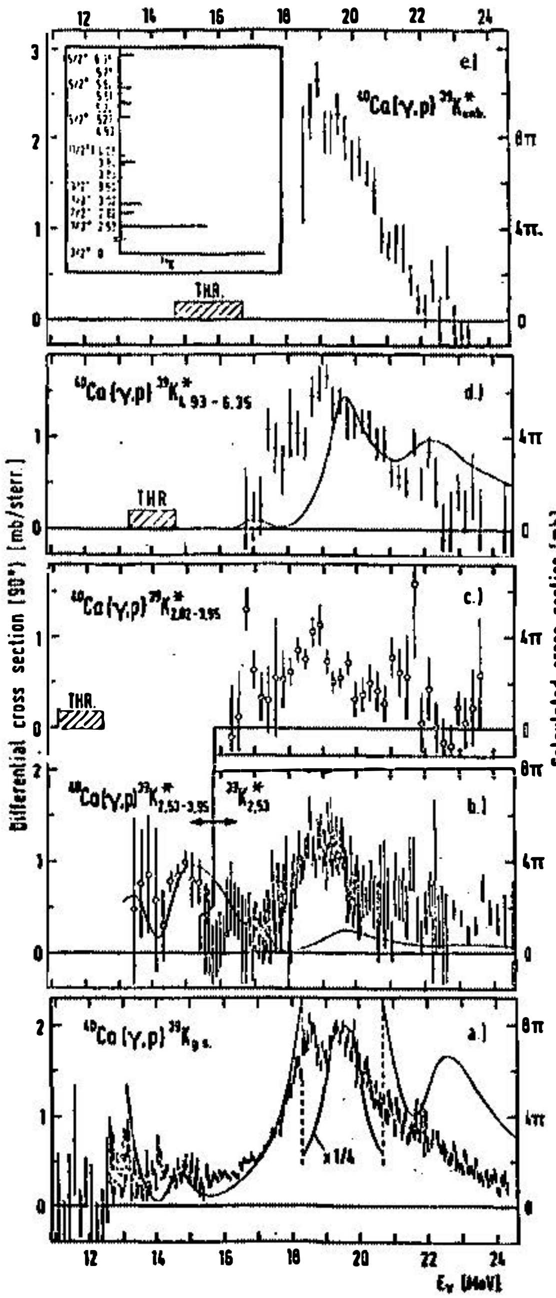

Fig. 1. Experimental points with error bars correspond to the 90° differencial cross section of the present experiment, while solid curves show calculated cross sections integrated over angles[4]. The absolute values of the cross sections are given by the scales on the left hand side for the experiment, and on the right hand side for the theory.

a) The photoproton cross section (γ, p_0) to the ground state of ^{39}K compared to the calculated cross section for the 1 $d_{3/2}$ hole proton channel;

b) The photoproton cross section to the first excited 2.53 MeV state compared to the calculated value for the $2\,s_{1/2}$ hole channel. At energies below 15.5 MeV the experimental cross section could not be resolved from the transitions to the states between 2.82 and 3.95 MeV;

c) Experimental photoproton cross section to the states of ^{39}K between 2.82 and 3.95 MeV;

d) The photoproton cross section to the ^{39}K states in the energy regional between 4.93 and 6.35 MeV compared to the calculated cross section for the $1\,d_{5/2}$ proton hole channel;

e) The cross section for the (γ, p) reaction, in which the residual nucleus ^{39}K is assumed to be left in the continuum states between 6.4 and 8.5 MeV. The insert shows schematically the population of different excited states of the residual nucleus ^{39}K in the photoproton reaction. It has been obtained independentely by measuring the deexcitation gamma-rays resulting from bombardment of a ^{40}Ca target with bremsstrahlung gamma-rays of an end-energy of 30 MeV.

The above state is considered to be predominantly a $2\,s_{1/2}$ hole state[3] and the cross section is therefore to be compared to the $1\,p - 1\,h$ prediction for the $2\,s_{1/2}$ channel. As seen from Fig. 1b the corresponding theoretical cross section is concentrated at energies below 17.5 MeV, in disagreement with the experiment. There does not seem to be much correlation between the measured and the calculated results in this case.

The cross section to the residual states in the energy region between 2.82 and 3.95 MeV (Fig. 1c) corresponds mainly to the reaction channels with negative parity hole states as it is seen from the population scheme in the insert of Fig. 1e. The existence of such reaction channels is out of scope of the model of Ref.[4].

The remaining cross section to residual bound states belongs to excitations between 4.93 MeV and 6.35 MeV in ^{39}K. About 60 % of the deexcitation gamma-ray yield in this energy region (see the population scheme in Fig. 1) is due to the 5.27, 5.62 and 6.35 MeV states which have a predominant $d_{5/2}$ hole configuration[3]. The study of the ^{40}Ca (d, ^{3}He) reaction[5] indicate that the $1\,d_{5/2}$ hole states in ^{39}K may extend to excitation energies as high as 8 MeV or more. It yields for the lower limit of the center of gravity of the $1\,d_{5/2}$ hole states an energy of 6.6 MeV. It is therefore probable that a substantial part of the measured cross section corresponding to the continuum residual states (uppermost diagram of Fig. 1) also belongs to the $d_{5/2}$ hole channel. If this is the case the absolute value of the experimental $d_{5/2}$ contribution is of the same order of magnitude[6] as the theoretically predicted one (the solid line in Fig. 1d)[4].

From the measured differential cross sections for the reactions ^{40}Ca (γ, p) one can draw the following main conclusions:

— the reactions cannot be quantitatively described in terms of the $1\,p - 1\,h$ shell model coupled-channel calculation of Ref.[4]. The most striking discrepancy between theory and experiment appears in the cross sections for the reaction (γ, p_1) to the first excited state of ^{39}K;

— the presence of an appreciable radiation width for the negative-parity hole channels could be explained by the impurities in the ground state of ^{40}Ca[7, 8] which have not been taken into account in the calculation of Marangoni and Saruis;

— the experiment suggests that the wave functions of the ^{40}Ca giant-resonance state contain more $1\,d_{5/2}$ hole configuration relative to the $1\,d_{3/2}$ configuration, than predicted by the simple $1\,p - 1\,h$ shell-model calculation[4, 9];

— it seems typical for the measured photoproton cross sections to have similar gross structure for all channels. This may suport the assumption of an energy independent configuration composition of the giant resonance wave function as already suggested in Ref.[10].

We thank F. Detter for his work on the design and construction of the target chamber.

References

1) C. P. Wu, J. E. E. Baglin, F. W. K. Firk and T. W. Phillips, Phys. Letters **29B** (1969) 359;
2) J. C. Hafele, F. W. Bingham and J. S. Allen, Phys. Rev. **135** (1964) B365;
3) S. Hinds and R. Middleton, Nucl. Phys. **84** (1966) 651;
4) M. Marangoni, private communication. In the paper M. Marangoni and A. M. Saruis, Nucl. Phys. **A132** (1969) 649 details of calculation are given, but only summed photoproton spectra are shown. Here their results for the absorptive potential W (MeV) = 0.06 E (MeV) — 0.5 are used;
5) J. C. Hiebert, E. Newman and R. H. Bassel, Phys. Rev. **154** (1967) 898;
6) The anisotropy of the photoproton reactions is given by the following average values of the ratio of Legendre polynomial coefficients A_2/A_0 : —0.4 (reaction a of Fig. 1), —0.5 (reactions b + c) and 0.0 (reactions d + e);
7) W. J. Gerace and A. M. Green, Nucl. Phys. **93** (1967) 110;
8) M. E. Cage, R. R. Johnson, P. D. Kunz and D. A. Lind, Nucl. Phys. **A162** (1971) 657;
9) V. Gillet and E. A. Sanderson, Nucl. Phys. **54** (1964) 472;
10) R. A. Allas, S. S. Hanna, L. Meyer-Schützmeister, R. E. Segel, P. P. Singh and Z. Vager, Phys. Rev. Letters **13** (1964) 628.