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Charged Particle Photoemission from ^{42}Ca

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Abstract

Experimental results are presented for the cross sections measured at 90° of the reactions ^{42}Ca(γ, p), ^{42}Ca(γ, p$_0$) and ^{42}Ca(γ, α_0) between excitation energies 16 and 28 MeV.

Introduction

This paper reports the results of the first measurement made so far of the reaction ^{42}Ca(γ, p)^{41}K, together with measurements of the reactions ^{42}Ca(γ, p$_0$)^{41}K and ^{42}Ca(γ, α_0)^{38}Ar. These results form part of a program designed to test predictions regarding the splitting of the photonuclear giant resonance due to isospin effects (Goulard and Fallieros 1967; Fallieros and Goulard 1970).

Experiment

The measurements were made at Tohoku University with the electron linac of the Laboratory for Nuclear Science. Electrons were directed onto a thin (5·06 mg cm^{-2}) target of metallic calcium enriched to 94·4% in ^{42}Ca. The target was placed in an evacuated chamber at 45° to the incident electron beam, and protons emitted at 90° to the beam were analysed using the broad range magnetic spectrometer available at the Laboratory and detected in 100 1-mm thick Si(Li) detectors placed along the focal plane. Details of the spectrometer design can be found in the paper by Browne and Buechner (1956).

The ^{42}Ca(γ, p) *Measurement*

Spectra were recorded at a series of electron energies ranging from 15·4 to 29 MeV at intervals of 200 keV. The yield of protons with energies greater than 3·7 MeV was obtained from each spectrum and an electrodisintegration cross section for the reaction was constructed.

The ^{42}Ca(e, e′p) cross section $\sigma_e(E_e)$ can be expressed in terms of the ^{42}Ca(γ, p) cross section $\sigma_\gamma(E)$ and a virtual photon spectrum (Dalitz and Yennie 1957; Barber and Wielding 1960). If the small effects of large momentum transfer are neglected, the relation between the two cross sections is given by

$$\sigma_e(E_e) = \int_0^{E_e} \sigma_\gamma(E)\, N(E, E_e)\, \mathrm{d}E\,,$$

where $N(E, E_e)$ is the spectrum of virtual photons of energy E, when electrons of energy E_e are incident on the sample.

Three separate sets of data from $E_e = 15 \cdot 4$ to 29 MeV were collected using the ^{42}Ca enriched target and the average of these was taken. To allow for the contribution from the 5% ^{40}Ca impurity in the target, a separate yield curve was measured using a thin target of natural calcium. The corrected ^{42}Ca(e, e′p) cross section was analysed to give the ^{42}Ca(γ, p) cross section using the Variable Bin Penfold–Leiss method developed by Bramanis *et al.* (1972). The resulting cross section is shown in Fig. 1.

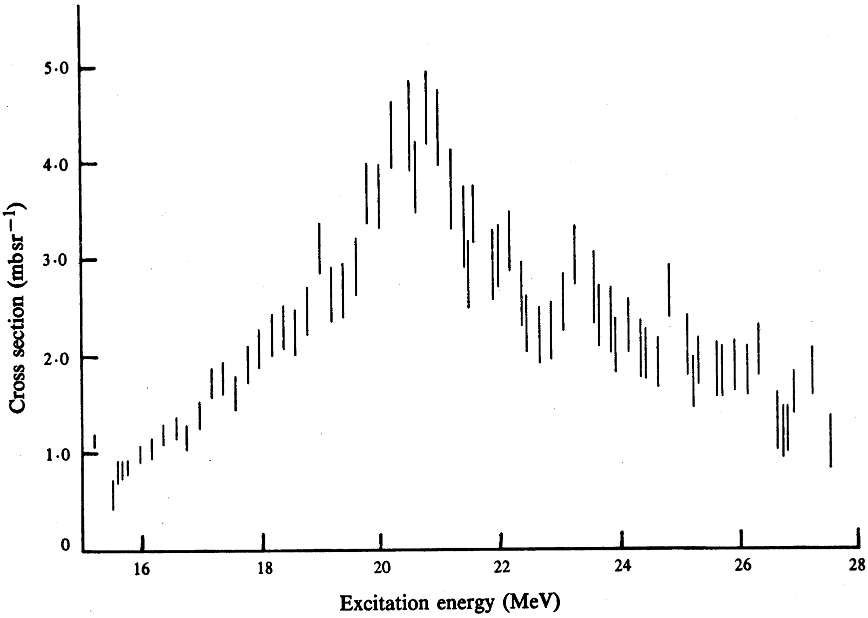

Fig. 1. Differential photoproton cross section of ^{42}Ca(γ, p) for $E_p > 3 \cdot 7$ MeV at a detection angle of 90° to the beam direction. Error bars are statistical only; there is a 15% uncertainty in the absolute cross section scale.

The ^{42}Ca(γ, p$_0$) *Cross Section*

The first excited state in ^{41}K is at 985 keV, and hence the topmost 985 keV of each proton spectrum is due entirely to ground state protons. By unfolding the virtual photon spectrum from this region of each spectrum the ground state cross section can be found. Combining this region of a series of consecutive spectra allows the complete (γ, p$_0$) cross section to be assembled.

For this procedure, spectra of better statistical quality are required than those obtained for deriving the (γ, p) cross section. However, a spectra spacing of 200 keV is not required, and thus spectra with good statistics could be taken at 600 keV intervals. Since the top 985 keV of each spectrum was analysed to produce a corresponding region of the (γ, p$_0$) cross section, there is an adequate overlap of about 400 keV in the cross sections produced from consecutive spectra. In practice, the top 200 keV of each spectrum was not used because of poor statistics in this region and the uncertainty in the shape of the virtual photon spectrum very close to its peak. However, consistency in the over-determined region of overlap confirmed the unfolding method. Again the contribution from the ^{40}Ca target impurity was measured separately with a thin natural calcium target and subtracted from the spectra obtained with the enriched ^{42}Ca target.

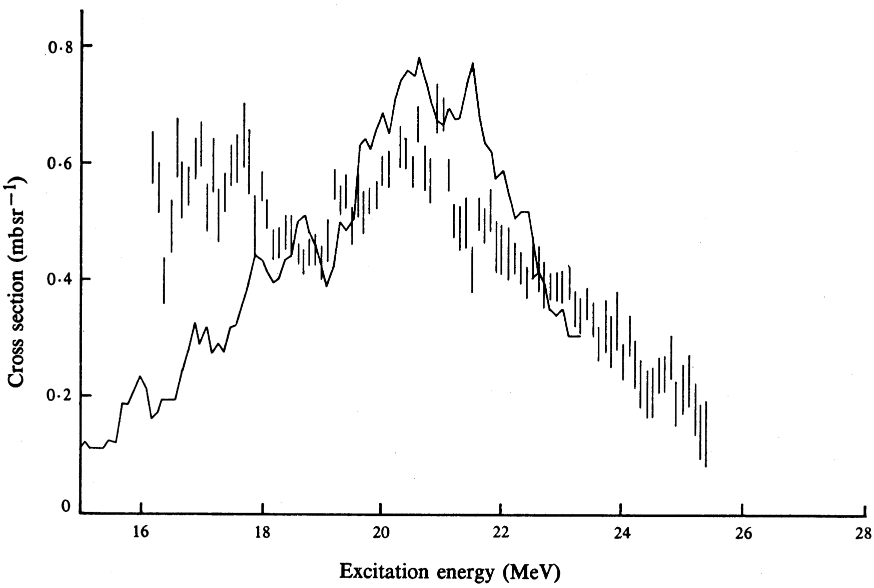

Fig. 2. Differential cross section of $^{42}Ca(\gamma, p_0)$ at $\theta = 90°$. Error bars are statistical only; there is a 15% uncertainty in the absolute cross section scale. The solid curve is the $^{42}Ca(\gamma, p_0)$ cross section derived by detailed balance from the $^{41}K(p, \gamma_0)$ data of Diener *et al.* (1973) and smoothed with a 0·5 MeV sliding interval.

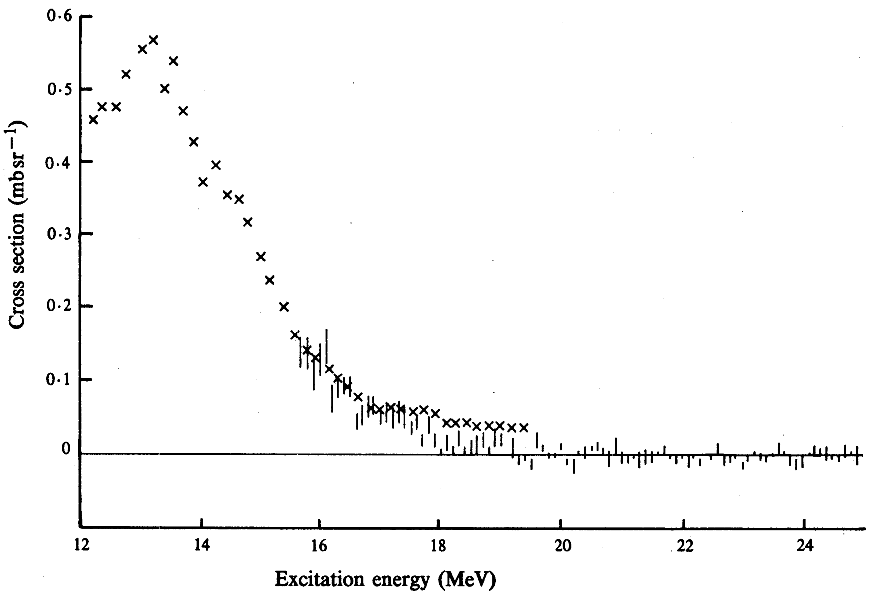

Fig. 3. Differential cross section of $^{42}Ca(\gamma, \alpha_0)$ at $\theta = 90°$. Error bars are statistical only; there is a 15% uncertainty in the absolute cross section scale. Crosses indicate the differential cross section for $^{42}Ca(\gamma, \alpha_0)$ derived from the cross section measured by Foote *et al.* (1976). The scale in this case is assigned on the assumption of an isotropic angular distribution.

The derived ^{42}Ca(γ, p$_0$) cross section is shown in Fig. 2. Also shown are the results of Diener *et al.* (1973) obtained from the inverse reaction ^{41}K(p, γ_0)^{42}Ca. Above 18 MeV the agreement is good, particularly as far as location of the peak cross section is concerned. Below 18 MeV the marked disagreement is due to α-particle contamination from the ^{42}Ca(γ, α) reaction. Alpha particles and protons of equal energy are incident on the same Si(Li) detector. Although pulse height separation can be achieved by inserting a thin foil in front of the detector array, this facility was not available at the time the present data were taken. In this energy region α-particle contamination is large, since the difference in threshold for proton emission (10·3 MeV) and α-particle emission (6·2 MeV) means that α particles produced in the energy range of the peak (γ, α) cross section at 13 MeV (see Fig. 3) appear in the same spectrum region as protons produced by photons of about 17 MeV.

The ^{42}Ca(γ, α_0) *Cross Section*

The difference in (γ, α) and (γ, p) thresholds, plus the fact that the first excited state in ^{38}Ar is at 2·17 MeV, allowed the ^{42}Ca(γ, α_0) cross section to be derived in a manner similar to that used to deduce the (γ, p$_0$) cross section. This cross section is shown in Fig. 3, and extends the work of Foote *et al.* (1976) who studied the inverse reaction ^{38}Ar(α, γ_0).

Discussion

The purpose of this paper is to present the new data. It is sufficient to comment that the location of the cross section peak of both the ^{42}Ca(γ, p) and ^{42}Ca(γ, p$_0$) cross sections is about 21 MeV, in good agreement with the location of the $T = 2$ isospin component of the GDR according to Goulard and Fallieros (1967). Since this component should be strongly favoured in the proton decay channel, qualitative support for the isospin predictions is indicated. The magnitude and position of the ^{42}Ca(γ, p) cross section are consistent with predictions of a model based on the statistical decay of the GDR as presented by Thompson *et al.* (1978). This model specifically takes into account isospin effects as described by Pywell and Thompson (1979). A more quantitative discussion of consistency with the expectations from isospin splitting of the GDR should be possible when the ^{42}Ca(γ, n) cross section becomes available.

Acknowledgments

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