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by

M.C.A. Campos, P. Gouffon, Y. Miyao, E. Wolynec,
M.N. Martins and G. Moscati

Instituto de Física, Universidade de São Paulo,
São Paulo, SP, Brazil

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Universidade de São Paulo, Instituto de Física,
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ABSTRACT

The (e,n) cross section for ^{197}Au was measured and the results analyzed using the known (γ,n) cross section and DWBA virtual photon spectra. The (γ,n) cross section contains an E2 component exhausting 66 ± 26 percent of the isoscalar E2 sum and an M1 component in the threshold region with a strength of 18.9 ± 1.2 MeV.mb. It is shown that the electrodisintegration cross section is very sensitive to M1 absorption and the technique can be used for other nuclei.

Measured $\sigma_{e,n}(E_o)$, $Y_{\gamma,n}(E_o)$

Deduced $\sigma_{\gamma,n}^{E2}$, $\sigma_{\gamma,n}^{M1}$

The location of M1 strength in medium and heavy nuclei has been a long standing and major problem in nuclear structure physics. Recently a broad resonance has been observed in (p,n) experiments(1), which is generally accepted as a Giant Gamow-Teller resonance and would imply apreciable strength for a giant M1 state in the target. This M1 state has been confirmed in several cases by (p,p') experiments(2). Some of these M1 states have also been observed in (e,e') experiments(3), but for reasons yet not understood the results from electron and hadron experiments are not always in agreement. The distribution of M1 strength in medium and heavy nuclei is still controversial.

In this paper we present evidence for M1 strength in ^{197}Au. The technique described here is very sensitive to M1 strength, relies in the well understood electromagnetic interaction and can be used for other nuclei.

We have measured the (e,n) cross section for ^{197}Au. The experiment was initially planned to measure the E2 strength in the neutron channel, using a technique already described in previous papers(4,5). In a heavy nucleus like ^{197}Au, the Coulomb barrier strongly inhibits charged particle emission. Since the isoscalar E2 resonance is at an excitation energy bellow the Coulomb barrier for protons and alpha particles, the neutron channel must contain nearly all of the E2 absorption.

The experiment was first performed using a 21 mg/cm^2 gold target, by detecting the emitted neutrons in four BF$_3$ counters. Since we could not explain the measured cross section in terms of the expected E1 and E2 components, we repeated the measurements in a completely independent experiment, in order to rule out instrumental errors. In the second experiment, the (e,n) cross section was measured by residual activity. The gold targets were 1.5 mg/cm^2 thick. The cross section was measured following the 356 keV γ-ray activity from the 6.18 days decay of ^{196}Au to ^{196}Pt, using a Ge(Li) detector. In this second experiment, the photodisintegration yield, produced by the bremsstrahlung from a 0.717 g/cm^2 copper radiator was also measured.

Since the energy scale of the electron linear accelerator from Universidade de São Paulo, where both experiments were performed, could be a common source of error, it was checked by measuring several (γ,n) and $(\gamma,2n)$ thresholds. The (γ,n) threshold derived from the present experiment for ^{197}Au is 8.03 ± 0.03 MeV. The agreement with the calculated value of 8.08 MeV is well within the 1% resolution of our electron beam.

The measured (e,n) cross section (triangles and open circles) and the photodisintegration yield (full circles) are shown in Fig. 1. The triangles refer to the measurement performed by detecting the neutrons, while the circles are the results obtained by residual activity. The uncertainty in the absolute scale is 12%.

The electrodisintegration cross section $\sigma_{e,x}(E_0)$ may be obtained from the photonuclear cross section $\sigma_{\gamma,x}(E)$ through an integral over the virtual photon intensity spectrun $N^{\lambda L}(E_0,E,Z)$

$$\sigma_{e,x}(E_0) = \int_0^{E_0-m} \sum_{\lambda L} \sigma^{\lambda L}_{\gamma,x}(E) N^{\lambda L}(E_0,E,Z) \frac{dE}{E} \qquad (1)$$

In Eq. (1), E_o stands for the total electron energy and E stands for the excitation energy of multipolarity λL. In the same spirit the photodisintegration yield is:

$$Y_{e,x}(E_o) = N_r \int_0^{E_o-m} \sum_{\lambda L} \sigma^{\lambda L}_{\gamma,x}(E) K(E_o-\Delta E_o,E) \frac{dE}{E} \qquad (2)$$

where N_r is the number of nuclei/cm^2 in the copper radiator, $K(E_o,E)$ is the bremsstrahlung cross section for copper and ΔE_o is the electron energy loss in half the radiator thickness.

Fig. 2 shows E1 , E2 and M1 DWBA virtual photon spectra for an electron of kinetic energy 11 MeV scattered by a gold nucleus.

The full curve Y in Fig. 1 results from calculating the integral of eq. (2) using for $\sigma_{\gamma,n}$ the results from Saclay$^{(6)}$. The ratio of measured to calculated photodisintegration yield has the average value of $R_\gamma = 0.99 \pm 0.02$. Thus our absolute scale coincides with that of the (γ,n) measurement. If we use Livermore data$^{(7)}$ for the (γ,n) cross section, the average value of the ratio is $R_\gamma = 1.13 \pm 0.03$. In this case we should multiply the (γ,n) cross section from Livermore by 1.13 to make both absolute values compatible. After that, the analysis that follows below would be the same, leading to the same conclusions.

It is impossible to fit the electrodisintegration data using the (γ,n) cross section$^{(6)}$ and assuming only E1 and E2 multipoles. To illustrate this, the curve E1+E2 in Fig. 1 shows the calculated electrodisintegration cross section, using

Eq. (1) with the (γ,n) data$^{(6)}$, assuming it has an E2 component represented by a Lorentzian shape peaking at the excitation energy of 10.8 MeV, with a width of 4 MeV and exhausting one E2 sum. In Fig. 3 we show the ratio of the measured (e,n) cross section to the calculated E1+E2 curve (circles). In contrast the triangles show the ratio of measured to calculated (e,n) cross section for ^{181}Ta. We are presently measuring this cross section and a preliminary analysis was carried out using the (γ,n) cross section from ref. 9, multiplied by 1.04 and an E2 component exhausting 80 percent of the isoscalar E2 sum. The factor 1.04 was necessary to merge our absolute scale with that of ref. 9. The large departure from 1.0 in the calculated ratio for the lower energy points in ^{197}Au is indicative of the existence of another multipole and it could only be M1. It is easy to show that an E3 or higher L component exhausting one sum would produce no measurable change in the calculated cross section. The enhancement of the E3 virtual photon spectrum$^{(8)}$ relatively to E1 is not enough to compensate for the corresponding decrease of E3 photoabsorption relatively to E1. The same holds for higher multipoles, for the electron energies used here.

An M1 resonance in ^{197}Au located at the excitation energy of 8 MeV with a width of ∿ 3 MeV has been observed in a 180^o electron scattering experiment. The results are published in the review article of L. Fagg$^{(10)}$, but the width $\Gamma = 144$ eV is quoted as doubtful value or ambiguous assignement.

We fitted the ^{197}Au (e,n) data assuming that the (γ,n) cross section contained an E2 component, represented by a

Lorentzian shape, with peak position at 10.8 MeV and a width of 4 MeV, as observed by Pitthan et al.(11), plus an M1 component with a constant cross section between 8.1 and 9 MeV. Since we are fitting an integral measurement, we are sensitive to the location and strength, but not to the detailed shape of the E2 and M1 components. The result of this fit is shown by curve E1+E2+M1 in Fig. 4. The E2 component exhausts 66 ± 26 percent of the EWSR (one E2 sum = 0.22 $Z^2 A^{-1/3}$ ub/MeV). The M1 component has an integrated cross section of 18.9 ± 1.2 MeV.mb. The errors are the statistical uncertainties of the fit. Because the M1 spectrum is much bigger than the E1 and E2 at the tip (see Fig. 2), around 10 MeV the M1 component contributes to half of the observed cross section. This is shown by curve M1 in Fig. 4, which is the M1 contribution to the calculated E1+E2+M1 curve.

In order to compare our result with the M1 strength observed in the (e,e') experiment(10) we have to compute the radiation width Γ :

$$\int \sigma_\gamma(E)\,dE = (\pi\lambdabar)^2 \frac{2I_K+1}{2I_o+1}\,\Gamma \tag{3}$$

where I_o and I_K are the spins of initial and final states. In the (e,e') work, Γ was calculated assuming that the statistical factor $g = (2I_K+1)/(2I_o+1)$ was the same as for a $0^+ \rightarrow 1^+$ transition, that is $g = 3$(12). Since ^{197}Au has a $(3/2)^+$ ground state, there are several possibilities for the final states but the experiment is unable to distinguish them. If we use

$g = 3$ in Eq. (3) we obtain $\Gamma = 119 \pm 8$ eV. Our value should be smaller than the value derived from the (e,e') experiment, since we are observing the fraction of M1 strength that decays by neutron emission. Our results implies that nearly all (γ,n) cross section between the threshold and 9 MeV is M1.

The present results suggest that ^{197}Au should be further investigated by (e,e') experiments and other probes used to study M1 states. The technique employed here may be very useful to locate M1 strength which is spread out and above particle emission threshold.

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REFERENCES

1. C. Goodman, in Proceedings of the Ninth International Conference on High Energy Physics and Nuclear Structure, edited by P. Catillon, P. Radvanyi and M. Porneuf (North-Holland Publishing Company, Amsterdam, 1982).
2. N. Anantaraman, G.M. Crawley, A. Galonsky, C. Djalali, N. Marti, M. Morlet, A. Willis, and S.C. Jourdain, Phys. Rev. Letters 46, 1318 (1981).
3. A. Richter, in Proceedings of the Ninth International Conference on High Energy Physics and Nuclear Structure, edited by P. Catillon, P. Radvanyi and M. Porneuf (North-Holland Publishing Company, Amsterdam, 1982).
4. E. Wolynec, W.R. Dodge, R.G. Leicht, and E. Hayward, Phys. Rev. C 22, 1012 (1980).
5. W.R. Dodge, R.G. Leicht, E. Hayward, and E. Wolynec, Phys. Rev. C 24, 1952 (1981).
6. A. Veyssière, H. Beil, R. Bergère, P. Carlos, and A. Leprette, Nucl. Phys. A159, 561 (1970).
7. S.C. Fultz, R.L. Bramblett, J.T. Caldwell, and N.A. Kerr, Phys. Rev. 127, 1273 (1962).
8. E. Hayward, in Giant Multipole Resonances, edited by F.E. Bertrand (Harwood, New York, 1980).
9. R. Bergère, H. Beil, and A. Veyssière, Nucl. Phys. A121, 463 (1968).
10. L.W. Fagg, Reviews Mod. Phys. 47, 683 (1975).
11. R. Pitthan, F.R. Buskirk, E.B. Dally, J.N. Dyer, and X.K. Maruyama, Phys. Rev. Lett. 33, 849 (1974).
12. X.K. Maruyama, private communication.

FIGURE CAPTIONS

Figure 1 Measured (e,n) cross section versus the electron kinetic energy. The arrow indicates the (γ,n) threshold. The open circles are the results obtained by residual activity and the triangles refer to the measurement performed by detecting the neutrons. The full circles show the photodisintegration yield measured by residual activity. The curves E1+E2 and Y are the electrodisintegration and photodisintegration yields, respectively, obtained using the (γ,n) cross section from ref. 6. It was assumed that the (γ,n) cross section contains an E2 component which exhausts one E2 sum (see text).

Figure 2 E1 , E2 and M1 virtual photon spectra produced by an electron of kinetic energy 11 MeV scattered by a gold nucleus.

Figure 3 Ratio of measured to calculated (e,n) cross section. Circles: ^{197}Au - the calculated (e,n) cross section is curve E1+E2 of Fig. 1; triangles: ^{181}Ta - the calculated (e,n) cross section has an E2 component exhausting 80 percent of the EWSR.

Figure 4 Measured (e,n) cross section. The full curve E1+E2+M1 results from fitting the data assuming that the (γ,n) cross section contains also E2 and M1 strength. The curve M1 shows the contribution from M1 strength.

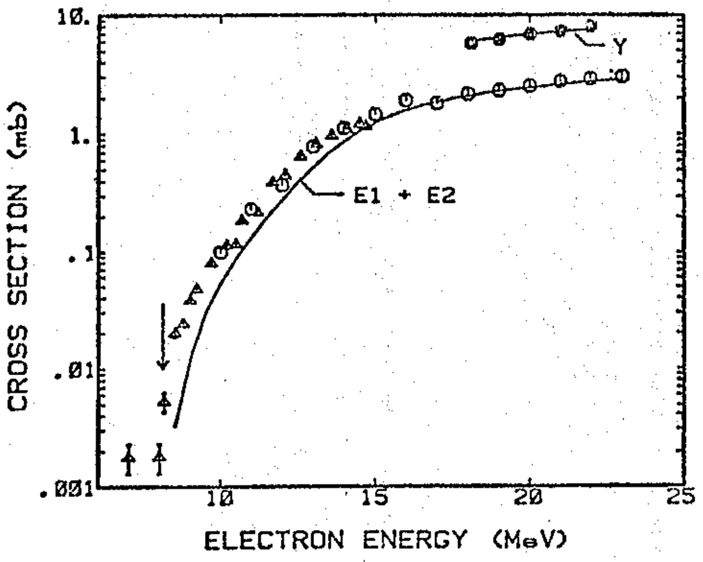
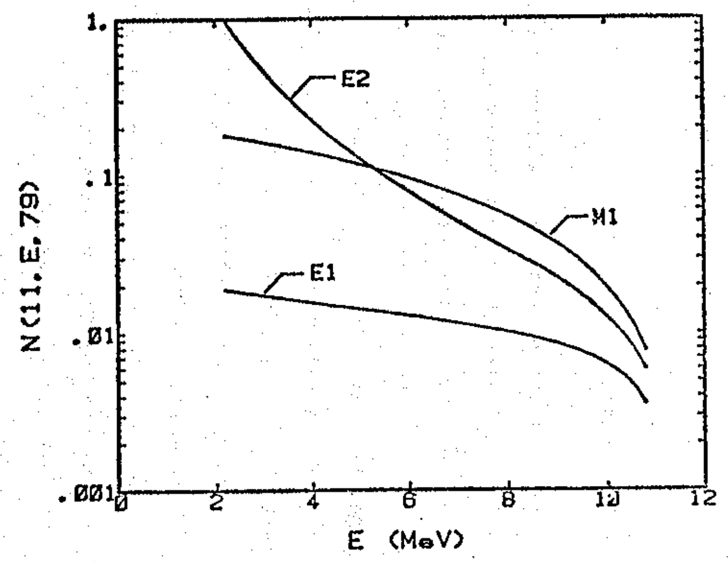


Figure 1



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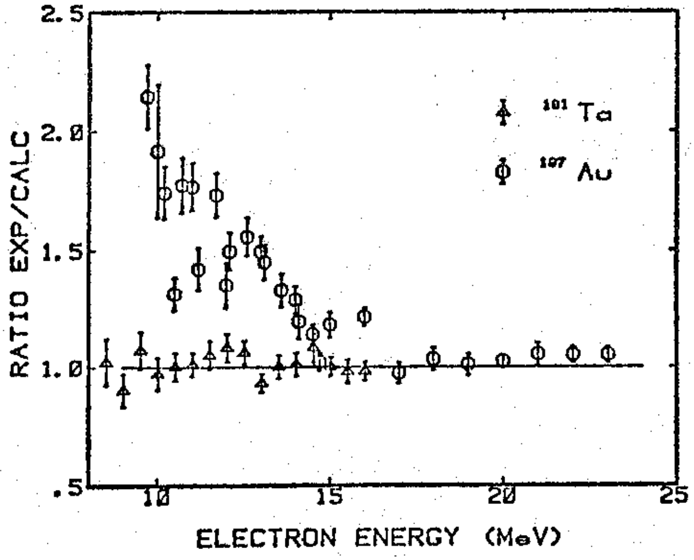

Figure 3

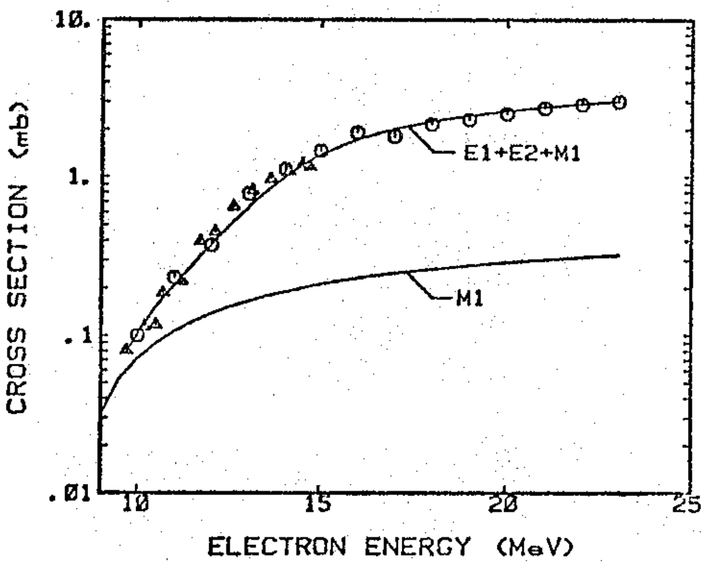

Figure 4