Electroexcitation of the nucleus ^{16}O with coincidence detection of the electron and the secondary particles

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The cross section $d^4\sigma/dE_e d\Omega_e dE_c d\Omega_c$ has been measured in the reaction $^{16}O(e,e'c)$, where c represents charged particles. An ultrathin internal target was used in an electron storage ring. Coincidences with secondary particles emitted along and opposite the direction of the momentum transfer were detected.

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In most previous experiments on the electroexcitation of nuclei at a small momentum transfer ($q \lesssim 1\,F^{-1}$), only one particle has been detected, because of the background conditions in linear-accelerator experiments. A study of the reaction $(e,e'c)$, where c is a charged particle, should yield important new information about the nature of the states which form giant resonances.[1] For example, it would be possible to observe the decay modes of excited nuclear states, to determine the multipolarity of resonances, and to distinguish direct and resonance processes. This information can be obtained by an experimental procedure developed at our Institute[2,3] which uses an ultrathin internal target in an electron storage ring.

In the present experiments (Fig. 1) an electron beam with an energy $E_0 = 112$ MeV and an average current of 0.5 A is scattered by a target of water vapor (pressure of 10^{-2}

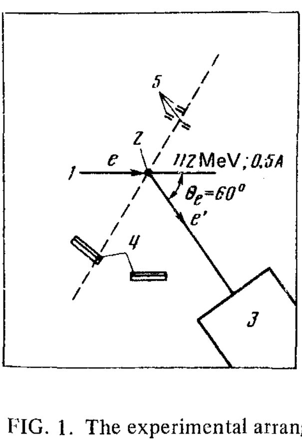

FIG. 1. The experimental arrangement. 1–Electron beam; 2–H_2O target; 3–magnetic spectrometer; 4–NaI(Tl) scintillation counters; 5–semiconductor-detector telescopes (I–III, from left to right). The dashed line is drawn along the momentum direction of the ^{16}O recoil nucleus in the case of elastic scattering of the electrons.

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Torr, 10 mm in diameter). Electrons scattered through an angle of 60° are detected by a magnetic spectrometer with a solid angle of 5×10^{-3} sr, an energy acceptance between E_0 and $E_0/2$, and a resolution $\Gamma_{1/2} = 400$ keV.

Three telescopes of silicon surface-barrier semiconductor detectors and two scintillation counters detect the secondary particles. The detectors lie 20 cm from the target.

The total solid angle of the surface-barrier detectors is 5×10^{-2} sr, and that of the scintillation counters is 0.35 sr. Each of the scintillation counters has two layers; the first layer encountered by the particles emitted from the target is a NaI(Tl) crystal 2 mm thick, and the second layer is a plastic scintillator. The short light pulses from the second layer of the scintillation counter signal the arrival of background electrons at the counter. In contrast with the surface-barrier detectors, which have a low particle detection threshold (1.5 MeV) and a negligibly thin dead layer, there is 50 mg of material between the target and the scintillation counters. This material stops all the α particles and increases the proton detection threshold to 5 MeV.

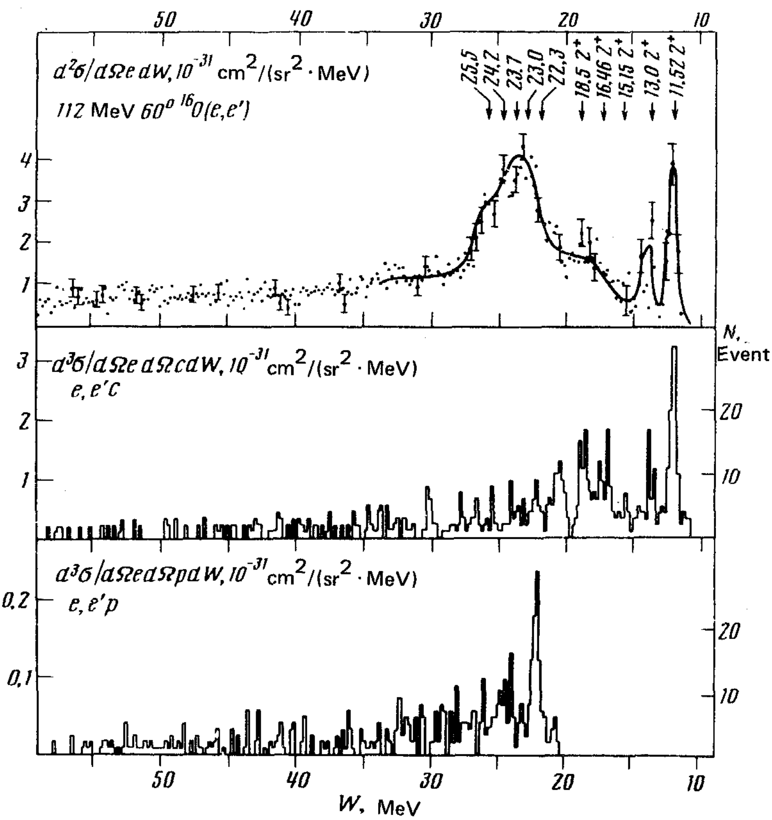

FIG. 2. Distributions of scattered electrons. a–Distribution from all events; b–from events having a coincidence with the first telescope of surface-barrier detectors; c–from events also having a coincidence with the NaI(Tl) counters.

Figure 2 shows energy distributions of the scattered electrons (W is the nuclear excitation energy). The distribution for events having coincidences with the surface-barrier detectors is shown for only the first telescope, which did not receive protons from the reaction $ep \to e'p\gamma$. Radiation corrections have been applied to all the distributions. The random-coincidence level is ~0.1 event/channel in distribution 2b and ~0.6 event/channel in distribution 2c. The levels of ^{16}O with the quantum numbers 2^+ and several levels from the region of the giant dipole resonance which are observed in electron scattering[4] are marked in Fig. 2. Distribution 2a agrees with the results of Ref. 5 for the reaction $^{16}O(e,e')$.

The predominant features in distribution 2b are the 2^+ quadrupole resonances which lie above the threshold for α detachment (7.2 MeV). The reason lies in the anisotropy of the decay of these resonances, which increases the flux density of secondary particles along the direction of the momentum of the excited nucleus. For certain other resonances, e.g., the 0^+ resonances, which decay isotropically, this flux density is lower. The situation is illustrated in Fig. 3 for the case of the resonances at 11.52 MeV (2^+) and 12.05 MeV (0^+). Both of these resonances decay primarily through the emission of monoenergetic α particles with a residual nucleus ^{12}C in the ground state. Figure 3a shows part of the electron distribution for all events corresponding to these resonances; Fig. 3b shows part of the distribution for events which have coincidences with the surface-barrier detectors. We see that in the case of the coincidences the ratio of the numbers of events in the peaks is changed by a factor of about 5.

For distribution 2c the detection of events begins at $W \gtrsim 20$ MeV. A peak corresponding to the level at 22.3 MeV is prominent. Its width is roughly equal to the $\Gamma_{1/2}$ resolution of the spectrometer. The other levels of the giant dipole resonance of ^{16}O are

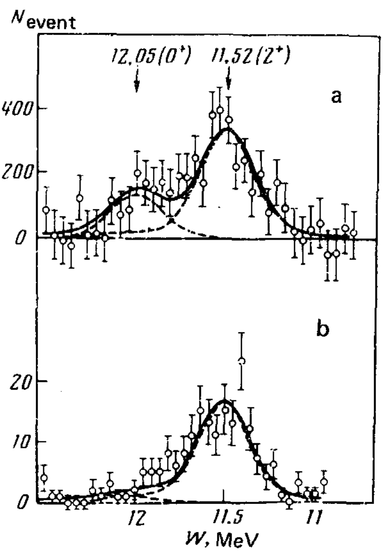

FIG. 3. The energy levels of ^{16}O at 11.52 MeV (2^+) and 12.05 MeV (0^+). a–A part of the distribution in Fig. 2a which contains these levels; b–part of a distribution which is also based on events in which there is a coincidence with the surface-barrier detectors.

relatively suppressed, apparently because of either the emission of low-energy protons during the decay of these levels or the operation of other decay modes, which are not detected by the coincidence counters.

The qualitative difference between distribution 2c and the corresponding distribution for the reaction[6] $^{16}O(\alpha,\alpha' p)$, in which there is no resonance structure, is apparently due to the excitation of isovector resonances in the electron scattering.

The importance of the information which can be obtained from coincidence experiments has been mentioned by several workers.[7] Unfortunately, it is difficult at present to analyze this information, because we lack the theoretical results of the type which have been calculated[1] for ^{12}C.

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