Isoscalar breathing mode states identified in ^{144}Sm and ^{208}Pb

from P. E. Hodgson

OVER the past few years many collective multipole excited states of nuclei have been found, mainly by inelastic scattering measurements. The energy spectra of the inelastically-scattered particles show separate peaks at the higher energies due to the excitation of the low-lying states and a broad peak at lower energy due to the excitation of multipole resonances. The multipolarity of the resonance can usually be found by studying the angular distribution of the resonance peak, and comparing it with the distribution calculated from a model of the resonant state with various assumed multipolarities. In this way much has been learnt about the giant quadrupole resonance, but so far it has proved difficult to identify the monopole or breathing-mode state. This is called the breathing mode because it corresponds to the nucleus changing size but not shape, and this shows that its energy is closely related to the nuclear incompressibility.

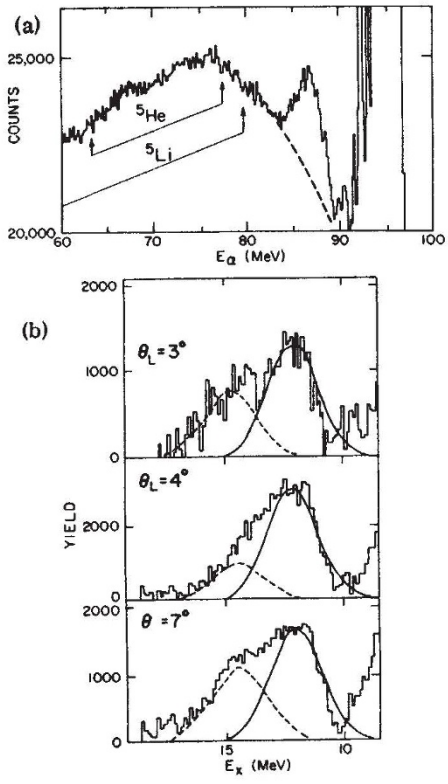

Fig. 1 Energy spectra of the α particles inelestically scattered from ^{208}Pb (*a*) and ^{144}Sm (*b*) showing the analysis of the giant resonances into two peaks.

In a recent experiment, Youngblood and colleagues of Texas A&M University have found that inelastic α-particle scattering at forward angles provides clear evidence for the breathing-mode excitation in ^{144}Sm and ^{208}Pb (*Phys. Rev. Lett.* **39**, 1188; 1977). In their earlier work with 97 and 115 MeV α particles they had found that the giant resonance peak has two components, but both had the same angular distribution and were assigned to the giant quadrupole resonance.

The new experiments were made with 98 MeV α particles, and measurements were made at much smaller angles than before, between 3° and 8° to the incident beam. Some of their results are shown in Fig. 1, together with the analysis of the giant resonance peaks into two components. The angular distributions of the two peaks are shown in Fig. 2, and it is clear that they are very different, especially around 4°. The multipolarities of the resonances were found by making calculations of the angular distributions assuming that the states are monopole, isovector dipole, quadrupole and hexadecapole, corresponding to $L = 0$, 1, 2 and 4 respectively. It is clear in each case that the data for the component at the lower energy is well fitted by the quadrupole curve and for the component at the higher energy by the monopole curve in each case. In particular, the predicted signature of the monopole state, a sharp minimum around 4°, is very clear in the data for the excitation to the higher energy for both nuclei, while it is absent in the data for the lower energy excitation.

The giant multipole excitations should satisfy sum rules, which means that the integrated strength of all their components should add to a value that can be calculated from the theory of the excitations. In the present experiments, it is found that all four resonances satisfy the energy-weighted sum rule to within the uncertainties of the analysis. This is a valuable confirmation of the correctness of the assignments.

The results for the breathing-mode excitation energies are in good agreement with previous experimental work, and with the recent theoretical estimates. According to the liquid drop model, the monopole excitation energy is related to the nuclear incompressibility K by

$$E_0 = \pi/3R(\hbar^2 K/m)^{\frac{1}{2}}$$

where R is the nuclear radius and m the nucleon mass. The excitation energies 13.7 MeV for ^{208}Pb and 15.1 MeV for ^{144}Sm give values of 208 and 197 MeV for K respectively, which are consistent with other theoretical estimates. □

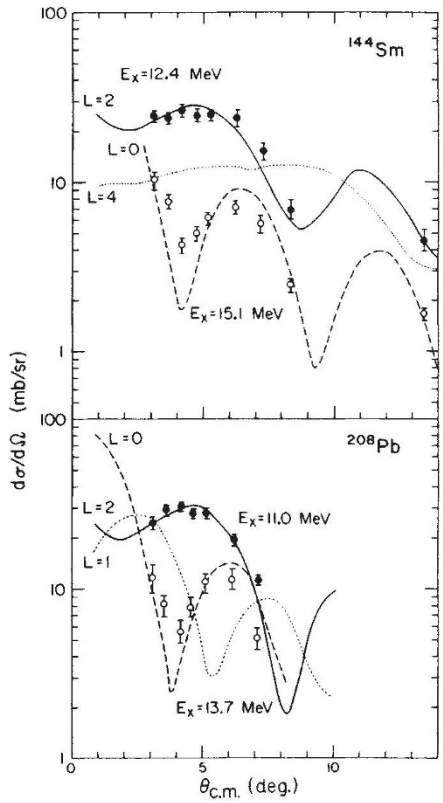

Fig. 2 Angular distributions of the two components of the giant resonance peaks in ^{144}Sm and ^{208}Pb compared with distorted wave calculations assuming various values of the multipolarity L.

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A hundred years ago

MR. STANLEY will probably arrive in England this week. He has been received with enthusiasm at Rome, Marseilles, and Paris. The Chamber of Commerce and the Geographical Society of Marseilles presented Mr. Stanley with medals. No doubt our own Geographical Society will take the lead in the warm reception which will certainly be accorded in this country to one of the foremost of explorers.

THE wolves in Eastern France have become unusually bold during this winter, and reports are constantly received of their depredations in various parts of the country. In one instance a letter-carrier was driven back by them from his regular route.

From *Nature* **17**, 17 January, 232; 1878.