^{38}Cl

Fig. 1 Comparison between the stripping strengths $(2J+1)S_n$ for the reaction ^{37}Cl(d,p)^{38}Cl to many states of ^{38}Cl (solid lines) and the reduced transition probabilities after thermal neutron capture ^{37}Cl(n,γ)^{38}Cl (open lines). Only the transitions with orbital angular momentum transfer $L_N = 1$ are included. The (n,γ) partial radiation widths were normalised so that their largest value equals the corresponding $(J+1)S_n$ values. The correlation coefficients are given for levels up to 2.8 MeV and for all levels.

as their charge and matter distributions, electromagnetic transition rates and quadrupole moments.

The theories used to analyse the experimental data, in particular the distorted wave theory, involve certain approximations and are subject to some assumptions that together limit the accuracy of the final results. The formalism contains some purely mathematical approximations, and physically there are for example uncertainties connected with the possible contribution of compound nucleus and two-step reaction processes. Some improvement in the accuracy of these analyses has recently come from the use of the j-dependent sum rules (*Nature*, 249, 695; 1974). More recently Clement in a contribution to a conference on nuclear structure and spectroscopy held last year in Amsterdam has drawn attention to the importance of comparisons between the (d,p) stripping and the neutron capture data.

The (d,p) deuteron stripping reaction and the (n,γ) neutron capture reaction both deposit a neutron in one of the unoccupied states of the final nucleus, and so both should give the same result for the structure of a particular nucleus. The important quantities are the spectroscopic factors that measure the single-particle strengths of the states in the final nucleus and the corresponding transition probabilities for neutron capture. Comparison of the numbers obtained for the same nucleus by the (d,p) and (n,γ) reactions is thus a good test of the reliability of both analyses.

Such a comparison was made for ^{38}Cl by Spits and Akkermans (*Nuclear Physics*, A215, 260; 1973). They measured the cross section for the ^{37}Cl(n,γ)^{38}Cl neutron capture reaction to many states of ^{38}Cl and compared the transition probabilities they obtained from their data with the spectroscopic factors found from the corresponding ^{37}Cl(d,p)^{38}Cl deuteron stripping reaction by Engelbertink and Olness (*Phys. Rev.*, C5, 431; 1972). The results are compared in Fig. 1 and show a remarkably high degree of correlation between the two sets of numbers. Indeed if the data are analysed statistically the correlation coefficient between the two sets is as high as 98%.

Similarly high correlations have now been obtained for a whole series of nuclei, a few cases of low correlation being readily explicable as due to the presence of nearby resonances. The result for ^{38}Cl is thus not an isolated example, but is quite typical.

These astonishingly high correlations between spectroscopic factors obtained by quite different reactions validate at a stroke essentially all the significant approximations and assumptions in the theories of deuteron stripping and neutron capture (Kopecký, Spits, and Lane, *Phys. Lett.*, 49B, 323; 1974). The reaction mechanisms are so different that it is inconceivable that any perturbing factor in the analysis should have the same effect in the two reactions. The excitation energies of the compound nuclei in the two cases differ widely, so the compound nucleus cross sections must be different and since they do not affect the results they must both be small. Similarly for the two-step contributions (*Nature*, 247, 179; 1974) which must be quite different in the two types of reaction. All perturbing factors, if important, could only reduce the correlation coefficients and since they are so high the analysis provides strong evidence that both sets of analysis are rather more accurate than has been generally believed. This very satisfactory result should be a welcome stimulus to further analyses of single particle states in nuclei.

New method of determining nuclear quadrupole moment

from P. E. Hodgson

THE recent theoretical work of Clement (*Nuclear Phys.*, A213, 492; 1973) on the nuclear shell model has made it possible to express the nuclear quadrupole moment in terms of single particle quadrupole integrals and the spectroscopic factors extracted from single proton transfer reactions. In some cases all the required data are available and the resulting values of the nuclear quadrupole moment are in excellent accord with those determined by atomic methods.

In a previous note (*Nature*, 249, 695; 1974) the work of Clement and Perez on the j-dependent sum rules was described. This shows how the spectroscopic factors for stripping and pickup reactions on the same nucleus can be related to each other, thus providing multiple checks of the values obtained for the spectroscopic factors and confirming the validity of the distorted wave theory used to obtain them. If all the necessary data are available, the spectroscopic factors can be obtained with an accuracy of better than 10%.

The single-particle quadrupole integrals are simply overlap integrals of two single-particle wavefunctions with the quadrupole operator. These may be evaluated very easily using harmonic oscillator wavefunctions, but the results are rather inaccurate, especially for valence nucleons. Much better results can be obtained with single-particle wavefunctions evaluated as the eigenfunctions of a Saxon–Woods potential with parameters adjusted to give the correct binding energies; these can now be obtained easily with an electronic computer.

Thus for nuclei for which a complete set of data are available it is possible to use the formalism of Clement to calculate the quadrupole moment.

Clement and Perez (*J. Phys.*, A7, 193; 1974) have now done this for ^{37}Cl, and find $Q = -0.057 \pm 0.005$ barn which compares very well with the atomic value $Q = -0.062$ barn, showing the reliability of the method. As more spectroscopic factors become available this should become a powerful method of determining nuclear quadrupole moments, which will be especially useful in cases where the atomic value is not easily obtained.