MIRROR SYMMETRY IN A=18 NUCLEI FROM ^{18}Ne(p,p') IN INVERSE KINEMATICS

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Since the time of Rutherford, nearly ninety years ago, the static and dynamic properties of the nucleus have been studied using a wide array of experimental probes [1]. With the advent of new radioactive beam facilities [2], it is now possible to extend these studies to unstable nuclei. Here we report new inelastic proton scattering data for the $0^+_{gs} \rightarrow 2^+_1$ transition in ^{18}Ne obtained via the scattering of a radioactive ^{18}Ne beam from a proton target. This is the heaviest $Z > N$ nucleus for which proton scattering data have been reported. These data provide the first hadronic test of mirror symmetry [3] for quadrupole transitions in $s-d$ shell nuclei. The $0^+_{gs} \rightarrow 2^+_1$ transition in ^{18}O has been studied earlier via scattering of nucleons [4, 5, 6], pions [7], and electrons [8]. Previously, the only type of data available on this transition in both ^{18}O and ^{18}Ne was from the $2^+_1 \rightarrow 0^+_{gs}$ γ-ray decay [9]. The γ-decay data are sensitive only to proton transition densities, while hadronic data are sensitive to both proton and neutron densities [1, 10]. Here we describe the present measurement of proton scattering on ^{18}Ne and compare data from inelastic scattering of low energy nucleons on both ^{18}O and ^{18}Ne to consistent folding model calculations using empirical densities obtained for ^{18}O.

We measured angular distributions for protons scattered from the ground and 1.89 MeV 2^+_1 states of ^{18}Ne by the p(^{18}Ne,p') reaction. The 30 MeV/nucleon ^{18}Ne beam was produced in the A1200 fragment separator [11] at the National Superconducting Cyclotron Laboratory via fragmentation of a 65 MeV/nucleon ^{20}Ne primary beam on a water cooled 360 mg/cm^2 ^{9}Be target. The intensity of the beam at the target position - as measured in the phoswich telescope - reached a maximum of 30,000 particles/second and averaged 25,000 particles/second during the experiment. Polypropylene foils were used as the hydrogen targets for the secondary beam. The arrangement for detecting the scattered protons was quite similar to that used by Kelley *et al.* for a measurement of the p(^{38}S,p') reaction [12].

If the nuclei ^{18}O and ^{18}Ne are mirror symmetric, then the proton ground state and transition densities in ^{18}O should be equal to the corresponding neutron densities in ^{18}Ne, while the neutron densities in ^{18}O and proton densities in ^{18}Ne should be equal as well, to the extent that Coulomb effects are small [3]. Below we describe folding model calculations to test this hypothesis. Proton densities (ρ_p) for the ground state and $0^+_{gs} \rightarrow 2^+_1$ transition in ^{18}O have been determined from electron scattering [8]. A study of ^{18}O via the scattering of 135 MeV protons provided corresponding information on neutron densities (ρ_n) in this nucleus [6]. The neutron and proton multipole matrix elements for the empirical quadrupole densities are $M_n = 6.18\, fm^2$ and $M_p = 3.00\, fm^2$, with $M_n/M_p = 2.06$ in the convention in which $B(E2; 0^+_{gs} \rightarrow 2^+_1) = 5M_p^2$.

Here the model of Ref. [13] is applied to the present 30 MeV ^{18}Ne(p,p') data using the empirical ^{18}O densities obtained from electron scattering [8] and intermediate energy proton scattering [6] analyses. As in Ref. [13], the present calculations were performed with the computer codes ALLWRLD [14] and TAMURA [15]. The ρ_p in ^{18}Ne are taken to be equal to the ρ_n determined for ^{18}O via proton scattering, and the ρ_n for ^{18}Ne are set equal to the ρ_p in ^{18}O determined from electron scattering. Additional results

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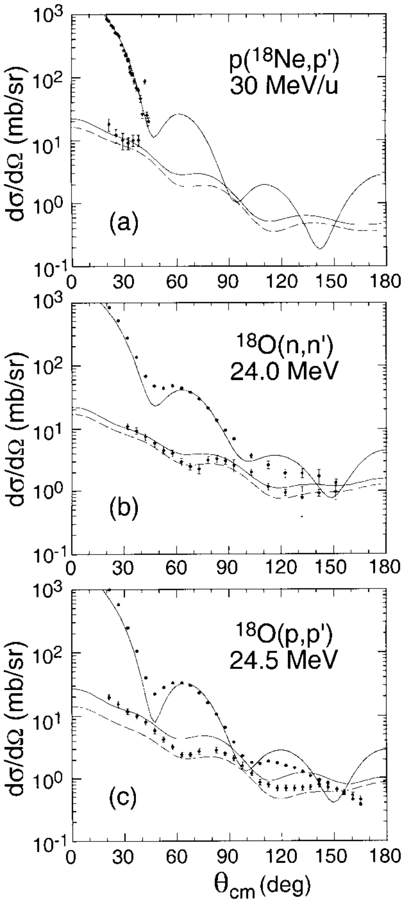

Figure 1: Comparison of data for the $0_{gs} \rightarrow 2_1^+$ transition from (a) the present p(^{18}Ne,p') reaction, (b) ^{18}O(n,n') reaction at 24.0 MeV [5], and (c) the ^{18}O(p,p') reaction at 24.5 MeV [4] to microscopic scattering calculations based on empirical densities for both protons and neutrons (solid curves) and densities set to obey the relationship $M_n/M_p = N/Z$ (dashed curves). The calculations are described in detail in the text.

for ^{18}O(n,n') at $E_n = 24.0$ MeV [5] and ^{18}O(p,p') at $E_p = 24.5$ MeV [4] are also presented for comparison. The reaction ^{18}O(n,n') is the mirror reaction to ^{18}Ne(p,p').

As can be seen in the theoretical results shown in Fig. 1, the calculations reproduce the experimental data extremely well, particularly for $\theta_{c.m.} < 60°$, which is quite impressive considering that there are no free parameters and extensive tuning of the nucleon-nucleus interaction has yet to be carried out in this energy region. The case for mirror symmetry is well supported by these results. The precision of the present test for mirror symmetry is limited by both the reaction model and the quality of the ^{18}Ne inelastic scattering data: a violation of mirror symmetry could be seen if the differential cross sections deviated by more than 30% from the predicted magnitudes.

Also shown as dashed curves in Fig. 1 are results obtained assuming $M_n/M_p = N/Z$ for the $0_{gs}^+ \rightarrow 2_1^+$ transitions in mass 18 with ρ_n in ^{18}Ne and ρ_p in ^{18}O taken from electron scattering on ^{18}O [8]. The empirical densities have $M_p/M_n > Z/N$ for ^{18}Ne and $M_n/M_p > N/Z$ for ^{18}O. The dashed curves clearly underestimate the experimental data in all cases. The difference between the dashed and solid curves are nearly identical for the ^{18}Ne(p,p') and ^{18}O(n,n') mirror reactions. A larger difference is obtained in the case of ^{18}O(p,p') because in ^{18}Ne(p,p') and ^{18}O(n,n') the coupling between the projectile and underestimated target density is only about one-third of that for ^{18}O(p,p'), as noted above.

The result $M_p/M_n > Z/N$ is expected for low-lying quadrupole transitions in a closed neutron shell nucleus like ^{18}Ne. In the extreme shell model only the valence protons would contribute to the transition and M_p/M_n would be infinite. Even with configuration mixing in the proton valence space M_p/M_n remains infinite. Mixing with complicated near space configurations, i.e. deformed states [16, 17], and core polarization, i.e. coupling to giant resonances [18, 19, 20], drives M_p/M_n toward Z/N. However, Z/N tends not to be achieved in single closed shell nuclei [21].

A more detailed report of this work can be found in Ref. [22].

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