Spectroscopic factors of the proton bound states in ^{23,25}F

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The proton quasi-free knockout reaction on ^{23}F (^{25}F) was studied in SHARAQ04 experiment at RIBF, RIKEN[1]. The spectrum of excitation energy of the residue ^{22}O (^{24}O) was deduced and partitioned by the neutron thresholds[2]. The orbital angular momentum of each partition was identified by comparison with the DWIA calculation, and then the sum of the spectroscopic factors (SFs) was extracted [3]. Figure 1 shows the spectra of excitation energy.

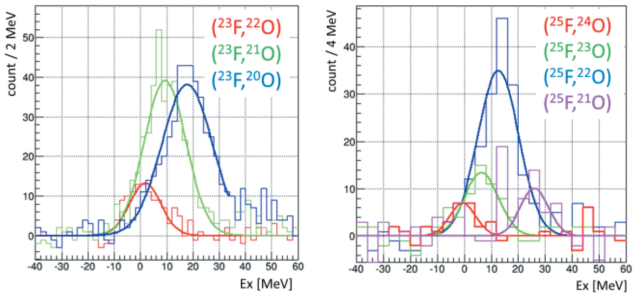

Fig. 1. Spectra of excitation energy of ^{23}F(p,2p) (left) and ^{25}F(p,2p) (right).

In ^{23}F(p,2p), the partition (^{23}F,^{22}O) originates from the 1d$_{5/2}$ shell and the SF is 0.4 ± 0.1. The partitions (^{23}F,^{21,20}O) originate from the p-shell with the sum of the SFs of 4.8 ± 0.7. In ^{25}F(p,2p), the partitions (^{25}F,^{24,23}O) originate from the 1d$_{5/2}$ shell and the sum of the SFs is 0.9 ± 0.7. The partitions (^{25}F,^{22,21}O) originate from the p-shell with the sum of the SFs of 4.4 ± 0.9.

The sum of the SFs of the 1d$_{5/2}$ proton of ^{25}F can be understood as a result of the double magic of ^{24}O [4]. The sum of the SFs of the p-shell for both ^{23}F and ^{25}F are approximately 75% of the shell limit. This result is similar to most stable isotopes. The extraordinary small SF of the 1d$_{5/2}$ of ^{23}F needs explanations.

The independent particle model should be valid in ^{23}F because the experimental proton shell gap between the 1d$_{5/2}$ and 1p$_{1/2}$ is 10 MeV, and the proton-neutron interaction energy is only 0.7 MeV. There could be missing strength at higher excitation energies. The wave function of ^{23}F $|^{23}F\rangle$ can be expressed as a linear combination of proton single particle wave functions $|p\rangle$ coupled to ^{22}O wave functions $|^{22}O\rangle$, such that

$$|^{23}F\rangle = \sum_{i,j} \beta_{ij} \left[|p\rangle_i |^{22}O\rangle_j \right],$$

where β_{ij} is the square root of the SF, and the square bracket [ ] represents the angular and isospin coupling and anti-symmetry operator. The known parities of the excited states of ^{22}O are all negative above 6.9 MeV (1-neutron threshold is 6.8 MeV). Because the residual interaction cannot mix different parity states, the sum of the SFs of the 1d$_{5/2}$ shell is almost limited up to 1-neutron threshold. However, the knowledge of the excited states is not complete that there could be undiscovered positive parity states above the neutron threshold.

A mean field calculation suggests that ^{23}F is slightly deformed ($\beta_2 = -0.2$) [5,6]. The deformed oxygen core has to be expanded into many excited states of free oxygen; therefore, the deformation could reduce the knockout cross section. In the reaction aspect, the (p,2p) cross section of a slightly deformed nucleus will be different from that of a spherical nucleus due to the focusing effect [7].

In conclusion, the SFs of the proton bound states of ^{23}F and ^{25}F were deduced. The 1d$_{5/2}$ proton of ^{25}F is a strong candidate of a single particle orbit. The nature of the 1d$_{5/2}$ proton of ^{23}F requires further study. The results will be compared with the shell model calculation in the near future.

References

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