Study of neutron-rich sd-pf shell nuclei using multi-nucleon transfer reactions

M. Wiedeking[1], E. Rodriguez-Vieitez[1,2], P. Fallon[1], R.M. Clark[1], M. Cromaz[1], M. Descovich[1], I-Y. Lee[1], M-A. Deleplanque[1], A.O. Macchiavelli[1], F.S. Stephens[1], D. Ward[1] M.P. Carpenter[3], R.V.F. Janssens[3], X. War[3], S Zhu[3]
D. Cline[4], R. Teng[4], C.Y. Wu[4]

[1] *Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720*
[2] *Department of Nuclear Engineering, University of California, Berkeley, California 94720*
[3] *Physics Division, Argonne National Laboratory, Argonne, Illinois 60439*
[4] *Department of Physics, University of Rochester, Rochester, New York 14627*

Nuclei in the sd-pf shell exhibit a rich variety of phenomena and physics. In nuclei far away from β-stability the neutron-proton interaction $V_{\sigma\tau}$ can become a driving force in determining the nuclear structure. Examples of this effect can be found in neutron-rich oxygen and fluorine isotopes. The latter can bind many more neutrons (up to ^{31}F) compared to oxygen (up to ^{24}O). The so-called "island of inversion" is another manifestation of the increased importance of the strong $V_{\sigma\tau}$ interaction. In this case the interaction between valence $f_{7/2}$ neutrons and $d_{5/2}$ protons favors the "intruder configuration" (corresponding to the promotion of a pair of neutrons across the N=20 shell to the $f_{7/2}$ orbital) and causes several N~20 nuclei (e.g. ^{30}Ne, ^{31}Na, ^{32}Mg) to have deformed ground-states despite having a "magic" number of neutrons. The understanding of the evolution of intruder configurations as protons are added along N~20 towards ^{40}Ca will provide important information on the underlying structure. Nuclei in this region have been mainly studied using reactions that are very selective. A more complete understanding of the nucleonic interplay and the underlying nuclear structure in the mass A~35 region can be obtained by applying less selective reaction mechanisms.

Two experiments were performed at the ATLAS facility of the Argonne National Laboratory to populate neutron-rich A~35 nuclei utilizing the reaction $^{208}Pb(^{36}S,X)$ at 230 MeV. In the first experiment a thin target of 0.5 mg/cm^2 was used to allow the reaction products to reach the particle detector. Identification of the target-like and projectile-like nature of the products as well as an event-by-event Doppler-shift correction was possible by utilizing the excellent spatial and timing resolution of the heavy-ion counter CHICO [1]. Gamma-radiation from the reactions was detected using GAMMASPHERE [2]. The second experiment utilized a 44 mg/cm^2 thick ^{208}Pb target providing high resolution GAMMASPHERE data. In addition to prompt gamma radiation both experiment were also sensitive to isomeric decay in the range of 10 ns to a few hundred ns. This allows for the search of new isomers in this mass region.

The analysis of the data sets reveals a wealth of information on neutron-rich Cl, S, P, Si, and Al isotopes. A detailed study of the intruder contributions and their effect in these nuclei is currently under way.

The observed level structures and transitions are compared to shell model calculations such as the Monte Carlo Shell Model using the SDPF interaction [3] and the Unified Shell Model Approach [4]. This comparison will test the models and help identify the underlying nuclear structure of the newly observed states.

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