Project for the final oral examination PHY981

Project G, Studies of electromagnetic transitions in Ar isotopes and ^{48}Ca

The aim of this project is to study the structure of selected low-lying states of the Ar isotopes and selected $B(E2;2_1^+\rightarrow 0_1^+)$ transitions using Alex Brown's Nushellx code. There is considerable interest in neutron-rich nuclei between $N=14$ and $N=28$, motivated particularly by the development of collectivity in nuclei such as ^{40,42}S and by questions concerning the strength of the N = 28 shell gap far from stability (see Refs. [1-5] and references therein). The Ar isotopes from ^{34}Ar ($N=16$) to ^{46}Ar ($N=28$) are important for studying this evolution of collectivity and for testing shell model calculations for neutron-rich nuclei in the region. Because they have two proton holes in the *sd* shell, the neutron-rich Ar isotopes offer a relatively âĂŸsimpleâĂŹ case to probe proton-neutron interactions and build up a microscopic description of nuclear structure in neutron rich nuclei near $N=28$. Being close to ^{48}Ca, there is great interest in understanding the role of such interactions. The lightest Ar isotopes can be studied with effective interactions for *sd*-shell only as a first trial. For the heavier ones, one would need to test effective interactions that include the $0f_{7/2}$ orbit as well and possibly the $1p_{3/2}$ single-particle state. In Refs. [2,3], shell-model calculations where performed with effective interactions that included parts of the *pf*-shell as well.

The task here is to compute low-lying states of the Ar isotopes from $N=16$ to $N=28$ and compute $B(E2;2_1^+\rightarrow 0_1^+)$ transition strengths and compare with available data. To achieve this you will need to use an effective interaction designed for the $1s0d$ and $1s0d1p0f$ shells. Since a full calculation in two major shells may be beyond reach, you will need to truncate the number of particles which can leave/occupy selected single-particle states. In the file which contains the single-particle data, you should block some of the single-particle orbis in the $1p0f$ shells.

The possible tasks are as follows

1. Compute the spectra of the low-lying spectrum of the above even Ar isotopes using the $1s0d$ shell as degree of freedom first. Add thereafter the $0f_{7/2}$ single-particle orbit and study the behavior of your results. Compare with Refs. [2,3].
2. Add thereafter the $1p_{3/2}$ single-particle state and commnet your results.
3. Compute thereafter the $B(E2;2_1^+\rightarrow 0_1^+)$ transition strengths and compare with available data using the above model spaces.
4. To study the similar transition in ^{48}Ca, you will need to use the $1p0f$ shell. Compute the above transition strength in ^{48}Ca and discuss the differences between ^{48}Ca and ^{46}Ar where two protons have been removed from the $1s0d$ shell.

Here follows a list of possible references.

1. H. Scheit et al., Phys Rev Lett 77, 3967 (1996)
2. J. Retamosa et al., Phys Rev C 55, 1266 (1997)
3. S. Nummela et al., Phys Rev C 63, 044316 (2001)
4. A.D. Davies et al., Phys Rev Lett 96, 112503 (2006)
5. A.E. Stuchbery et al., Phys Rev C 74, 054307 (2006)
6. S. Raman et al., At Data Nucl Data Tables 78, 1 (2001)

TABLE I: Experimental excitation energies, B(E2) values and lifetimes for the Ar isotopes. Data are from [1,6-11].

A	N	$E(2^+)$ [keV]	B(E2) [e2fm4]
38	20	2167	130(10)
40	22	1461	330(40)
42	24	1208	430(100)
44	26	1158	345(41)
46	28	1577	196(39); 218(31)

7. B. Fornal et al., Eur Phys J A 7, 147 (2000)
8. A. Gade et al., Phys Rev C 68, 014302 (2003)
9. K.-H. Speidel et al., Phys Lett B632, 207 (2006)
10. J. Cub et al., Nucl Phys A 549, 304 (1992)
11. E. A. Stefanova et al., Phys Rev C 72, 014309