Tutorial on shell model calculations and the production of nuclear Hamiltonians

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Tutorial of the *Espace de Structure Nucléaire Théorique*

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I. PROBLEM SET 2

1. Selection of model space and interaction (part 1)
   (a) Suppose you have an upcoming experiment which will produce states in ^{47}TI from a ^{48}Ti secondary beam. What model space and interaction should you use to produce calculations of theoretical spectroscopic factors (label.dat is helpful for this problem) ?
   (b) Calculate the ground state of ^{48}Ti and all necessary states in ^{47}Ti with the gx1 interaction. Full calculation should take approximately five minutes. Assuming that the empirical gx1 interaction reproduces experimental data in the pf model space, which states would you expect to observe in an experiment measuring ^{48}Ti(d,t)^{47}Ti ?
   (c) Compare to results from H. Pohl et al., Z. Physik **245**, 216 (1971), included in the supplemental materials.[1] Would you discard this effective interaction based on the observation that the calculated ground state spin of ^{47}Ti does not agree with the experimental value ? What do the calculations suggest about the experimental state at 2.16 MeV with unassigned spin ?
2. Selection of model space and interaction (part 2)
   (a) What low-lying levels would you expect for ^{11}Be from the standard harmonic oscillator plus spin-orbit mean field ? In what oscillator shell would you expect to perform calculations ?
   (b) The ground state of ^{11}Be has been determined experimentally and has $J^\pi = \frac{1}{2}^+$, with a $J^\pi = \frac{1}{2}^-$ excited state at 320 keV. Which model spaces in label.dat allow you to calculate both states ?
   (c) Calculate $J = \frac{1}{2}, \frac{3}{2}$ positive and negative parity states of ^{11}Be with both the psdmk and psdmwk interaction in the *psd* model space. What is the ground state spin ? What is the calculated energy difference between the $J^\pi = \frac{1}{2}^\pm$ states in each case ? Assess the agreement with experimental data, keeping in mind that experimental states with $J \geq \frac{5}{2}$ will not have theoretical counterparts. Should one interaction be preferred over the other ?[2]
3. **Conceptual :** From your calculations in these first two problem sets, what do you observe about the reliability of shell model calculations ? Think specifically in terms of the neutron-proton ratio N/Z.

Supplementary information

States in ^{47}Ti obtained from (d, t) reaction[3]

E_x (MeV)	J	C^2S
0.00	$\frac{5}{2}$	0.2
0.16	$\frac{7}{2}$	4.43
1.55	$\frac{3}{2}$	0.22
2.16	$\frac{1}{2}$ or $\frac{3}{2}$	0.12
2.59	$\frac{7}{2}$	0.32
3.18	$\frac{7}{2}$	0.56

Note : Only states which involve transfer of pf neutrons are included

1. Compare the states in the ti471.lpt file directly to the experimental results. Do not use 'toi' or ti471.eps for this question !
2. For a modern *psd* model space interaction, see Y. Otsuno and S. Chiba, Phys. Rev. C **83**, 021301(R) (2011).
3. H. Pohl et al., Z. Physik **245**, 216 (1971)