

EFFECTS OF  $^{56}\text{Ni}$  CORE EXCITATIONS

P.W.M. Glaudemans, R.J.G. Goossens, A.G.M. van Hees,  
B.C. Metsch and R. Vennink

*Fysisch Laboratorium, Rijksuniversiteit, Utrecht, The Netherlands*

The A = 57-66 isotopes of Ni and Cu have been treated <sup>1)</sup> in a model in which the  $^{56}\text{Ni}$  core is assumed to be closed and the remaining particles are restricted to the orbits  $2p_{3/2}$ ,  $1f_{5/2}$  and  $2p_{1/2}$ . In this study two interactions MSDI and ASDI [ref. 2] are compared.

The very large renormalizations of the effective transition operators determined empirically <sup>3)</sup> (e.g.  $e = 1.7 e$  and a reduction of about 50 %  
n

of the M1 matrix elements) indicate that the assumption of a closed  $^{56}\text{Ni}$  core may be a too severe restriction. However, for the Ni isotopes inclusion of one and two  $f_{7/2}$  hole states leads to maximum dimensions of about 1500 and 26000, respectively. For Cu isotopes even larger dimensions result such that truncation of the model space is necessary.

In order to investigate several truncation techniques we have focussed our attention first on the A = 57-59 isotopes of Ni and Cu for which the

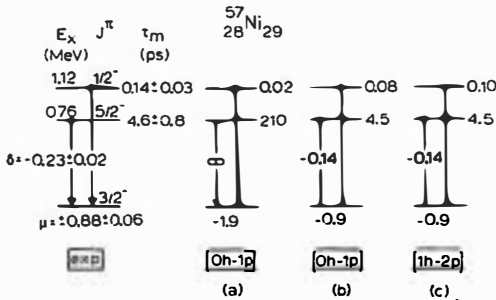


Fig. 1. Electromagnetic properties of  $^{57}\text{Ni}$  calculated with three different model assumptions.

(a) A closed  $^{56}\text{Ni}$  core and one particle in the orbit  $2p_{3/2}$ ,  $1f_{5/2}$  or  $2p_{1/2}$ . The bare-nucleon M1 operator has been used and an effective neutron charge of  $e_n = 1.7 e$ .

(b) The same model as in (a) but with the M1 effective reduced single-particle m.e. of ref. <sup>3)</sup>.

(c) A model with one  $1f_{7/2}$  hole in  $^{56}\text{Ni}$ . The bare-nucleon M1 operator has been taken and effective charges of  $e_p = 2e$  and  $e_n = e$ .

dimensions are less prohibitive. From an exact one-hole calculation with the SDI effective two-body matrix elements we obtained results nearly identical to those performed without  $f_{7/2}$  holes in  $^{56}\text{Ni}$ . As an illustration the results for  $^{57}\text{Ni}$  are given in fig.1. However, the one-hole space is superior since bare-nucleon M1 operators can be used and effective proton and neutron charges are reduced to  $e_p = 2e$  and  $e_n = e$ , respectively. Moreover, states of much higher spin can be generated when

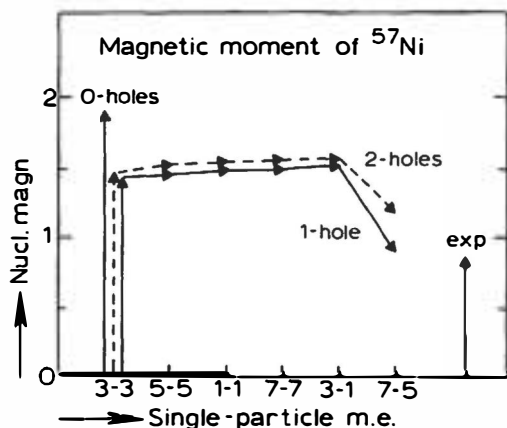


Fig. 2. The contributions of the various reduced single-particle m.e. to the magnetic moment of the  $^{57}\text{Ni}$  ground state ( $J^\pi = 3/2^-$ ). The symbols 1, 3, 5 and 7 refer to the  $2p_{1/2}$ ,  $2p_{3/2}$ ,  $1f_{5/2}$  and  $1f_{7/2}$  orbits, respectively. The results of calculations for zero, one and two  $f_{7/2}$  holes in  $^{56}\text{Ni}$  are shown.

are large whereas they are small in the two-hole space.

An interesting problem is the evaluation of the effective single-particle energy gap  $\Delta = e p_{3/2} - e f_{7/2}$ . In the literature the assumed values of  $\Delta$  which strongly affect the amount of core excitation, vary between 1.5 and 6.5 MeV. It turns out indeed that the excitation energies of the low-lying levels in light Ni isotopes barely depend on  $\Delta$ . However, the value of e.g. the magnetic moment  $\mu(3/2^-)$  in  $^{57}\text{Ni}$  depends strongly on  $\Delta$ . It follows from table 1, calculated for a one-hole space, that a 15% admixture of  $f_{7/2}^{-1}$  components reproduces the experimental value  $|\mu| = 0.88 \pm 0.06$  n.m.

Table 1. The  $^{57}\text{Ni}$  magnetic moment as a function of the  $f_{7/2}^{-1}$  contributions

$f_{7/2}^{-1}$ (%)	$\mu_{\text{calc}}$ (n.m.)
30	-0.38
20	-0.70
10	-1.00
0	-1.91

It is observed that the effective value of  $\Delta$  depends on the number of holes taken into account. For the one-hole space a value of  $\Delta \approx 4$  MeV seems optimal. Preliminary results from an exact four-hole calculation on  $^{54}\text{Fe}$  suggest a smaller value.

$f_{7/2}$  holes are included.

The effect of inclusion of two-hole states is illustrated for the dipole moment of  $^{57}\text{Ni}$ . In fig.2 the dependence of the dipole moment on the single particle m.e. is given for the one- and two-hole space. It is seen that the calculated dipole moment in both spaces is determined only by the  $p_{3/2} \rightarrow p_{3/2}$  and  $f_{7/2} \rightarrow f_{5/2}$  matrix elements, which yield a positive and negative contribution, resp. The wave functions in these model spaces are quite different, however. In the one-hole space the  $f_{7/2}^{-1}$  admixtures

- 1) J.E. Koops and P.W.M. Glaudemans, Z. Physik A280 (1977) 181.
- 2) P.J. Brussaard and P.W.M. Glaudemans, Shell-model applications in nuclear spectroscopy (North-Holland, Amsterdam, 1977).
- 3) J.E. Koops, thesis (Utrecht, 1978).