JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN VOL. 34, SUPPLEMENT, 1973
PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON NUCLEAR MOMENTS AND NUCLEAR STRUCTURE, 1972

VI-4

Moments of the $f_{7/2}$-Shell Nuclei

H. HORIE and T. ODA

Department of Physics, Tokyo Institute of Technology, Meguro, Tokyo

Nuclear moments provide a sensitive test of the nuclear wave functions, because the proton and the neutron have magnetic moments of different signs and only the proton has electric quadrupole moment. In this respect, the moments of the $f_{7/2}$-shell nuclei were investigated. The wave functions of the $f^n_{7/2}$ configurations were classified in terms of the seniority scheme for the proton and neutron systems.[1] For the pure $f^n_{7/2}$ configurations, four types of the effective interactions were chosen: (a) the MBZ matrix elements,[2] (b) matrix elements deduced from the ^{48}Sc experimental data,[3] (c) those deduced from ^{42}Sc[4] and (d) the Dieperink and Brussaard[5] matrix elements. In Table I, the calculated magnetic moments for the pure $f^n_{7/2}$ configurations are shown with the experimental values. We have omitted those nuclei from the table which give the same value of the magnetic moment independent of the effective interactions, that is Ca isotopes, $N = 28$ isotones and self-conjugate nuclei. Although the effective interactions are quite different, we have obtained almost same values of the magnetic moments.

Some examples of the calculated magnetic moments are taken from Table I and are shown in Table II. The interactions adopted are the case (c) and the free g-factors are assumed for protons and neutrons. The agreement between the calculated and experimental values are fairly good. Especially, the magnetic moments of the odd nuclei provide very good agreement. In the table, the main component of the seniorities are also shown together with their amplitude and calculated values for the pure seniority states. It is seen that the higher seniority states give large changes in the moments and approach to the experimental values.

It is expected that the excitations of nucleons to the $f_{5/2}$ orbit give rise to further contribution to the magnetic moments. We are investigating the con-

Table I. Magnetic moments of $f^n_{7/2}$ configurations.

	Spin	exp.	(a)	(b)	(c)	(d)
^{43}Sc	7/2	+4.62 (4)	4.966	4.963	4.932	4.969
^{44}Sc	2	+2.56 (3)	2.368	2.498	2.239	2.512
	6	+3.88 (1)	3.596	3.514	3.434	3.662
^{45}Sc	7/2	4.75594 (1) +4.75633 (10)	5.220	5.209	5.325	5.151
^{46}Sc	4	+3.04 (2)	3.293	2.962	3.026	3.022
^{47}Sc	7/2	+5.34 (2)	5.553	5.524	5.589	5.492
^{45}Ti	7/2	0.095 (2)	−0.855	−0.907	−1.009	−0.752
^{47}Ti	5/2	−0.7881 (2)	−1.108	−1.085	−1.181	−0.997
^{49}Ti	7/2	−1.1036 (2)	−1.673	−1.645	−1.710	−1.612
^{49}V	7/2	4.46 (5)	5.184	5.186	5.334	5.030
^{50}V	6	+3.347 (1)	3.341	3.406	3.367	3.354
^{49}Cr	5/2	0.476	−0.664	−0.707	−0.667	−0.685
^{51}Cr	7/2	0.933	−1.341	−1.330	−1.446	−1.272
^{51}Mn	5/2	3.583	3.844	3.879	3.888	3.834
^{52}Mn	6	3.075 (1) 3.00 (15)	3.053	3.135	3.216	2.986
	2	0.0077 (3)	−0.152	−0.281	−0.022	−0.296

(a) the MBZ matrix elements
(b) matrix elements deduced from the ^{48}Sc experimental data
(c) those deduced from ^{42}Sc
(d) the Dieperink and Brussaard

Table II. Examples of $f^n_{7/2}$ calculations.

	Spin	$\mu_{exp.}$	Seniority, amplitude and μ of the main component	$\mu_{cal.}$
^{43}Sc	7/2	4.62 (4)	(1, 1/2) (0.9109) 4.080	4.932
^{44}Sc	2	2.56 (3)	(2, 1) (0.9013) 0.558	2.238
^{44}Sc	6	3.88 (1)	(2, 1) (0.8208) 1.674	3.433
^{45}Sc	7/2	4.75633 (10)	(1, 1/2) (0.9031) 5.107	5.325
^{45}Ti	7/2	0.095 (2)	(1, 1/2) (0.8864) −1.342	−1.009
^{46}Sc	4	3.04 (2)	(2, 1) (0.7369) 1.849	3.026
^{47}Sc	7/2	5.34 (2)	(1, 1/2) (0.9464) 5.547	5.589
^{51}Mn	5/2	3.583	(3, 3/2) (0.8972) 2.914	3.888
^{52}Mn	6	3.075 (7)	(2, 1) (0.8208) 4.976	3.216
^{52}Mn	2	0.0077 (3)	(2, 1) (0.9013) 1.658	−0.022

figuration mixing effect by the first order perturbation theory. We assume individual particle model in which only the pure seniority state is considered in the $f^n_{7/2}$ configurations, in other words only the main component of the $f^n_{7/2}$ calculations is considered. Some results are shown in Table III. In this table, corrections for the values of individual particle model due to the seniority mixing and the configuration mixing are indicated with the experimental values. In the calculations of the configuration mixing, we replace the energy denominator with those averaged over intermediate states. It is to be noted that the seniority mixing effect and the configuration mixing effect give complementary effects to reproduce the experimental value in each nucleus.

As the alternative calculation, we adopt the wave functions, which are obtained by the diagonalization in the full $f^n_{7/2}$ space, as zeroth-order wave functions of perturbation theory. By similar calculation of configuration mixing, we have the results of Table IV. Effect of seniority mixing has been taken into account to higher order by the diagonalization. Energies of intermediate states were assumed as calculated values of $f^{n-1}_{7/2}$ configuration.

^{48}V is a self-conjugate nucleus. Therefore we expect the same gyromagnetic ratio independent of angular momentum J in the pure $f^n_{7/2}$ configurations. The values of g-factors of the ground ($J=4$) and the first excited ($J=2$) states of ^{48}V are 0.41(2) and 0.188(17), respectively. In the framework of our calculations, these J dependence of g-factors is caused only by the configuration mixing effect and is

Table III. Seniority mixing and configuration mixing to the individual particle model.

		^{43}Sc	^{45}Sc	^{47}Sc	^{45}Ti	^{44}Sc	
	J	7/2	7/2	7/2	7/2	2	6
(I)	Seniority mixing	0.852	0.218	0.042	0.333	1.680	1.759
(II)	Config. mixing ($f_{5/2}$)	−0.054	−0.381	−0.566	0.626	0.419	0.353
	(I) + (II)	0.798	−0.163	−0.524	0.959	2.099	2.112
	$\delta\mu_{exp.}$	0.540	−0.351	−0.207	1.437	2.002	2.206

Table IV. Configuration mixing to the $f^n_{7/2}$ configurations.

	^{43}Sc	^{45}Sc	^{47}Sc	^{44}Sc		^{46}Sc
J	7/2	7/2	7/2	2	6	4
$\delta\mu$	0.068	−0.100	−0.268	0.192	0.242	0.244
$\delta\mu_{exp.}$	−0.312	−0.570	−0.249	0.321	0.446	0.02

Table V. Quadrupole moments of $f^n_{7/2}$ configurations.

		$Q_{exp.}$		$Q_{cal.}$ free	$Q_{cal.}$ eff.
Sc	43 7/2	−0.26 (6)		−0.081	−0.376
	44 2	+0.10 (5),	+0.14 (8)	0.013	0.117
	44 6	−0.19 (2),	0.37 (29)	−0.073	−0.466
	45 7/2	−0.22 (1)		−0.093	−0.381
	46 4	+0.119 (6)		−0.019	0.087
	47 7/2	−0.22 (3)		−0.104	−0.322
Ti	45 7/2	0.015 (15)		0.0086	−0.070
	47 5/2	+0.29 (1)		0.028	0.237
	49 7/2	+0.24 (1)		0.062	0.318
V	50 6	0.07		0.052	0.225

not able to be renormalized into the one body operator.

In Table V, the calculated values of the quadrupole moments are shown. The effects of configuration mixing have not been taken into account. So, the effective charges are assumed as $1.97e$ for protons and $1.87e$ for neutrons[6] as well as the charge for free nucleons.

References

1) H. Horie and T. Oda: Progr. theor. Phys. Suppl. Extra number (1968) 403.
2) J. D. McCullen, B. F. Bayman and L. Zamick: Phys. Rev. **134** (1964) B515.
3) H. Ohnuma, J. R. Erskine, J. P. Schiffer, J. A. Nolen, Jr. and N. Williams: Phys. Rev. **C1** (1970) 496.
4) J. J. Schwartz, D. Cline, H. E. Gove, R. Scherr, T. S. Bhatia and R. H. Siemssen: Phys. Rev. Letters **19** (1967) 1482.
5) A. E. L. Dieperink and P. J. Brussaard: Nuclear Phys. **A106** (1967) 177.
6) F. J. Lynch, K. E. Nysten, R. E. Holland and R. D. Lawson: Phys. Letters **32B** (1970) 38.