MAGNETIC MOMENTS OF NUCLEAR ISOSPIN DOUBLETS

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The magnetic moments of nuclear isospin doublets are examined under the assumption that $\vec{\mu}=\vec{\mu}_0$ (isoscalar)$+\vec{\mu}_3$ (isovector). For fixed J and P, the magnetic moments of nuclei with odd numbers of neutrons or protons all lie on two straight lines. The slope of the lines is approximately the same for any J and P.

The aim of this Letter is to point out some interesting regularities of the magnetic moments of light odd nuclei ($A \leqslant 39$). Under very general assumptions the magnetic moment of a nucleus transforms under rotation in isospin space like a scalar and the third component of a vector. Thus, for given A, only two parameters are needed for fixing the magnetic moments of an isospin multiplet. With obvious notations we write

$$\vec{\mu}=\vec{\mu}_0+\vec{\mu}_3. \tag{1}$$

For the moment we will fix our attention on doublets with $A \leqslant 39$. In this region, the validity of the isospin formalism is out of discussion and many experimental data are available. Moreover, the shell model provides a simple method for calculating the isoscalar part of the magnetic moment.

As far as the isovector part is concerned, the shell model in its most naive form is unable to give correct predictions because of the importance of various effects such as configuration mixing,[1] exchange currents, etc.

The isoscalar part[2] satisfies the sum rule

$$\sum_{T_3}\vec{\mu}(J,T,T_3)=(2T+1)\langle J|\vec{\mu}_0|J\rangle. \tag{2}$$

In order to evaluate Eq. (2) we must know the state $|J\rangle$, i.e., the nuclear wave function. In the shell-model approximation, the right-hand side of Eq. (2) is independent of A. This is in agreement with the available experimental data [see Figs. 1(a), 1(c), and 2(b)]. In view of this agreement we shall in the following assume that $\langle J|\times\mu_0|J\rangle$ is independent of A.

We will now group the isodoublets in the follow-

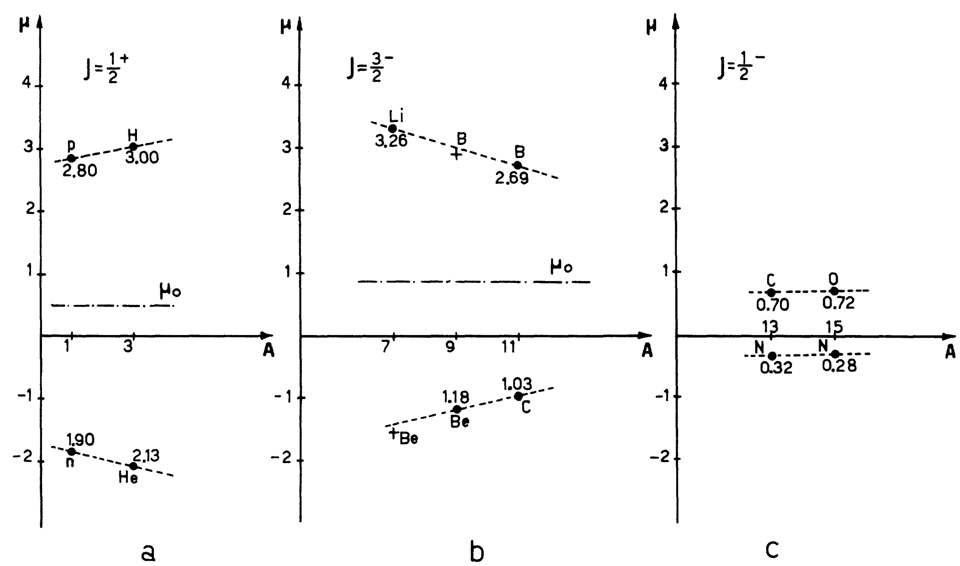

FIG. 1. Magnetic moments (in units of μ_N) of isospin doublets for (a) $J^P=\frac{1}{2}^+$(1s region), (b) $J^P=\frac{3}{2}^-$, and (c) $J^P=\frac{1}{2}^-$. Dots are experimental points; crosses represent theoretical points.

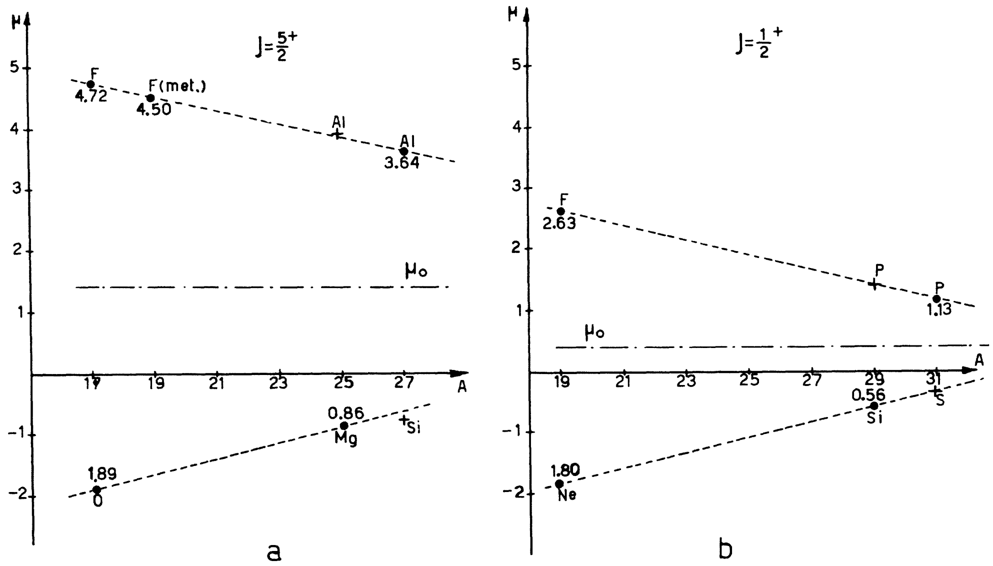

FIG. 2. Magnetic moments (in units of μ_N) of isospin doublets for (a) $J^P = \frac{5}{2}^+$, and (b) $J^P = \frac{1}{2}^+$ (2s region).

ing way:

Group	J of nuclei	Comments
I	$\frac{1}{2}^+$	1s region; see Fig. 1(a)
II	$\frac{3}{2}^-$	See Fig. 1(b)
III	$\frac{1}{2}^-$	See Fig. 1(c)
IV	$\frac{5}{2}^+$	See Fig. 2(a)
V	$\frac{1}{2}^+$	2s region; see Fig. 2(b)
VI	$\frac{3}{2}^-$	See Fig. 3

In all these groups, the magnetic moments of both components of at least one isodoublet have been measured. Thus the isoscalar part of μ may be directly obtained for each group by using Eq. (2). The agreement with the numerical values obtained from the shell-model is good. Once μ_0 is known, within a given group, only one measurement is needed for each isodoublet to determine the magnetic moments of both nuclei. The set of data[3] so obtained for fixed J and P (= parity shows very impressive regularities as can be seen from Figs. 1-3. The following comments are in order:

(a) For fixed J and P, the magnetic moments of nuclei with odd numbers of neutrons or protons all lie on two straight lines which are obtained from the following prescription:

$$(A, T_3 = \tfrac{1}{2}) + n\text{-}n \to (A+2, T_3 = -\tfrac{1}{2}) + p\text{-}p \to (A+4, T_3 = \tfrac{1}{2}) + n\text{-}n \cdots, \quad (3)$$

$$(A, T_3 = -\tfrac{1}{2}) + p\text{-}p \to (A+2, T_3 = \tfrac{1}{2}) + n\text{-}n \to (A+4, T_3 = -\tfrac{1}{2}) + p\text{-}p \cdots. \quad (4)$$

(b) In each group the first isodoublet would correspond to nuclei with closed shell plus a nucleon. [$A = 5$ in Fig. 1(b); $A = 17$, $J = \frac{1}{2}^+$ in Fig. 2(b); etc.] However, in many cases such configurations do not correspond to stable nuclei and the magnetic moments have not been measured. For this reason, those nuclei have not been plotted. The extrapolation of the lines up to those nuclei would assign them a magnetic moment which essentially coincides with the Schmidt provision. Thus, for each diagram, the lines have the Schmidt values as natural origins. For nuclei of group VI (Fig. 3) the single-particle approximation is not justified because of the nonspherical shape of the nuclei, and caution may be used in assigning the magnetic moments according to the Schmidt model. Apart from problems connected with the starting values of the magnetic moments, the slope of the two lines is in agreement with the others.

(c) We want to stress that the slope of the lines in Figs. 1(b), 2(a), 2(b), and 3 is approximately the same, 0.23-0.25. This suggests that any pair n-n or p-p in the chains (3) and (4) gives a constant contribution of the order of 0.23-0.25 to the isovector magnetic moment. This contribution has a quenching effect on the Schmidt values. In Fig. 1(a), the order of magnitude is still the same but the sign is opposite (antiquenching). Figure 1(c) shows an apparent discrepancy with respect to the above stressed regularity. However, in both cases one has to deal with nuclei

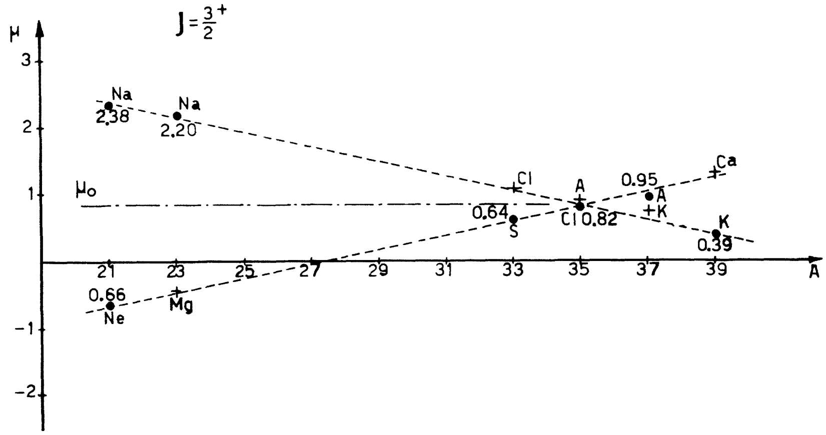

FIG. 3. Magnetic moments (in units of μ_N) of isospin doublets for $J^P = \frac{3}{2}^+$.

with one hole in a double closed shell. It is plausible that in these cases, additional effects play a definite role in compensating[4] the "regular" value ($A = 15$) or in changing the sign of the expected contribution ($A = 3$).

(d) By an analysis of all the diagrams, the important role played by the "pairings" n-n and p-p is apparent (see especially Figs. 2 and 3). For example, in Fig. 2(a), the magnetic moment of ^{25}Mg seems to be related to the number of n-n and p-p pairs by which ^{25}Mg differs from ^{17}O. Similar considerations hold for Figs. 2(b) and 3. In conclusion we want to stress the importance of further experimental data to confirm that these regularities are not accidental.

A possible theoretical interpretation of these regularities will be discussed in a subsequent paper.

[1]H. A. Mavromatis and L. Zamick, Phys. Letters 20, 171 (1966).

[2]R. G. Sachs, Phys. Rev. 69, 611 (1946).

[3]For experimental data, see Nuclear Moments (Academic Press, Inc., New York, 1958); and Nuclear Data Sheets, compiled by K. Way et al. (Printing and Publishing Office, National Academy of Sciences–National Research Council, Washington, D. C., 1965), Appendix 1; and M. A. Preston, Physics of the Nucleus (Addison-Wesley Publishing Company, Inc., Reading, Massachusetts, 1962).

[4]For example, for nuclei with one hole beyond a closed shell the configuration mixing effect is antiquenching. (See Ref. 1.)

SHELL-MODEL FRAGMENTATION OF THE Sc^{49} ANALOG LEVELS

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The fragmentation of the Sc^{49} analog levels is calculated and is shown to result from two-particle, one-hole $T_<$ states that include higher energy bound proton contributions. In addition, the damping widths of the fragmented levels due to three-particle, two-hole couplings $\Gamma^\downarrow$ and the escape widths $\Gamma^\uparrow$ are computed. The theoretical analog-level energies and widths are compared with experiment.

The analog resonances in Sc^{49} have been the subject of many recent experiments.[1-5] Because the target Ca^{48} consists of closed shells ($Z = 20$, $N = 28$) a theoretical microscopic shell-model description should be possible. We study here the 2p-1h (two-particle, one-hole) $T_<$ fragmentation of these resonances and present the energies, elastic-proton escape widths $\Gamma^\uparrow$, and damping