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Abstract: Nuclear ground state spins of the odd-mass strontium isotopes between A = 79 and 97 were determined by measurements of the hyperfine structure in the ionic transition 5s $^2S_{1/2}$ - 5p $^2P_{3/2}$. The spins of ^{93}Sr and ^{97}Sr are revised to I = 5/2 and I = 1/2, respectively, while assignments for the remaining isotopes are confirmed.

The sequence of strontium isotopes ranges from the N = 50 shell closure for ^{88}Sr into the regions of well-developed deformation for both neutron-deficient and neutron-rich isotopes. Laser spectroscopy measurements of the ground state moments and radii mainly cover the transitional region of the neutron-deficient branch [1,2]. We have recently started a more extended investigation of the nuclear ground state properties in strontium in an on-line experiment at the mass separator ISOLDE at CERN. In this communication we report the determination of the spins for the odd-A isotopes with 79 ≤ A ≤ 97 from the atomic hyperfine structure (hfs). This series of spins includes two controversial cases, ^{93}Sr and ^{97}Sr, where first spin assignments from nuclear spectroscopy were revised later on [3 - 7]. Among these, ^{97}Sr deserves special attention since the odd-mass isotones with N = 59 are considered to be an excellent testing ground for nuclear models because of their unique situation in the narrow range of neutron numbers where shape coexistence is indicated [7,8].

Our hfs measurements have been performed in the 5s $^2S_{1/2}$ - 5p $^2P_{3/2}$ transition (λ = 407.8 nm) of the Sr$^+$ ion. We used the technique of collinear fast-beam laser spectroscopy and the experimental procedure is similar to that one described in ref. [9].

The determination of the nuclear spin I from the hfs is based on the relation

$$W_F = \frac{1}{2} KA + \frac{3/4\, K(K+1) - I(I+1)J(J+1)}{2I(2I-1)J(2J-1)}\, B \qquad (1)$$

where W_F is the hfs energy of a sublevel with angular momentum F ($|I-J| \leq F \leq I+J$) and K = F(F+1)-I(I+1)-J(J+1). A is the magnetic dipole and B the electric quadrupole interaction constant. Eq. (1) contains the spin as a parameter and usually the complete hfs of a multiplet (e.g. 3 intervals between the 4 hfs components of the $^2P_{3/2}$ state) determines I unambiguously. These intervals are obtained from the 6 hfs components of the $^2S_{1/2}$ - $^2P_{3/2}$ transition observed for I ≥ 3/2. For I = 1/2 the total number of components reduces to 3.

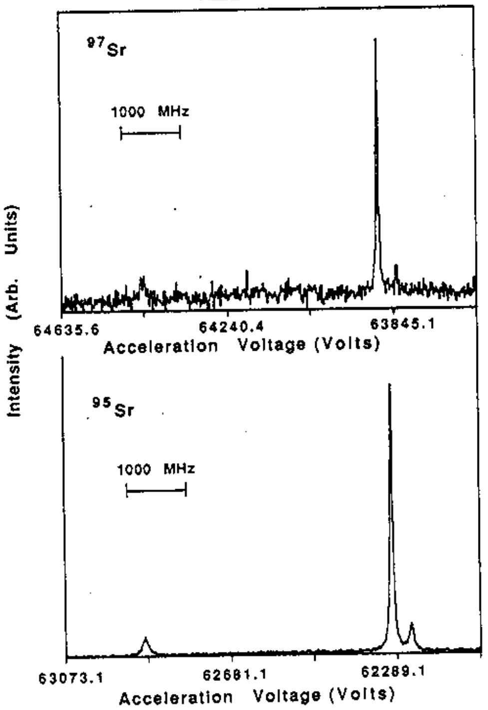

Fig. 1: Resonance signals observed for the I = 1/2 isotopes ^{97}Sr (upper part) and ^{95}Sr (lower part).

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Such an example is shown in Fig. 1, which compares the observed spectrum of ^{97}Sr with ^{95}Sr for which I = 1/2 was also suggested from nuclear spectroscopy [5].

A stringent test for the correct parametrization according to (1) is provided by the comparison of the factors A and A' deduced for the $^2S_{1/2}$ and $^2P_{3/2}$ states. Apart from small hfs anomaly effects these factors are connected to the magnetic moment μ_I by

$$A = \mu_I\ H(0)/IJ \quad \text{and} \quad A' = \mu_I\ H'(0)/IJ' \qquad (2)$$

where H(0) and H'(0) are the magnetic hyperfine fields. Thus the ratio A/A' depends only on electron shell parameters and must be constant throughout the isotopic series.

The spins and A-factor ratios for the ground states of all odd-A isotopes between ^{79}Sr and ^{97}Sr and for the isomeric states of ^{83}Sr, ^{85}Sr and ^{87}Sr are shown in Fig. 2. For ^{79}Sr, ^{83m}Sr and all isotopes beyond ^{89}Sr, these results constitute the first direct spin measurements. The results confirm the assignments from nuclear spectroscopy [5,10,11], except for ^{93}Sr and ^{97}Sr. For ^{93}Sr Bischof and Talbert [4] have argued that the spin should be 7/2. This is in discrepancy to I = 5/2 obtained from our analysis which, on the other hand, confirms an earlier assignment of Herzog and Grimm [3]. For ^{97}Sr, our data clearly determine the spin I=1/2, in contrast to the most recent assignments of other authors. Kratz et al. [6] have investigated the possibility of extracting single-particle and collective properties from gross beta decay features reflected in the beta strength function. From their systematics they conclude that the ground state configuration of ^{97}Sr should be [411 3/2] which revises their earlier assignment of $I^\pi = 1/2^+$ [5]. A change from this correct assignment to I = 3/2 had been suggested by the work of Meyer [7] on the basis of some striking analogies within the N = 59 isotones and in particular with ^{99}Zr. It will need further investigation to locate the shortcomings of this systematics which finally depends on the assignment of $5/2^+$ for the ground state of ^{99}Y.

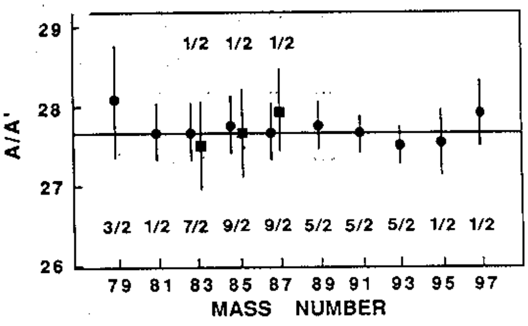

Fig. 2: Ratios of A-factors for the $^2S_{1/2}$ ground state (A) and $^2P_{3/2}$ excited state (A') of Sr isotopes (full circles) and isomers (full squares). The spins for the respective isotopes are indicated, those for the isomers being above the data points.

Our result for the spin of ^{97}Sr establishes a basic piece of information in this important region of the nuclear chart, characterizing the ^{97}Sr ground state as a $s_{1/2}$ shell model state. This conclusion is supported by our isotope shift measurements and by a systematics of the magnetic moments of the heavy Sr isotopes. The isotope shift follows the trend of the near-spherical isotopes with N < 59, and the onset of deformation is reflected in a pronounced discontinuity between N = 59 and 60. The magnetic moment $\mu_I = -0.5\ \mu_N$ is nearly the same for ^{97}Sr as for ^{95}Sr, and consistent with the assignment of a $s_{1/2}$ configuration for the odd neutron. These aspects will be taken up later in a comprehensive presentation of nuclear properties extracted from our laser spectroscopy data.

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