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LETTER OF INTENTION: HYPERNUCLEAR SPECTROSCOPY

by

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Recently several proposals have been put foward to study atomic and nuclear structures with the use of stopping K^- mesons (1-4). It is the purpose of this note to indicate our interest in a counter experiment similar to that described in reference (3) in which an investigation of γ rays from excited states of the lithium-7 hypernucleus has been suggested. Such an experiment will open a new field of investigation: hypernuclear spectroscopy, which has been limited up to now to an analysis of some hyperisomeric and hypernuclear resonance states (5-7,11). The results of experiments on hypernuclear spectroscopy will enlarge essentially our knowledge about the interaction between hyperons and nucleons.

Several theoretical approaches have been used to interpret the basic data accumulated in hypernuclear physics. In the simplest approach, two-body central and charge-independent forces have been considered to be dominant, whereas non-central and three-body forces have been neglected. The strongly manifested spin dependence was usually described by two separate hard-core potentials, one for the singlet and the other for the triplet state. In this way the stability of the lightest, i.e. s-shell,hypernuclei could be explained satisfactorily. However, the problems of the p-shell hypernuclei, i.e. those heavier than hyperhelium 5, could not be solved in this way. The parameter Δ corresponding to the difference between the spin-dependent potentials increases within the p shell by a factor of 10 instead of being constant (10). Another discrepancy is observed when we compare the hypernuclear data with the results of the experiments on the elastic scattering of Λ^{o} hyperons on protons. The cross-sections for low momenta of Λ^{o} hyperons are systematically higher than the corresponding values deduced under the most reasonable assumptions from the hypernuclear data (9). (It would be interesting to know the cross-sections for lambda-neutron scattering). One may try to explain all these discrepancies assuming a contribution of three-body or non-central, i.e. tensor and spin-orbit, forces. In order to answer at least the question which of these factors is mainly responsible for the actual situation, the excited states of hypernuclei should be studied.

The best example to start with is hyperlithium 7. Theoretical considerations lead to the conclusion that the contribution of different components of the lambda-nucleon interaction to the binding energy of ${}_{\Lambda}^{7}Li$ in the ground and first excited spin-doublet states is different (5). It can be shown that the contribution of the tensor and spin-orbit forces may appear only in the excited states changing the spin-splitting of the levels (see the table), whereas no significant difference is expected for the ground and excited states in the case of three-body forces (8). The experimental data on the excited states should thus tell us which component of the Λ-N interaction is the most important.

Hyperlithium 7 is obtainable from the ordinary lithium target irradiated with a stopping-K^{-} beam. The interesting excited states of ${}_{\Lambda}^{7}Li$ are expected to lie well inside the interval 0.5 - 3.5 MeV. Of the other hypernuclei that can be produced from a lithium target only ${}_{\Lambda}^{7}He$, ${}_{\Lambda}^{4}He$ and ${}_{\Lambda}^{4}H$ can have particle-stable excited states which are expected to lie most probably between 1.0 and 2.0 MeV (10). The γ quanta from these hypernuclei can be distinguished if the accompanying pions are observed. No background of γ quanta from other nuclides is expected in the interval 0.5 - 3.5 MeV. The energies of the K^{-}-mesic X rays do not exceed 0.1 MeV. The background of γ quanta in the experimental room has a continuous spectrum and is expected to be eliminated by a coincidence technique.

It may be added that γ quanta, not only from ${}^{7}_{\Lambda}Li$ but from all other hypernuclei expected in this experiment, i.e ${}^{4}_{\Lambda}H$, ${}^{4}_{\Lambda}He$ and ${}^{7}_{\Lambda}He$, will provide important information. The existence of the excited states of the mirror hypernuclei ${}^{4}_{\Lambda}H$ and ${}^{4}_{\Lambda}He$ was discussed in the past and such states are expected to exist only in case of hard-core potentials of the Λ-N interaction. The data on these states might be used for checking the theoretical description of the stability of the s-shell hypernuclei (from well-known considerations of parity conservation one may expect that they could be produced by K^- mesons more easily from lithium than helium targets). In case of ${}^{7}_{\Lambda}He$ a spin doublet, which results from the splitting of the 2^+ excited state of the ${}^{6}He$ core nucleus, should produce a hyperisomer. This was the first excited state considered in hypernuclear physics (6).

For the past years our group has been involved in hypernuclear studies using the emulsion technique. The results obtained with this method are not incompatible with the existence of another hyperisomer: ${}^{7}_{\Lambda}Li^*$, the lambda-binding energy distribution for ${}^{7}_{\Lambda}Li$ being slightly asymmetric (5). It is clear, however, that the problem could be solved only by the direct investigation of γ rays carried out with the counter technique.

The counter experiment suggested here should be feasible if a K^--meson beam of intensity not less than 100 particles per pulse were available.

TABLE

HF	SPIN OF THE CORE	SPINS OF THE HF DOUBLET	CONTRIBUTION OF DIFFERENT TERMS SPIN-SPIN	TENSOR	SPIN-ORBIT
${}^{6}_{\Lambda}He$	$\frac{3}{2}^-$	$1^-, 2^-$	$-\frac{5}{12}\Delta, \frac{1}{4}\Delta$	$-\frac{5}{12}T, \frac{1}{4}T$	$-\frac{5}{12}K, \frac{1}{4}K$
${}^{7}_{\Lambda}Li$	1^+	$\frac{1}{2}^+, \frac{3}{2}^+$	$-\Delta, \frac{1}{2}\Delta$	0,0	0,0
${}^{7}_{\Lambda}Li$	3^+	$\frac{5}{2}^+, \frac{7}{2}^+$	$-\frac{2}{3}\Delta, \frac{1}{2}\Delta$	$-\frac{2}{3}T, \frac{1}{2}T$	$-\frac{3}{2}K, \frac{1}{2}K$
${}^{8}_{\Lambda}Li$	$\frac{3}{2}^-$	$1^-, 2^-$	$-\frac{5}{12}\Delta, \frac{1}{4}\Delta$	$-\frac{1}{4}T, \frac{3}{20}T$	$-\frac{5}{12}K, \frac{1}{4}K$

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