V. G. Serbo, V. V. Serebryakov, and L. D. Solov'ev for useful discussions.

[1] We note that the result of Lee and Nauenberg [4] cannot be applied directly to the total hadron scattering cross sections. Inasmuch as $\sigma_{tot} \sim m_h^{-2}$, the transitions $s \to \infty$ and $m_h \to 0$ are not equivalent here.

[2] Of course, the cross section includes also other electromagnetic corrections, for example those connected with interference between strong and Coulomb amplitudes in elastic and inelastic scattering. They can become appreciable at moderately high energies, but decrease with increasing s [6].

[3] We did not try here to obtain the best approximation, bearing in mind only a demonstration of the effect.

[1] V. N. Gribov, Yad. Fiz. 5, 399 (1967) [Sov. J. Nuc. Phys. 5, 280 (1967)]; F. E. Low, Phys. Rev. 110, 974 (1958).
[2] R. N. Cahn, Phys. Rev. Lett. 29, 1481 (1972).
[3] V. G. Gorshkov, Zh. Eksp. Teor. Fiz. 56, 597 (1969) [Sov. Phys.-JETP 29, 329 (1969)].
[4] T. D. Lee and M. Nauenberg, Phys. Rev. 133B, 1549 (1964).
[5] A. V. Efremov, Dissertation, Dubna, 1970.
[6] V. M. Budnev, I. F. Ginzburg, ZhETF Pis. Red. 13, 519 (1971)[JETP Lett. 13, 370 (1971)]; L. A. Kondratyuk and V. B. Kopeliovich, ibid. 16, 201 (1972) [16, 142 (1972)].
[7] U. Amaldi et al., CERN Preprint, 1973; S. R. Amendolia et al., CERN Preprint, 1973; Phys. Lett., in print.
[8] G. B. Yodh, Y. Pal, and J. S. Trefil, Phys. Rev. Lett. 28, 1005 (1972).
[9] Yu. P. Gorin et al., Yad. Fiz. 14, 998 (1971) [Sov. J. Nuc. Phys. 14, 560 (1972)].
[10] K. J. Foley et al., Phys. Rev. Lett. 19, 857 (1967).
[11] V. Bartenev et al., ibid. 29, 1755 (1972).
[12] J. W. Chapman et al., ibid. 29, 1686 (1972).
[13] G. Charlton et al., ibid. 29, 515 (1972).
[14] F. T. Dao et al., ibid. 29, 1622 (1972).

EXCITED STATES OF p-SHELL HYPERNUCLEI

A. B. Kochetov and B. A. Khrylin
Moscow Institute of Radio, Electronics, and Automation

Submitted 6 June 1973
ZhETF Pis. Red. 18, No. 2, 136 - 138 (20 July 1973).

We calculate the excitation energies of p-shell hypernuclei with ΛN potentials having strong repulsion in odd states.

A few recent papers [1 - 3] report the existence of excited states of the hypernuclei C_Λ^{12} and N_Λ^{14} with approximate excitation energy and width 11 and 0.5 MeV, respectively, which are stable against Λ-particle emission (see also [4]). There are two possibilities for excited-state production, excitation of the core nucleus and excitation of the Λ particle. According to the Dalitz hypothesis [5], the Λ particle in the observed excited states is in the p-state relative to the mass center.

A theoretical analysis of the excited states of p-shell hypernuclei is of interest for the following reasons: With further progress in the physics of hypernuclei, our ideas concerning the ΛN interaction are altered appreciably and, unfortunately, still remain unsatisfactory at present. The failure to describe the binding energies of hypernuclei with mass number A > 5 on the basis of a paired central ΛN potential has stimulated investigations of other possible components of lambda-nucleon interaction (three-particle ΛNN forces, effects of ΛΣ suppression, etc.). The excited states of p-shell hypernuclei yield new data, which make it possible to verify the correctness of our notions concerning ΛN interactions.

One of the possible methods of eliminating the overestimate of the binding energies of hypernuclei with A > 5 is to introduce Majorana ΛN forces. Assuming equality of the singlet and triplet ΛN potentials and taking the Majorana forces into account, the paired ΛN potential takes the form

$$V_{\Lambda N} = \frac{1}{2}V_0(1 + P_x) + \frac{1}{2}V_1(1 - P_x),$$

	ΛN-potential					Excit. energy, MeV		
	V_+, MeV	r_+, F	V_-, MeV	r_-, F	k	Be^9_Λ	C^{13}_Λ	O^{17}_Λ
	–	–	–	–	−0.8	7.9	11.4	15.7
1	497.1	0.75	198.2	1.2	−1.0	7.7	11,2	15.4
	–	–	–	–	1,2	7.5	10,9	15,1
	–	–	–	–	−0,8	7,3	11,2	14,8
2	588,6	1,0	418.0	1,2	−1,0	7,2	10,9	14,4
	–	–	–	–	−1,2	6,9	10.6	13,9

where $V_0 = (V_s + 3V_t)/4$, V_s and V_t are the singlet and triplet ΛN potentials in the relative s-state, P_x is the coordinate permutation operator. Assuming further that the interaction has the same radial dependence in the even and in the odd states, we can put $V_1 = kV_0$. The binding energies of the hypernuclei with $5 \le A \le 41$ are reproduced quite satisfactorily at $k \simeq -1$, i.e., at a repelling ΛN interaction in the p-state approximately equal to the interaction force in the s-state [6].

We present here the results of a calculation of the excitation energies of p-shell hypernuclei with ΛN potentials having a strong repulsion in the relative p-state. A description of the calculation technique and the parameters of the employed NN potentials can be found in [6], where the variation of the Λ-particle detachment energy with increasing mass number A is also given.

The obtained excitation energies of the hypernuclei Be^9_Λ, C^{13}_Λ, O^{17}_Λ with the Λ particle in the p-state, for certain variants of the ΛN potentials with a Gaussian radial dependence

$$V_0(r) = V_+\exp(-r^2/r_+^2) - V_-\exp(-r^2/r_-^2)$$

are listed in the table. In the field of the spherically asymmetrical core nucleus, the p-level of the Λ particle is split, and the table indicates only the lower values of the excitation energy.

Although we have analyzed hypernuclei with unknown excitation energies, it is reasonable to assume that the excitation energy is no less smooth a function of the mass number A than the Λ-particle detachment energy, and we are justified in interpolating the obtained values.

It is of interest to note the following circumstances: 1) the assumed strong repulsion in the odd states leads to excitation energies that agree satisfactorily with experiment; 2) the excitation energy depends less on the details of the ΛN potential than the Λ-particle detachment energy; 3) according to the result, we should expect excited states with p-shell Λ particles to be found in the discrete spectrum only for hypernuclei with $A \gtrsim 12$.

The authors thank A. I. Baz', Yu. T. Grin', and M. V. Zhukov for a discussion of the results of the work.

[1] D. H. Davis and J. Sacton, Proc. Int. Conf. on Hypernuclear Physics, Argonne, 1969, p.159.
[2] G. Bohm et al., Nucl. Phys. B24, 248 (1970)
[3] H. Juric et al., ibid. B47, 36 (1972).
[4] B. A. Khrylin, Usp. Fiz. Nauk 105, 185 (1971) [Sov. Phys.- Usp. 14, 616 (1972)].
[5] R. H. Dalitz, Proc. Int. Conf. on Hypernuclear Physics, Argonne, 1969, p. 708.
[6] B. A. Khrylin and A. B. Kochetov, Phys. Lett. 42B, 38 (1972).