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PHYSICS

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Abstract

Full Text

PHYSICS

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CAPTURE OF A K^- -MESON WITH EMISSION OF ${}_{\Lambda}^5\text{He}_2$

(Presented by Academician N. N. Bogolyubov, 1 VI 1957)

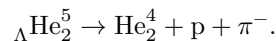
In a stack of photographic emulsions irradiated at high altitude, a case was found of capture of a K^- -meson with subsequent emission of the hyperfragment ${}_{\Lambda}^5\text{He}_2^*$. The microprojection is shown in Fig. 1.

Particle 5 entered the stack from outside. After passing 27.3 mm in the emulsion, it stopped and at point A formed a σ -star. Measurement of the mass of particle 5 from its range and scattering gave the value $m = (823 \pm 160)m_e$. Ionization measurements led to $m \simeq 700m_e$. Apparently this is a K^- -meson.

The black track F of star A , in turn, ends in star B , one of whose rays turned out to be a π^- -meson. Rays 1, 2, and 3 are coplanar. This argues in favor of the fact that star B was formed in the mesonic decay of a stopped hyperfragment into 3 charged particles.

Measurements of the widths of the tracks of particles F , 2, and 3 showed that each of these particles has charge $Z \leq 2$.

The kinematic analysis of star B was carried out on the assumption that particles 2 and 3 could have all possible mass values for these charges. The analysis showed that the decay scheme was



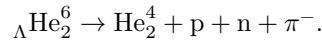
Here the kinetic energy of the decay products is $Q_k = (34.2 \pm 0.4)$ MeV. The sum of the momenta of the particles formed is $p = (13 \pm 26)$ MeV/ c . The binding energy $B_{\Lambda} = (2.7 \pm 0.4)$ MeV, which agrees well with published data.

The angle formed by the normal to the decay plane and the direction of flight of the hyperfragment is 82° .

In the case described, as also in other published cases of ${}_{\Lambda}^5\text{He}_2$, one may of course assume that in the decay an additional neutron of very low energy was emitted. This would not violate the coplanarity of the rays of star B . In that case the decay scheme would be

Fig. 1

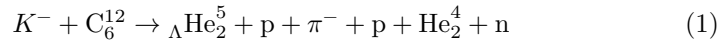
Figure 1: Fig. 1



However, the kinematic analysis of the primary star A carried out below makes it possible to refine the identification of hyperfragment F .

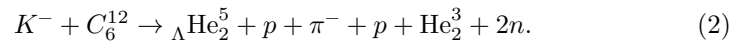
If particle 8 were a proton or an α -particle, then its energy would respectively be 1.19 or 4.6 MeV, which is considerably lower than the Coulomb potential barrier in the heavy nuclei of the emulsion. It was therefore assumed that the nucleus which captured the K^- -meson was C^{12} , N^{14} , or O^{16} .

For all possible (according to Table 1) values of the masses and charges of particles 4, 6, 7, and 8 and for two types of hyperfragments (${}_{\Lambda}\text{He}_2^5$ and ${}_{\Lambda}\text{He}_2^6$), all variants of reactions on C^{12} , N^{14} , and O^{16} were considered. The momentum and energy balance showed that only the reaction



satisfies the conservation laws, and, possibly, the reaction

* The case was found by N. V. Kirsanova.



(1) and (2) differ in the number of emitted neutrons and in the type of particle δ . In both cases the particle F turns out to be ${}_{\Lambda}\text{He}_2^5$.

Fig. 1

The value of the K^- -meson mass obtained from reaction (1), $m_{K^-} = (494.3 \pm 6.8)$ MeV, is in good agreement with the data of other works*.

From reaction (2) it was possible to obtain a lower limit for the value of the K^- -meson mass. It turned out to be equal to (506.7 ± 6.6) MeV. The lower limit was calculated under the unlikely assumption that both neutrons were emitted with momenta equal in magnitude and direction. Otherwise the calculated value of m_{K^-} increases still more. For this reason reaction (2) is excluded from further analysis as improbable.

Without contradicting existing theoretical ideas, one may suppose that the formation of a hyperfragment can sometimes occur with the participation of a Σ -particle**. A Σ -particle formed inside the nucleus can fly out as part of a hyperfragment. After a very short interval of time it turns into a Λ^0 -particle, as

a result of which the initial hyperfragment decays into a lighter hyperfragment containing a Λ^0 -particle and one or several nucleons***.

If, in the case described, the formation of the hyperfragment occurred precisely in this way,

* $m_{K^+} = (493.66 \pm 0.36) \text{ MeV}$ (¹). The mass of K^- -mesons is known with less accuracy. It is natural, however, to assume that $m_{K^-} = m_{K^+}$.

** The energy of the π -meson formed in the σ_{K^-} -star is rather small (53 MeV). This does not contradict the assumption that, in the capture of the K -meson, a Σ -particle was initially formed.

*** The possibility under consideration can make sense only if, during the transition of the Σ -particle into a Λ^0 -particle, the hyperfragment has time to fly beyond the boundaries of the initial nucleus. In principle, the Gell-Mann scheme does not exclude this.

Table 1

Track	F	1	2	3	4	5	6	7	8
True range length, μ	161	8481	19.3	401	54.7	> 27300	> 27500	4880	18
Error in range measurement, %	0.4	0.1	4.2	0.5	1.7	—	—	0.1	5.1
Range straggling, %	1.2	3.0	2.0	1.6	1.8	—	—	1.4	2

Track	F	1	2	3	4	5	6	7	8
Angle β with the hor- i- zon- tal plane in the un- treated emul- sion, deg. *	0	-9.0	+12.4	-18.5	+16.0	-	+7.9	-19.8	+15.8
Error in mea- sure- ment of an- gle β , deg. **	-	4	7	2	2	-	0.3	1	7
Azimuthal an- gle φ , deg. **	0	232.3	79.5	278.2	44.5	-	126.6	167.8	269.8
Error in mea- sure- ment of an- gle φ , deg.	0.7	0.7	1.7	0.7	0.7	-	0.7	0.7	1.7

Track	F	1	2	3	4	5	6	7	8
Number of δ -electrons with range > 4 grains	0	—	0	0	0	—	—	—	0
Charge Z	≤ 2	—	≤ 2	≤ 2	≤ 2	-1	± 1	+1	≤ 2
Method of mass measurement and its value, m_e	—	—	—	—	—	$\langle \alpha \rangle - R : 014 \pm 170I - R : 658 \pm 55$	$\langle \alpha \rangle - R : 343 \pm 62R : 340I - R : 2700 \pm 300$	$1250 \pm$	$1250 \pm$
Particle identification	${}_{\Lambda}^5\text{He}$	π^-	He_2^4	p	p	K^-	π^-	p	He_2^4
Energy, MeV	21.3 ± 0.3	21.0 ± 0.4	4.8 ± 0.2	8.4 ± 0.1	2.47 ± 0.04	—	66.3 ± 6.5	35.3 ± 0.3	4.6 ± 0.2

* For tracks directed toward the surface, the sign + is used; for tracks directed toward the glass, the sign —.

** With respect to an arbitrarily chosen direction, the same for all tracks of the star and of the hyperfragment track.

*** 1 grain on the track, 3 outside the track.

then the track of the hyperfragment ${}_{\Lambda}^5\text{He}$, and one or several rays of star A , were produced by particles emitted in the decay of the primary fragment with the Σ -particle. The momentum of these particles must be equal to the momentum of the fragment with the Σ -particle before decay. From the momentum of the fragment one can determine its energy. The total energy of the initial fragment must then be equal to the total energy of the particles emitted in its decay. This makes it possible to determine B_{Σ} —the binding energy of the Σ -particle.

In this way all possible combinations of 2, 3, 4, and 5 particles of the primary star were tried. For almost all combinations B_Σ took either negative or very large positive values, and only for two combinations were acceptable values obtained (of the order of several MeV).

1st combination. ${}_\Lambda\text{He}_2^5$, n , and $2p$ were produced in the decay of the fragment ${}_\Sigma\text{Be}_4^8$.

$$B_\Sigma = (5.9 \pm 2.0) \text{ MeV},$$

if the fragment contained a Σ^0 -particle.

$$B_\Sigma = (5.5 \pm 2.0) \text{ MeV},$$

if the fragment contained a Σ^+ -particle.

2nd combination. ${}_\Lambda\text{He}_2^5$, p , n , and He_2^4 were produced in the decay of the fragment ${}_\Sigma\text{B}_5^{11}$.

$$B_\Sigma = (1.3 \pm 2.0) \text{ MeV},$$

if the fragment contained a Σ^0 -particle.

$$B_\Sigma = (0.2 \pm 2.0) \text{ MeV},$$

if the fragment contained a Σ^+ -particle.

The result obtained does not, of course, mean that the process of formation of the hyperfragment necessarily proceeded by the route assumed above, since it may have happened that the values of B_Σ only accidentally turned out to be small. The question could be resolved after carrying out an analogous analysis of other cases. Especially useful would be the consideration of σ -stars that allow a complete kinematic analysis ⁽²⁾.

It is not excluded that the hyperfragment may sometimes be formed in an excited state, with subsequent transition to the ground state by emission of a γ -quantum or a nucleon*.

With the aid of an analysis analogous to that described above, given sufficient statistics, it would be possible to try to detect such excited hyperfragments.

In the particular case under consideration it turned out that there exist two combinations of particles for which the binding energy B_Λ^* takes nonnegative values.

1st combination. ${}_\Lambda\text{He}_2^5$ and p were produced in the decay of the excited hyperfragment ${}_\Lambda\text{Li}_3^{*6}$. The binding energy is

$$B_\Lambda^* = (2.2 \pm 0.7) \text{ MeV}.$$

The proton energy in the center-of-mass system is

$$E_p = (10.6 \pm 0.2) \text{ MeV.}$$

2nd combination. ${}_{\Lambda}\text{He}_2^5$ and n were produced in the decay of the excited hyperfragment ${}_{\Lambda}\text{He}_2^{*6}$. The binding energy is

$$B_{\Lambda}^* = (-0.9 \pm 2.0) \text{ MeV.}$$

The neutron energy in the center-of-mass system is

$$E_n = (9.9 \pm 1.1) \text{ MeV.}$$

The authors consider it their duty to express their gratitude to M. I. Podgoretsky for assistance in the work, and also to Z. P. Golovina, E. V. Esina, and N. V. Kirsanova for carrying out the measurements.

Joint Institute
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CITED LITERATURE

1. R. W. Birge, D. H. Perkins et al., *Nuovo Cim.*, **4**, No. 4, 834 (1956).
2. F. C. Gilbert, C. E. Violet, R. S. White, *Phys. Rev.*, **103**, No. 1, 248 (1956).
3. F. Ajzenberg, T. Lauritsen, *Rev. Mod. Phys.*, **24**, No. 4, 321 (1952).
4. D. S. Craig, W. F. Cross, R. G. Jarvis, *Phys. Rev.*, **103**, No. 5, 1427 (1956).

* Similar to the way in which the compound nucleus Li_3^5 goes over into He_2^4 with emission of a proton ⁽³⁾, or He_2^5 goes over into He_2^4 with emission of a neutron ⁽⁴⁾.

Note: Figure translations are in progress. See original paper for figures.

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